MODERN FISHING GEAR OF THE WORLD

Edited by

HILMAR KRISTJONSSON

Chief, Fishing Gear Section, Fisheries Division, Food and Agriculture Organization of the United Nations

THIS volume represents a further important stage in the work being done by the Fisheries Division, F.A.O. to develop and expand the fish production of the world. Just as the Conferences of 1953 at Paris (France) and Miami (U.S.A.) concentrated on the design and operation of fishing boats and craft, so the Congress held at Hamburg in September 1957, had as its theme the comprehensive investigation and survey of substantially all advanced and commercially important gear and equipment used for catching fish.

Over 500 representatives from all countries of the globe interested in the commercial fisheries of both salt and fresh water then attended to hear and discuss more than one hundred papers contributed by scientists, technologists and manufacturers on the gear and equipment devised for the better catching of fish.

On the foundation of those papers and discussions, this volume has been built by the editor and technologists of the Fishing Gear Section of the Fisheries Division. The papers have been collated into some thirteen logical sections, amplified where necessary, and supplemented as required to round out as full and authoritative a presentation as possible on all aspects of modern fish catching equipment, from the use of man-made fibres in various lines, nets and trawls to electronic aids in fish location and detection, and to the latest techniques in electric fishing.

The editorial work necessary to avoid duplication and repetition was tremendous and because of the need frequently of translation and close co-operation with the authors of papers in widely

Continued on inside back cover

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HILMAR KRISTJONSSON

Chief, Fishing Gear Section, Fisheries Division, Food and Agriculture Organization of the United Nations, Rome, Italy

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NOTICE TO THE READER

Containing the papers and proceedings of the International Fishing Gear Congress convened by F.A.O. in Hamburg, October 1957, this book has been edited in the Fishing Gear Section of the Fisheries Division, F.A.O., where a very big share of the work was done by Mr. P. Lusyne and Dr. J. Schärfe, Gear Technologists.

Due to its origin the text is divided into more than a hundred articles written by different authors. During editing we have attempted to minimize repetition, unify terminology, etc., and also arranged the contributions into sections according to subject matter. It is, however, inevitable that information on one subject is often found in many widely separate parts of the book, but it is hoped that the detailed list of Contents—and particularly the Index which appears at the end of the literary contents of the book -- will be of help when using this volume as a reference book.

No attempt was made to include material ably covered in well known and accessible books on basic net making, knots and splices, nor on the English ground trawls already fully described by Hodson, Garner and other authors. For such general references the readers are referred to the Annoted Bibliography of Fishing Gear and Methods available from F.A.O., Rome.

HILMAR KRISTJONSSON
Editor

GENERAL ILLUSTRATIONS

To supplement the specific diagrams and illustrations in the various papers a number of general illustrations covering fishing craft and activities in various parts of the world have been included on the pages listed below.

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ABBREVIATIONS

A	=	Ampère
°C.	=	Degrees Centigrade
cm.	=	Centimetre(s)
sq. cm.	=	Square Centimetre(s)
cu. cm.	=	Cubic Centimetre(s)
col.	=	Column
cu.	=	Cubic
diam.	=	Diameter
°F.	=	Degrees Fahrenheit
fm.	=	Fathom(s)
ft.	=	Feet
g.	=	Gram(s)
gal.	=	American gallon(s)
ha.	=	Hectare(s)
h.p.	=	Horsepower
hr.	=	Hour
hrs.	=	Hours
in.	=	Inch(es)
kg.	=	Kilogram(s)
km.	=	Kilometre(s)
kw.	=	Kilowatt
l.	=	Litre(s)
lb.	=	Pound(s) avoirdupois
m.	=	Metre(s)
sq. m.	=	Square metre(s)
cu. m.	=	Cubic metre(s)
mg.	=	Milligram(s)
min.	=	Minute(s)
ml.	=	Millilitre(s)
mm.	=	Millimetre(s)
sq. mm.	=	Square millimetre(s)
cu. mm.	=	Cubic millimetre(s)
oz.	=	Ounce(s) avoirdupois
p.	=	Page
pp.	=	Pages
p.p.m.	=	Parts per million
r.p.m.	=	Revolutions per minute
sec.	=	Second(s)
sp.	=	Species
spp.	=	Plural of species
V		Volts
Vol.	=	Volume
W	=	Watt(s)
wt.	=	Weight

PREFACE

THE International Fishing Gear Congress, which was held in Hamburg, Germany in October, 1957, was the first meeting of its kind, and it marked an important step forward in international cooperation in dealing with some of the many problems concerned with the development of fisheries throughout the world. This book contains the edited versions of more than one hundred technical papers presented to the Congress, as well as the gist of the discussions which took place.

Broadly speaking, FAO's function is to promote food production, especially through international cooperation. One part of the work of the Organisation is to provide, at the request of any of the 77 Member Governments, direct technical assistance by assigning specialists to deal with specific fisheries problems.

The other part of FAO's function is to act as a clearing house for technical information, stimulate the exchange of ideas and experience, and to focus attention of governments on key problems, particularly those which need to be dealt with through international cooperation. The International Fishing Gear Congress provides an example of this function of the Organisation.

While a great deal of FAO's work concerns the fisheries in the underdeveloped countries, it is also of value to technically developed countries. This was shown at the Congress where a major part of the 540 participants were from countries in the front rank of fishing nations. These people found, for example, that the papers and discussions were most useful in focusing attention on the problems concerned with the development of fishing gear technology. This is a new concept in the fishing world which has emerged in recent decades because of the growing complexity of fishing.

Literature in this field is scattered and incomplete and this book is the first comprehensive reference work covering net materials, rational gear design, description of modern fishing gear and its operation as well as the strategy and tactics of finding and attracting fish. Although the profession of gear technology is still in the development stage, and gear research facilities are, as yet, available only in a few countries, much progress has been made towards evolving the methodology and tools of the trade. But experimenting with fishing gear is expensive and, in view of the economic pressure under which the fishing industry generally works and the need to increase gear efficiency, this is clearly a field for governmental action. If rapid progress is to be made, then Governments must set up and/or support gear research institutes. Such institutes are as essential as the already well established biological and fish processing stations now found in all fishing countries. The need for such institutes is underlined by the fact that, despite the progress made, fishing is, broadly speaking, still a very inefficient operation. For example, in the most highly developed fishing countries each fisherman produces over 80 tons of fish per year but there are more than two million fishermen in the less advanced countries who produce only about one ton of fish per man per year, i.e. a little over 1 per cent. of the former. This illustrates the great need to spread existing knowledge from those countries with the technical "know-how" to regions where it is lacking.

In conclusion, I must put on record the gratitude of FAO to the Government of the German Federal Republic and the Senate of the Frei und Hansastadt, Hamburg, for so generously providing the facilities for holding the Congress. Many individuals, too, from a great number of countries did much to assist us in preparing and conducting the Congress. There is no space for me to mention them all so that I must limit myself to naming those who were particularly closely associated with the Congress. Much of the burden of making local arrangements was carried by Prof. Dr. A. von Brandt, Director of the Netz und Material Forschungsinstitut, Hamburg, and his staff, and we are especially grateful to them for all their help. Special thanks are also due to Dr. G. Meseck, Director of Fisheries, Germany, and Mr. A. W. Anderson, Assistant Director, Bureau of Commercial Fisheries, United States Fish and Wildlife Service, who acted respectively as Honorary Chairman and General Chairman of the Congress.

D. B. FINN

Rome, Italy, January, 1959

INTRODUCTION — MODERN TRENDS IN FISHING

THE oceans, seas and other waters cover more than 70 per cent. of the earth surface. They occupy about 90 million sq. miles but produce less than 10 per cent. of humanity's food. How much food could eventually be taken by man from the sea cannot be assessed.

From time to time estimates are made of how much fish we might expect to catch. Only a few years ago, it was thought the sustained catch would hardly exceed some 25 million metric tons per year. But already fish production nears 30 million metric tons (1957). Biologists and other experts now suggest this catch might be increased to some 60 million tons a year from known stocks, without taking into account the possible discovery of new fisheries.

In a recent statement summing up reasons for the increase in world fish catch since the start of the twentieth century, Dr. D. B. Finn, Director of the Fisheries Division, F.A.O. declared that progress in fisheries has been greater in the past 30 years than in the previous three thousand!

Modern fishing has developed through three main technological revolutions.

The first one, **mechanization,** began late in the 19th century with the use of steam propulsion in fishing vessels—later followed by steam-driven winches. Semi-diesel and diesel engines began to make their mark at the turn of the century and have been gaining ground steadily till now steam is almost displaced except in North Atlantic long distance trawlers. But even there steam is gradually yielding to the diesel and such innovations as diesel-electric drives and turbine propulsion are finding limited application—and perhaps atomic energy is not far beyond the horizon. Mechanical propulsion of the craft is important in itself, but power handling of the gear greatly extends the trend towards fully mechanised fishing—a trend which still offers great scope for development.

The second revolution to influence modern fishing is the use of electronic **echo sounding** and **echo ranging** equipment. Echo sounders had already become standard equipment in big North European distant water trawlers before 1939, but were only used for depth sounding. The improvement of acoustical underwater equipment during the Second World War paved the way for electronic fish detection and after the war recording echo sounders were speedily adopted in all medium and large fishing vessels in the developed fishing countries. This can be likened to giving a blind man his sight. Fishermen once accustomed to these facilities feel they are groping in the dark if deprived of them.

The third major revolution in modern fishing is the advent of **synthetic fibres.** Nylon in various forms was the first of the man-made fibres to be widely applied in fishing nets, but in recent years, several other synthetics have also become important, especially in Japan, which leads the world in using synthetic fibres for fishing, both as regards quantities and variety. Nylon is for instance stimulating an important renaissance in gillnetting the world over, giving this age-old, simple but really basic form of fish net, a new lease of life.

In the economically developed countries fishing has met ever keener competition from land industries which offer steady and relatively comfortable employment. To meet this challenge, the fishing industry has been forced to increase the size of fishing units, put more horse power behind each man on the sea, and back him with expensive shore installations for processing his catch. This capitalization necessitates operation at an even and high efficiency to pay dividends. Thus economic pressure relentlessly forces further technological development.

Every fishing method has been affected by this development. Even handlining which was well on the way to becoming extinct in the Western World has gained new importance through the use of nylon monofilament, artificial lures and hand-powered reels.

Longlining, both bottom set and floating, is still an important method in the North Atlantic cod fisheries, the North Pacific halibut fishery and the Japanese high seas tuna fishery, but technique of handling the gear has greatly improved. The lines are now streamed out at 7 to 9 knots and hauled in on mechanically or hydraulically driven gurdies at a rate of 2 to 5 miles/hr. Longlining is, however, still laborious, and formidable quantities of bait are also consumed. For each day's fishing an Icelandic longline boat for instance will use 700 to 1,000 lbs. of frozen herring which is caught in another season and stored frozen for several months. It is therefore tempting to contemplate the savings in bait and labour which could be achieved if an effective artificial bait were developed—such as possibly pieces of spongy material, suitably shaped and coloured, permanently attached on each hook. The line might then be immersed in, doused with, or drawn through a tank with a liquified fish, fish oil or other natural or artificial liquid attractant. The testing of such sponge baits, suitably treated is certainly one of many interesting problems awaiting solution.

Over two hundred thousand fishermen in India and Ceylon fish from log rafts with primitive gear, landing on the average only half to one ton of fish per man per year. Photo: FAO

Gillnetting has been more affected by the man-made fibres than any other fishing method and, as already mentioned, is stimulating a renaissance in this technique. The elastic properties of nylon, its flexibility, softness, high tensile strength and other characteristics have so profoundly enhanced the catching power of gillnets that the name itself is hardly appropriate any longer except where school fish of a uniform size are truly gilled. In most other forms, loosely hung gillnets of nylon act more as tangle nets, catching fish in a wide range of size and shape.

One attractive feature of the gillnet is that it can be used even from primitive unpowered craft—a fact of great importance in countries with underdeveloped fisheries. In F.A.O's Technical Assistance work in tropical countries, the introduction of nylon gillnets, both bottom-set and drifting, has invariably met with almost immediate success and acceptance by the local fishermen who are quick to realise the advantages. The non-rotting character of synthetics is, of course, of the greatest importance in hot climates. Indian fishermen operating log rafts (see above) increase their catches 5 to 10 times when equipped with nylon gillnets, thus raising their income and eventually enabling them to replace their primitive craft with small mechanized boats.

When selecting synthetic fibre twines for fishing, due attention should be paid to the fact that nylon, for instance, is drawn to different degrees during manufacture to give either high tenacity and relatively low extensibility or else lower tensile strength and high extensibility. For certain uses, the latter may be preferable.

Initial high price of nylon has come down to a competitive level, and the early difficulties of knot slippage, etc., have now been largely overcome with bonded twines and/or heat-setting of knots. This is still not fully realized in some countries, nor is the fishing industry everywhere fully

In sharp contrast to the facing photo, modern purse seining exemplifies the high level of efficiency of modern fishing units as this one on the British Columbia coast, where hundreds of tons of herring are frequently caught in one set.
Photo: Info. Serv., Dept. of Fisheries, Ottawa

informed of the development and rapidly increasing use of other synthetic fibres such as the polyvinyl alcohol and polyester fibres. While practically all new gillnets used in the North Atlantic cod fisheries, the Pacific salmon fisheries and in inland waters, even in the great lakes of Africa, are now made of synthetics, man-made fibres have not yet been adopted in European herring drift net fisheries. It seems, however, likely that this is only a matter of time, despite initial difficulties with thin nylon twine which cut herring and make it difficult to shake out of the nets. The Japanese in their drift netting for herring, sardines, mackerel and salmon already use man-made fibres extensively.

In world fisheries, gillnets, bottom-set and drifting, rank next after trawls and purse seines in importance in terms of total catch. Growing awareness of the danger of depleting fish stocks which, in some cases, has led to the closing of coastal waters to trawling, is another factor in favour of such methods as gillnetting and longlining.

At the turn of the century purse seining came into general use, having evolved basically from Mediterranean roundhaul nets. American two-boat menhaden purse seines were first introduced into Icelandic and Norwegian herring fisheries in 1903-4, and in a few years largely replaced the big locknets used previously for fencing in large schools of herring in bays and fjords. Until the mid-thirties, two-boat purse seine dories were rowed, but became mechanised soon after. While pursing is normally done with a power driven winch, the net itself is still hand hauled so this method of fishing requires a crew of sixteen to thirty men—an increasingly serious handicap to-day.

On the other hand significant progress has been made in the power handling of one-boat purse seines, on the Pacific Coast of America. The Puretic power block is the latest example of

Gillnetting for threadfin ("Dara") north of Bombay where engines have been installed in almost a thousand boats, but the nets are still hauled by hand. With a power driven net hauler costing only about $100, this boat could easily fish twice as many nets with a smaller crew. Photo: FAO.

this. There is great scope for saving labour and otherwise improving efficiency by applying mechanical power to other types of purse seines and roundhaul nets elsewhere.

Trawling has come a long way since sailing smacks drifted downwind with beam trawls. Mechanization and the use of otter boards, amplified later by Vigneron-Dahl gear, led to the development of many widely different trawl types for various operating conditions, both on and off the bottom. While midwater trawling has attracted considerable attention throughout the world, other important developments have gone almost unnoticed outside the areas where they are used. This is true for instance of the high-opening trawls now widely used in Sweden, Denmark, Germany, Netherlands and Belgium.

Before the war large German herring trawlers had fished for years with moderately high-opening bottom trawls where the headline was lifted by kites and the fish schools depressed by kites riding on false headlines. It was, however, mainly after the war that high-opening trawls for vessels in the 20 to 200 ton class were developed and came into general use. These trawls are of many different types but in general they have certain main features in common, i.e. they are lightly built of thin twine, have short but high wings and the pull of the net is transmitted to the towing bridles along the lastrich lines or side seams in order not to drag back the headline but release it to rise high. These trawls do not depend on kites or hydrodynamic floats to secure a high vertical opening but are so proportioned that they billow out—somewhat like a parachute.

Measurements have shown that such light trawls for relatively low-powered vessels (100 to 300 h.p.) frequently open as high as 20 to 30 ft. (6 to 9 m.) headline height. They are therefore,

Bottom set cod gillnets of nylon hauled on a hydraulically driven gurdy off Iceland. 2,000 to 2,500 fms. of nets are operated by each motor boat and the average catch is 6 to 10 tons per day. Photo: FAO

particularly efficient for catching semi-pelagic and pelagic species schooling at some distance above the bottom, such as herring, sprat, mackerel, etc.

During the last decade, general adoption of this type of trawl has had a profound effect in certain fisheries. In Denmark, for instance, the fish catch is now five times greater than it was before the war, i.e. has risen from about 100,000 tons (1938) to about 530,000 tons (1957), largely through changing over from quality fishing with Danish seines and low opening trawls to quantity fishing with high-opening and midwater trawls.

Certainly there is scope for such nets in many other parts of the world and it is hoped the information contained in this book will help accelerate this.

Another rather recent development not widely appreciated is the extension of trawling into deeper water, even with relatively small boats of modest power. Both on the U.S. Pacific Coast and in the Mediterranean 30 to 80 ton vessels of 150 to 250 h.p. commonly trawl down to 350 fms. which is as deep as the deepest grounds fished now by the biggest trawlers in Northern Europe of over 1,000 h.p. While the Pacific Coast deep trawlers use relatively very short warps and heavy doors, the Mediterranean boats commonly use about 3:1 warp/depth ratio and rather light trawl doors with bracket adjustment giving an outward tilt and fitted with broad mud skis to avoid wasting towing power on ploughing deep ditches in soft mud bottoms. To fish such depths, an echosounder is indispensable for staying on bottom contour lines.

In both these regions all boats use stern trawling which, with wheelhouse forward and clear deck aft, facilitates mechanical handling of the gear and simplifies manoeuvring during hauling and shooting light trawl gear (without bobbins) as compared with side trawling.

Yet Mediterranean trawl boats normally carry crews of 6 to 9, while comparable boats in the Gulf of Mexico shrimp fishery or Danish side trawlers, carry only 3 or 4. Growing demands for better income among Mediterranean fishermen will force streamlining and reduce the number of the crew. A similar need for rationalization of working methods and equipment exists in most of the world's fisheries and there is certainly very great scope for applying work study techniques on board fishing vessels of all types to accelerate this development just as is done in industry on land.

A trend in modern trawling which must be mentioned is the big stern trawlers pioneered by the *Fairtry*. The Russians now have a sizeable fleet of such factory ships, and three distant water trawlers of a similar design, but smaller, have also been built for German owners. All these vessels are built to fish in distant waters, normally more than a thousand miles from their home port. Despite rational methods of handling the gear, most of these factory ships carry very large crews for filleting, freezing and otherwise processing the catch. Such elaboration of the catch at sea is inherently expensive, and perhaps the future trend may be towards further simplifying the handling of the catch so that distant water fishing vessels could carry a small crew, provided with good accommodation and labour-easing as well as labour-saving appliances. A similar development is long overdue on the conventional deep sea trawlers.

The use of bigger and more powerful vessels has led to higher trawling speeds. This gives rise to various problems in relation to the hydrodynamical properties of floats and trawl boards and it also brings up the choice between towing a relatively small net fast or using a much bigger net at a slower speed. Here the decisive factors are, firstly, the fish behaviour and, secondly, the economical or critical speed of the gear, beyond which a doubling or trebling of the power expenditure results in only insignificant increase in towing speed. A careful study of these little-known factors may well lead to improved fishing efficiency and saving of costly fuel.

Hydrographic and biological observations, coupled with organized fish searching are now beginning to supplement the empirical knowledge and intuition of experienced fishing skippers in locating fish concentrations. A good example of this is the service rendered to the Norwegian herring industry by Asdic equipped research vessels which track the annual migration of the herring during its feeding run in the summer in the Norwegian Sea and the winter spawning run to the Norwegian west coast. Other examples lie in the large fleets of Russian herring fishing vessels which, serviced by mother ships, follow these same herring stocks throughout the year in the sea between Norway, Iceland and Scotland; also the Japanese high seas fishery for salmon in the North Pacific and tuna longlining in equatorial waters around the world.

The echo sounding equipment developed for fish detection after the last war has had a profound effect on most modern methods of fishing. The latest technical developments overcome some of the limitations of conventional models and open up new horizons; for instance, the considerable increase in sound output, enlarged recording of small depth segments and suppression of the bottom echo greatly improve the detection of fish near the bottom and in great depths. Some of these new features can be built into older models. Fishing Asdic units are coming into use in the North Atlantic herring fisheries and in whaling.

Apart from finding fish the new echo sounders can sometimes indicate whether to use a trawl of high opening (and limited spread) or of the widest possible spread (and small gape).

Echo fish detection made midwater trawling possible. An absolute prerequisite is, of course, to find the fish and its depth. The next step is to regulate and determine accurately the fishing depth of the trawl, and this has presented difficulties in the past. At the time of this writing encouraging progress is, however, being made towards evolving and introducing a simple, workable and inexpensive arrangement of using an echo sounder transducer attached to the headline or the footrope of midwater trawls as outlined on p. 491 in this book. Not only does this clearly show the exact depth of the trawl but the vertical opening is also indicated and the fish entering the trawl mouth or evading below or above it. This may well lead to a much wider application of midwater trawling which is still very limited.

The use of light for attracting fish is an important method in Japan, Philippines and the Mediterranean region, but amazingly enough, it is still largely neglected elsewhere. One notable exception is, however, the novel use of conical lift nets and, more recently, of pumping in conjunction with light attraction in the Caspian Sea.

Attracting fish by light is of special value where sardine, anchovy, mackerel, saury or other light seeking species are present, but do not spontaneously form dense schools that are easily located. Definitely the use of lights should be thoroughly tested not only throughout the tropics, but in the temperate and cold-temperate zones. When experimenting with light attraction, negative initial results should not be taken as conclusive, as a great deal of patience is often needed to develop a suitable technique for each species under each set of circumstances.

While electrical fishing is already used to some extent in fresh water, serious problems are met with in applying it to saltwater fishing, due to the progressive increase in power requirements as range increases. Several years ago, optimistic reports were published heralding bright future prospects for revolutionary development, but this news, unfortunately, proved to be premature and interest in electrical fishing waned. Full-scale experimentation at sea is expensive, and while some tests have been made in recent years, much more work needs to be done in this field to assess the practicability of using electrofishing in salt water, and particularly in conjunction with conventional fishing methods, including the use of light which might possibly help to bring fish within range of the electric fields. Spontaneously formed dense schools of herring and other pelagic fish also appear to offer prospects in this connection.

The International Fishing Gear Congress dealt mainly with the latest types of commercially important fishing gear and with current thought and experiment concerned with making it more efficient and operating it more effectively. This book therefore emphasizes the recent developments rather than describing traditional types of gear which have long been used in fishing in various countries.

In the past almost all fishing gear has been evolved entirely by trial and error, but in the last few years a small beginning has been made towards supplementing the empirical approach by theoretical calculations—as is clearly evidenced by Section 6 of this book. When dealing with living nature the use of mathematical theory and other forms of pure logic is often severely limited by our generally incomplete knowledge of the complex factors affecting the problems under study and this applies particularly to fishing where, undoubtedly, many of these factors are still unidentified while others have not been properly evaluated. In this respect fishing is in the same boat as many fields of engineering, i.e. that theoretical solutions must be carefully checked against empirical knowledge and tested in the field before they can be trusted. Thanks to recent technological advances we are, however, rapidly learning more about the behaviour of fishing gear under water and the reaction of fish to it, and it seems safe to say that we stand at the threshold of a new era where systematic gear research will be increasingly fruitful.

Mention has been made of three major revolutionary changes which have altered the scope, nature and effectiveness of fishing, namely mechanization, echo fish finding and synthetic fibres. A fourth one is perhaps just around the corner—and may be brought about by applying engineering theory and rational methods to the development of fishing gear and its operation.

HILMAR KRISTJONSSON

TERMINOLOGY AND COUNT OF SYNTHETIC FIBRE TWINES FOR FISHING PURPOSES

by

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Abstract

The author, speaking as a manufacturer, tries to bring some sort of order into the present day chaos which surrounds textile fibres. He gives a comprehensive classification of all kinds of fibres pointing out the difficulties of using different numbering systems as well as different units of measurement (cm., g., lb., and inch).

La terminologie et le numérotage des fils de fibres synthétiques pour la pêche

Résumé

L'auteur, parlant en tant que fabricant, essaie de mettre de l'ordre dans le chaos qui règne actuellement dans le domaine des fibres textiles. Il donne une classification compréhensive de toutes les sortes de fibres en faisant ressortir les difficultés à l'utilisation de différents systèmes de numérotage et de différentes unités de mesure (cm., g., et pouce).

Terminología y numeración de los hilos sintéticos para artes de pesca

Extracto

El autor, hablando como fabricante, trata de ordenar el caos en que se encuentran las fibras textiles. Para este objeto clasifica detalladamente todos los tipos existentes, señalando las dificultades que ofrece el uso de diversos sistemas de numeración y unidades de medida (cm., g., lb., y pgda.).

LACK of agreement on the definition of technical terms creates difficulties in translating papers from one language to another. Indeed, it is not always easy for experts speaking the same language to understand each other as a particular term may have several meanings.

NAMES OF FIBRES

Consider, for instance, the large number of names for the various fibres which are on the market today. At first sight they may not seem to have any relationship with each other but anyone who makes an effort to introduce some kind of order with these fibres will recognise that they are connected with each other in certain ways. Table I shows one way of placing the variety of textile fibres into a system.

Most of the fibres used in the manufacture of cordage and nets are included, although the list is by no means complete as far as trade names are concerned.

Two of the problems of terminology which concern manufacturers are:

(1) Tenacity data
(2) Determining the diameter or thickness of filaments, threads, etc.

SPECIFIC WEIGHT AND TENACITY

It is customary to measure and indicate the Breaking Load of a yarn, filament or thread in kilograms. For the purpose of comparing yarns, etc., of different thicknesses (yarn count or diameter), a mathematical factor, the "Specific Breaking Load" (G), is introduced and the "Breaking Length" (R) is known from the spinning and processing of natural fibres.

The following relations exist :

$$R = N_m \times P_1 = N_e \times P_2$$

$$G = \frac{P_3}{T} = \frac{P_3}{T_{den}} \quad \text{(g/den.)}$$

N_e = Yarn count in English number
N_m = " " " metric number
P_1 = Breaking-load in kg.
P_2 = " " " lbs.
P_3 = " " " gr.
T = Titer in denier or tex.

The specific weight of the great variety of natural and

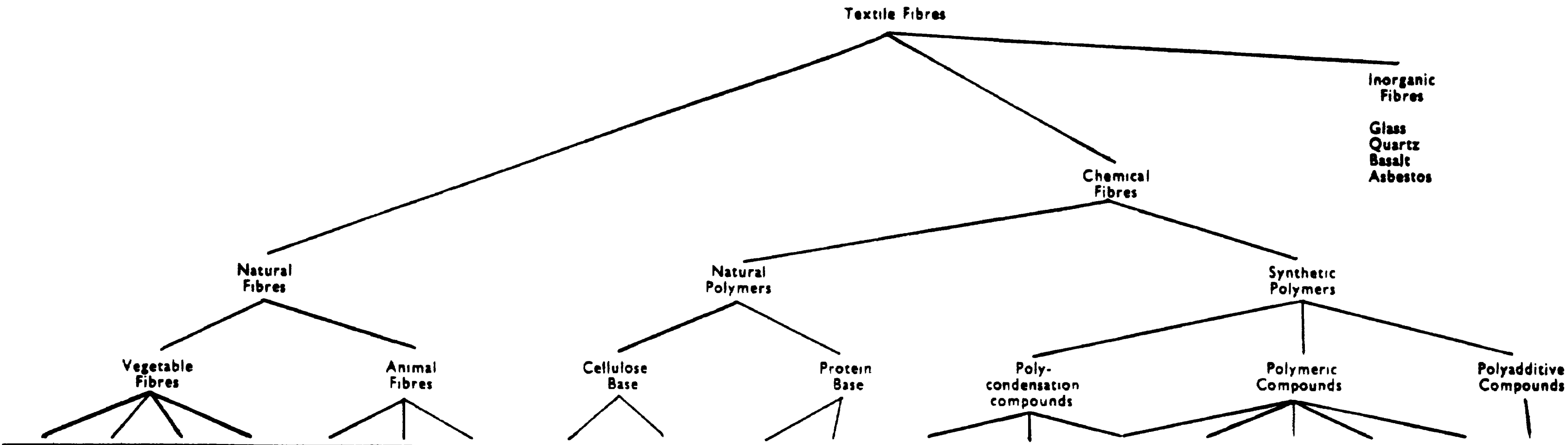
Editor's Note: In editing the papers and discussion for uniformity of terms and expression it was found necessary to adopt the following standard terminology for "yarn", "twine", "extension", "elongation", etc.:

Twine Twisting Stages:

1st step: fibres spun or twisted into *yarn*
2nd step: yarns twisted into *strand* (or twine)
3rd step: strands twisted into *twine* (or rope)
4th step: twines twisted into *cord* (or cable)

Thus nets are normally made of "twine".

When describing the various properties of net materials, ***total extension*** is the increase in length under load. This may consist of ***elastic extension*** (recoverable on release of stress) and ***permanent elongation***.



Seed Fibres	Stalk Fibres	Leaf Fibres	Fruit Fibres	Wool	Hair	Silk	Regenerated Cellulose	Cellulose Derivatives	Vegetable Base	Animal Base	Polyester	Polyamide	Mixed Polymerics	Polyvinyl alcohol	Polyvinyl Chloride	Polyacryl nitrile	Poly-ethylene	Poly-urethane
Cotton	Flax	Sisal	Coir				Viscose	Acetate	Alginate	Lanital	Terylene	Nylon	Dynel	Vinylon	PCU	Orlon	Polythene	PerlonU
Kapok	Hemp	Manila					Cupronium	Tri-Acetate	Vicara	Fibrolan	Dacron	Perlon	Saran	Kuralon	PeCe	Acrilan	Courlene	Fibre 32
	Jute	Yucca							Ardil	Casenka	Terital	Grilon	Vinyon	Kannebian	Rhovyl	PAN	Reevon	
	Kennaf	New-Zealand Hemp							Silkool	Caslen	Tergal	Kapron	Harlon	Cremona	Thermovyl	Dralon	Wynene	
	Ramie								Azlon	Merinova	Terlenka	Enkalon	Verel	Mewlon	Vinyon-HH	Redon	Teflon	
										Wipolan	Trevira	Amilan		Synthofil	PeCe-U	Courtelle		
											Diolen	Lilion		Woolon		Crylor		
											Lanon	Caprolan				Dolan		
												Delfion				Prelana		
												Steelon				Wolcrylon		
												Niplon						
												Rilsan						
												Silon						

Table I

New fibres developed since the 1957 Congress and the time of this reprinting are as follows in the different categories mentioned:—Polyester: Tetoron; Polyamide: Dederon; Mixed Polymerics: Krehalon; Polyvinyl alcohol: Hanryo, Trawlon; Polyvinyl Chloride: Tevilon, Envilon, Nip, Chloril; Polyacril Nitrite: Vonnel, Cashmilon, Exlan; Polyethylene: Hi-Zex, Kanelight, Ethylon, Platilon, Pylen, Drylene, Rigidex, Nymplex.

man-made fibres existing today varies very much, as is shown in the following Table:

Natural Fibre	γ *(g/cm.³)*	*Chemical Fibre*	γ
Cotton	1·47–·56	Polyamids	1·12–1·15
Wool	1·31–·32	Polyester	1·38–1·40
Hemp	1·48	Polyacrylinitrile	1·13–1·20
Flax	1·43–·50	Polyvinylchloride	1·35–1·72
Jute	1·43–·48	Polyvinylalcohol	1·31–1·60
Ramie	1·50–·52	Polyethylene	0·92
Natural Silk	1·25–·37	Regenerated Cellulose	1·50–1·60

The following relations exist :

$\sigma = P \times Nm \times \gamma$ (kg./mm.²) P = Breaking load in kg.

$= Rkm \times \gamma$ (kg./mm.²) Nm = Yarn count metric

$= 9 \times G \times \gamma$ (kg./mm.²) γ = specific weight (g/cm.³).

With these very different specific weights, the substanc; cross-sections of yarns of equal weight are also different the cross-sectional areas are inversely proportional to the specific weights. When, on the other hand, tenacity values are compared, only the Substance Cross Sectional Area is decisive. Hence in the case of two yarns, twines, etc., made from fibres of very different specific weights, far more accurate and comparable values are obtained by the term "Specific Tenacity" σ, which has long been applied in testing metals and plastics and which represents a force or tension related to the cross-sectional area.

NUMBERING SYSTEMS

The second problem, namely the indication of the diameter or thickness of the yarn, twines, etc., is considerably more difficult because of deep rooted and varying customs and traditions in the various industries and among processors and users.

To achieve mutual understanding, measures and descriptions should as far as possible characterize unequivocally the thickness of yarn, twines, ropes and cordage. Experience shows that the thinner the filament the greater the difficulty in measuring the diameter. Therefore the indirect course was adopted for the fine yarns and filaments. The length and weight of a particular piece of filament was determined in a relatively simple and unequivocal manner. Mathematical calculations made it possible to obtain from these quantities the count, the length per weight, and the titre, etc.

Unfortunately various systems of measurements (cm., g., lb., inch, etc.) still exist so that even in such a small sector of the textile industry as throwsters, rope, cordage and net manufacturers there are a multitude of coexisting and partly confusing count systems in use as, for example:

Nm_B, Ne_B, Ne_L, Nt, Schokker-Nr, m-weight, denier, tex, diameter, circumference (the latter two even in mm. and inches).

It is obvious that these numerous units of measure for the same term are confusing, and are contrary to uniformity and rationalization. However, each industry is very reluctant to give up old customs so that the efforts made to introduce standards make little headway.

The man-made fibres industry has always used the weight count in accordance with the formula:

$$\text{Titre: } Td = \frac{G}{L_1} \text{ (den.)}; \quad G = \text{Weight (g)}$$

$$L_1 \text{ Length (9000 m.)}$$

$$Tt = \frac{G}{L} \text{ (tex)}; \quad L = \text{Length (km.)}$$

The weight count has certain advantages, e.g. for calculating more accurately the twist count of coarser threads. This is also shown clearly by the recommendation of Committee No. 38 (ISO Textiles of the 9th July 1951) which states that in the future a weight count with the units "tex" should be applied and that it would be sensible to adjust this system to metric units of length. The formula for conversion of this new unit of measure into the units hitherto used is as follows:

Conversion Formula

$$tx = \frac{1000}{Nm} = \frac{590{,}541}{Ne_B} = \frac{1653{,}52}{Ne_L}$$

$$= 0{,}111\ Td = \frac{10}{\text{Schokker No.}} = \frac{1}{Nt}$$

Another peculiarity in establishing the count of net yarns and twines, although in general use, is contrary to the standards applicable in Germany, DIN 60900.

A commonly used net twine or cord, is for example, "Nm 20/45". On further consideration, however, it is found that this means a multiple twist (twine or cord) which actually ought to be expressed as follows:

Nm 20/5/3/3

Using the tex unit this would be expressed as follows:

$50\ tx \times 5 \times 3 \times 3$,

which, by simple multiplication, give the total

2250 tx (without loss of length during twisting)

CONSTRUCTION AND NUMBERING OF SYNTHETIC NET TWINES

by

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Abstract

This paper is written from the twine-maker's point of view. The construction of twines is described and the merits of 2, 3 or 4 stranded twines are mentioned. There is also a review of twine size descriptions.

Fabrication et numérotage des fils à filets synthétiques

Résumé

Cette étude est écrite du point de vue du fabricant de fil. La fabrication des fils est décrite et il est fait mention des avantages des fils à 2, 3 ou 4 brins. Les descriptions des dimensions des fils sont aussi passées en revue.

Fabricación y numeración de los hilos sintéticos para redes de pesca

Extracto

En este trabajo, desde el punto de vista del fabricante, se describe en detalle la manufactura de los hilos de 2, 3 o 4 hebras, as como sus méritos. También se pasa revista a las descripciones de la numeración de los hilos.

YARNS

It is sufficient to mention the two main types—

(*a*) Continuous Filament Yarns

These have a shiny, lustrous appearance and the size or length/weight ratio is usually described by denier measurement. Tensile strength varies from 5 grams per denier up to 8·8 grams per denier when tested in the dry state on a straight pull.

(*b*) Staple Yarns

Appearance is similar to cotton because the filaments are cut and spun to form a continuous yarn. Size may be described by reference to French metric count or English cotton count. Tensile strength varies between 2·3 and 3·3 grams per denier according to type of fibre, staple length, method of spinning, and similar considerations.

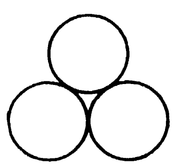
TWINES

Basically the manufacture of twines from single yarns consists of two twisting operations, first twisting together two or more single yarns to form a strand, and then twisting two or more strands together to form a twine. This appears deceptively simple and the following points merit attention:

(*a*) Constructions

Nearly all fish-net twines are made up of 2 strands, 3 strands or 4 strands. The two strand twine has the advantage that the strands cannot become displaced due to one strand "riding" over another. On the other hand, if one strand is slacker than the other, the load falls almost entirely on only half the total number of yarns in the cord. In all two strand twines the interstices are wide and the angle of lay is also wide, so that the twine does not have a round appearance.

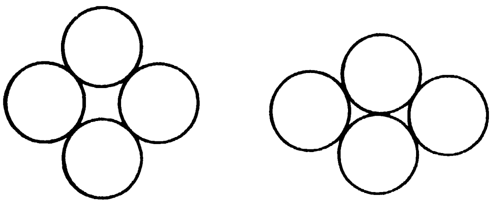
The three strand twine is a construction which is exceptionally stable and free from distortion, the reason being that the sectional view is in the form of a triangle which is not easily pushed out of shape.



a

In spite of the precautions taken in the design of modern machinery, one strand occasionally rides over another and thus creates a fault in the twine. Such faults are infrequent in a good quality product and where they do occur the load is borne by at least $66\frac{2}{3}$ per cent. of the total yarns in the twine. The angle of lay is more acute (compared with 2 strand twines), the interstices are narrower, and the twine has a rounder appearance.

Four strand twines of synthetic fibres give an exceptionally round formation, which some users seem to prefer, but in fact the lay is easily distorted like this:



b *c*

This causes uneven stresses, and there is a tendency for "riding" strand faults to occur frequently.

(*b*) Twist Constants

The suitability of the twine for a particular use is influenced by the amount of twist inserted into the strand and twine. However, mass production methods require that one standard be adopted for all netting twines manufactured in a factory. The twines are therefore a compromise of the characteristics most generally in demand and the economic production possibilities.

Additional twist has four effects:

(i) Breaking strength is reduced
(ii) Extension at break is increased
(iii) Length per weight is reduced
(iv) Resistance to abrasion and general wear is improved.

Every twine manufacturer has to compromise between these factors. It is impossible to have the advantage of item (iv) without sacrificing something as regards items (i) and (iii).

(*c*) Twine Size Descriptions

The most usual description for cotton fish-net twines is to state the counts of the single yarn and the total number of yarns, e.g. 10s/9 means 10s. cotton count, 3 yarns in each strand, 3 strand construction.

Unfortunately, there is no universally adopted description method for synthetic fibre twines, and confusion is the result. Some Japanese manufacturers have used systems similar to that for cotton twines, so that a twine described as 210 Den/60 will probably be 210 denier, 20 yarns per strand, 3 strand construction. Note that the description is not quite explicit, for the construction might possibly be 210 denier, 30 yarns per strand, 2 strands or even 210 denier, 15 yarns per strand, 4 strand. Yet another interpretation would be a cabled strand construction giving 210 denier, 15 yarns, folded 2 ply, 2 strands in cord, or possibly 210 denier, 10 yarns, 2 ply, 3 strands in cord.

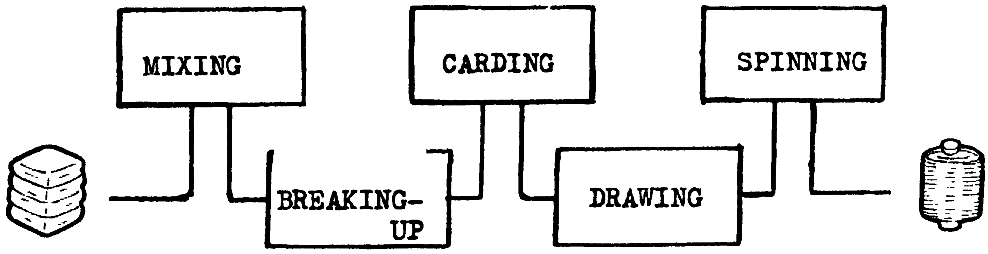
The Fisheries Research Board of Canada has adopted a system which calls for definition by yarn denier, number of yarns in strand and number of strands in twine.

Thus 210-33 means 210 denier, 3 ends in each strand, 3 strand construction. Similarly 210-63 means 210 denier, 6 yarns in each strand, 3 strand construction. No doubt this system is excellent where all persons understand fully that the Fisheries Research Board system is being used. It will be appreciated that in the Japanese system 210-63 could mean 21 yarns per strand, 3 strand construction. Many other systems could be mentioned as examples.

We would suggest that a simple yet effective and easily understood size description system would be to state—

(i) Yarn denier
(ii) Number of yarns in strand
(iii) Number of strands in twine

On this basis 210 denier, 6 yarns per strand, 3 strand would be described as 210/6/3, and it is quite certain that everybody would understand this system, without any additional explanation and without the slightest doubt as to the size and construction required. A further advantage is that if the strands are sub-divided into 2 or 3 plies this can be clearly indicated, e.g. 210/10/2/3 would mean 210 denier, 10 yarns, 2 ply in each strand, 3 strands in twine.



Conversion of fibres into twine.

TERMINOLOGY AND NUMBERING SYSTEMS USED IN JAPAN

by

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Abstract

Technical terms and numbering systems differ from country to country and there exists today no standard for comparison. Fisheries technologists find it difficult to compare the characteristics of materials and gear when studying foreign publications, and placing orders for gear is a problem to the fishermen. It would be beneficial to the whole industry if an international standard of terms and measurements could be agreed upon. As an example, a description is given of the specification of fishing twines now used in Japan.

Terminologie et Systèmes de Numérotage au Japan Utilisés

Résumé

Les termes techniques et les systèmes de numérotage diffèrent d'un pays à l'autre, et actuellement il n'existe aucun talon de comparaison. Pour les spécialistes des pêches il est difficile de comparer les caractéristiques des matériaux et des engins quand ils étudient les publications étrangères. De même c'est un problème pour les pêcheurs quand il s'agit de commander des engins. Il serait bon que toute l'industrie se mette d'accord sur des termes et des mesures standard et internationaux. Comme exemple, il est donné une description de la spécification des fils de pêche utilisés actuellement au Japon.

Terminología y Sistemas de Numeración Usados en el Japón

Extracto

Los términos técnicos y sistemas de numeración difieren de un país a otro, no existiendo en la actualidad normas de comparación. Por estos motivos, los técnicos pesqueros tropiezan con dificultades al cotejar las características de los materiales o de los artes que se describen en publicaciones extranjeras. Estas circunstancias también son un problema para el pescador cuando desea adquirir dicho equipo.

Seria beneficioso para toda la industria acordar la normalización internacional de términos y médidas. Como ejemplo de esto se describen las especificaciones de los hilos para artes de pesca que se usan actualmente en el Japón.

TECHNICAL terms and numbering systems related to fishing gear and its operation often differ from area to area, depending upon customary practices of fishermen. Thus, a standardization of the terms and system is not easy even in a single country and still more difficult on an international scale. In Japan, British measurements are used side by side with the metric system, despite the fact that the latter has been encouraged by the Government for years. However, fishermen of the country prefer their own traditional denominations, taking little heed of the other systems.

It is felt, nevertheless, that simplification of the terminology and the numbering system, once established on an international scale, would make an invaluable contribution to advancement of fishing techniques. It would benefit fishing gear technologists reading foreign publications, and fishermen and others in related industries. Standardized measurements would also eliminate many difficulties between fishermen, experts, gear manufacturers, their export agencies, and so forth in technical assistance programmes.

We would like to make the following suggestions:

1. That Member Governments and their qualified personnel be requested to report to FAO all the technical terms that are used in major types of commercial fisheries in their countries, with descriptive explanations and/or illustrations.
2. That Member Governments be requested to aim at adjusting or simplifying technical terms as much a possible in accordance with a numbering system or on any other rational basis. It would be desirous to set out the relationships between their own systems with those existing in other countries.
3. That the Secretariat of FAO compile and publish, on the basis of the reported data, regional classifications of the terms, numbering systems, conversion tables and any other pertinent reference, for distribution among the countries interested.

It is suggested that FAO endeavour to extend advice and assistance wherever needed on how to indicate standards for fishing materials and equipment.

Furthermore, we hope that Fisheries Division of FAO will encourage the Member Governments to promote standardization in the various methods and procedures now employed in the different fisheries research organizations in experiments on fishing materials, equipment and methods, so that the results can be brought to a comparable basis.

Such action would be in accord with the work of FAO in promoting the use of modern fishing gear and techniques throughout the world.

SPECIFICATIONS OF FISHING MATERIALS IN JAPAN

So far as Japan is concerned, this is how we specify various items of fishing gear materials:

1. Raw Material: the raw materials used for fishing nets and ropes are:
   - 1-1. Cotton (American, Indian or Egyptian cotton)
   - 1-2. Flax 1-3. Hemp 1-4. Ramie 1-5. Manila
   - 1-6. Sisal 1-7. Maguey 1-8. Coir 1-9. Rice straw
   - 1-10. Silk 1-11. Synthetic fibre (Nylon, Vinylon, Vinylidene, etc.)
   - 1-12. Others
2. Yarn Number: different counts of yarn are used according to kinds of raw material:
   - 2-1. For Cotton: English count system is used, in which

     $$\text{Count number } N = \frac{840 \text{ yards} \times N}{1 \text{ pound}}$$

   - 2-2. For ramie and flax:

     $$\text{Count number } N = \frac{300 \text{ yards} \times N}{1 \text{ pound}}$$

   - 2-3. For silk and synthetic fibre: Denier system is used, in which
   - 2-4. For synthetic spun yarns: English cotton numbering is used.

     $$\text{Denier number } N = \frac{450 \text{ metres of a yarn}}{0.05 \text{ gr.} \times N}$$

3. Direction of Twisting: Left twist is indicated by 'Z' right twist by 'S'.
4. Degree of Twisting: A degree of twist is indicated by the number of twists in a unit length (0·25 metre). It is ordinarily denoted by terms: soft, medium, hard, or extra hard.
5. Number of Strands: is specified as 2 strands, 3 strands, 4 strands, and so forth. The term "strand" is used as defined in the next paragraph.
6. Denotation of Thread, Twine, Rope and Cord: The following formula may help one understand the relation between various composites of a thread and so forth.

   Fibre, ", " } Yarn
   Yarn, ", " } Strand
   Strand, ", " } Thread / Twine / Rope

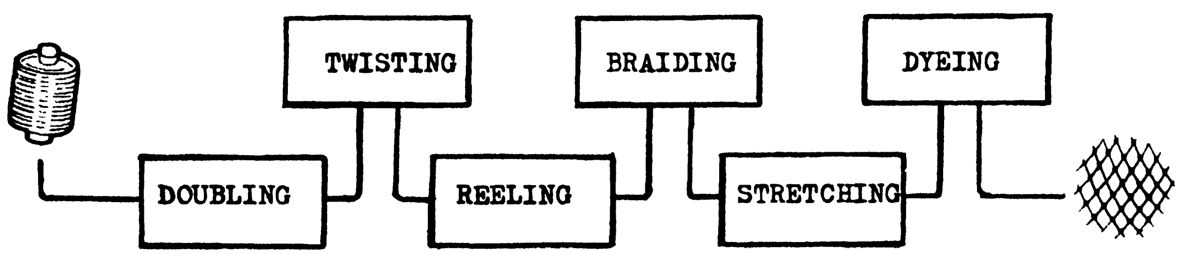
   As seen above, a number of fibres are twisted into a yarn; a number of yarns into a strand, and again a number of strands into a thread, twine or rope. Usually, the term thread is used for small sized material, twine for medium size, and rope for material large in size.
7. Size of Thread, Twine and Rope:
   - 7-1 Diameter system is usually employed for indicating the size of thread and so forth.
   - 7-2 Size of twine and rope is sometimes indicated by the weight for a unit length as "monme"/5 ft. (One "monme" approximates 0·13 ounce or 3·75 grams.)
   - 7-3 Numbering system of cotton thread is also used by counting the number of yarns in one strand. Cotton No. 1 has two strands, one strand consisting of two yarns, but the other numbers of cotton thread have 3 strands.
8. Denotation of Net Material: By use of the above indications, a piece of net material which consists of a thread, for example, count 20, 2 yarns twisted, 3 strands, may be expressed as 20S/2/3 or 20/2/3S. Another example, 210 denier, 6 yarns, 3 strands left twisted thread 210d/6/3 left ply.
9. Conversion Table: of various items pertaining to fishing gear whose indications may vary from case to case, the following has been prepared as an example.

Conversion Table for Size of Yarn, etc.
(Denier to English Count)

Denier	English Count	Denier	English Count
10	531·5	90	59·1
20	265·2	100	53·2
30	177·8	120	44·3
40	132·9	150	35·4
50	106·3	200	26·6
60	88·6	250	21·3
70	75·9	300	17·7
80	66·4	500	10·6
		1000	5·3

Correlation Formulae: $\text{English count} = \frac{5315}{\text{denier}}$

$$\text{Denier} = \frac{5315}{\text{Eng. Count}}$$



Main operation stages in net manufacture.

YARN COUNT OR NUMBERING SYSTEMS

by

BRITISH STANDARDS INSTITUTION

London, U.K.

Abstract

There are many different ways of designating yarn count or number, and these can be classified as either a *direct* system, in which the yarn count or number is expressed in terms of its mass per unit length or an *indirect* one, in which the count or number is stated in terms of its length per unit mass. It has been recommended that the Tex system should be universally used and, as it will take some time to implement this recommendation, it is suggested that whenever the traditional yarn count or number is used, the Tex equivalent should also be quoted. Conversion tables are given for changing from one system to another.

Systèmes de numérotage des fils

Résumé

Il existe un grand nombre de types de numérotage des fils. On peut les classer suivant deux méthodes: le système *direct* dans lequel le numérotage du fil est exprimé d'après son poids par unitè de longueur, ou le système *indirect*, dans lequel il est exprimé d'après sa longueur par unité de poids. On a recommendé l'adoption universelle du système TEX et, en raison du délai nécessaire à sa mise en application, il est suggéré de mentionner également l'équivalent d'après le système TEX, chaque fois que l'on utilise le numérotage traditionnel des fils. On trouve dans cet ouvrage des tables de conversion permettant de passer d'un système à un autre.

Sistema de numeración de los hilos

Extracto

Las sistemas de numeración de hilos pueden clasificarse en *directos*, o sea, expresando el número en términos de su peso por unidad de longitud o, *indirectos*, considerando la longitud por unidad de peso. Se ha recomendado adoptar universalmente el sistema "Tex" (peso de 1 Km. de hilo expresado en gramos) pero como esto tomará tiempo, se sugiere que al utilizar el sistema de numeración también se dé el equivalente en unidades "Tex".

En el trabajo también se incluyen tablas de conversión para los diversos sistemas.

THE many ways of designating yarn count or number may be classified into two systems, (a) the Direct System in which the yarn count or number is expressed in terms of its mass* per unit length, and (b) the Indirect System in which the yarn count or number is expressed in terms of its length per unit mass.

With the increasing use of yarns containing more than one kind of fibre and of fabrics containing yarns made from different fibres, it has become evident that the adoption of a single yarn count or number system would avoid confusion and save time.

The International Standards Organization conference held at Southport in 1956 recommended that a universal direct system should be adopted by all member nations and that it should be the Tex system described below.

Inevitably, some time will be required to implement this recommendation. It is therefore suggested that *wherever traditional yarn count or number is mentioned, the equivalent Tex value should be given in brackets.*

TEX SYSTEM

The yarn number in the Tex system is obtained by dividing the weight of a given length of yarn (expressed in grams) by its length in kilometres; the unit in this system is the Tex multiples and submultiples recommended in preference to other possible combinations are mg. per km., named millitex, and g per m or kg. per km., named kilotex. Where a symbol is needed (e.g. in formulae) to represent the yarn number in Tex, it is recommended that this symbol should be the capital letter N.

DIRECT SYSTEMS

System	*Unit of Mass*	*Unit of Length*
Tex	Gram	Kilometre
Denier	gram	9,000 metres
Linen (dry spun), Hemp, Jute	pound	14,400 yards (spindle)

INDIRECT SYSTEMS

System	*Unit of Length*	*Unit of Mass*
Cotton (British)	840 yards (hank)	pound
Cotton (Continental)	1,000 metres	½ kilogram
Linen (wet spun)	300 yards (lea)	pound
Metric	kilometre	kilogram

CONVERSION

Within either direct or indirect systems, conversion from one yarn number to another is done by means of multi-

* The term mass is normally used to describe the quantity of matter in a body: the term weight describes the force exerted by gravity on a body. To continue to use the word weight when one means mass leads to confusion when the yarn number is used in derived quantities such as tenacity.

Based on B.S. 947 Yarn Count Systems and their conversions.

plying factors. These factors can be conveniently arranged in tabular form.

Table I gives the multiplying factors for converting from one to another of selected direct systems.

TABLE I

Multiplying Factor for Converting from one Direct System to another

Known yarn number in	*Multiplying factor to give yarn number* Tex	Denier	Linen (dry spun) Hemp, Jute
Tex	1	9.000	0·29 03
Denier	0·111 1	1	0·003 225
Linen (dry spun), Hemp, Jute	34·45	310.0	1

Example: The equivalent of yarn number 10 in the linen (dry spun) system is the yarn number 10 × 34·45 or 344·5 in the Tex system.

Table II gives the multiplying factors for converting from one to another of selected indirect systems.

TABLE II

Multiplying Factors for Converting from one Indirect System to another

Known count in	*Multiplying factors to give equivalent count in* Cotton and Spun Silk	Linen (wet spun)	Metric Count
Cotton and spun silk	1	2.800 0	1·693 4
Linen (wet spun)	0·357 1	1	0·604 8
Metric	0·590 5	1·653 5	1

For conversion from an indirect system to a direct system, and vice versa, a constant into which the known yarn number is divided is necessary. Commonly required constants are set out in Table III.

TABLE III

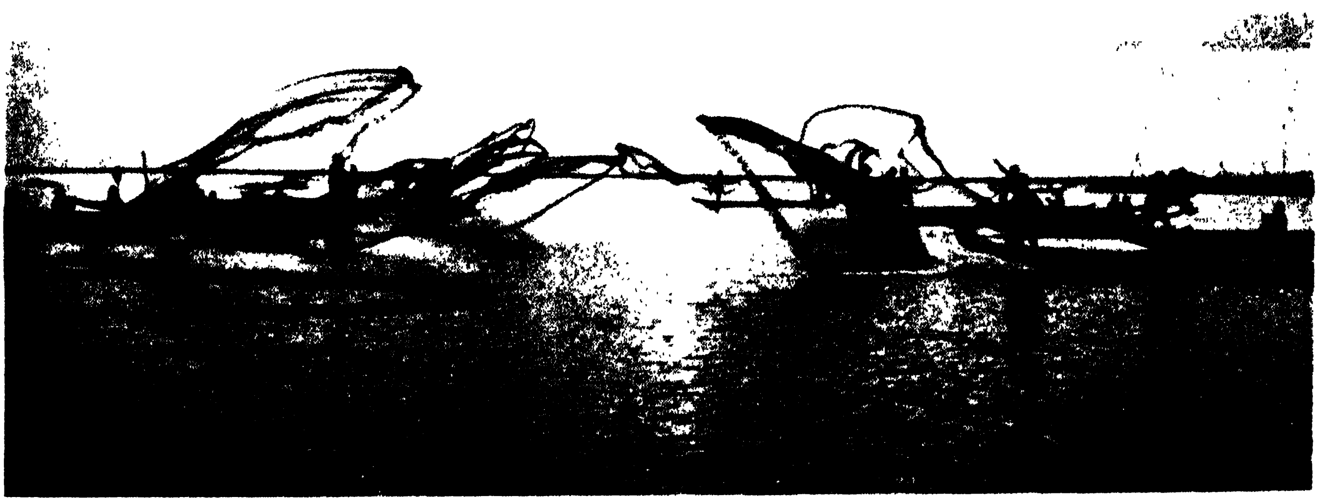
Selected Constants for Converting from Direct to Indirect Systems and Vice Versa

	Constant into which the known yarn count is divided in order to obtain the equivalent yarn number in the other systems Tex	Denier	Linen (dry spun) Hemp, Jute
Cotton and spun silk	590·5	5 315	17·14
Linen (wet spun)	1 654·0	14 880	48·00
Metric	1 000·0	9 000	29·03

For the conversions from British units to metric units and vice versa the following equivalents have been used:

1 yard -- 0·91440 metres

1 lb. 453·592 grams



Throwing cast nets on a lake in Indonesia. Photo FAO

TERMINOLOGY AND NUMBERING SYSTEMS — DISCUSSION

Mr. J. E. Lonsdale (U.K.) Rapporteur : Just as in this room we speak many languages, so do we have many ways of describing fishing gear, fishing methods and the properties of fishing materials. There is a need for all interested in fishing to know what other people mean when they talk about these subjects, particularly when they must compare the properties of different types of net. This concerns not only the fishermen, who want to compare the various fibres and textile materials from different countries, but also scientists and manufacturers.

The first difficulty is that of translation. It is often impossible to find correct translations for technical words which carry exactly the same meaning. These papers make no specific references to the difficulties of translation but a good deal of work on this problem has been carried out by the Institut für Netz-und Materialforschung, Hamburg; their Paper No. 77 deals with fishing gear nomenclature. The next difficulty is in the use of trade names, variations occurring even in one class of textile fibre, from country to country and from manufacturer to manufacturer.

The papers before us give us two main ways of describing the properties of textiles. The first is the *strength* of the net or twine, and the second is the *weight* of the net or twine which is, of course, of importance commercially. But firstly the size of the yarn, and then the size of the twines must be described.

To clarify the terms "twine" and "yarn" I will adopt the definition given in Dr. van Wijngaarden's paper (No. 6). A "yarn" is a continuous strand of fibres and/or filaments from which all twist, if any, can be removed in one untwisting operation, and "twine" is the product of twisting together two or more yarns. The basic yarn may be a continuous monofilament, a continuous multifilament, or a yarn spun from short lengths of fibre.

Yarn Size. The size of yarns cannot easily be described by thickness and diameter because of the practical problems involved. It is more common to describe size by the weight method either directly, that is by giving the weight for a fixed length, or indirectly, by comparing it to a yarn of standard size.

The main systems in use throughout the world are:

(1) *The Tex System.* Tex is a theoretically attractive unit but is not yet in practical use. It is attractive because it is a c.g.s. unit, a metric unit based on centimetres and grams. The tex is the weight in grams of one kilometre of the yarn.

(2) *The Metric System* (Nm.) giving the number of kilometres of the yarn which weigh one kilogram. It is therefore a reciprocal of tex multiplied by 1,000. You will notice that in the case of tex the heavier the yarn the greater the number, but in the case of Nm. the heavier the yarn the smaller the number.

(3) *The Denier System* (*den.*) is in very widespread use. This is the weight in grams of 9,000 metres of the yarn. This is also a c.g.s. unit, but introduces a factor of 9.

(4) *The English Cotton Count* (N.e.) which is an indirect non-c.g.s. system and is the number of hanks, each of 840 yards which weigh one pound.

Mr. Shimozaki (Paper No. 75) suggests relating twine thickness to a cotton yarn of 20's cotton count—a size in common use. The size will then be called the C20 equivalent.

The papers give some 25 other methods of describing size, but fortunately not all of these are used in fishing technology. This does raise the important question of whether there should be one or possibly two international methods of measuring size, and what attempts should be made to rationalize systems of size numbering, particularly in view of the international nature of fishing. There is a natural reluctance on the part of manufacturers to change from their old standard of measurement. The paper that puts forward the advantages of a tex system (52) suggests that it should first be introduced as an addition to the older systems. This subject of standardization has been worked on by textile bodies for a number of years and among those who have made recommendations on the subject are the Bureau International pour la Standardisation de la Rayonne et des fibres synthetiques, the American Society for Testing Materials, BISFA, the British Standards Institute, the Textile Institute and a number of other bodies. Suggestions for standardization come mainly from technologists and fibre manufacturers. The papers before us do not reveal what the fishermen think about this subject.

Construction. A number of methods exist to describe the construction of the twine from individual yarn. Examples of methods for describing the same fishing twine are as follows:

(1) 100 Tex Z 200 × 2 S 300 × 3 Z 400

The term 'Z' and 'S' refer to direction of twist, and fortunately are now fairly standard. The numbers 200, 300 and 400 refer to the degree of twist in turns per metre.

(2) 210 × 2 × 3

This is similar to the first example, but omits twisting descriptions.

(3) 210 × 23 denier

This is referred to as size 23.

(4) 1,260 denier

This being the total denier.

(5) 126—obtained by dividing the gross denier by 10.

From the papers it would appear that the lengthy and accurate way serves a different purpose to the shorter way, but obviously the quick method (which appeals to fishermen) can lead to confusion. Perhaps there is a need to standardize on two methods, a longer one for manufacturing purposes and a short one for commercial use.

An important part of the papers is devoted to the *measurement* of strength. The strength of a twine is expressed as the breaking load in pounds or kilos. To compare different yarns or twines, it is necessary to express the load divided by the size of the yarn or twine. Usually size is measured by the weight system just mentioned. However, it is also an advantage to choose other expressions so as to compare different textile fibres more easily. These points are very fully discussed in the papers, particularly by Stutz (79), Arzano (80), and Carrothers (16). Two useful units for strength measurement often mentioned in the papers are, first the length of twine whose weight equals the breaking strength of that twine, i.e. breaking length. Second, there is the unit which is related to the breaking length by specific gravity, so as to compare fibres of different specific gravities. This measures the load per cross-sectional area. All these strength measurements are further complicated by whether c.g.s. units or other units are adopted.

Apart from the papers listed in the programme, Papers Nos. 16, 80, 95 and 104 also have some relevance to this subject.

Dr. A. von Brandt (Germany): In Germany there are three main numbering systems for materials: the English cotton number; the metric number; and the denier system. Sometimes other numbers are invented by the net makers themselves. Three papers propose the tex number. One proposes that the tex number should be in addition to the national numbers. That is, I believe, a good idea and could help us to understand each other. On this subject, one should hear not only the textile people but also—and more important—the fishermen and net makers.

Mr. H. Warncke (Germany): My firm is a net manufacturing company. We have found no major difficulty in interpreting any definition given either by the English, metric or denier systems. However, a designation of international importance should be useful, and as a net maker I feel that the system used should be followed by a tex number in order to accustom the fishermen to the new system, and thus make way for the eventual use of the tex system alone.

We use the metric system for the Federal Republic of Germany and inside the factory, and the English system in the trade with foreign countries. In the net industry the composition of twine is mainly given by one size only, and this complicates the use of the tex system. For instance, the English term 9-ply, which is always 3 times 3 strands, is merely designated by '9', without specifying the composition of the twine. This, however, has been found sufficient to meet our requirements.

Mr. H. C. Smith (Netherlands): As a net maker, I fully agree with Mr. Warncke. Great confusion is caused by these numbering systems and we feel it would be in the best interest of the fisherman if all the net makers adopted the tex system. I am not in favour of using two systems; i.e. the old system followed by the tex system. We have to get the fishermen used to one system and I think it should be the tex system. It will certainly take some time, maybe 2 or 3 years, before the public will become accustomed to it, but it will contribute to a better understanding of the numbering of yarns.

STATEMENT FROM NETHERLANDS

Apeldoornse Nettenfabriek (Netherlands): in a written statement on a plea for a universal numbering system. He set out that four classification systems are officially and universally applied to yarn.

1. The English yarn number (Ne_1) for the classification of cotton yarns and spun yarns, manufactured from synthetic fibres.
2. The English yarn number (Ne_2) for the designation of linen and hemp yarns.
3. The metric yarn number (Nm) for the designation of cotton yarns and spun yarns from synthetic fibres.
4. The denier system for the designation of yarns from continuous filament synthetic fibres, such as nylon.

It is difficult even for experts in the industry to convert one numbering system to another to compare yarns. As far as synthetic yarns are concerned, it is often impossible to make a comparison on the basis of the number indication only. The composition of a yarn must be established by a test. How confusing therefore must the numbering be for the fisherman who has to be certain he buys the right yarn.

It would be logical and most profitable to adopt the Tex system, rather than add it to the existing systems.

The Tex numbers should also indicate how the yarn has been composed.

This can be affected by indicating the twined yarns by numbers and/or figures, connected by an X-mark and preceded by the indication Tex, Millitex and Kilotex The numbers in order of sequence could show:

1st: which yarn has been used for the construction of the finished yarn in units of the Tex system.
2nd: how many threads are twisted for the first twining.
3rd: whether the second twining is 2, 3 or 4-ply.
4th: the direction of the twist, indicated by the letters s and z behind each number.

This system of yarn numbering, if practised universally for twined yarns, would enable the manufacturer and the trader to use the same numbering and would make a comparison between various yarns and different raw materials much easier because all numbers would be indicated in Tex units.

Some examples by way of illustration

Old system

Ne_1 20/12 cotton 3-ply z-z-s.
Ne_1 20 = Tex 29,4, rounded off to e.g. Tex 30.
Twist of yarn z, 1st twining z, second twining s.

New system

Tex 30z × 4z × 3s cotton or
Tex 30 × 4 × 3 z-z-s cotton.

Old system

Nylon Td 210 × 24 3-ply z-s.

New system

Tex 23 × 8z × 3s nylon or
Tex 23 × 8 × 3 z-s nylon.

Mr. H. Kobayashi (Japan): As far as Japan is concerned, the denier system is preferred for monofilaments as well as continuous multifilaments, while English count is used for spun nylon yarn and also for cotton yarn.

Mr. Rack (Northern Rhodesia): Our interest is in gillnet fishing and our fishermen are just emerging from very primitive methods. We need a system which will be uniform.

Our fishermen are primarily interested in the following: the diameter, expressed in a constant term; (this is important to the gillnet fishermen who are buying yarn for making and mending nets); the runnage; i.e. the amount of twine he will get to his given weight; and the breaking strength. At present large quantities of twine are sold without even a written guarantee that they are made of a certain synthetic fibre and not a blend of fibres, and it would be our suggestion to introduce Merchandise Mark Acts in which we might invite the manufacturer to state the specification. This would, we hope be one which our government officers could check in our own laboratories.

Mr. S. Krohn-Hansen (Norway): It might be better to use the metric system than the tex system, because then the fishermen know the runnage—how many metres there are to a kilo. The metric system is in use in Norway with other generally used numbering systems, and I would suggest it as an international standard system.

Mr. A. Percier (France): I would support the adoption of the metric system which is the most widely used and because it is easier for the fishermen to learn and would generally be more useful. The Tex and the Tex and Denier systems are more complicated.

Mr. J. K. van Wijngaarden (Netherlands): In the textile industry and in other scientific and technological fields attempts are being made to standardize measuring systems based on the c.g.s. system. The tex system does not only have a following in the textile industry but also throughout the scientific and technological fields.

Mr. A. O'Grady (Australia): We import our netting material, and the fishermen are accustomed to using the English yarn counts number. With the introduction and growing popularity of the synthetic fibres, plus the added problem of import restrictions, we find that a fisherman will deal with a particular firm, changing to another only when that firm is out of stock of what he requires. One firm may perhaps be using the nylon numbering, 210/3; the alternative firm may be using only, say, No. 6 nylon thread number. But instead of making the purchase easier for the fisherman, this simple numbering leads to confusion. Irrespective of what system is decided upon, we should have one only. Initially we might, however, retain the old measuring system which the fisherman knows and also print the new equivalent on the label of the bundle of netting. Eventually the fisherman will get used to the new system and adopt it.

Mr. H. Keller (Switzerland): I am of the opinion that the metric numbering system is the best and most practical for use between the producer and the fisherman. It is almost impossible to devise a system to cover all the characteristics of certain materials.

Captain D. Roberts (U.K.): I am skipper of a Grimsby trawler. Last week I was fishing at Iceland and next week I shall be fishing at Iceland. I like to read publications from Holland, Norway, Germany, besides from my own country, and it takes me a long time to work out the difference of these measurements. From a practical fisherman's point of view, I do not mind what system is used as long as it is one system alone!

Mr. D. Olafsson (Iceland): I would like to support what has been said by various delegates here, on the necessity of agreeing on some unification of the numbering systems. I know the fishermen in Iceland have great difficulties in choosing net materials because of the many different numbering systems used. There is one question I would like to ask: are these discussions going to be followed up by some action by FAO or by some other institution, or are we going to wait indefinitely before we get something practical done? I know that many of the people here would like to see something practical coming out of these discussions.

Mr. H. Kristjonsson (FAO), General Secretary: We have in mind to appoint today a small Working Group to study this complex problem, and report back to the Congress on Saturday. What action we can take thereafter depends on the findings of that Group.

This Congress itself cannot pass any binding resolutions: it will be the aim of the Working Group* to indicate a solution to the problem. Various international bodies are directly concerned with the unification of standards, and FAO will collaborate with them.

Mr. J. E. Lonsdale (U.K.)—Rapporteur: To summarise this discussion, the fishermen with one voice have said "let there be a simple and uniform method of numbering".

The fibre scientists and technologists have suggested the tex system, which is not yet in practical use. Between the fibre manufacturers and the fishermen there are the twine and net manufacturers, and any simplification of numbering systems inevitably start in that section.

* Later in the day a Working Group on Terminology and Numbering Systems was formed, consisting of representatives from fibre manufacturers, net makers and gear technologists. Mr. Lonsdale was appointed Chairman.

MAN-MADE FIBRES

The Synthetic Polymer Fibres and Filaments: their general characteristics, chemical and biological properties, with special reference to their use in Fishing Gear

by

R. ARZANO

Chairman of the Industrial Uses Sub-Committee of International Rayon and Synthetic Fibres Committee.

Abstract

This paper deals with the following synthetic fibres: *Polyamides* (Nylon, Perlon and Rilsan); *Polyesters* (Terylene); *Vinyl Fibres* (Saran, Polyvinyl chloride, Courlene and Courlene X3, and Vinylon). Basic information is given about these fibres, with special reference to their uses in fishing gear and also their employment (mixed with cotton or wool) in the manufacture of fishermen's protective clothing. The traditional seaman's jersey can be made of a blend of 50 per cent. viscose staple and 50 per cent. wool, or 15 per cent. nylon, 35 per cent. viscose rayon staple and 50 per cent. wool, and these mixtures can also be used for very serviceable sea-boot stockings.

Les fibres synthétiques

Résumé

Cette communication traite des fibres synthétiques suivantes: *Polyamides* (Nylon, Perlon et Rilsan); *Polyesters* (Térylène); *Fibres vinyliques* (Saran, chlorure de Polyvinyl, Courlène et Courlène X3, et Vinylon). On donne des renseignements fondamentaux sur ces fibres, en particulier sur leur emploi dans les engins de pêche et aussi (mélangées au coton ou à la laine) pour la fabrication de vêtements protecteurs destinés aux pêcheurs. Le chandail traditionnel du marin peut être fait avec un mélange de 50 pour cent. de fibres de viscose et 50 pour cent. de laine, ou 15 pour cent. de nylon, 35 pour cent de fibres de viscose rayonne et 50 pour cent. de laine, et ces mélanges peuvent aussi servir à faire des bas qui sont d'une grande utilité dans les bottes de mer.

Fibras artificiales

Extracto

Este trabajo trata de las fibras sintéticas de los siguientes materiales: *Poliamidas* (nylón, perlón y rilsán); *poliésteres* (terileno); *vinilo* (sarán, cloruro de polivinilo, "courlene", "courlene X3" y vinilón). También contiene información básica sobre estas fibras y su empleo (mezcladas con algodón o lana) en la confección de prendas de vestir para proteger a los pescadores. El tradicional "sweater" marinero puede tejerse con una mezcla de 50 por cent de hilado de viscosa, y 50 por cent. de lana, o 15 por cent. de nylón, 35 por cent de hilado de rayón con viscosa y 50 por cent de lana. Estas mezclan también se utilizan para tejer calcetas muy durables que se usan con botas de mar.

GENERAL

HIGH polymer chemistry, called also macromolecular chemistry, is a very young science, dating back only 35 years. The term "macromolecule" was first introduced in 1922 by Staudinger, who used it to describe the high molecule hydrocarbon obtained by the hydrogenation of natural rubber. Since then a great deal of research has been carried out and eventually, as a result of work started in 1928, W. H. Carothers, discovered a fibre-forming synthetic condensation polymer, for which the name "nylon" was coined. The discovery was made public in 1938.

The researches of W. H. Carothers and his associates led, within a relatively short time, to further important developments in the field of polymers, and to the discovery, by Whinfield and Dickson, of polyester fibres from polyethylene therephthalate (1939-41).

During the period 1939-1940 a great expansion took place in high polymer research. Some old polymers were carefully reinvestigated and many new ones discovered. But the effect of the discoveries and researches made during the 1930s and the 1940s have not yet been fully investigated, and their impact is not yet fully realised.

Besides polyamides and polyesters, the production of many new synthetic fibres—polyethylene, polyacrylonitrile, polyvinyl chloride, polyvinylidene chloride, polyurethanes and various vinyl copolymers—was also started and reached the commercial stage.

The chemical industry was thus given the opportunity of producing a wide variety of new fibres, the characteristics of which could be, to a point, modified in order to make them suitable for specific needs and end-uses. It has been rightly stated by Harold DeWitt Smith[1] that "mankind has initiated a second great textile project, namely, the creation of textile fibres". This implied, however, extensive research for improving, on one hand, the characteristics of the fibres for the various applications and developing, on the other, new uses or expanding already accepted ones.

At the same time the vast industrial expansion of the post-war years called for ever increasing quantities of those specialized products known as "industrial textiles" and imposed more and more exacting requirements. The new synthetic fibres have enabled the textile industry to keep abreast of the increased demand and to meet successfully the particular needs of processes and trades using textiles.

The industrial use of man-made fibres has increased very rapidly. In the United States, industrial uses took a substantial proportion of man-made fibres in the early 1950s; in England, 34 per cent. of all continuous filament man-made fibre yarn went to industrial uses in 1953 and 1954[2].

Industrial textiles comprise, however, a very wide range of products, from cloth for filter presses to conveyor belts, from tyre cords to tarpaulins, from ropes and cordages to boat sails, from cigarette filter tips to fishing nets. Each of these applications requires efficient and lasting performance, under the respective conditions of use, and the textile technologist has to meet very different needs and stringent specifications. In the case of industrial textiles, quality is of paramount importance and where these products are part of a process, a breakdown in performance will at least cost money and may even cost lives. It is imperative, therefore, that quality and performance characteristics be of the highest possible standard.

Not so many years ago, we could hardly speak of a "fishing industry". For thousands of years, fishing had been a handicraft and down the ages the methods and equipment showed little progress. Now the picture has changed, and is changing, rapidly. To keep pace with development, scientific and application research is essential; the more the properties of the various fibres are known, the better we shall be able to employ them in the most useful and appropriate way.

PROPERTIES

The following main properties of fibres are to be specially considered for use in the fishing industry:

- Density
- Tenacity
- Tensile strength
- Knot strength
- Loop strength
- Elastic properties
- Toughness
- Stiffness
- Water absorption
- Effect of: heat
  - age
  - sunlight
  - chemicals
  - sea-water
- Resistance to bacteria, mildew and insects

Density. According to J. T. Marsh[3] "the density of a substance is the quantity of matter contained in unit volume". The relative density is the ratio of comparison between a given substance and a standard one (usually water).

When the C.G.S. System is used (unit of volume : c.c., unit of mass : gram-standard substance : water at 4 deg. C.) the values of absolute and relative densities are identical. Specific gravity and specific volume are reciprocally proportional, so that the lower the density, the higher the bulk and vice versa.

Strength is a general name for defining both tenacity and tensile strength of fibres. The difference between these two terms is clearly stated by Marsh[3] as follows: "Tenacity is the breaking force in terms of the fibre or yarn denier, whereas tensile strength is the breaking force in terms of the unit area." The first is expressed in terms of grams per denier, the latter in terms of grams per square millimetre. In this respect, it must be pointed out that values for tenacity are not directly comparable, as they do not take into account the density of the material; values for tensile strength, on the other hand, are directly comparable.

The breaking force is often expressed as "breaking length" which according to "Textile Terms and Definitions"[4] is: "the length of a specimen whose weight is equal to the breaking load"

The conversion formulae are:

—breaking length (in Km.) = 9 × tenacity (in g/den.)

—tensile strength (kg./mm.^{2}) = breaking length (in Km.) × specific gravity.

Knot strength is the tenacity of a fibre or a yarn in which a plain knot has been tied. As Prof. Viviani[5] points out "the knotting test may give an idea of the transverse strength of the fibre". The ratio of the knot strength to the single fibre or yarn strength gives the effect of bending due to the tying of the knot.

Loop strength. To show to what extent a fibre or a yarn is affected by bending, the "loop strength ratio" is a very useful figure. To determine this value the free ends of linked loops of fibre or yarn are secured in the grips of the testing machine, and the load required to break them is found.

Elastic properties, i.e. extensibility and elastic recovery of a fibre are as important as strength. Too much stress has been placed on tenacity as the most valuable property of textile materials and, although high breaking load is of significance, extensibility is at least of equal importance. An inextensible fibre, or a fibre possessing very poor extensibility—even when combined with high tenacity—is of little actual value, if the extension at break is considered[3]. For the evaluation of a fibre, however, the extension at break is not the only point to be considered; from the practical point of view, the behaviour of the fibre when stressed or extended to a degree not reaching the breaking point is of great value.

The elastic behaviour of a fibre is referred to as Young's Modulus, which is the relationship between stress and strain at loads below the elastic limit. It is expressed in grams of stretching force per denier of fibre (g/den.) and corresponds to the tension required to produce an extension of 1 per cent. The values thus expressed are based on the denier of the fibre and not on the cross-sectional area and may be converted into kilograms per square millimetre by multiplying by 9 times the specific gravity in grams per cubic centimetre.

It must be borne in mind, in this respect, that textile fibres do not obey the physical law (Hooke's Law), according to which strain is proportional to stress or, to be more accurate, they obey this law up to a point, called "yield point" beyond which the fibre exhibits a "viscous or plastic flow". Consequently Young's Moduli are useful for comparison, but only in the region where Hooke's Law applies, when they are "constants".

Elasticity is the power of recovery from strain or deformation. The total extension of a fibre is formed by two components: an elastic extension, which is recoverable on release of stress, and a permanent (or plastic) elongation which is not recoverable. In its turn elastic extension comprises partly "immediate recovery" and partly "delayed recovery", so that the time factor has to be taken into account in determining it.

According to Kornreich[6] "the elastic limit is reached when stress results in a permanent extension, known as 'elongation'". The ability of a fibre to recover from strain is of importance for several end-uses.

Toughness. Of practical importance also is the "toughness", "work of rupture", or "energy absorption" of a fibre. According to Kaswell[7] "the load is a force, the extension is a distance and the area under the load-extension (stress-strain or stress-elongation) diagram is the product of force and distance, or work (energy)". The area therefore depicts the fibre's ability to have work done upon itself, i.e. to absorb energy. The "toughness index" may be just the same for a fibre of high tenacity and low extensibility as for fibre of low tenacity and high extensibility. In general, the higher the "toughness index", the better is the fibre from the standpoint of use, as work of rupture shows the ability of a fibre not only to absorb energy, but also to withstand a sudden load. (i.e. a "live-load").

Stiffness is defined by Harold DeWitt Smith[1] as resistance to deformation. Average stiffness is the ratio of breaking stress to breaking strain; elastic stiffness the ratio of stress to strain at the yield point.

Moisture content affects the physical properties of fibres and, in particular, their tenacity, extensibility, rigidity and swelling. In this respect the hygroscopic nature of fibres, i.e. their power to absorb and desorb water, is of importance, as water acts as a plasticizer to a higher degree for hydrophilic fibres and to a lesser degree, or scarcely at all, for hydrophobic ones.

Water influences the fibres in various forms, e.g. as relative humidity (in the atmosphere), as liquid water (water or imbibition), and as steam; furthermore, the action of cold water is different from that of hot water.

The amount of atmospheric moisture that a fibre is able to absorb when exposed, fully dried, to surrounding air is referred to as "regain" and is expressed as a percentage of the dry weight of the fibres. To ensure that the regain of different fibres be comparative, tests are conducted in a standard atmosphere. "Standard regain" is the amount of moisture a fibre absorbs at 65 per cent. relative humidity at a temperature of 20 deg. C. (international standards). The standard testing atmosphere allows a tolerance of ± 2 per cent. R.H. and ± 2 deg. C.

The moisture content of the fibres affects their tenacity in different degrees. Natural cellulosic fibres (cotton, ramie, linen) show an increase in tenacity from the dry to the wet state; regenerated cellulosic fibres are, on the contrary, stronger in the oven-dry state than moist; synthetic fibres show no significant variation in strength from the dry to the wet state.

Liquid water, entering the fibre structure, causes swelling according to the water imbibition properties which are related inversely to wet-strength. Hot or boiling water affects the plastic properties of the fibres. For most of the synthetic fibres it causes shrinkage and, for some types, even degradation.

The action of steam is dependent upon its temperature and saturation. It has a great influence on the plasticity of the fibres, and it is accompanied by shrinkage, more pronounced with synthetic than with other fibres.

The property of synthetic fibres to shrink under the action of heat (wet or dry) is utilized by a special treatment (thermo-setting) to impart to fabrics and articles a dimensional stability, which is permanent as long as they are not treated at higher temperature than that of setting.

Brief definitions of mechanical properties. It might be useful to sum up briefly the basic mechanical properties of textile fibre materials to be evaluated under the influence of tensile forces as defined by Harold De Witt Smith[1]:

- strength —the ability to support a load
- elongation—the deformation produced by a load, along the line of action of the load
- stiffness —resistance to deformation
- toughness - the ability to absorb work
- elasticity —the ability to return to original shape and dimensions upon cessation of deforming force
- resilience —the ability to absorb work without suffering permanent deformation.

SYNTHETIC POLYMER FIBRES

The physical and chemical properties of some synthetic polymer fibres, all satisfactorily resistant to sea water and fresh water, are given below:

Polyamides: The principal commercial polyamide fibres are:

- polyamide 66 (Nylon) made from polyhexamethylene adipamide
- polyamide 6 (Perlon) made from polycaprolactam
- polyamide 11 (Rilsan) obtained by auto-condensation of ω-aminoudecanoic acid (based on castor oil)

They are produced both in the form of continuous filament yarn and staple fibre, in a wide range of deniers.

As already mentioned, the discovery of polyamide 66 is due to Dr. Wallace Hume Carothers (b. Burlington, Iowa, 1896—d. New York, 1937), who since 1928 had been entrusted with research in the laboratories of E.I. Du Pont de Nemours Co.

It should be mentioned, incidentally, that many suppositions have been made and several explanations (often fantastic) given about the origin of the name "nylon". In a publication of E.I. Du Pont de Nemours Co.[8] it is stated, however, that "the name given to the new product was 'nylon'—a term just as synthetic as nylon itself. It was chosen because it was short, catchy, pleasant to the ear and not easily mispronounced".

Polyamide 66 (nylon) and polyamide 6 (Perlon) yarns and fibres are available in normal and high-tenacity types. The characteristics of each quality and type are as follows:

(A) Polyamide 66 (Nylon)

	Normal tenacity		High tenacity
(1) *Density*		1·14	
(2) *Tenacity* dry (g/den.)	4·5 — 6		6·5 — 8·5
breaking length: dry (Km.)	40 — 54		58 — 76
wet (% of dry)	85 — 90		90
(3) *Tensile strength* (Kg./mm²)	46 — 62		67 — 87
(4) *Knot strength* (% of tenacity)		85—90	
(5) *Loop strength* (% of tenacity)		84—87	
(6) *Extension at Break* %: dry	26 — 32		15 — 20
wet	30 — 37		18 — 28
(7) *Elastic recovery*	100% up to 8%		100% at 4%
(8) *Toughness*	1·08		0·77
(9) *Stiffness* (g.p.d.)	18		32
(10) *Water absorption* at 65% R.H.		4·5%	
at 100% R.H.		7—9%	
(11) *Effect of heat* melting point		250°C	
softening point		235°C	

Effect of age. Virtually none.

Effect of sunlight. Loss of strength on prolonged exposure.

Effect of chemicals. Concentrated hydrochloric acid, concentrated nitric acid, sulphuric acid cause rapid disintegration of the fibre. Phosphoric acid degrades the fibre, at elevated temperatures. Formic acid in concentrations above 80 per cent. will dissolve the fibre.

Acetic acid, oxalic acid, glycollic acid, lactic acid in high concentration have similar effect to that of formic acid. Other organic acids have little or no effect on the fibre.

The resistance to alkalis is outstanding.

Bleaching agents containing available chlorine will cause degradation on the fibre; hydrogen peroxide too causes degration though less rapid.

Solution of neutral inorganic salts have no effect on the fibre, at room temperature. At 100 deg. C concentrated solutions of magnesium perchlorate, lithium bromide or lithium iodide will dissolve fibre. The fibre is inert towards liquid ammonia, sulphur dioxide and cuprammonium solutions.

Petrol, mineral oils, benzene, xylene, ethers, esters, ketones, alkyl halides and mercaptans have no effect, even at elevated temperatures.

Alcohols (except benzyl alcohol), glycols, and aldehydes (except formaldehyde, glyoxal, and chloral under certain conditions) have only a little effect.

Benzyl alcohol, nitrobenzene, chlorhydrins, chloral hydrate, nitroalcohols, and adiponitrile are solvents for the fibre at high temperatures.

Phenols, particularly phenol itself (i.e. carbolic acid), meta-cresol, and cresylic acid are solvents for the fibre.

Resistance to bacteria and fungi. Untreated fibres are immune to attack from all micro-organisms, whether fungi or bacteria (i.e. air borne). Yarns and cords show extreme resistance to attack by marine algae.

Resistance to insects. There is no known instance of insects or moth larvae deriving sustenance from polyamide 66 fibres.

Resistance to abrasion. In the whole field of textile fibres, polyamide fibres have the highest resistance to abrasion.

Polyamide 66 fibres are also produced in the form of staple fibres; the characteristics of these are the same as for continuous filament, except for the following items:

Tenacity: dry (g/den.)	4·1 — 5
wet (% of dry)	85 — 90
Breaking length: (Km.)	37 — 45
Tensile strength: (Kg/mm²)	42 — 51
Total extension: % dry	37 — 40
wet	42 — 46
Stiffness (g.p.d.)	11

(b) Polyamide 6 (Perlon)

	Normal tenacity		High tenacity
(1) *Density*		1·14	
(2) *Tenacity* dry (g/den.)	4·1 — 5·8		6·5 — 8
breaking length: dry (Km.)	37 — 52		58 — 72
wet (% of dry)		85—90	
(3) *Tensile strength* (Kg./mm²)	42 — 60		67 — 82
(4) *Knot strength* (% of tenacity)		85—90	
(5) *Loop strength* (% of tenacity)		85—90	
(6) *Extension at Break*: dry	24 — 30		16 — 24
wet	27 — 34		19 — 23
(7) *Elastic recovery*	100% up to 8%		100% at 4%
(8) *Toughness*	0·67		0·68
(9) *Water absorption* at 65% R.H.		4·8%	
at 100% R.H.		7—9%	
(10) *Effect of heat* melting point		217°C	
softening point		170 - 180°C	

Effect of age. Virtually none.

Effect of sunlight. Loss of strength on prolonged exposure

Effect of chemicals.

Resistance to bacteria and fungi, Resistance to insects, Resistance to abrasion: Similar to polyamide 66 fibre.

Polyamide 6 fibres are available also in the form of staple, which have as in the case of polyamide 66, a lower tenacity and a higher extension than continuous filament.

(c) Polyamide 11 (Rilsan)

Polyamide 11 (Rilsan) fibres are relatively new, as their production was started only a few years ago. For this reason, the data about the properties and characteristics of these fibres are not yet complete.

(1) *Density*	1·04
(2) *Tenacity* dry (g/den.)	4·7 — 5·5
breaking length: dry (Km.)	42 — 50
wet (% of dry)	100%
(3) *Tensile strength* (Kg./mm²)	44 — 51
(4) *Extension at Break* %: dry and wet	25 — 40
(5) *Elastic recovery*	100% up to 8%
(6) *Water absorption* at 65% R.H.	1·2%
at 100% R.H.	3%
(7) *Effect of heat* melting point	189°C
softening point	178°C

(8) *Effect of chemicals.* The resistance to chemicals (acids) alkalis, organic solvents, mineral salts and oxidising agents, is slightly superior to that for polyamide 66 and 6.

In respect to ageing, effect of sunlight, resistance to bacteria, fungi, insects and to abrasion there is no substantial difference between Rilsan, nylon and Perlon.

Yarns, cords and ropes made from polyamides (66 and 6) are already well established in the field of fishing gear, because of their special characteristics, namely high strength combined with extensibility, low absorption of moisture and water, quick drying, outstanding resistance to abrasion, bacteria and fungi and seawater and algae.

POLYESTER FIBRES

The principal polyester fibre is made from polyethylene terephthalate, which was first synthesized by Whinfield and Dickson in the laboratories of the Calico Printers Association, in Great Britain.

Mr. Whinfield designated the fibre "Terylene" for convenience in writing and was surprised that the name has survived.

We report below the data regarding polyester filament yarn:

	Normal tenacity	*High tenacity*
(1) *Density* . .	1·38	
(2) *Tenacity* dry (g/den.)	4 — 5·5	6.0 — 7
breaking length (Km.)	36 — 50	54 — 63
wet (% of dry) .	100%	
(3) *Tensile strength* (Kg./mm²)	50 — 68	74 — 87
(4) *Loop strength* (% of tenacity)	90	80
(5) *Knot strength* (% of tenacity)	70	70
(6) *Extension at Break* dry and wet	27 — 17	15 - 7
(7) *Elastic recovery* .	97% at 2%	100% at 2%
	80% at 8%	90% at 8%
(8) *Toughness* . . .	0·78	0·5
(9) *Stiffness* (g.p.d.) .	23	51
(10) *Water absorption* at 65% R.H.	0·4%	
at 100% R.H.	0·5%	
(11) *Effect of heat* melting point	260°C	
softening point	230 - 240°C	

Effect of age. Virtually none.

Effect of sunlight. Only slight loss of strength on prolonged exposure.

Effect of chemicals. Resistance of a high order to chemical attack; outstanding resistance to mineral and organic acids (expecially hydrofluoric acid). Only fair resistance to alkalis but adequate for most purposes. Resistant to oxidising agents and to organic solvents (except at the boiling point). Most phenols dissolve the fibre.

Resistant to bacteria, fungi and insects.

Resistance to abrasion: ranks second to polyamide fibres only.

Polyester staple fibre is also commercially available; the characteristics are the same as those of continuous filament, except for tenacity and extension, which are respectively lower and higher than for filament yarn.

Vinyl fibres

The first vinyl fibre was described in the literature nearly fifty years ago. Polymer chemistry had first of all to prepare polymers possessing suitable properties for spinning and as a result of a great deal of research and experiments, fibres having satisfactory physical and chemical properties were obtained. From the standpoint of utilization in the fishing industry, the following vinyl fibres are to be mentioned: polyvinyl chloride, vinylidene chloride (Saran), polyethylene (Courlene and Courlene X 3) and polyvinyl alcohol (Vinylon).

We summarize below the main properties of these fibres:

(a) Polyvinyl chloride fibres

(1) *Density* . . .	1·39
(2) *Tenacity* dry (g/den.) .	2·7 — 3·7
breaking length (Km.) .	24 — 33
wet (% of dry) .	100%
(3) *Tensile strength* (Kg./mm²) .	33 — 46
(4) *Loop strength* (% of tenacity)	70%
(5) *Knot strength* (% of tenacity)	70%
(6) *Extension at Break* dry and wet	13 — 30
(7) *Elastic recovery* . .	80 to 85% at 3%
(8) *Water absorption* . .	0·1 at 95% R.H.
(9) *Effect of heat* . .	softens at 110 — 120°C
	shrinkage starts at 60° to 70°C.

Effect of age. Virtually none.

Effect of sunlight. Substantially unaffected after prolonged exposure.

Effect of chemicals. Resistant to acids, including aqua regia and to concentrated (caustic) alkalis. Dissolves or swells in some aromatics, chlorinated hydrocarbons, ketones, esters. Generally good resistance to other chemicals.

Resistant to bacteria, fungi, insects and algae and sea water.

(b) Vinylidene chloride fibres

(1) *Density* . . .	1·70
(2) *Tenacity* dry (g/den.) .	1·5 — 2·6
breaking length: dry (Km.)	13·5 — 23
wet (% of dry)	100%
(3) *Tensile strength* (Kg./mm²) .	23 - 40
(4) *Loop strength* (% of tenacity)	70 — 80
(5) *Knot strength* (% of tenacity)	70 - - 80
(6) *Extension at Break* (%)	
dry and wet .	18 — 33
(7) *Elastic recovery* . .	98 to 100% at 5%
(8) *Water absorption* . .	0·1% at 95% R.H.
(9) *Effect of heat* melting point .	150 — 160°C

Effect of age. Virtually none.

Effect of sunlight. Slight discoloration after prolonged exposure.

Effect of chemicals. Unaffected by most acids, including aqua regia. Affected by some alkalis, including concentrated ammonium hydroxide, and sodium hydroxide. Substantially inert to organic solvents. Generally good resistance to other chemicals.

Resistant to bacteria, fungi, insects, moth larvae, algae and sea water.

(c) Polyethylene fibres

(The data refer to polyethylene yarns produced by Courtaulds Ltd. under the registered trade-names of "Courlene" and "Courlene X 3".)

	Courlene	*Courlene X 3*
(1) *Density* . . .	0·93	0·96
	(i.e. the lowest density of all the synthetic polymer fibres—giving good flotation properties).	
(2) *Tenacity* dry (g/den.) .	1 — 1·5	4·0 — 6·0
breaking length: dry (Km.)	9 — 13·5	36 — 54
wet (% of dry) .	100%	
(3) *Tensile strength* (Kg./mm²) .	8·5 – 12·5	34·5 - 52
(4) *Extension at Break* (%)		
dry and wet .	25 - - 50	20 - 40
(5) *Elastic recovery* . .	90 to 95% at 5%	
(6) *Water absorption* . .	practically none	
(7) *Effect of heat* .	Courlene softens above 90°C; melts between 110° and 120°C.	
	Courlene X 3 (High tenacity) softens at 120°C; melts at 135°C.	

Effect of age. Virtually none.

Effect of sunlight. Loss of strength after prolonged exposure.

Effect of chemicals. Remarkable resistance to attack by alkali, acids, solvents, organic salts, unequalled in this respect by other fibres.

Resistant to bacteria, fungi, insects, moth larvae, algae and sea water.

The abrasion and electrical resistance of Courlene X 3 is very good and both Courlene and Courlene X 3 are flexible at very low temperatures such as 70 deg. C.

(d) Polyvinyl alcohol fibres

Vinylon is the generic term for polyvinyl alcohol fibres: these are produced in staple and in filament.

	Staple		*Filament*	
	Normal Tenacity	*High Tenacity*	*Normal Tenacity*	*High Tenacity*
(1) *Density*	1·26—1·30		1·26—1·30	
(2) *Tenacity* dry (g/den)	4·2—6·0	6·7—8·0	3·5—4·5	7·7—9·2
breaking length:				
dry (Km.)	38—54	60—72	32—41	69—83
wet (% of dry)	77—85%	80—85%	80—90%	80—90%
(3) *Tensile strength* (Kg./mm)	50—70	78—94	41—53	90—110
(4) *Loop strength* (% of tenacity)	35—43%	35—40%	90—95%	58—65%
(5) *Knot strength* (% of tenacity)	60—67%	64—70%	75—80%	39—52
(6) *Extension at break* (%) dry	17—26	13—16	14—19	9—20
Wet	19—30	14—17	14—22	12—22
(7) *Elastic recovery*	75—80% at 3%	78—82 at 3%	70—90% at 3%	85—98 at 3%
(8) *Water absorption* (at 65% R.H.)	4·5—5·0%	4·5—5·0%	3·5—4·0%	3·0—5·0
(at 95% R.H.)	10—12·0%			
(9) *Effect of heat* melting point	220—225°C			
shrinkage	starts at abt. 200°C			

Effect of age. Virtually none.

Effect of sunlight. Loss of strength after prolonged exposure.

Effect of chemicals. Concentrated sulphuric, hydrochloric, formic acids cause decompositions or swelling. Strong alkalis cause yellowing but do not affect strength. Good resistance to organic solvents. Soluble in hot pyridine, phenol, cresol. Resistant to oils.

Resistance to bacteria, fungi, insects: not affected.

Polyvinyl chloride, polyvinyl alcohol and polyvinylidene chloride fibres are being used in making set nets, trawl nets and seine nets. Polyethylene is the only textile fibre that has a specific gravity lower than that of water. Owing to this low density, the diameters of Courlene filaments are greater than those of other textile fibres of the same denier. In the case of 125 denier monofilaments, for instance, the diameters in 1/1000ths/inch are Courlene 5·4, nylon 4·9, acetate 4·5, viscose 4·2.

Courlene and Courlene X3 are used in making ropes of all kinds for use on board ship. The tensile strength is sufficient to make it suitable for most applications, while improvements being made may increase the tensile strength from 4 to 6 g/den. to 8 g/den. The yarn is spun-dyed, which makes it easy to produce coloured ropes; it does not absorb water and therefore does not swell; ice does not form inside it, and snow, etc. can easily be brushed or shaken off. Its specific gravity is low and ropes made from it will float on water. The yarns, being inert, will not support fungal or weed growth.

The fibre is useful where tensile strength and buoyancy are important, as in trawl nets where the upper net will tend to rise of its own volition; it is claimed that consequently fewer floats are required. The fibre has been used both for the main-lines and snoods in longline fishing, and for weaving canvases which do not become hard and are relatively easy to handle in wet, cold conditions. Insoles made from Courlene provide thermal insulation in the fisherman's boots.

MAN-MADE FIBRES AND FINISHES IN PROTECTIVE CLOTHING FOR FISHERMEN

The fishermen are exposed to wet, cold climatic conditions and must, to work efficiently, receive adequate protection. In the past they wore oilskins, made of a heavy cotton, flax or similar fabric, coated with many layers of linseed oil. Today many of the basic fabrics are made from 100 per cent. viscose rayon staple or blends with cotton. The fabrics are produced with good tear and tensile strength and a surface smooth enough to allow even coatings, now generally of p.v.c. All types of garments, such as coats, sou'westers and leggings, are made from them.

One of nylon's chief contributions is as a lightweight base for waterproof clothing. Fabric of 1½ to 2½ ozs./sq. yd. can be successfully proofed with p.v.c. neoprene and polyurethane resins. These cloths have the advantages of lightness, flexibility and a smooth p.v.c. coating which is of special advantage in collar fittings where the fabric may be flat against the wearer's face.

Another innovation is the double textured rainproof jackets, coats and leggings. These are made from two similar fabrics laminated with rubber. The textile fabric provides resistance to abrasion and the rubber lamination provides waterproofing.

The traditional seamen's jersey can be made in a blend of 50 per cent. viscose staple, 50 per cent. wool or 15 per cent. nylon, 35 per cent. viscose rayon staple, 50 per cent. wool. The latter blend has good resistence to abrasion and can be made to resist shrinkage. The same yarns have also been used in heavyweight half-hose and seamen's stockings, comfortable in use and hard wearing.

Yarns made from 100 per cent. viscose rayon staple and viscose rayon/staple cotton blends can be knitted on interlock machines, and lend themselves to coating with vinyl compounds, rubber or p.v.c. Gloves are now made of this type of fabric and also rubber leggings and waders. The fabrics can be raised to give a fleecy lining.

REFERENCES

[1] Harold De Witt Smith—"Textile Fibres—An Engineering Approach to their Properties and Utilization", ASTM Proceedings, 1944.

[2] Douglas C. Hague—"The Economics of Man-Made Fibres", London, 1957.

[3] J. T. Marsh—"Textile Science", London, 1949.

[4] "Textiles Terms and Definitions"—The Textile Institute, Manchester. 3rd Edition, 1957.

[5] E. Viviani and L. Graziano—"Fibre Artificiali e Sintetiche", Turin, 1952.

[6] E. Kornreich—"Introduction to Fibres and Fabrics", London, 1952

[7] E. R. Kaswell—"Textile Fibres, Yarns and Fabrics", New York, 1953.

[8] E. I. Du Pont de Nemours Co.—"Nylon Textile Fibres in Industry", Wilmington, 1947.

CHARACTERISTICS OF SYNTHETIC TWINES USED FOR FISHING NETS AND ROPES IN JAPAN

by

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Abstract

The main physical properties of synthetic netting twine used for fishing gear in Japan are discussed in this paper. The items considered include the sinking speed, breaking strength, knot strength, friction resistance, resistance to sunlight, and seawater, etc. and reference is also made to treatments by tar and resin for improving the characteristics of nets and ropes.

Caractéristiques des ficelles synthetiques utilisées pour les filets et les cordes de pêche au Japon

Résumé

Cet article examine les principales propriétés physiques des ficelles à filets synthétiques utilisées pour les engins de pêche au Japon. Les sujets traités comprennent la vitesse de plongée, la résistance à la rupture, la résistance des noeuds, la résistance à la friction, la résistance à la lumière solaire et à l'eau de mer, etc. et il est aussi fait mention des traitements par le goudron et la résine pour améliorer les caractéristiques des filets et des cordes.

Caracteristicas de los hilos sintéticos usados en la fabricación de redes e hilos en el Japón

Extracto

En este trabajo se estudian las principales propiedades físicas de los hilos sintéticos usados en el Japón para fabricar artes de pesca. Entre los puntos considerados figuran la velocidad de inmersión, resistencia a la rupture y de los nudos, así como al roce, luz solar agua salada, etc. También se mencionan los tratamientos con alquitrán de hulla y extractos curtientes para mejorar las caracteristicas de las redes e hilos.

1. Introduction

FISHING gear is dependent on several factors, such as the fishing techniques to be employed, the fish to be caught, the material for nets and ropes, and so on. With regard to the latter, there are requirements which largely influence characteristics and efficiency of the gear. They are:

- the thickness or diameter of the netting twine;
- the weight of the twine in air and in water;
- sinking speed;
- strength and extension up to the breaking point;
- strength and extension knotted;
- friction resistance;
- resistance to sunlight and seawater;
- knot fastness;
- resistance to factors such as shock, heat, chemicals and fatigue;
- elasticity;
- susceptibility to dye and dye fastness;
- stiffness or handiness;
- plying and fabricating capacity.

In evaluating these properties different methods and means would give different values. Therefore when selecting one kind of material out of a group each attribute must be evaluated with a uniform method which should approximate the actual fishing conditions as far as possible.

The efficiency of a fishing net is partly predictable from the quality of the twine, therefore the results of twine testing will be first described in regard to two of the factors (1) the nature of the fibre, and (2) the number of twists given to the yarn as well as the strand.

2. How to Indicate the Structure and Size of Net Twines

One group of synthetic fibres made of spun yarn just as with cotton or hemp includes Kuralon (Manryo) and Mulon yarns. As in cotton the strands made by twisting the yarn are then again plied to form twine. Most of the synthetic yarns used for fishing nets are made equivalent to English 20's of cotton yarn in size, and are usually of 2 or 3 plies. The size is indicated by the number of yarns used for a strand with the number of strands (e.g. No. 5 with 3 plies), or by the total number of yarns contained in a twine (e.g. 15 yarns in 3 plies). The latter is more often used.

In another group the continuous filaments are plied into strands or threads. Amilan (nylon), Saran, Krehalon, Teviron, Envilon, Kyokurin and Kuralon No. 5 (Manryo No. 5) generally belong to this group. In this case, however, the strand may be formed by a single filament (monofilament) or by yarns consisting of several fila-

TABLE I. **Construction of Some Kinds of Netting Twines**

Material	*Chemical name*	*Construction of yarn and/or strand and twine*
Amilan	Polyamide	$(250D/15F_1 = Y) \times n_1 = S, S \times n_2 = T$
,,	,,	$(210D/15F_1 = Y) \times n_1 = S, S \times n_2 = T$
,,	,,	$(110D/30F_1 = Y) \times n_1 = S, S \times n_2 = T$
,,	,,	$(60D/20F_1 = Y) \times n_1 = S, S \times n_2 = T$
Kuralon No. 5 (Manryo No. 5)	Polyvinyl alcohol	$(500D = F_2) \times n_3 = S, S \times n_2 = T$
Saran	Polyvinylidene	$720D/6F_1 \times n_2 = S, S \times n_2 = T$
,,	Polyvinyl chloride	$1080D/9F_1 \times n_4 = S, S \times n_2 = T$
		$(360D = F_2) \times n_3 = S, S \times n_2 = T$
		$(1000D = F_2) \times n_3 = S, S \times n_2 = T$
Krehalon		$720D/4F_1 \times n_4 = S, S \times n_2 = T$
		$1080D/6F_1 \times n_4 = S, S \times n_2 = T$
		$(360D = F_2) \times n_3 = S, S \times n_2 = T$
		$(1000D = F_2) \times n_3 = S, S \times n_2 = T$
Teviron	,, ,,	$(300D/30F_1 = Y) \times n_1 = S, S \times n_2 = T$
Envilon	,, ,,	$(450D = F_2) \times n_3 = S, S \times n_2 = T$
Cotton	not applicable	$(20's = Y) \times n_1 = S, S \times n_2 = T$
Kuralon	Polyvinyl alcohol	$(20's = Y) \times n_1 = S, S \times n_2 = T$

D : denier.
multifilaments.
monofilaments.
yarn.
number of yarns contained in a strand. Each yarn of this type comprises multifilaments.
strand.
number of strands (usually 3 but sometimes 2 or 4) constructing a twine.
twine.
number of monofilament contained in a strand. The thickness of a strand varies depending on n_3.
number of multifilaments, usually one or two bundles.

ments (multifilament). Amilan, Teviron, and Kyokurin, and small diameter twines of Saran, Krehalon have strands made of multifilament yarns. Kuralon No. 5 and other large diameter twines, such as those of Saran and Krehalon, have strands made of monofilament. Table I illustrates how these yarns, strands and twines are constructed.

In the Table, 250/15F × n_1 of (nylon) Amilan, for instance, means that a strand is made by twisting a number of yarns of 250 total denier, each of which is constructed in 15 filaments. The thickness of a filament in that yarn is 16·6 denier approximately. As a (nylon) Amilan yarn of 210 denier corresponds in thickness to cotton-20-counts (20's), the number of yarn of any other denier in this twine, equivalent to cotton 20's (hereinafter called C20-equivalent), is converted by dividing the total denier of the twine by 210 denier. The twines consist of 3 and sometimes 4 strands, e.g. for some salmon gillnets. Similar calculations can be made for other synthetic fibres produced in Japan.

In all these synthetic products, the numbers of yarn for C20-equivalent twine are obtained by dividing the total denier of the twines with the thickness of the C20-equivalent. It should be remembered, however, that the thickness of C20-equivalent determined for these twines does not necessarily represent, in a strictly physical sense, the true thickness of cotton 20's.

3. Thickness of Netting Twines

No matter how similar may be the indicated thickness of different kinds of twines, the indication does not warrant that they are all alike in diameter, circumference or weight per unit length (Tables III and IV). Naturally, the real thickness of a twine, viz. the whole area of the horizontal section of all the filaments of the twine, varies according to the kind of twine, making it impossible to assess the characteristics of twines on a comparable basis. As, however, no other standard than the conversion into C20-equivalent has become available for the purpose, characteristics of both synthetic and natural twines will be compared with the help of this conventional method.

The thickness of net twines has been measured (Table III) in a wet state. The twines were immersed in water for 24 hours and hung until the water stopped dripping from them. The twines used are generally

TABLE II. **Number of Twist per 30 cm. of Twines**

Number of yarn		4	6	9	12	15	18	21	27	36	45	54	60	75	84
Amilan	A	132	123	111	—	72	69		64	57	51		43	35	
	B	198	189	167		112	124		131	117	104		78	70	
Kuralon (Manryo)	A	—	96	81	—	59	50		44	38	36		33	29	
	B		241	189		115	92		78	62	57		52	49	
Saran	A	—	76	68	64	59	57	—	53	45	33		*25 (66)	23	
	B		135	123	110	98	94		83	75	60		45	41	
Krehalon	A	—	68	63	—	56	51	—	48	46	44		39	36	33
	B		104	100		93	90		87	85	81		75	66	60
Teviron	A	138	90	96	84		60	*51 (24)	—	48			42		
	B	246	202	158	148		123	114		102			84		
Cotton	A	—	102	95	—	75	66	—	60	51	42		38	34	
	B		405	336		264	212		171	135	90		60	53	
Kyokurin	A	81	68	57	51	—	—	42	—	31			—	—	
	B	126	114	95	81			65		52					

A: twist for twine. B: twist for strand.

* The number within parentheses is the number of yarn equivalent in the thickness to cotton 20's, and the number outside parentheses is the number of twist of that twine.

TABLE III. **Diameter of Wet Netting Twines**

(Unit: mm.)

Ply/No. of yarn of C20-equivalent	3/6	3/12	3/18	3/24	3/30	3/36	3/42	3/48	3/54	3/60	3/66	3/72
Amilan	0·68	0·92	1·15	1·37	1·56	1·76	1·94	2·11	2·26	2·41	2·54	2·78
Kuralon (Manryo)	0·83	1·10	1·36	1·60	1·83	2·08	2·23	2·42	2·59	2·75	2·90	3·04
Saran	0·66	0·86	1·03	1·22	1·37	1·52	1·66	1·77	1·88	2·00	2·09	2·18
Krehalon	0·66	0·88	1·05	1·24	1·40	1·55	1·69	1·83	1·95	2·06	2·16	2·25
Teviron	0·70	0·96	1·21	1·43	1·64	1·84	2·03	2·21	2·37	2·03	2·66	2·79
Kyokurin	0·67	0·90	1·08	1·28	1·46	1·63	1·78	1·93	2·06	2·18	2·28	2·40
Cotton	0·78	1·06	1·32	1·56	1·77	1·98	2·18	2·36	2·53	2·70	2·83	2·97

considered to be of medium twist (Table II). Roughly speaking, the twist below that range has about 3 to 5 per cent. greater thickness.

4. Weight of Net Twines in the Air and in Water

(1) *Weight in the air:* In the air, the weight of fishing nets has a close relation, particularly when they are wet, with the loading capacity of small boats as well as with the working conditions for fishermen. Although weight is largely governed by the thickness of the twine, mesh size and type of knot, a table of weights prepared by actually weighing nets in use is useful reference. In preparing such a table, the weight per metre of dry twine and the rate of weight increase for wet twine may be taken as the basis for estimating the wet weight of various types of nets.

The wet weight of a net in air can be obtained by multiplying the known dry weight of the net with the ratio W_w/W_d, as in Table IV.

The situation is somewhat different with nets processed with resins. The amount of water that sticks to the nets differs according to the kind of fibre and thickness of the resin coating as well as the water absorption or repellency of the resin, so that it is difficult to estimate the wet weight of a net. However, an experiment has proved that resin-processed nets gain in weight over those not processed by 30 to 80 per cent. which includes the weight of the resin adhering to the material.

Coal tar treated nets in dry state are 70 to 150 per cent. heavier than non-treated nets. If the coal tar is diluted with creosote or gasoline, the weight gain is approximately from 50 to 100 per cent. Use of a centrifugal machine when dyeing can reduce the amount of tar on the net and bring the weight gain down to 60 to 80 per cent.

(2) *Underwater weight:* Increase in underwater weight of twines implies a quicker sinking capacity and in some cases a better shape of the net. This is an important quality for fixed nets, purse seines and stickheld dip nets. Table V presents the underwater weight of various kinds of netting twines on the basis of the unit length of one metre measured in air. In the case of webbing, the same relation may be expected between synthetic twines and cotton (Wo/Woc) and between tarred synthetic and tarred twines (Wt/Wtc.)

5. Sinking Speed

Sinking velocity, an important factor especially for such types of nets as purse seines, has a close connection with the thickness and specific gravity of the raw material, is affected by the degree of twist given to the yarn, strand and twine, and by the smoothness of the twine surface. In a sinking speed test, a piece of twine, 2 cm. long with each end glued, was immersed in water for 24 hours. The air bubbles were then removed from the surface of the twine. The terminal velocity shown by the test piece in sinking straight down in a salt solution (specific gravity 1·020) was then determined (fig. 1). The solid line indicates the sinking speed of non-treated twine, and the dotted line the sinking speed of the tarred twine. It is obvious that the velocity differs even between the same kind and quality of twines depending upon the thickness of the twines as well as on the nature of the raw material, the number of twists, twisting technique, dyeing and/or heating.

Table VI shows comparative sinking speeds for various twines. The coal tar treatment, which was first used for cotton twines to increase the sinking speed by preventing water absorption, has been found still more effective

TABLE IV. **Weight of Dry or Wet Netting Twines**

Items	*Amilan*	*Kuralon*	*Saran*	*Krehalon*	*Teviron*	*Kyokurin*	
Wd (mg/m)	25·0 × n	36·0 × n	46·6 × n	45·3 × n	38·0 × n	35·0 × n	35·0 × n
Ww (mg/m)	34·0 × n	64·8 × n	50·5 × n	50·3 × n	50·0 × n	-	57·5 × n
Ww/Wd	1·36 × n	1·80 × n	1·08 × n	1·11 × n	1·32 × n	-	1·64 × n

Ww : wet weight.
Wd : dry weight.
n : number of yarn equivalent in the thickness to cotton 20's.

TABLE V. Underwater weight of Netting Twines

Items	*Amilan*	*Kuralon (Manryo)*	*Saran*	*Krehalon*	*Teviron*	*Kyokurin*	*Cotton*	*Manila Hemp*
Wo (mg/m)	3·33 × n	6·70 × n	17·7 × n	17·2 × n	8·35 × n	11·8 × n	12·8 × n	10·8 × m
Wo/Woc	0 [illegible]	0·52	1·38	1·34	0·65	0·92	1·00	0·84
Wt (mg/m)	8·[illegible] n	13·2 × n	24·2 × n	23·7 × n	15·7 × n	—	25·4 × n	21·8 × n
Wt/Wtc	0·32	0·52	0·96	0·94	0·62	·	1·00	0·86
Wt/Woc	0·62	1·03	1·89	1·85	1·24	—	1·98	1·70
$\frac{Wt - Wo}{Wo} \times 100$ (%)	140	97	37	38	88	—	98	102

Wo : the weight of non-treated netting twine.
Woc : the weight of non-treated cotton twine.
Wt : the weight of tarred twine.
Wtc : the weight of tarred cotton twine.
n : number of yarn equivalent in the thickness to cotton 20's.
m : monme. One monme equals 3·75 gr. The number of monme per 151·5 cm. in abaca twine are used as the unit of thickness in Japan. One monme of abaca twine is equivalent to 66 yarns of cotton 20's.

when applied to some synthetics. For this reason, coal tar and similar products are widely used in Japan.

About 80 per cent. tar adhesion results in the quickest sinking speed[1] while, according to our experiments, twines over or undercharged with tar sank slowly.

6. Tensile Strength of Net Twine, and the Knot Strength

(1) *Differences in strength:* Tensile strength of twine depends upon that of the raw material used, whether the twine consists of short or long fibres, and on the number of twists given to the strand and twine. The balance between the primary twist for making the strands from the yarns and the secondary twist to make the twine from strands is also very important because, while an increased twist augments the tensile strength up to an optimal point, an excessive increase in the twist produces the opposite effect[2]. This also applies to the strength of a fishing net itself.

Among twines with various twists used for fishing in Japan there is a difference of about 15 to 20 per cent. in

TABLE VI

Comparison of Sinking Speed between Non-treated Twines and Tarred Twines

Material	*Items*	*3 plies, 15 yarns*	*3 plies, 30 yarns*	*3 plies, 60 yarns*
Amilan	Vo/Vc	0·57	0·54	0·51
	Vt/Vo	1·68	1·65	1·75
	Vt/Vtc	0·55	0·60	0·66
Kuralon (Manryo)	Vo/Vc	0·74	0·73	0·66
	Vt/Vo	1·88	1·55	1·53
	Vt/Vtc	0·75	0·76	0·77
Saran	Vo/Vc	1·77	1·65	1·50
	Vt/Vo	1·09	1·08	1·07
	Vt/Vtc	1·20	1·18	1·17
Krehalon	Vo/Vc	1·65	1·56	1·43
	Vt/Vo	1·14	1·10	1·10
	Vt/Vtc	1·17	1·15	1·14
Teviron	Vo/Vc	1·43	1·21	1·17
	Vt/Vo	1·20	1·14	1·10
	Vt/Vtc	0·93	0·92	0·92
Kyokurin	Vo/Vc	1·37	1·27	1·21
	Vt/Vo	—	—	—
	Vt/Vtc		—	—
Cotton	Vo/Vc	1·00	1·00	1·00
	Vt/Vo	1·63	1·50	1·38
	Vt/Vtc	1·00	1·00	1·00

The number of yarn is equivalent in the thickness to cotton 20's.
Vo : sinking speed (cm./sec.) of non-treated twine.
Vc : „ „ „ non-treated cotton twine.
Vt : „ „ „ tarred twine.
Vtc : „ „ „ tarred cotton twine.

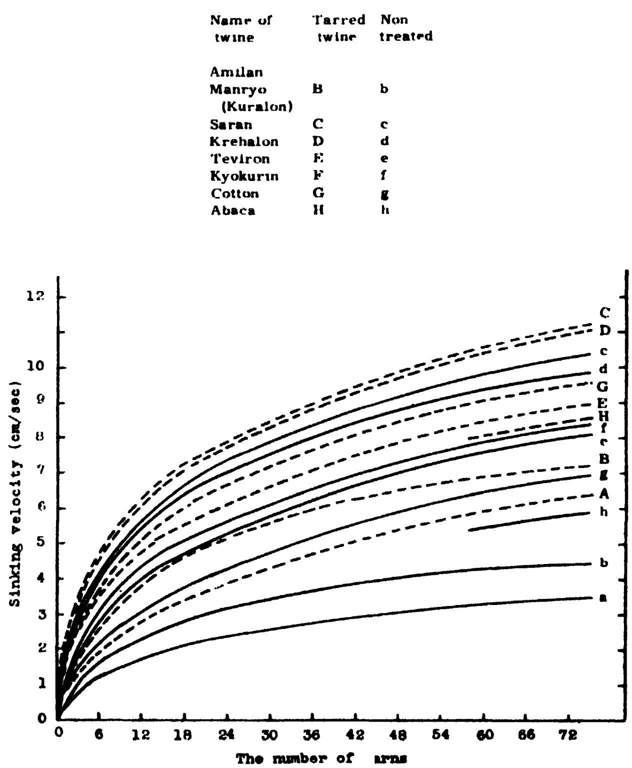


Fig. 1. Relation between the sinking velocity and thickness of netting twines of various kinds. Dotted lines show the sinking velocity of tarred twines, and solid lines non-treated twines.

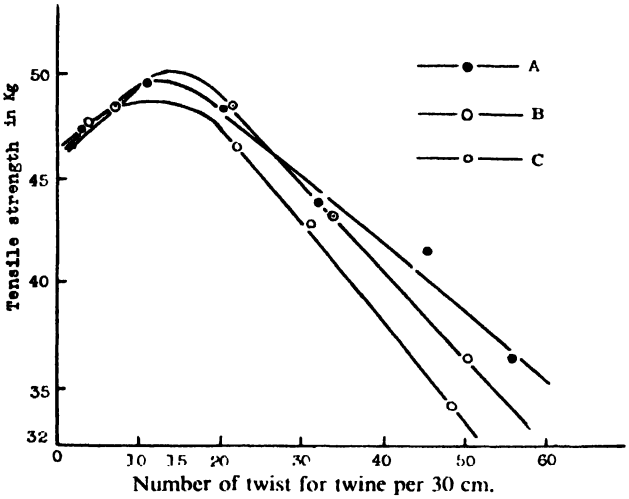


Fig. 2-a. Relation between the breaking strength and number of twists given to twines, A, B and C, 1000 D, 3 plies, 24 monofilaments, produced by different makers.

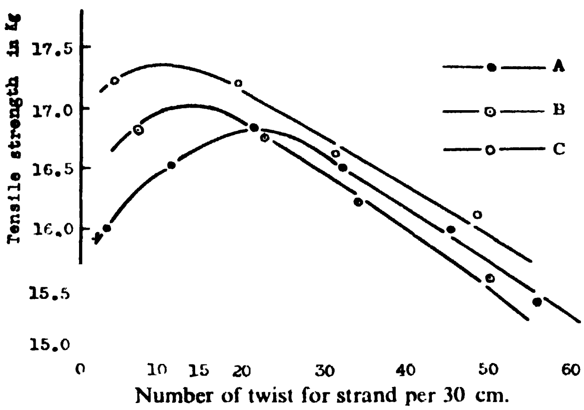


Fig. 2-b. Relation between the breaking strength and the number of twists given to a strand of the twines as of fig. 10.

tensile strength, that is, an overtwisted and weaker twine may be found side by side with a correctly twisted stronger one, as shown in fig. 2. Kondo and Koizumi[3-6] pointed out the same in regard to both cotton and synthetic twines. Even with identical twines, and whether the balance is good or not, there are differences of 10 to 15 per cent. in the tension resistance because of the different numbers of twists. That is why careful attention must be paid to the amount of the twist in the twine when buying fishing nets and ropes[7].

In regard to the difference in the wet and dry strengths of netting twines, an experiment proved that natural fibre twine is about 10 to 20 per cent. stronger wet than dry, but the contrary is true with Amilan and Kuralon (Table VII). With Teviron, Envilon, Saran and Krehalon, the wet twines are slightly (3·5 per cent.) stronger than dry ones[8]. Similar results applied to the tensile strength of knots of fishing nets[9].

Temperature is another influencing factor, the tensile strength of nets decreasing by 10 to 20 per cent. in temperatures between 30 deg. C. and 0 deg. C., and the strength of twines by about 5 to 10 per cent. according to the kind of twine[10]. The effect of temperature on the tensile strength of synthetic twines and knots is greater than on natural twines.

There is a disparity in the breaking strength between twines of less than 50 cm.; the longer the stronger they are, and *vice versa*, whereas between twines of a same material and thinner than 60 yarns of C20-equivalent, there is little difference in the breaking strength[11]. An approximate breaking strain for each twine specified in Table II can be obtained by multiplying $\alpha 1$ or $\alpha 2$ in Table VII with number of C20-equivalent yarn (fig. 3).

(2) *Strength at knot:* A series of tests have been conducted at temperature 18·0 deg. C. + 1·5 deg. C. for tensile strength at knot with 30 cm. long wet pieces of twine. In one test, two pairs of the legs (AB and CD) of an English knot were pulled asunder (figs. 4 to 6). Although not convincing as a proof of the tensile strength of a

TABLE VII

Coefficients α_1 and α_2 for Breaking Strength of Wet or Dry Twines

	Wet α_1	*Dry* α_2
Amilan	0·89	0·94
Kuralon (Manryo)	0·78	0·96
Saran	0·70	0·68
Krehalon	0·60	0·56
Teviron	0·72	0·68
Kyokurin	0·76	0·81
Cotton	0·59	0·47
Envilon	0·76	0·74

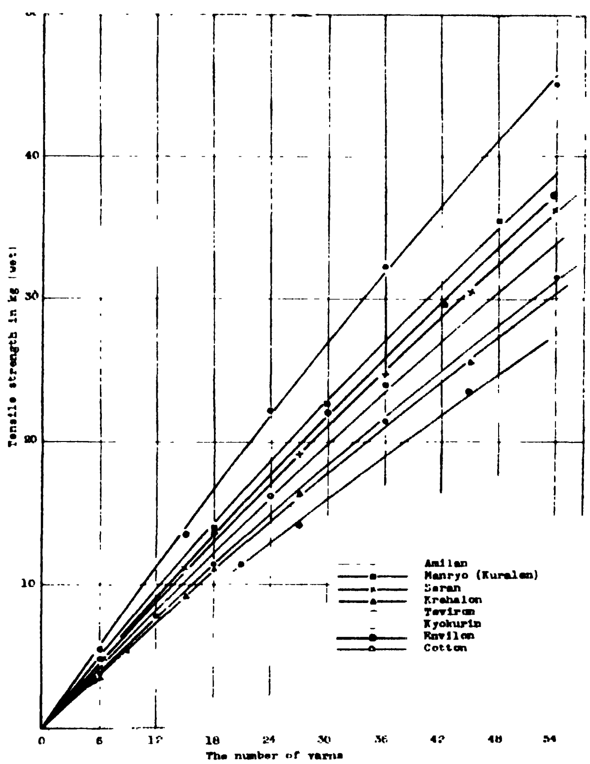


Fig. 3. Wet tensile strength of twines of various kinds, each with the number of yarns equivalent in thickness to cotton 20's.

TABLE VIII

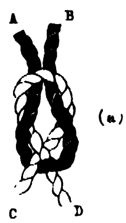
The Constant in Proportion to Tensile Strength at the Knots of Various Kinds of Twines

Kind of knot	*English knot*				*Flat knot*			
*Drawing direction**	*AB — CD*		*AC — BD*		*AG — CD*		*AC — BD*	
β_1 *and* γ_1	β_1	γ_1	β_2	γ_2	β_3	γ_3	β_4	γ_4
Amilan	1·25	30	1·28	28	1·25	30	1·23	31
Kuralon 18	0·86	45	0·93	40	0·93	40	0·77	51
Kuralon 21	0·80	49	0·86	45	0·90	42	0·74	53
Saran	0·78	43	0·83	41	0·78	43	0·70	50
Krehalon	0·76	35	0·79	32	0·74	36	0·68	41
Teviron	0·84	34	0·87	32	0·81	37	0·71	45
Kyokurin	0·93	37	0·97	33			—	—
Cotton	0·97	18	0·99	16	0·96	19	0·86	27
Kuralon No. 5 (Manryo No. 5)	—	39	—	37			—	—

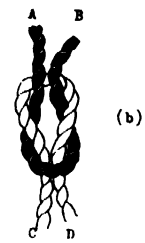
* Drawing direction of test twines is shown in fig. 4.

β_1, β_2, β_3, and β_4 are coefficient of proportion of tensile strength at knots of various kind and in every direction.

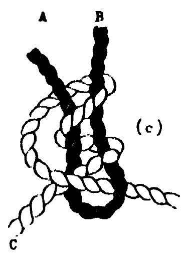
γ_1, γ_2, γ_3, and γ_4 are ratios of decrease in tensile strength of these twines.



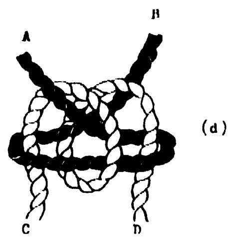
English knot ("Kaerumata" in Japan). This type is most popular all over the world.



Reef knot or Square knot ("Homme" in Japan).



Double English knot ("Niju kaermata" in Japan).



Lock Knot

Fig. 4. Type of Knot.

fishing net, such a test may still be significant enough for comparing the strength of various types of nets webbed by the same knotting technique. The strength of the knots differs considerably according to the type of knot and the directions in which they are drawn[12]. Figs. 7-A and -B show the strength of the various types of knots (a and b in fig. 4) when their legs were strained in either direction, AB apart from CD (lengthwise) or AC apart from BD (crosswise).

Breaking strength of knotted twine can be regarded to be nearly in proportion to n, the number of yarns of C20-equivalent of a twine in which the knot is constructed; coefficients of proportion β_1, β_2, β_3, and β_4 are shown in Table VIII. Decreasing percentage γ_1, γ_2, γ_3, and γ_4 in knot strengths are represented by

$$\gamma_i = \left(1 - \frac{\beta_i}{2\alpha_i}\right) \times 100$$

where α_i is derived from Table VII, and β_i represents any one of β_1 to β_4.

In fig. 4, knots c and d are the types required for repairing broken nets and making gillnets, and nets in which the knots should never work loose. Knot c is called the double English knot, and Knot d the Lock knot. However, the tests showed no noticeable differences in strength between the English knot and those stated above[13]. A study is now under way in connection with the strength of a knotless net.

TABLE IX

Breaking Extension of Wet Netting Twines (Unit %)

Thickness of twines	*3-plies 4-9 yarns*	*3 plies 12-18 yarns*	*3 plies 21-30 yarns*	*3 plies 33-45 yarns*	*3 plies 48-60 yarns*	*3 plies over 63 yarns*
Amilan	30	30	30	32	35	40
Kuralon (Manryo)	21	25	24	24	32	37
Saran	23	25	26	28	28	30
Krehalon	22	25	26	28	30	36
Teviron	18	20	24	24	26	26
Cotton	20	22	24	29	30	32
Kyokurin	21	22	26	28	30	—

TABLE X

Breaking Elasticity at Wet Knot (Unit %)

Number of yarn	4–15				18–24				27–45				48 or more			
Kind of knots	English knot		Flat knot		English knot		Flat knot		English knot		Flat knot		English knot		Flat knot	
Drawing* direction	AB↕CD	AC↕BD	AB↕CD	AC↕BD	AB↕CD	AC↕BD	AB↕CD	AC↕BD	AB↕CD	AC↕BD	AB↕CD	AC↕BD	AB↕CD	AC↕BD	AB↕CD	AC↕BD
Amilan	20	21	21	20	20	22	21	21	25	26	24	23	30	30	28	27
Kuralon (Manryo)	21	22	22	21	22	24	25	24	—	—	—	—	30	30	26	26
Saran	17	18	18	15	19	19	19	18	18	19	19	17	18	19	16	17
Krehalon	18	18	18	16	17	18	19	17	20	20	21	19	23	22	24	22
Teviron	13	13	12	11	19	18	18	17	19	19	18	18	20	20	19	19
Cotton	22	23	21	20	27	28	26	24	30	31	30	28	34	34	32	30
Manila hemp	—	—	—	—	—	—	—	—	12	13	13	11	14	15	15	13
Kyokurin	17	18	—	—	20	23	—	—	20	23	—	—	—	—	—	—
Kuralon No. 5 Manryo No. 5)	—		—				·	—	—	—	—	·	24-26	25-27	·	—

* See Fig. 4 for drawing direction.

(3) *Extension of twine and knots:* The breaking extension of various kinds of twine and their knots is affected by the heating and stretching procedures during twisting (see Tables IX and X). Most of the twines tested were not elongated, except Amilan which was extended 10 per cent.

7. Abrasive Resistance

(1) *The relation of twist to frictional pressure and strength:* Generally speaking, there are two forms of friction which wear down fishing nets: one between net twines at the seam and the knots, and the other against comparatively

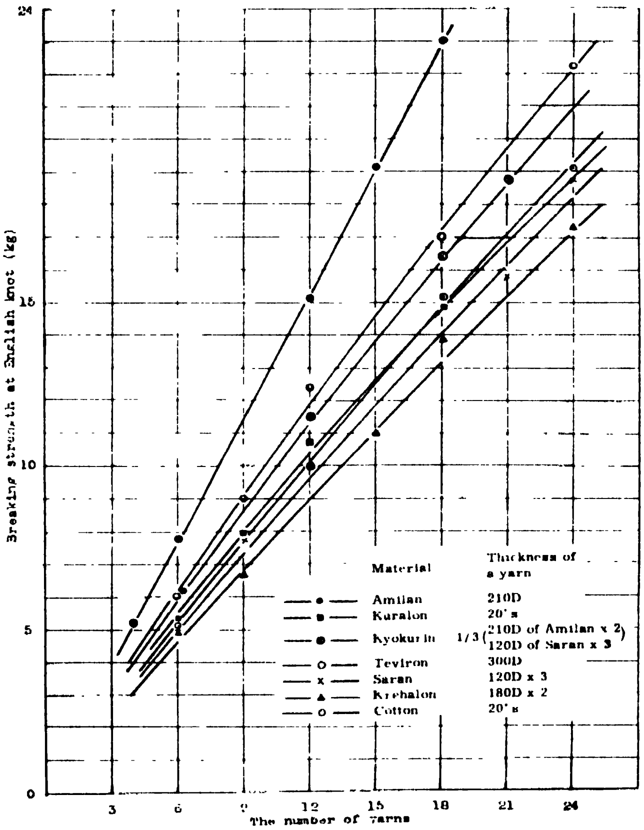


Fig. 5. Relation between wet strength of an English knot and the number of yarns of C20-equivalent less than 24. In the test, two pairs of the legs of the knot, AB and CD, as in fig. 4 were pulled asunder.

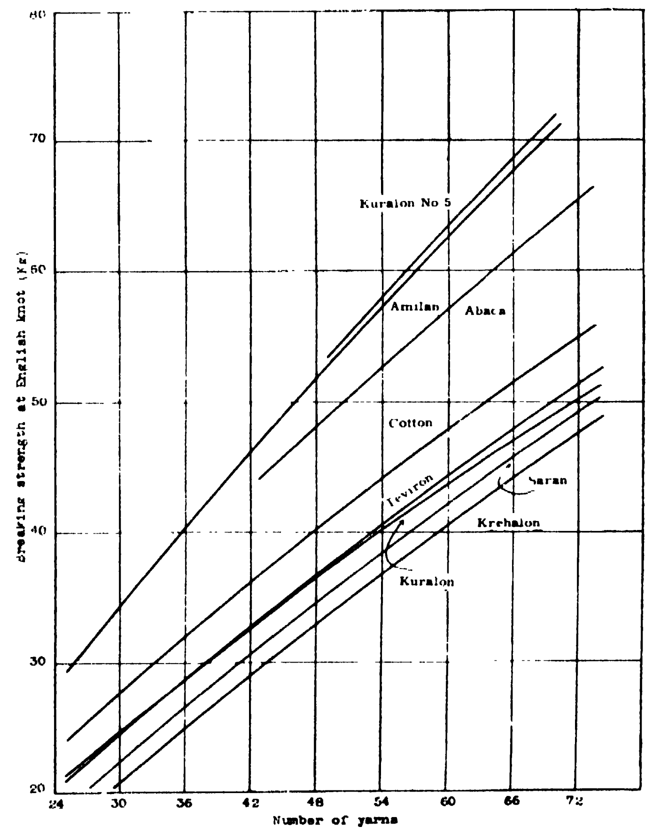


Fig. 6. Relation between wet strength of an English knot and the number of yarns of C20-equivalent more than 24. The pulling direction was the same as in fig. 4.

TABLE XI

Number of Twist of Amilan Netting Twine used for the Wear Test

(Indicated on the basis of length 30 cm.)

Kind of products	*Low Twist (L)* For twine	*Low Twist (L)* For strand	*Low Twist (L)* For yarn	*Medium Twist (M)* For twine	*Medium Twist (M)* For strand	*Medium Twist (M)* For yarn	*Hard Twist (H)* For twine	*Hard Twist (H)* For strand	*Hard Twist (H)* For yarn
A	56·4	39·2	56·3	67·7	65·7	89·7	77·1	68·0	87·0
B	70·0	46·3	66·0	65·8	50·4	65·6	78·5	50·8	69·9
C	54·0	32·3	47·3	51·5	35·7	53·0	64·1	55·4	71·7

A, B and C are the names of the twine manufacturers.

hard substances, such as the sea bottom, hull of the boat, and net or line haulers. The friction between the net twines and hard objects was examined by use of a device shown in fig. 8. In order to keep the temperature constant, water was made to drip on the sample of twine under test. The twine stretched across an oil-stone C fixed on a block. The block was kept moving back and forth between E and F at 80 oscillations per minute, and the number of rubs counted.

The results of these tests with Amilan twines of various twists are seen in fig. 9. The number of twists in the twines is shown in Table XI. Of the twists, those of the strand affect the abrasive resistance most, as they seem to play the greatest role in increasing the rigidity of the twine. Judging from the results, it seems that hard twisted twine should be used in that part of the net which comes into friction with hard objects. The utmost care should, however, be taken to ensure that the number of twists in the strand should not be too much to the detriment of tensile strength for the sake of friction resistance.

TABLE XII

Decreasing Percentage of Strength of the Twines subjected to the seawater and the Sunlight

(Unit %)

Kind of test	*Name of twines*	*Non-treated cords except cotton*	*Tarred group A* a	*Tarred group A* b	*Tarred group A* c	*Tarred group B* a	*Tarred group B* b	*Tarred group B* c
Submerged in the Sea	Amilan	8	8	5	12	8	6	10
	Kuralon (Manryo)	5	26	0	31	17	0	30
	Saran	3	16	6	12	9	8	10
	Teviron	0	14	6	19	17	8	16
	Cotton	100	0	0	0	—	—	—
Exposed to the Sunlight	Amilan	16	21	9	20	18	15	23
	Kuralon (Manryo)	24	9	7	18	17	10	27
	Saran	10	10	8	12	6	4	10
	Teviron	6	11	7	19	13	6	18
	Cotton (Cutched)	8	4	10	4	8	0	—

Refined coal tar used in treating samples in group A was different in component from the one used for group B. Both were used with or without other ingredients as follows: Sample 'a' was treated only with the tar, 'b' with emulsion of alkaline-soap-water (30%) and coal tar (70%), and 'c' with water (30%) and coal tar (70%).

TABLE XIII

Characteristics of Various Kinds of Synthetic Twine Comparable with Cotton Twine*

Items	*Amilan*	*Kuralon (Manryo)*	*Saran*	*Krehalon*	*Teviron*	*Envilon*	*Cotton*
Susceptibility to dye and dye fastness	0	2					0
Head resistance	+2	+1	−1	−1	−2	−1	0
Rigidity when wet	2	2	+2	+1	1	+3	0
Elasticity	+2	0	−2	+1	−1	−2	0
Resistance to chemicals	1	0	+1	+1	+1	+1	0
Shock resistance	+3	+1	−1	0	−1	−1	0

Obtained on the basis of cotton twine regarded as standard (0).

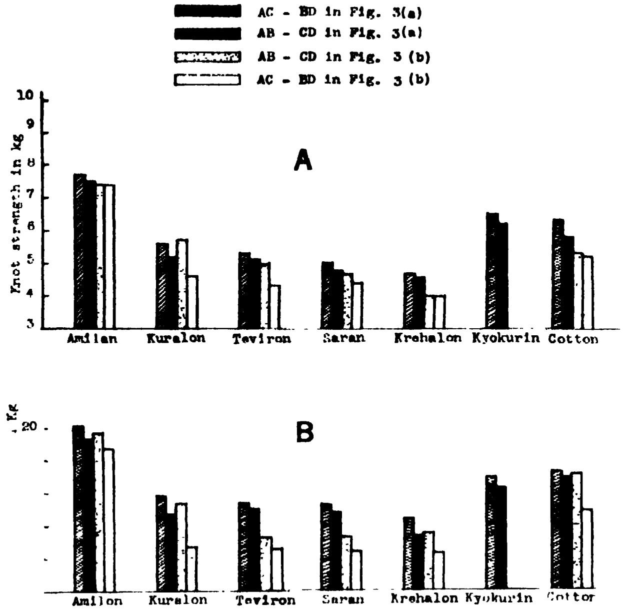


Fig. 7 A-B. Relation between the knot strength and types of knot of various twines. In test A, twines consisting of 6 yarns, and in B 12 yarns, of C20-equivalent were used. The pulling direction was the, same as in fig. 4.

The size of net twines is not always in conformity even when they have the same number of yarns, consequently, it is not feasible to compare the abrasive resistance of one type of fishing net with another that has different characteristics. However, for general purposes, comparison between various net twines made of C20-equivalent yarns is given in fig. 10. The method and the device employed for the test were identical with those described in the preceding paragraph. For this test the twines were of medium twist, having the same twist range as given in Table II.

Twine made of spun yarns, including cotton and some synthetics, have a comparatively greater resistance (figs. 9 and 10). In fig. 10 the solid lines show the abra-

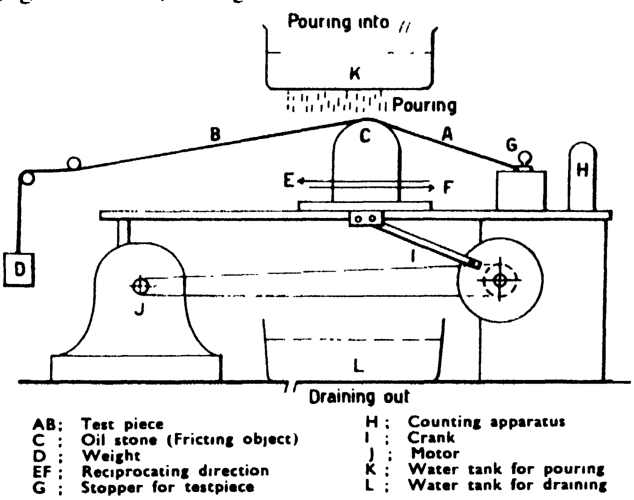


Fig. 8. A device used for testing the wear resistance of twines. The velocity of the reciprocative abrasion is 80 per minute both back and forth.

TABLE XIV

Contraction in Length of Netting Twine by Heating in Water
(Unit %)

Heating temperature	40°C	60°C	70°C	80°C	90°C	100°C
Amilan	0	0	0	−1	−1	−1
Kuralon (Manryo)	5	7	8	11	12	15
Saran	0	6	1	3	5	6
Krehalon	0	1	3	5	7	11
Teviron	5 (3)	15 (8)	25 (15)	30 (20)	45 (30)	56 (35)
Cotton	6	7	8	8	8	9

Numerals in parentheses show the percentage of contraction the length of twine heated before test.

sive resistance of tarred twine, and one may see that tar treatment enhances the abrasive resistance of net twine. As a result of tarring long fibre twines resist friction better than others which have the same number of C20-equivalent yarn.

With resin treatment the increase in abrasive resistance depends upon the thickness of the coating. A 3 to 5 per

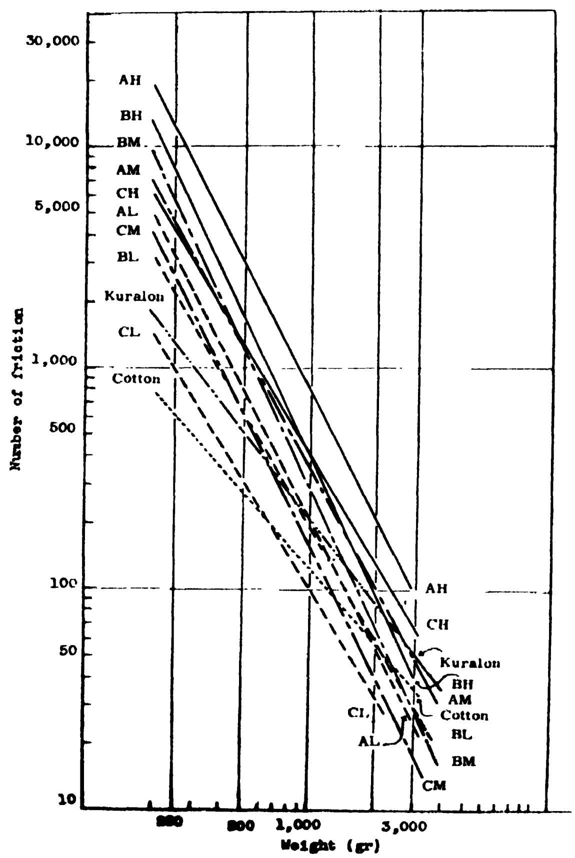


Fig. 9. Friction resistance of Amilan netting twines, A, B and C, each produced by different makers with different twists. The test temperature was kept at 18°C ± 1°C. The notation AH, for instance, indicates the twine made by A maker with hard twist. See Table XI for further information.

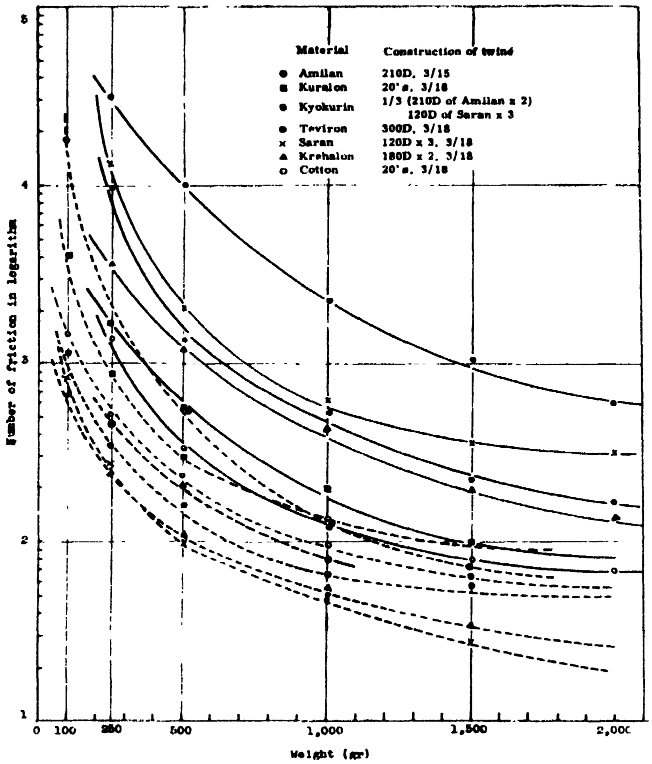


Fig. 10. Relation between the friction resistance of netting twines and the fricative load increased at the place D of fig. 8. The test temperature was the same as in fig. 9.

cent. adhesion may double or quadruple the strength. But, as the resin would be washed off during fishing operations a more practical method of fixing it must be developed as a counter measure to dilution.

(2) *Interfriction between twines:* The results obtained by Miyamoto and Mori[15] may be summarized as follows: When synthetic fibre twines are rubbed against another, abrasion between hard quality twines results in quick snapping; when a hard twine is rubbed against a soft one the latter breaks first; if both are soft the abrasive resistance of both seems to be increased. Hardness has a big influence on the abrasive strength. For example, when cotton twine is rubbed against Kuralon twine it needs 260 rubbings to snap the latter, yet Kuralon can withstand up to 530 rubbings against the cotton. When Kuralon is rubbed against Saran it snaps after only 60 rubbings and the same applies when cotton is rubbed against Teviron and Kyokurin. Between twines of the same kind, the number of rubs needed to break them is mostly as many as, but sometimes a little more than, the number required to break cotton.

8. Other Characteristics

(1) *Knot fastness:* With natural fibre twines, knot slippage hardly constitutes a problem as compared to synthetic fibre twines. In Japan, the synthetic twines which lend themselves best to knotting are Kuralon, Teviron, Envilon, Krehalon, Saran, Kuralon No. 5, Kyokurin and Amilan in the order named. For fixing the knots, various types of knots as shown in fig. 4 are

TABLE XV. **Breaking Strength of Various Kinds of Ropes in Dry State**

Thickness			*Manila hemp (JIS)*		*Amilan*		*Kuralon (Manryo)*		*Kuralon No. 5 (Manryo No. 5)*		*Saran*		*Krehalon*		*Envilon*		*Teviron*	
Diameter mm	*inch*	*Circum. inch*	*W*	*BS*	*W*	*BS*	*W*	*BS*	*W*	*BS*	*W*	*BS*	*W*	*BS*	*W*	*BS*	*W*	*BS*
3			—	—	2·74	0·13	2·54	0·085	—		-	—		-	-	—	—	-
4	5/32	1/2	5·2	0·13	4·4	0·210	4·24	0·145	—	---		0·130	- -		—	-	5·5	0·130
5			—	- -	6·6	0·310	6·8	0·235	-	-	—	—	—	—		--	8·6	0·195
6	1/4	3/4	11·7	0·27	10·0	0·470	10·2	0·335	10·5	0·357	14	0·250	14	0·240	10·74	0·270	11·2	0·270
7			—	---	13·2	0·630	13·6	0·455	14·4	0·490	18	0·325	18	0·310	15·34	0·350	15·7	0·360
8	5/16	1·0	20·7	0·46	16·6	0·790	17·0	0·580	19·2	0·653	24	0·430	24	0·410	19·94	0·450	19·8	0·450
9	3/8	1 1/8	26·2	0·57	21·6	1·030	21·6	0·730	24·0	0·816	30	0·540	30	0·510	26·08	0·590	25·1	0·570
10	13/32	1 1/4	32·4	0·70	26·4	1·270	25·6	0·920	30·0	0·970	36	0·640	36	0·610	33·8	0·720	31·4	0·715
11			—	- -	31·4	1·500	--	—	36·0	1·160	—	—	--	—	39·8	0·850	—	.
12	15/32	1 1/2	46·6	0·98	39·6	1·900	39·2	1·360	42·0	1·380	54	0·970	54	0·930	46·0	1·000	44·0	1·000
14	9/16	1 3/4	63·4	1·30	52·8	2·530	51·2	1·850	57·0	1·870	72	1·300	72	1·240	61·4	1·350	62·2	1·380
16	5/8	2·0	82·9	1·67	66·0	3·170	64·8	2·400	66·0	2·460	96	1·730	96	1·650	82·8	1·830	80·5	1·830
18	23/32	2 1/4	105·0	2·08	87·8	4·230	85·4	2·850	92·0	3·130	120	2·160	120	2·100	104·8	2·300	102·5	2·380
20	13/16	2 1/2	129·0	2·53	109·8	5·290	108·2	3·520	116·0	3·800	150	2·700	150	2·570	128·8	2·850	125·5	2·860
22	7/8	2 3/4	157·0	3·02	131·8	6·350	131·0	4·260	140·0	4·600	180	3·240	180	3·100	156·4	3·480	151·0	3·430
24	15/16	3·0	186·0	3·55	151·4	7·300	157·2	5·080	162·0	5·510	216	3·890	216	3·700	183·6	4·000	175	4·000
26	1 1/32	3 1/4	219·0	4·12	177·8	8·570	184·4	5·960	192·0	6·530	252	4·540	252	4·350	214·2	4·750	207	4·720
28	1 1/8	3 1/2	254·0	4·73	210·8	10·160	211·8	7·000	222·0	7·560	294	5·300	294	5·100	244·0	5·000	245	5·570
30	1 3/16	3 3/4	291·0	5·38	237·2	11·430	247·6	7·940	258·0	8·780	336	6·050	336	5·800	287·6	6·450	277	6·280
32	1 1/4	4·0	331·0	6·06	270·6	13·040	281·8	9·030	294·0	10·000					3·242	7·300		
34	1	4 1/4	374·0	6·79	298·0	14·390	315·6	10·000	330·0	11·300								
36	1 7/16	4 1/2	419·0	7·55	336·0	16·190			372·0	12·600								
38	1 1/2	4 3/4	467·0	8·34	374·0	17·800												
40	1 19/32	5·0	518·0	9 18	410·0	19·800												
42	1 21/32	5 1/4	571·0	10·05	458·0	22·000												
45	1 25/32	5 7/8	655·0	11·43	522·0	25·200												
50	2·0	6 1/4	809·0	13·90	644·0	31·000												
55	2 3/16	6 7/8	979·0	16·60	784·0	37·800												
60	2 3/8	7 1/2	1165·0	19·52	932·0	45·000												
65	2 9/16	8·0	1367·0	22·65	1092·0	52·500												

JIS : Japanese Industrial Standard.
W : Weight in pounds per 200 metres.
BS : Breaking strength in metric tons

used by Japanese fishermen. Most synthetic fibre nets except Kuralon and Mulon need heat treatment to fix the knots.

Heating with hot water, gas, or air, is widely applied to synthetic fibre nets for knot setting, as the treatment can reduce the amount of complicated knotting, which means that the finished product weighs less. Amilan nets may be heated at the temperature 100 deg. C. or higher, while the others, except Kuralon, can be treated at lower than 72 deg. C.

(2) *Resistance to sunlight and seawater:* Table XII shows the results obtained from one group of tarred net twines immersed in the sea and another exposed to the sunlight, both for one year. From the table it appears best to use coal tar with low isolated acid content or to neutralize the tar with alkali before use[16].

(3) *Characteristics of ropes:* For comparison, the breaking strain of manila and synthetic ropes is reproduced in Table XV by courtesy of the Tokyo Seiko Kaisha, Limited.

REFERENCES

1 Shimozaki, Y.: Unpublished.

2 Tauti, M.: Studies of Netting Cords—IV. Strength of Cord in Relation to the Twist. Vol. 25, No. 2. Jour. Imp. Fish. Inst. pp. 31-41, (1929).

3 Shimozaki, Y. and K. Mori: Studies on the Breaking Strength of Netting Cords Made with Various Twisting Machines—I. Bull. Tokai Reg. Fish. Res. Lab., No. 13, pp. 61-72 (1956).

4 Kondo, J.: Influence of the Difference in Size of Cotton Yarns Composing the Netting Cord on the Breaking Strength and the Flexibility of the Cord. Bull. Japan. Soc. Sci. Fish. Vol. 4, No. 5.

5 Koizuma, T. : The Tensile Strength of Saran Netting Cord of Various Twist. Bull. Japan. Soc. Sci. Fish. Vol. 20, No. 7 pp. 569-570 (1954).

6 ——— The Tensile Strength of Amilan Netting Cord of Various Twist, *Ibid.* Vol. 21, No. 3, pp. 139-140 (1955).

7 Shimozaki, Y. and K. Mori : Studies on the Breaking Strength of Netting Cords Made with Various Twisting Machines—I; Bull. Tokai Reg. Fish, Res. Lab., No. 13, pp. 68-70, (1956).

8 Shimozaki, Y. : Synthetic Fishing Nets and Ropes. Fish. Technol. Series. No. 3, pp. 68-69, Assoc. Fish. Material (1951).

9 ——— Unpublished.

10 ——— On the Change in Strength of Netting Cords Immersed in the Sea—I. Relation between the Strength of Synthetic Netting Cords and the Temperature, and Comparison of Power of Various Kind of Cords Changing when Immersed in the Sea. Bull. Japan. Soc. Sci. Fish. Vol. 20, No. 5 (1954).

11 Honda, K.: Influence on the Length of Test Piece on the Breaking Strength and Elongation of Netting Cord. Bull. Japan. Soc. Sci. Fish., Vol. 22, No. 6 (1956).

12 Shimozaki, Y.: Synthetic Fishing Net and Ropes. Fish. Technol. Series. No. 3, pp. 77-79, Assoc. Fish. Material (1957)

13 ——— *Ibid.* pp. 79-81.

14 ——— Unpublished. Lectures delivered at Japan Soc. Sci. Fish. April (1956) and (1957).

15 Miyamoto, H. and K. Mori: How Netting Threads Wear Down Due to Interfriction. "TEICH" No. 12, Nippon Set Net Fish. Soc. pp. 9-12 (1957).

16 Shimozaki, Y. : Synthetic Fishing Nets and Ropes. Fish. Technol. Series. No. 3, pp. 94-95 (1957).

Although synthetic fibres are being used in ever increasing quantities even in those countries where the fishing industry is not highly developed technically, the majority of fishing nets are still being made of natural fibres. The woman in the photo is spinning a yarn from sun-hemp in Ceylon. Photo FAO.

NYLON IN FISHING NETS

by

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Abstract

In this paper, the author gives an outline of the desired characteristics of the ideal fibre to be used for fishing nets, and then compares this specification with the properties of nylon 66. The physical properties of this material are discussed in detail—yarn strength, twine strength, knot strength and the comparison between the strengths of wet and dry twines—and in general, nylon nets are able to withstand attacks by chemicals, oils, insects, vermin, bacteria and moulds, and their ability to stand up to considerable flexing and abrasion is very good. Since the nets do not rot, it is not necessary to dry them in the sun, and in certain African fisheries it is the habit to store gillnets in the water when they are not being fished.

Le nylon dans les filets de pêche

Résumé

L'auteur expose dans cette étude les caractéristiques de la fibre idéale destinée à la confection des filets de pêche, et les compare avec les propriétés du nylon 66. Il fait un examen approfondi des propriétés physiques de ce matériau: résistance des filés, des fils, des noeuds, et résistance comparée des fils secs et mouillés. En général, les filets de nylon sont insensibles aux produits chimiques, aux huiles, aux insectes, à la vermine, aux bactéries et aux moisissures, et la résistance à la flexion et à l'abrasion est excellente. Comme les filets ne pourrissent pas, il n'est pas nécessaire de les faire sécher au soleil, et dans certaines entreprises africaines de pêche on a coutume de conserver les filets maillants dans l'eau quand ils ne sont pas utilisés pour la pêche.

El nylón en las redes de pesca

Extracto

En este trabajo el autor hace una reseña de las características que debe tener una fibra ideal para red de pesca y las compara con las propiedades del nylón 66. También analiza, en detalle, las propiedades de este material—resistencia de las fibras, hilos y nudos, comparación de la resistencia de los hilos húmedos y secos—y expresa que, generalmente, las redes de dicha fibra resisten el ataque de compuestos químicos, aceites minerales, insectos, gusanos, bacterias y mohos. Además, dicha fibra ofrece bastante resistencia a la flexión y al desgaste causado por el roce.

Como las redes de nylón no se pudren, es innecesario secarlas al sol, y en algunas pesquerías africanas existe la costumbre de mantener los artes de enmalle en el agua cuando no se usan.

SPECIFICATION FOR IDEAL FISH NET FIBRE

(1) The basic cost should be low.

(2) Processing into net form should be cheap, easy and efficient. For example, shrinkage on setting should be low.

(3) In both wet and dry states it should have high strength, by which is meant:
   - (a) high tensile strength;
   - (b) good ability to withstand repeated shocks;
   - (c) good flex strength or fatigue resistance;
   - (d) high knotting efficiency and
   - (e) good resistance to abrasion

   which leads to fine, long-lasting nets, capable of holding large catches.

(4) It should maintain its strength in use.

(5) It should have good dimensional stability and should not distort in size or shape during use.

(6) It should have low moisture absorption so that the increase in weight is small when a net becomes wet and handling is consequently easier.

(7) The fibre should have a low specific gravity, since this allows a greater length of netting for a given weight of yarn, and may permit lighter fittings and savings in power and manhandling. On the other hand, a low specific gravity may not be desirable where quick sinking of the net is required.

(8) It should be resistant to damage and attack by chemicals, oils, moulds, bacteria, insects and vermin in order that treatments and routine maintenance can be kept to a minimum.

(9) The performance of the fibre should remain constant at extremes of temperature.

TABLE I

Specific Gravity of Fibres

Nylon 66 and nylon 6	·14
Polyvinyl alcohol .	·30
Polyester fibre . .	·38
Hemp	·48
Flax	·50
Cotton . . .	·52
Polyvinylidene chloride	·72

(10) The net should hold the fish firmly when caught, yet not damage them.

(11) Some types of fishing nets may demand other requirements, such as translucency for gillnets or a lower initial elastic modulus as is required for salmon gillnets.

The initial modulus (calculated by measuring the load to produce a 5 per cent. extension under conditions of 70 deg. ± 4 deg. F. and 67 ± 2 per cent. R.H.) for nylon yarns lies in the range 20 to 40 grams/denier, with nylon 66 high tenacity yarns at the top end of the bracket, while, for comparison, the initial modulus of high tenacity polyester fibre lies in the range 90 to 100 grams/denier.

The basis of the specification can be extended to methods of fishing which do not employ nets. It could include the principles involved in the choice of fibre for long-lines or whaling foregoers, etc. There is now a wide range of fibres available to satisfy the diverse needs of the fishing industry. None meets, nor could meet, the specification completely.

Even when one fibre is isolated and examined alone, it can be seen that there is ample variety of choice. Thus, nylon can be divided into classes according to the type of polymer used, and whether the yarn is assembled from continuous filament or spun fibre; within each of these classes there is a range of yarns with varying properties.

The task facing a supplier of continuous filament nylon for the production of fishing nets is to provide a yarn which measures well in comparison with the specification. Some of the conditions are met automatically (e.g. low specific gravity, rot resistance, high strength, good stability and small temperature influence), while others have to be met as nearly as possible. One of the chief ways in which a nylon yarn can be upgraded is by increasing its strength.

YARN STRENGTH

The dry tensile strength of all nylon yarns—66 and 6—lies in the range 4·5 to 9·0 grams/denier. The yarns at the top end of the bracket are stronger than any other commercially available fibre. The equivalent range of extension at break is 25 to 12 per cent. Generally speaking a higher tenacity implies a lower extension at break.

Fig. 1 shows typical load-extension curves for three yarns of B.N.S. nylon 66 (measured under a rate of load application of 0·5 grams/denier/sec.), and illustrates the different forms these may take. The energy absorption of each, as measured by the area under the curve, is shown in Table II, together with values for tenacity and extension at break.

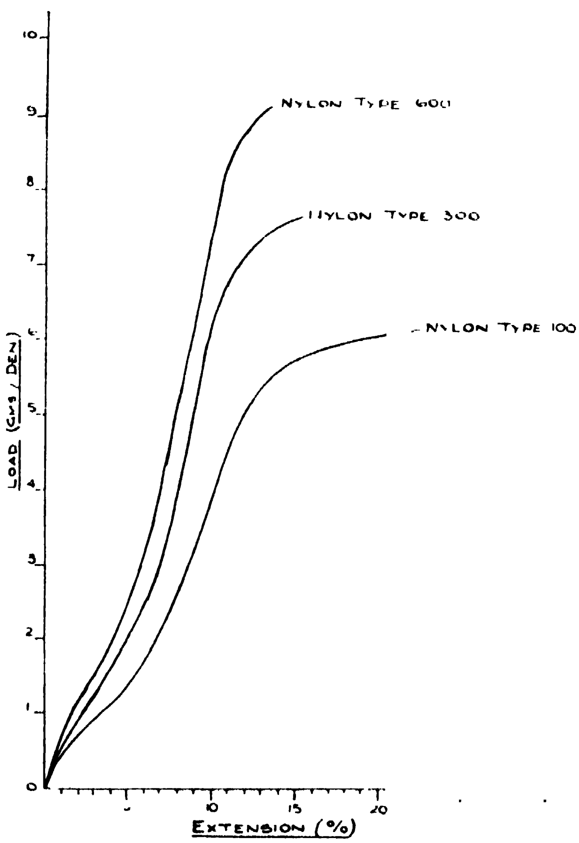

Fig. 1. Load/Extension Curves of BNS nylon 66 yarns.

TABLE II

Load/Extension Properties of Nylon 66 Yarns

Yarn Reference	*Tenacity (grams/denier) min.*	*Extension at (break (%)*	*Energy Absorption (inch lbs./inch)*
B.N.S. nylon 205 denier type 100	4·5	22	0·27
B.N.S. nylon 210 denier type 300	7·4	15	0·31
B.N.S. nylon 840 denier type 600	8·8	13	1·11

It will be seen that the energy absorption of 210 denier type 300 on a weight for weight basis is higher than the other two yarns. This very high energy absorption has been a factor in its ready acceptance for fishing nets.

TWINE STRENGTH

As in the case of all fibres, nylon twines are made with twist in order to bind the yarns together. The degree of twist and the construction control the feel of the twine. Increasing the degree of twist in a nylon yarn lowers the tensile strength. The ratio of twine strength to aggregate yarn strength is known as the doubling efficiency. Most nylon twines are made with a doubling efficiency of 95 per cent. or more. This can be affected, not only by twist, but also by conditions of setting and heat stretching.

Twine strength is commonly expressed in lbs. or other units of weight. Another method is to refer to specific strength (or breaking length), this being defined as the greatest length of twine which can be supported by a

TABLE III
Average Specific Strength of Fibres[1]

	Twine		*Mesh*			
			Single Knot		*Double Knot*	
	Dry (*yd.*)	*Wet* (*yd.*)	*Dry* (*yd.*)	*Wet* (*yd.*)	*Dry* (*yd.*)	*Wet* (*yd*).
Nylon 66	63700	56000	30800	28100	34300	29900
Nylon 6	39100	35200	24400	22000	26600	23100
Polyester fibre	48600	50200	20000	20700	24100	23500
Linen	44000	58800			19900	31600

single piece of that twine without breaking it. The supporting piece may be dry, wet or knotted.

Specific strength (or breaking length) (in yards)
Twine strength (lbs) × twine weight (yds./lb.)

This unit is of value in comparing different fibres. Results on nets tested in Canada appear in Table III, which lists the specific strength of dry and wet twine and knots. Nylon 66 will be similar to type 300.

KNOT STRENGTH

When a knot is tied in a twine, it constitutes a place of weakness, and reduces the effective strength of the twine. The term "knotting efficiency" can be used to describe the ratio of dry knot strength to dry twine strength (or alternatively wet knot to wet twine strength). The knotting efficiency, measured either way, of nets made from nylon 66 yarn is of the order of 40 to 50 per cent. for single knots and 50 to 60 per cent. for double knots.

An investigation[2] has been carried out into the factors influencing the loss of strength on knotting. This has resulted in a clearer appreciation of the mechanism of knotting and the effect of yarn properties on knotting efficiency.

Practical tests have shown that every type of knot has a different knotting efficiency, and that their order of efficiency approximates to the same for all fibres examined (nylon 66, nylon 6, polyester fibre, and polyvinylidene chloride). The differing configurations of various knots is responsible for the variations; it has been shown that a decrease in the angle through which the loop is formed decreased the loop strength; increasing the number of loops or hitches in a knot increased the knot strength. The effect of molecular orientation on knotting efficiency was investigated to study the nature of the rupturing forces more closely. Nylon 66 yarn of the same nominal denier and number of filaments was used to tie three types of knots—the overhand, warpers and double weavers. It was shown that with increasing molecular orientation the yarn tenacity increased linearly, knotting efficiency decreased linearly, whilst knot strength assumed a parabolic curve (fig. 2). The shape of the latter could be confirmed by calculation from the two straight line relationships. The degree of orientation of the yarn exhibiting maximum knot strength is of obvious practical importance. The manufacturer of nylon yarn, having the opportunity to tailor-make his fibre, should attach proper importance to this effect.

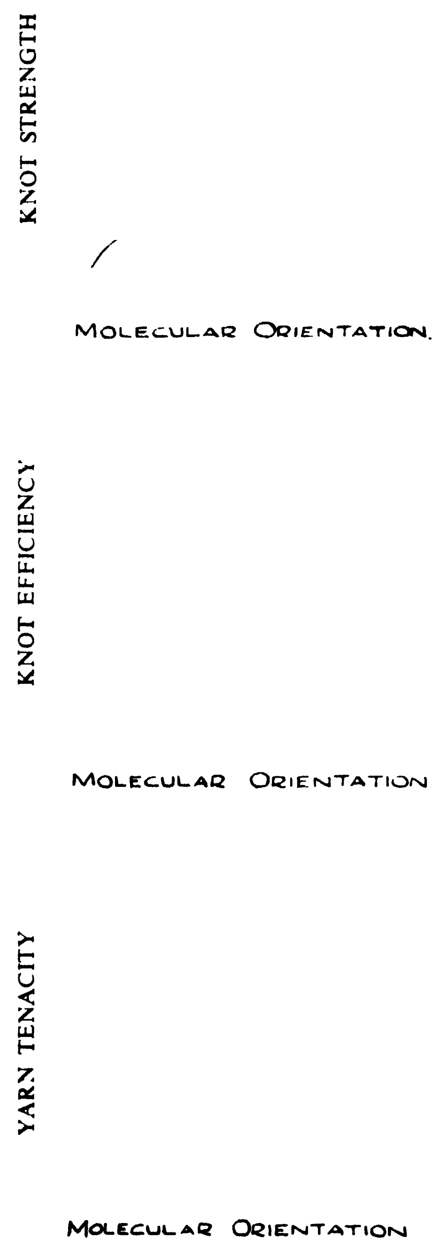

Fig. 2. ***Individual Effect of Molecular Orientation.***

The investigation was continued by studying the effect of change of molecular orientation on shear, torsion and compression. No appreciable effect on shear and torsion could be detected, but compressive force, as represented by loop tenacity, described a parabola. From these facts, it was deduced that compressive and tensile forces act in opposition as orientation is changed (fig. 3).

The effect of compressive forces was subsequently shown experimentally by knotting unstretched polythene and examining it visually, and subjecting broken nylon knots to cross-polarised light. Tests on various knots

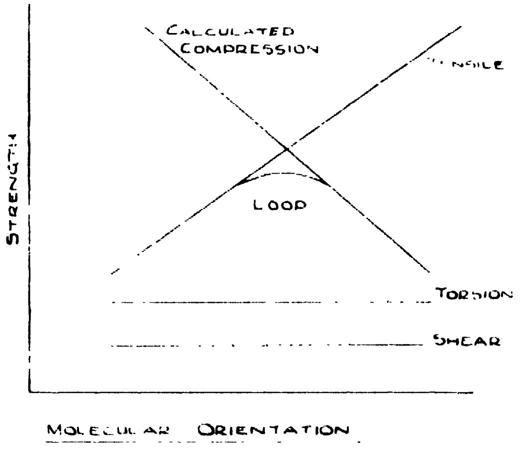

Fig. 3. Combined Effect of Molecular Orientation.

showed that the break always occurred under the looped section. In symmetrical knots, such as the Blood, two positions of stress concentration corresponding to the two looped sections were observed.

WETTING

When nylon twines are wetted they lose strength but gain in extensibility. The loss in strength (of both type 66 and 6) whether in yarn, twine or net form is of the order of 10 to 15 per cent. The increase in extension at break of twines made from nylon 66 is of the order of 15 to 20 per cent. according to size and construction. The importance of this effect is to counterbalance the loss of tensile strength when assessing the change in energy absorption. It is this latter property which is of critical importance in deciding whether a net will break or not under dynamic conditions. Nylon's present place in fishing nets is largely due to its comparatively high energy absorption under dry and, even more so, wet conditions.

A typical 3/3/210 denier nylon 66 twine had the properties shown in Table IV. By measuring the area under

TABLE IV

Comparison of Dry and Wet Twine Properties for a Typical 3/3/210 Denier B.N.S. Nylon 66 Twine

	Dry	*Wet*	*Change on Wetting*
Breaking load	32·4 lbs.	28·6 lbs.	12%
Extension at break	21·0%	24·9%	19%
Energy absorption	3·36 in.lb./in	3·96 in.lb./in.	18%

the load/extension curves, dry and wet, it was found that the energy absorption actually increased when wet by 18 per cent.

IN USE

Nylon nets, in common with those made from all other fibres, slowly lose strength in use. In certain African fisheries it is now the habit to store gillnets in the water when they are not being fished.

The abrasion resistance, dry and wet, of nylon 66 is extremely good. This can be varied by choice of filament denier. All nylon fishing twines are based on a filament denier of about 6 (as opposed to 1 to 3 for most apparel uses), thus providing a happy compromise between good abrasion resistance and flexibility (which decreases with increased filament denier).

ACKNOWLEDGMENTS

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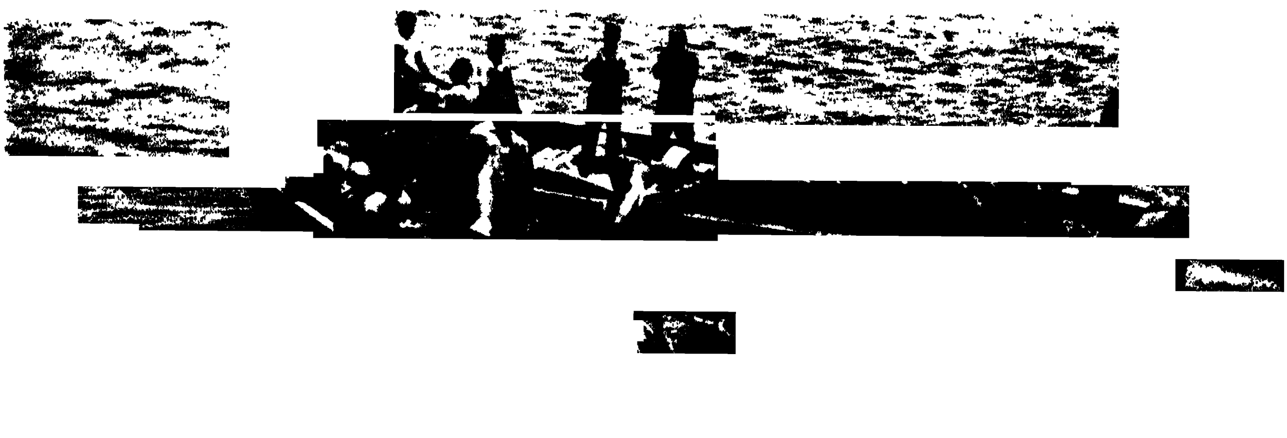
REFERENCES.

[1] "The Selection and Care of Nylon Gillnets for Salmon." P. J. G. Carothers, Fisheries Research Board of Canada

[2] "Knots, Their Effects, and the Forces Involved." R. J. Harrison, Associateship Thesis, Royal College of Science and Technology, Glasgow, June 1957.



Menhaden purse seine dories with the catch "dried up" in the bunt. Photo FAO.

THE TECHNOLOGICAL CHARACTERISTICS OF PERLON FOR FISHING EQUIPMENT

by

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Abstract

Perlon is a synthetic fibre which, like nylon, is one of the polyamides. It is made as Monofilament, Continuous Filament and Staple Fibre and this comprehensive paper deals with its chemical and physical properties and discusses its suitability for trawls, seines, setnets, whaling ropes and cordage, also for tarpaulins and protective coverings.

Les caractéristiques technologiques de Perlon pour le matérial de pêche

Résumé

Comme nylon, Perlon est une fibre synthétique du groupe des polyamides. On le fabrique en monofilament, fibres continues et fibres filées et cette communication détaillée traite de ses propriétés chimiques et physiques et examine s'il convient pour la confection de chaluts, de sennes, de filets fixes, de câbles pour la chasse à la baleine et de cordes, et aussi pour faire des bâches et des enveloppes protectrices.

Características tecnológicas del perlon para equipo de pesca

Extracto

En este trabajo se estudian las propiedades químicas y físicas del perlón que, como el nylón, es una poliamida, y se analizan sus condiciones para usarlo en la fabricación de redes de arrastre, fijas y de cerco, estachas para arpones, cordelería, encerados y cubiertas protectoras. Esta fibra sintética se fabrica en forma de hilo y filamento continuos o como hilado.

I. WHAT IS PERLON ?

PERLON,* like nylon, is a synthetic fibre which belongs to the polyamides' group. Like all fibre-forming materials, it consists of large elongated molecules. It results from the assembly of a large number of molecules of a homogeneous material, caprolactam.

Perlon:

$(CH_2)_5$

n. $\ldots HN(CH_2)_5COHN(CH_2)_5CO\ldots$

NHOC

ε—Aminocaprolactam

Both fibres are manufactured in the United States, where the fibre developed by Du Pont is called Nylon 66, as opposed to Nylon 6 for Perlon, a fibre developed by the former IG-Farbenindustrie combine in Germany. In their technological properties Perlon and nylon are largely identical, except for the melting point which, in the case of nylon, is approximately 30 deg. C. higher.

Both fibres are manufactured by the extrusion process. As a result the fibres are cylindrical and have a smooth featureless surface.

By adding titanium dioxide or other suitable substances during the polymerization process, a matt fibre can be extruded. This does not affect the physical properties of the fibre except resistance to sunlight which is considerably reduced. Matt fibres should not be chosen for the manufacture of nets.

II. FORMS OF PERLON

Perlon is available in 3 basic forms for the fishing industry:

Monofil
Continuous Filament and
Staple Fibre.

(a) Monofil

Monofil has the advantage that it can be used for the manufacture of nets without having to undergo further processing (e.g. twisting or plaiting).

Monofils are continuous transparent wires, with a diameter of between 0·1 and 2 mm. (0·004 in. to 0·08 in.). Table I gives average values of breaking load and length per unit weight.

(b) Continuous Filament

Continuous filament has greater strength and less extensibility than staple fibre and is lighter in weight than

* The name Perlon and its emblem are registered trademarks of the PERLON-Warenzeichenverband e.V. (PERLON Trade Mark Association), Frankfurt/Main, Germany.

TABLE I

Monofils

Diameter In mm.	*Breaking Load In kg.*	*Length per Unit Weight m/kg.*	*Nm (Metric Number)*
0·10	0·5	app. 92,000	92·0
0·15	1·1	43,000	43·0
0·17		32,200	33·0
0·20	1·8	25,000	25·0
0·25	2·7	15–16,000	15–16·0
0·30	3·7	10–12,000	10–12·0
0·35	5·1	8,600	8·6
0·40	6·5	6,600	6·6
0·45	8·4	5,300	5·3
0·50	10·0	4,300	4·3
0·55	12·2	3,500	3·5
0·60	14·5	3,000	3·0
0·65	16·5	2,600	2·6
0·70	19·0	2,200	2·2
0·75	22·0	1,900	1·9
0·80	25·0	1,700	1·7
0·85	28·0	1,500	1·5
0·90	31·5	1,300	1·3
0·95	33·5	1,200	1·2
·00	36·0	1,100	1·1
·10	42·0	900	0·9
·20	50·0	760	0·76
·30	57·0	650	0·65
·35		600	0·60
·40	66·0	560	0·56
·50	76·0	490	0·49
·60	87·0	430	0·43
·70	98·0	380	0·38
·80	110·0	340	0·34
·90	125·0	300	0·30
2·00	140·0	270	0·27

the equivalent cotton product. It is supplied in fine and coarse qualities.

TABLE II

Perlon Continuous Filaments in Fine Deniers

Denier	*Metric Number Nm.*	*Length per Unit Weight m/kg.*	*Number of Filaments*
210	43·0	42,860	35
630	14·0	14,290	105
750	12·0	12,000	125
840	10·7	10,710	140

Heavier deniers ("cables") is used as the raw material for net twines subject to severe stress, and for the manufacture of ropes (Table III).

The choice of 6 and 20 filament denier allows for different degrees of stiffness required, the stiffness of Perlon increasing with the denier.

Consequently Perlon made up to 20 denier filaments

TABLE III

Perlon Continuous Filaments in Heavy Deniers

Denier	*Metric Number Nm.*	*Length per Unit/Weight m/kg.*	*Filament Denier*	*Number of Filaments*
1,050	8·6	8,570	6	175
1,260	7·1	7,140	6	210
2,500	3·6	3,600	20	125
3,000	3·0	3,000	6; 20	500; 150
3,210	2·8	2,800	20	160
4,500	2·0	2,000	20	225
5,000	1·8	1,800	20	250
6,200	1·5	1,500	6	1,035
7,500	1·2	1,200	6; 20	1,250; 375
9,300	1·0	1,000	6	1,550
10,000	0·9	900	20	500
11,250	0·8	800	6	1,875
12,500	0·7	700	20	625
15,000	0·6	600	6; 20	2,600; 750
30,000	0·3	300	20	1,500

should be used where the end product is subjected to a sustained process of kneading and flexing.

However, where a highly flexible product is required 6 denier filaments are more suitable.

(c) Staple Fibre

Spun staple fibre twines are particularly suitable for inland and coastal waters. The yarns are spun like cotton yarns to attain the highest possible degree of strength or produced from a spinning tow and then spun into yarn by means of a modified schappe spinning process after cutting.

The following types of staple fibre are available in yarn numbers up to Nm. 50:

Cotton spinning process:
2 den., cut length 60 mm.
27 den., cut length 60 mm.

Schappe spinning process:
2, 7 den. average length of staple 100 mm.

The optimum tensile strength of spun staple fibre yarn should be a breaking length of 30 km. in a Nm. 34/1 yarn.

Where net yarns must be stiffened with black varnish, spun staple fibre yarn is superior to continuous filament yarn, since the staple fibre yarn absorbs the stiffening preparation more thoroughly.

III. PROCESSING INTO NET TWINES, CORDAGE AND ROPES

(a) Perlon Monofils

Table IV gives the appropriate monofil strength for *gillnets* to replace cotton net twines.

For mesh sizes in excess of 30 mm. at least 0·20 mm. diameter should be chosen even for the finest types of nets.

The monofils are available as fishing lines in diameters between 0·1 and 2 mm. The rope making industry is

TABLE IV

Monofils suitable for Gillnets

Cotton Net twine Nm.	*Perlon Monofils Diameter mm.*	*Length per Unit Weight m/kg.*	*Nm. (Metric Number)*
270/6	15·0 or 0·20 app.	43,000 resp.	43·0 resp. 25·0
240/6	,, ,,	25,000	,,
200/6	0·20	25,000	25·0
160/6	0·20	25,000	25·0
140/6	0·20	25,000	25·0
120/6	0·25	16,000	16·0
100/6	0·25	16,000	16·0
100/9	0·25	16,000	16·0
85/6	0·30	12,000	12·0
85/9	0·30	12,000	12·0

using Perlon monofils as raw material for the manufacture of braided and twisted cordage.

TABLE V

Comparison in length per unit weight of coarser monofils with cotton twine of equal wet strength

Cotton Net twine		*Perlon Monofils*	
Cotton Metric Number Nm.	*Length per Unit Weight m/kg.*	*Diameter mm.*	*Mean Length per Unit Weight m/kg.*
50/9	5,000	0·35	8,600
50/12	3,600	0·40	6,600
50/15	2,900	0·45	5,300
50/18	2,400	0·50	4,300
20/6	2,900	0·45	5,300
20/9	1,950	0·50	4,300
20/12	1,400	0·60	3,000
20/15	1,100	0·70	2,200
20/18	940	0·70	2,200
20/21	830	0·70	2,200
20/24	680	0·80	1,700

(b) Twines of Perlon Continuous Filament

Twines for equipment exposed to little or moderate strain differ from twines for nets subject to severe stresses.

Net twines are produced from the following materials:

Denier	210	630	750	840
Metric Number Nm.	43·0	14·0	12·0	10·7
Length per Unit Weight m/kg.	42,860	14,290	12,000	10,710

Table VI gives examples of approximate lengths per unit weight and diameters of net twines made of 210 denier filaments.

Only the finest deniers listed in Table VI are suitable for bottom-set gillnets; the others, including deniers heavier than those listed can be used for line fishing, baskets, trap nets, bagnets, trawls, seines, purse seines, etc.

Given an equal wet knot strength the weight of nets made of these twines are less than that of the equivalent cotton product.

TABLE VI

Net twine den.	*Length per Unit Weight m./kg.*	*Diameter mm.*	*Net twine den.*	*Length per Unit Weight m/kg.*	*Diameter mm.*
210/2	20,000	0·28	210/18	2,100	0·88
210/3	13,000	0·30	210/21	1,850	0·95
210/6	6,400	0·48	210/24	1,600	1·00
210/9	4,300	0·60	210/27	1,450	1·10
210/12	3,200	0·70	210/30	1,320	1·15
210/15	2,480	0·80			

Continuous filament twines are quite smooth and much less dirt adheres to nets made of such material than to nets made of cotton or spun staple fibre twines. Continuous filament or Perlon monofil is particularly suitable for heavily polluted waters. Braided or twisted twines of 840 denier, 1,059 denier, 1,260 denier, and 3,000 denier are especially suitable for equipment subject to severe strain such as bottom trawls. Perlon continuous filament twisted twines are considerably stronger than manila twines. This makes it possible to manufacture lighter weight nets to reduce the towing drag and allowing the use of less power.

TABLE VII

Twisted Twines

Manila-Extra			*Perlon Continuous Filament*		
Length per Unit Weight m/kg.	*Breaking Load (kg.) dry*	*Breaking Load (kg.) wet*	*Length per Unit Weight m/kg.*	*Breaking Load (kg.) dry*	*Breaking Load (kg.) wet*
186	120	127	192	260	221
–	—	—	250	208	177
248	95	100	256	195	165
—	—	—	312	167	142
	—	-	315	173	147
375	65	68	385	130	110
--	—	—	1,248	43	37

Table VIII gives examples of Perlon continuous filament *braided* twines:

TABLE VIII

Perlon Continuous Filament Braided Twines

Length per Unit Weight m/kg. app.	*Breaking Load (kg.) dry*	*Breaking Load (kg.) wet*
1,440	40	34
1,270	51	43
1,040	55	47
840	74	62
690	83	71
650	101	81
500	110	94
450	130	110
402	151	128
350	160	136
300	190	162
265	200	170
190	280	238

(c) Cords and Ropes of Continuous Filament

Manila, sisal, hemp, and cotton have up to now been used as raw materials for the cords and ropes used in the fishing industry.

Cords and ropes of natural fibres shrink and swell which renders wet ropes hard and stiff. Natural fibres rot in the water. Coarser qualities dry very slowly and when stored are destroyed by mould. Synthetic fibre ropes should therefore be used with synthetic fibre nets.

Allowance must be made for the extensibility of Perlon which is many times that of the natural fibres. To prevent the ropes from untwisting or developing kinks, it is necessary to adjust the angle and direction of the twist so that the individual yarn constructions reinforce each other within the body of the rope.

Cords and ropes are made of Perlon continuous filament yarn in the heavier deniers as listed in Table III.

TABLE IX

Comparison of Weight and Breaking Load

Hemp, Manila and Sisal untarred				*Continuous Filament Perlon*			
				Weight % m		*Breaking Load in kg.*	
Diameter in mm.	*Circumference in inches*	*Weight % m*	*Breaking Load in kg*	*Hawser laid*	*Cable-laid*	*Hawser-laid*	*Cable-laid and Twisted*
1		2·6	230	1·5		410	
6	¾	3·6	380	2·25		580	
8	1	5·8	572	3·7		1,000	
10	1¼	7·4	763	5·9		1,500	
12	1½	11·5	1,143	8·7		2,250	
14	1¾	14·4	1,525	12		3,100	
16	2	18·8	1,970	14·5		3,800	
18	2¼	23·7	2,460	18·5		4,900	
20	2½	29·5	3,000	25·0		5,700	
22	2¾	35·5	3,580	31		6,950	
24	3	42·3	4,210	36		8,400	
26	3¼	49·6	4,870	42		9,750	
28	3½	57·5	5,580	49		11,200	
30	3¾	66·1	6,310	57	52	13,000	11,500
32	4	75·1	7,090	65	59	14,800	12,200
36	4½	95	8,720	82	74·5	18,700	15,700
40	5	117·5	10,500	101	92·5	(23,000)	19,500
44	5½	142	12,500	124	111	(27,800)	23,900
48	6	169	14,700	145	132	(33,000)	29,000
52	6½	198	17,000	170	155	(39,000)	34,600
56	7	230	19,400	197	180	(45,000)	40,800
60	7½	264	21,900	227	208	(52,000)	47,500
64	8	301	24,600	252	236	(59,000)	55,000
72	9	380	30,100	315	299	(75,000)	69,000
80	10	470	36,000	388	367	(92,000)	84,000
90	11¼	570	43,000	493	467	(116,000)	106,00
100	12½	710	50,000	608	577	(144,000)	130,000

The values in brackets merely serve purposes of comparison. With these sizes it is advisable to use cable-laid ropes, a construction which has proved particularly efficient.

(d) Perlon Staple Fibre Twines

Two yarn counts: Nm. 50 and Nm. 20 are mainly used for net twines; details of strength are given in Table X.

TABLE X

Cotton and Perlon Staple Fibre Net twines of Equal Wet Strength

Cotton Net twine		*Perlon Staple Fibre and Net twine*	
Metric Number Nm.	*Length per Unit Weight m/kg.*	*Metric Number Nm.*	*Length per Unit Weight m/kg.*
50/9	5,000	50/6	7,500
50/12	3,600	50/9	5,000
50/15	2,900	50/12	3,600
50/18	2,400	50/15	2,900
20/6	2,900	50/9	5,000
20/9	1,950	50/12	3,600
20/12	1,400	20/6	2,900
20/15	1,100	20/9	1,950
20/18	940	20/12	1,400
20/21	830	20/12	1,400
20/24	680	20/15	1,100
20/27	620	20/18	940
20/30	540	20/18	940
20/32 to 20/36	460	20/24	680

IV. PROPERTIES

1. Specific Gravity

Perlon has a lower specific gravity than natural fibres:

Perlon	1·14	g/cu. cm.
Cotton	1·54	g/cu. cm.
Hemp, jute	1·48–1·50	g/cu. cm.
Ramie	1·51	g/cu. cm.

Coupled with a high degree of strength, this property enables the industry to make very light nets.

2. Rot Resistance

Perlon does not rot as it is not attacked by bacteria or fungi, nor does it need preservative treatment.

Perlon net twines continuously immersed in the brackish water of a North Sea harbour for a period of 3½ years have shown no more than a 10 per cent. loss of strength.

3. Tensile Strength

The specific tenacity of monofilaments is highest with a small diameter. The breaking length varies between 37 and 47 kilometres. The tenacity of water-saturated Perlon is between 80 per cent. and 90 per cent. of its air-dry tenacity. The knot strength shows an equally close relation to the diameter:

(in % of tenacity)

70—80%	for small diameter	(0·10—0·30 mm.)
60—70%	„ medium „	(0·35—0·70 mm.)
50—60%	„ large „	(over)

The strength of the filaments is determined by the degree to which they have been stretched or "drawn" during manufacture, as shown in an example of Perlon continuous filament of 1,060 denier:

		Ordinary	*Special Pre-stretch*
Breaking Length air-dry	km	55	71
Breaking Length wet	km	47	61
Break air-dry	%	20	17
Break wet	%	22	19
Extension at Knot Strength air-dry	km	44	41
Extension at Knot Strength wet	km	41	36

A high degree of stretching results in a considerable increase in strength coupled with an appreciably reduced extension at break. However, as filament strength is raised, there occurs a reduction in knot strength, particularly when water-saturated.

This phenomenon is particularly important when the fibre is subjected to a specially high pre-stretch as for fishing net twines. High strength and a low extension at break are desirable, but can only be achieved at the price of low knot strength.

A comparison in knot strength of filament composition 10,000 denier, single filament denier 20, and of monofils with a hemp string of equal strength:

	Hemp	*Perlon Filament*	*Perlon Monofil*
Strength dry kg/sq. mm.	35	59	52
Strength wet kg/sq. mm.	38	52	42
Knot Strength dry kg/sq. mm.	23	26	26
Knot Strength wet kg/sq. mm.	23	24	20
Relative Knot Strength dry %	66	44	50
Relative Knot Strength wet %	66	41	48

Experience has shown the knot strength of all fibres to be below their ordinary strength.

4. Extensibility and Elastic Properties

The extension at break of Perlon monofil varies between 20 and 35 per cent.

Other characteristic values for the extensibility and elasticity of Perlon monofils are:

Elastic extension	75–90%	of the total extension at
Permanent elongation	10–25%	80% of breaking load

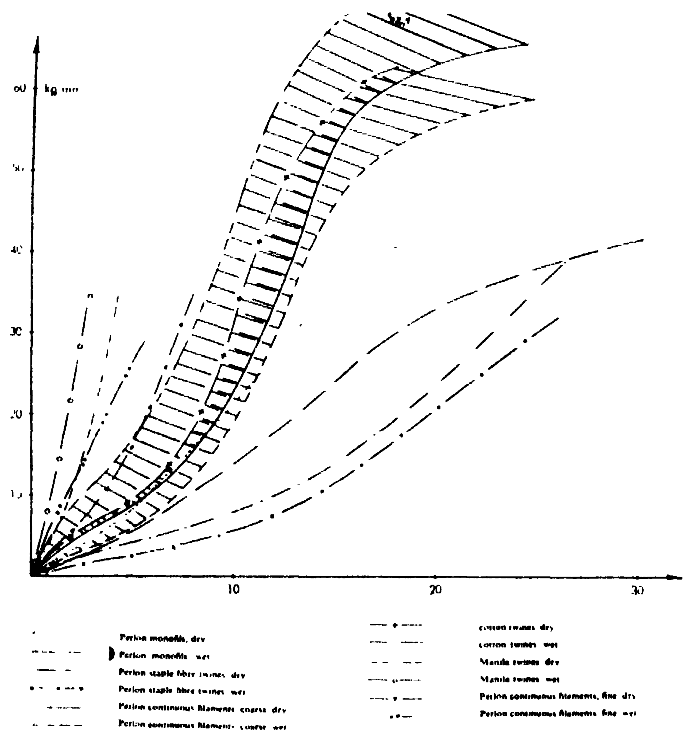


Illustration I. *% extension*

Load/Extension curves of Perlon Products compared with Cotton and Manila twines.

Details of the relationship between load and total extension are shown in the graphs of Illustration I.

These diagrams show that the load extension curves of Perlon climb at a more obtuse angle than those of natural fibres.

This divergence becomes conspicuous in a comparison of hemp and Perlon ropes with a circumference of 1¼ in.

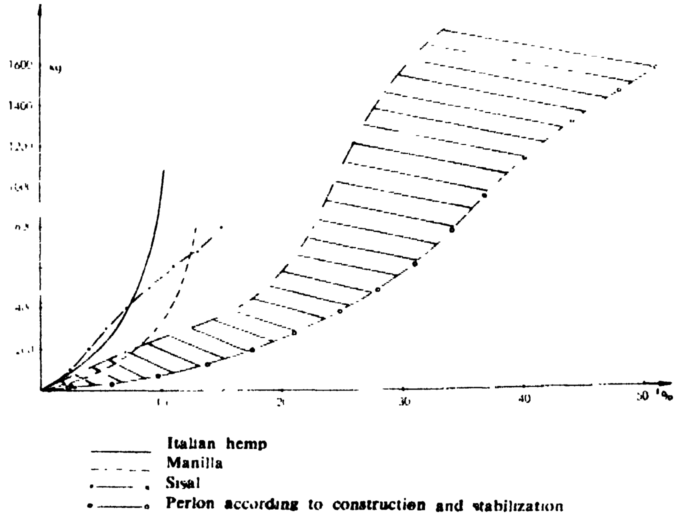


Illustration II.

Load/Extension curves of Ropes in Natural Fibres and Perlon, circumference 1¼ in.

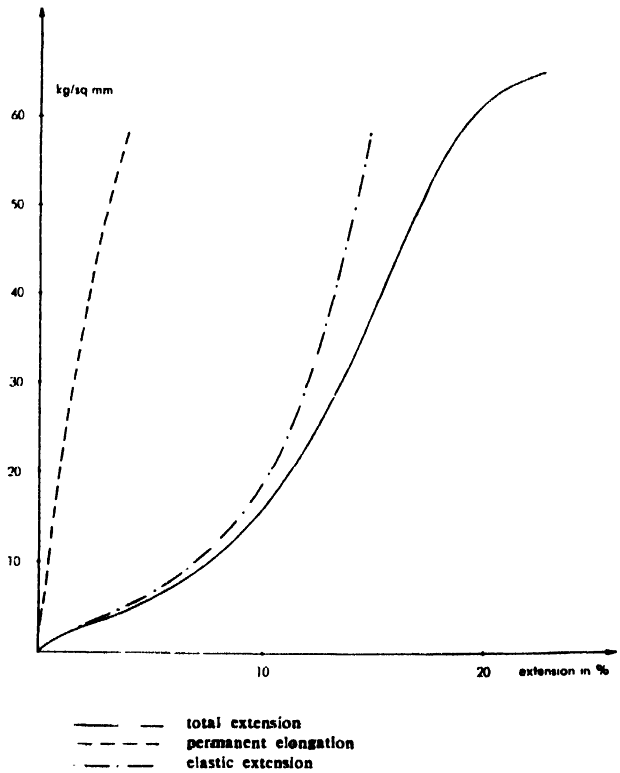


Illustration III.

Elasticity Graph of Perlon Continuous Filament in Denier 7,500 (Single Filament Denier 6).

The graph shows not only the greater strength of Perlon rope but also its higher working capacity, which enables it to absorb shocks like a spring; when stretched it recovers its original length very soon except for a slight, but permanent elongation of approximately 10 per cent.

Illustration III gives some idea of this elasticity as shown by a composition of 7,500 denier, single filament denier 6, with a tensile strength of 64 kg. sq. mm. Natural fibres can achieve similar values only through special construction. There is complete elasticity up to approximately 5 per cent. of the breaking load i.e. the permanent elongation is nil. Above this load a permanent deformation occurs which becomes relatively less as the extension increases. As a result the difference between total extension and permanent elongation increases further.

The relation of elastic extension to total extension gives the elastic ratio, which can be said to hold good for Perlon proportionate to the magnitude involved. Illustration IV compares the elastic ratios of Perlon and cotton yarns.

The load/extension curve has already shown up fundamental differences, which occur once again in a comparison of elasticity. Whilst Perlon shows a high proportion of elasticity within the total extension, with cotton fibres the permanent elongation predominates and leads to a much steeper fall of the elasticity graph.

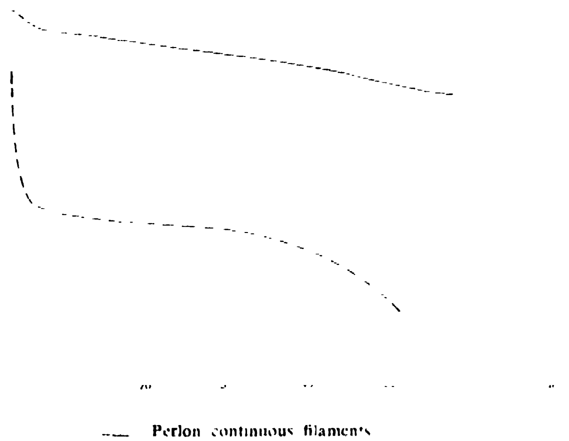


Illustration IV.
Elasticity Graph of Perlon Continuous Filament in Denier 7,500 (Single Filament Denier 6) and of a Cotton Yarn.

From Illustration V it appears that immediately the load has been applied a high degree of extension ensues, which regains its equilibrium within the next 15 and 30 minutes respectively. The extension is not proportional to the increase in the load, but is relatively greater at low and medium loads than at high loads.

This gives Perlon a springy quality which enables it to absorb kinetic energy as shown below.

Material	*Dry*	*Wet*
Manila	100	60
Italian Hemp	160	110
Perlon	700	500

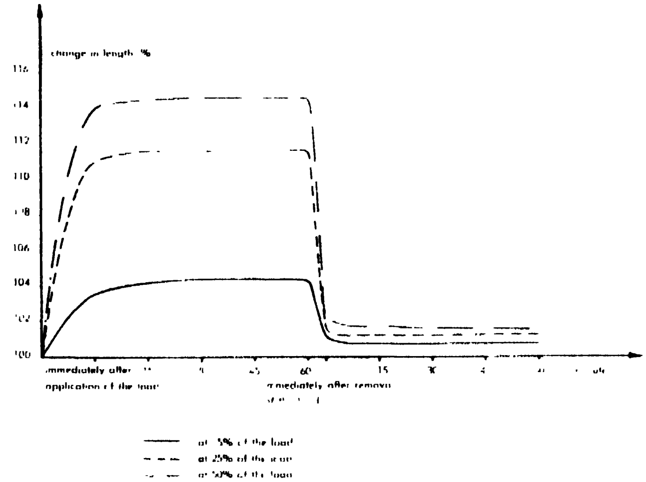


Illustration V.
Extensibility and Elasticity of Perlon Continuous Filament (Denier 7,500, Single Filament Denier 6) in Relation to Time and Load.

5. Flexibility

Net twines made of continuous filament and staple fibre are softer than those made from natural fibres. This applies particularly to their wet state as shown in tables.

Hardness, dry and wet of Net Twines of 2·3 mm. Diameter

Raw Material	*Dry*	*Wet*
Manila	700	410
Hemp	120	110
Cotton	42	140
Perlon Filament	44	21

The higher the figure the harder the net twine.

For some fishing nets, in particular fine gillnets, flexibility is a very desirable quality; for others it is of minor importance. This can be achieved by applying a stiffening preparation which at the same time gives the nets greater resistance to abrasion and sunlight.

6. Abrasion Resistance

Perlon has a high resistance to abrasion which together with non-rotting quality determine the useful life of nets.

Wet abrasion tests of net twines showed the following results related to their weight per metre:

Net Twine Weight g/m	*Wet Abrasion Rubs* *Hemp*	*Manila*	*Perlon Filament*
1·5	420	--	660
2·5	630	380	930
3·0	940	400	1,510
4·0	1,210	540	2,120
4·5	1,340	580	2,430

Staple fibre net twines show a lower abrasion resistance than those made of continuous filament but still show considerably greater resistance than those made of cotton fibres. A staple fibre net twine Nm. 20/24 has a wet abrasion resistance of 270 whereas a resistance of 150 was shown by a cotton net twine of the same strength.

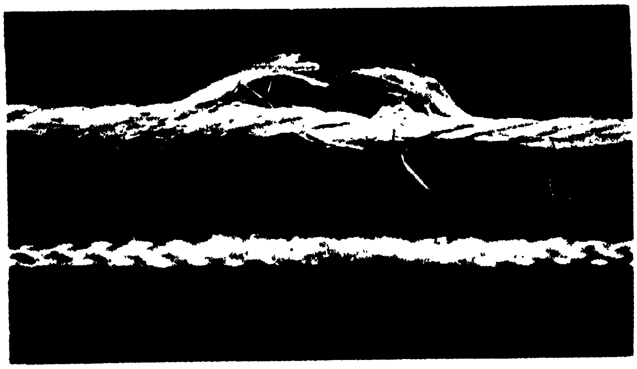


Illustration VI.
Manila net twine and Perlon continuous filament braided cord after 500 wet abrasion double rubs.
Photo: Klust 1957

A breaking extension test showed a 62 per cent. loss of tensile strength for the manila cord, compared with 19 per cent. for the Perlon braided cord.

7. Weather Resistance

Both synthetic and natural fibres, are weakened by exposure to sunlight, but monofils display a high degree of resistance to sunlight and weather conditions, superior to that of vegetable fibres, and close to the immunity of poly-acrylonitrile fibres.

Net twines of staple fibre or continuous filament lose more strength than natural fibre twines when exposed to intense sunlight, but because of their high initial strength they remain in the last analysis superior to natural fibres. The bigger the diameter the less noticeable the photo-degradation, which is insignificant for thick ropes as the layers below are protected by the degraded outer layer and which is probably no deeper than 1 mm. to which ultraviolet rays can penetrate.

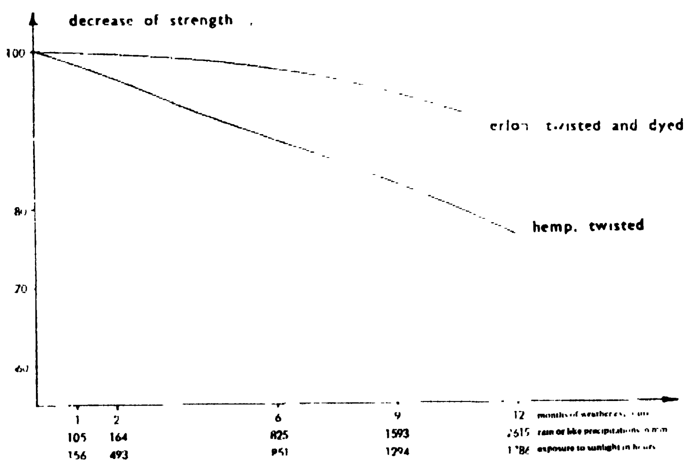


Illustration VII.
Influence of weather exposure on ropes made of Perlon continuous filament and hemp respectively. Rope circumference: 1½ in. Weather exposure at 6,230 ft. above sea level.

Where Perlon twines are exposed to intense sunlight for long periods, as for example, in the case of fyke nets, it is advisable to dye them. They can easily be dyed with *Perliton* dyes, which dyes must be selected with a view to fastness and with acid dyes—*Telon*—light and fast dyes respectively, which are remarkable for their fastness in water. Treatment with a mixture of tannic acid and antimony potassium tartrate is particularly durable in seawater. Treatment with a catechu solution has proved an excellent protection against sunlight.

8. Hygroscopic Behaviour

Perlon has a low moisture regain. An examination of moisture content in air-dry conditions (65 per cent. relative air humidity, 20 deg. C.), and swelling ratio (degree of saturation) shows the following results:

Raw Material	*Moisture Content in Air-Dry-Conditions* %	*Swelling Ratio* %
Cotton	7·8	45
Bast Fibres	7 13	100–110
Perlon	4·2	12–14

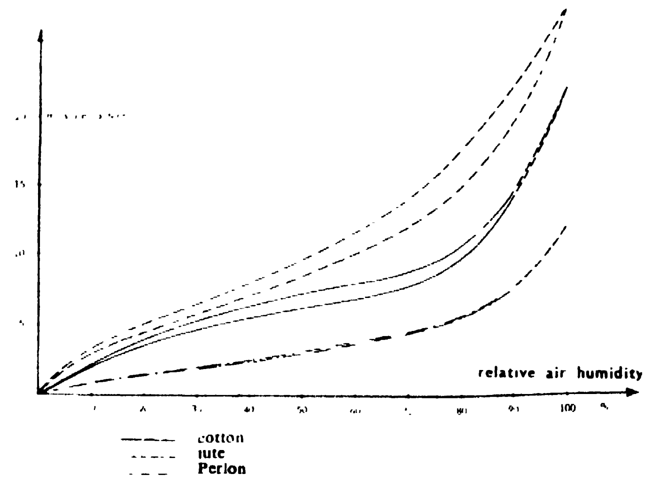


Illustration VIII.
Absorption and Desorption of cotton, jute and Perlon.

For Perlon, absorption and desorption are of almost identical magnitude in contrast with the far more marked "swelling hysteresis" of natural fibres and it therefore dries appreciably faster.

The level of moisture regain is known to be closely related to the lateral and longitudinal swelling caused by wetting. Cotton net twines receiving a first wetting of 24 hours, showed lateral swellings of between 5 and 15 per cent.; bast fibre net twines showed an increase of 20 to 40 per cent. in their cross-sectional area whereas Perlon continuous filament net twines contract rather than swell. The following comparison in thickness of a Perlon cable Nm. 0·9, single filament denier 20, with a hemp cord of equal size may serve as an example:

		Hemp	*Perlon*
Diameter dry	mm	1·65	1·42
Diameter wet	mm	2·02	1·38
Variation in Cross-section	%	+22	—3

Net twines made of natural fibres swell considerably and shrink as a result. It amounts to approximately 6 to 9 per cent. for cotton net twines, and to approximately 2 to 8 per cent. for hard bast fibres.

Continuous filament twine behaves quite differently. An immersion in water gives rise to an extension proportionate to the cross-sectional shrinkage, in the region of 1 to 3 per cent. The changes in length and cross-section are only slight and consequently assure a constant mesh size.

9. Chemical Resistance

Perlon is resistant to rot in both fresh and seawater. Solvents which do not affect it and may be used in preparations to increase resistance to sunlight or stiffness are listed below:

Methyl ethyl ketone	(+60° C);
perchlorethylene	(+20° C);
acetone	(+56° C);
trichlorethylene	(+80° C);
carbon disulphide	(+20° C);
dimethyl formamide	(+20° C);
benzine	(+60° C);
cyclohexanone	(+80° C);
chloroform	(+20° C);
carbon tetrachloride	(+60° C);
formamide	(+20° C);
(base) alcohols	
ethyl oxide	(+35° C);

Perlon solvents include concentrated solutions of formic, hydrochloric and sulphuric acid, as well as phenol (carbolic acid), cresylic acid and resorcin.

Products with a phenol content, such as tars, can in certain cases cause swelling and consequently a loss of strength. Specially treated tars contain only small quantities of phenol derivatives and of phenol itself. In crude tar, however, these substances, "acid oils", may be present in fairly large quantities, although there is a steep variation in the percentage. It seems advisable to draw special attention to this aspect, since tars are also used as stiffeners.

10. Thermal Properties

Perlon has a high resistance to cold and retains its elasticity even when frozen. There is, in fact, an increase in strength and conversely a loss of extensibility down to a temperature of −40 deg. C. The temperature needed in dyeing processes does not damage the nets, but a certain amount of shrinkage must be expected and therefore ascertained by preliminary tests on small samples.

11. Visibility

Perlon net twines can be very fine and accordingly inconspicuous in the water.

The translucent monofil is almost invisible under water and this property has increased the catches of monofil setnets and fyke nets.

12. Processing

Staple fibre net twines can be processed into netting without difficulty, manually or by machinery. They can be tied in non-slip knots in the same way as cotton net twines. With monofil and continuous filament twine, however, slip-proof knots cannot be assured because of the smoothness of the fibre. Tests are about to be completed which aim at giving monofils a rough surface while preserving the inherent strength to increase the knot fastness.

Continuous filament net twines can be roughened by treating them, preferably while they are being twisted, with a preparation insoluble in water, which gives them adhesive properties (bonding).

The resistance to slippage of Perlon continuous filament twine has been improved by blending spun staple fibres.

Another possibility is the heat-setting of the knots under tension, at temperatures of 150 to 180 deg. C. usually applied for *short* periods only.

With nets it is essential to maintain an even tension and twist in the Perlon material. Hawser-laid or cable laid ropes must be heat-set if necessary. No stabilization is needed, however, if the individual twists reinforce each other. With such a construction heat-setting is only needed where splices have to be made.

Cordage can be set by hot air treatment, saturated steam treatment or boiling. Boiling is preferable for heavier types since neither hot air nor saturated steam can penetrate evenly enough through the rope.

In continuous filament too hard a twist should be avoided as this would reduce strength and increase extension, particularly that proportion which is permanent. Braided twines for fishing nets should be braided with a medium degree of hardness. On no account should a high degree of hardness be employed.

13. Storage

Perlon nets and ropes should not be left exposed to the sun. They are best kept in dark rooms and can be stowed while still wet. Nets which are freshly treated with preservatives should be handled in the same way as natural fibre nets: they should only be stored after having been used at least once. This applies particularly when stiffening preparations have been used.

14. Attack by Micro-Organisms

Perlon is immune to attacks by micro-organisms such as bacteria or fungi, nor do molluscs, barnacles and other organisms harm it. However, the larvae of the mayfly which settle particularly on stationary fishing gear in inland waters can cause considerable damage to nets; synthetic fibres are as much affected as cotton nets. Treatment with pesticides (Arkotine, Dieldrin) ensures a high degree of protection.

In running waters which contain organic effluents thick clusters of "sewage fungi" occur which soon cover the nets. Frequent cleaning is needed, or catches are lost. Rhine fishermen are particularly affected by this fouling of their stow nets. Nets made of Perlon filament braided twine are less affected because of their smooth surface and can be cleaned easily and quickly.

V. USE OF PERLON IN VARIOUS TYPES OF FISHING GEAR

The economics of fishing gear depend, generally speaking, on initial costs, useful life, costs of preparation, maintenance and efficiency.

The initial cost for a given weight of nets is higher for Perlon than for cotton, hemp and especially manila, but the useful life of Perlon is considerably longer because of the high degree of resistance to rot and abrasion. While these nets need little or no preservative treatment nets of cotton, hemp and flax must be treated frequently. The expenditure in money and time involved represents a severe burden.

Maintenance largely consists in preventing unnecessary exposure to sunlight and with monofil even this protective measure becomes unnecessary.

The following paragraphs outline the use of Perlon for some of the more important types of equipment.

1. Trawls

At the Fishery Industry Fair 1957 in Copenhagen was a still usable bottom trawl made of Perlon braided twine used by a German trawler to catch 128,000 cwt. of herrings having a performance and useful life between 8 to 10 times as great as that of the customary manila trawls. Although Perlon trawls cost two or three times as much as manila trawls, their economic advantages are beyond question. Their low weight, flexibility and smoothness make them easier to handle and the finer net twines noticeably reduce the tow drag.

Probably the most important advantage is the capacity of Perlon to absorb kinetic energy. The nets also ensure the safe landing of big catches on deck as shown by the big catches of Norway haddock when Perlon codends were used. About half the German cutter fishermen use Perlon for the codends in drag-nets for catching herring. The material in this case was spun staple fibre twine in counts Nm. 20/15 to 20/21.

2. Purse Seines

This type of equipment plays an important part in the fishing industry of many countries, although not in Germany. Its traditional net material is cotton twine of medium strength. In the Portuguese fishing industry, for example, cotton nets treated with preservatives may have a useful life of between 400 and 500 fishing days.

Large pieces of Perlon spun staple fibre webbing have been employed in Portuguese purse seines for 1,300 fishing days without becoming unusable. These nets were not dyed or prepared in any way. For purse seines Perlon has the following advantages: reduction in the total weight of fishing equipment (essential considering the size of the equipment involved); almost no expenditure on net preservatives; no necessity to keep one set of nets on land for preservation purposes; less labour required to handle the gear; water-saturated nets can be safely stowed and a useful life at least double compared with cotton nets.

Perlon continuous filament rope of 30 mm. in diameter has been used for 1,164 days as a purse line. It should have five times the useful life of a sisal rope to justify its higher price; it has already had nineteen times the life of a sisal rope.

3. Bottom-Set Gillnets

Set and floating nets used as fine gillnets are highly selective, helping to conserve young stock and supplying fish of high quality. Bottom-set nets are passive rather than active and must be as fine and as soft as possible having the least degree of visibility, requirements met by net twines of Perlon continuous filament yarn in a denier even finer than that quoted in IIIb (100 denier and finer). Monofils are particularly suitable for set gillnets due to their extremely low visibility in water. Now that the problem of providing non-slip knots has been solved and mechanically produced netting can be obtained, set gillnets of monofil assumed considerable importance for fishing in inland waters.

4. Stationary Fishing Gear

Perlon products have proved their efficiency and economy when used for fyke and stow nets and traps.

A cotton eel trap such as those used by fishermen in the North German inland lakes, costs about DM 24.00 and lasts 4 years with preservative treatment. A Perlon spun staple fibre eel trap costs DM 17.08, needs no additional expenditure and remains completely efficient for approximately four years.

Monofils proved even more suitable for eel traps; owing to their translucence they catch more eels.

Cotton stow nets have a useful life of about two years if treated between 7 and 10 times with hot tar to preserve and stiffen them. A stow net of Perlon staple fibre twine has been in use for six years now and has been stiffened twice, once with black varnish and once with tar. Total costs for this stow net, which is still in full use, amounts to DM 1,625.00. During the six years, at least 3 cotton stow nets would have had to be purchased, costing DM 3,270.00.

5. Whaling Ropes and Cordage

In antarctic whaling, ropes of Perlon continuous filament between 100 and 120 metres in length used with the 70 kilogram explosive harpoons have proved their worth as "foregoers".

The strength of the fibres makes it possible to use ropes with a diameter of 33 to 34 mm., as compared to 38 mm. for manila ropes. Perlon ropes do not stiffen in water and hardly ever ice up. The elasticity can absorb the high shock loads involved and greatly reduces the danger of a rope breaking.

6. Tarpaulins and Protective Covers

Tissues of Perlon continuous filament yarns, PVC= Polyvinyl Chloride coated on both sides are used for tarpaulins, lifeboat covers, etc. They can be folded quickly and require little storage space, They are rot-proof, watertight, tough and can be fireproof.

"TERYLENE" POLYESTER FIBRE AND ITS RELATION TO THE FISHING INDUSTRY

by

IMPERIAL CHEMICAL INDUSTRIES LTD.

(Fibres Division), Harrogate, U.K.

Abstract

"Terylene" polyester fibre is a new synthetic fibre of British manufacture which, although being of considerable importance in the textile trade, is comparatively new to the fishing industry. It has physical properties that make it suitable for fishing twines and nets. It has high tensile strength and a high wet knot strength. It is rot-proof and has good resistance to sunlight, and, under wet conditions has also good resistance to abrasion. Like other synthetics, knot slippage is a problem, but this can be overcome by bonding agents either before or after the weaving of the net. Dyeing is preferably done during the manufacture of the nets and it is not recommended that the fishermen should do it themselves because of difficulties in temperature control. Terylene is used with success for gillnets in many parts of the world, mainly for catching "hard" fish such as salmon and cod. For "soft" fish like the herring, it has not yet been fully accepted because of the damage done to the fish when hauling the nets. Trawls, however, have proved very successful, for on test they have lasted for 9 trips instead of the usual single trip with the conventional trawl. The comparatively high cost of "Terylene" is to some extent offset by the length of its life.

La fibre polyester "Térylène" et ses applications dans l'industrie des Pêches

Résumé

La fibre polyester "Térylène" est une fibre synthétique nouvelle de fabrication britannique; bien qu'elle soit très répandue dans le commerce textile, son emploi dans l'industrie des pêches est relativement récent. Elle possède des propriétés physiques qui font qu'elle convient à la confection de fils et de filets de pêche. La résistance à la traction des fibres et des noeuds mouillés est très élevée. Elle est insensible à la pourriture et possède une bonne résistance à l'action du soleil; à l'état humide elle possède également une bonne résistance à l'abrasion. Les noeuds exécutés avec des fils de Terylène, comme avec les fils constitués par d'autres fibres synthétiques, ont tendance à glisser, mais on peut résoudre ce problème en traitant les fils avec des adhésifs soit avant, soit après la confection du filet. Il est préférable de procéder à la teinture au cours de la confection du filet et il est déconseillé aux pêcheurs de l'éxécuter aux-mêmes en raison des difficultés qu'entraine le contrôle très exact de la température pendant l'opération. Le Térylène est utilisé avec succès dans de nombreux pays pour la fabrication des filets maillants, principalement pour la capture de poissons "durs" comme le saumon et la morue. Pour des poissons "mous" comme le hareng, il n'a pas encore été universellement adopté car il endommage les poissons lorsque l'on embarque les filets. Mais il a donné d'excellents résultats pour la confection de chaluts qui, à la suite d'essais, ont tenu neuf campagnes au lieu d'une seule avec le chalut conventionnel. Le coût relativement élevé du Térylène est compensé dans une certaine mesure par sa plus longue durée.

La fibra de "terileno" y su relación con la industria pesquera

Extracto

La fibra sintética llamada "terileno" es un nuevo tipo de poliéster manufacturado en Gran Bretaña, que tiene gran importancia en la industria textil pero es comparativemente nuevo en las faenas de pesca. Sus propiedades físicas se prestan para fabricar hilos y redes, a causa de su gran resistencia a la tracción aun cuando está anudada y húmeda; además no se pudre, sufre bien la acción de la luz solar y ofrece bastante resistencia al desgaste cuando está mojada. Como en otros productos sintéticos, los nudos presentan el problema de correrse pero esto se soluciona mediante agentes de unión que se aplican antes o después de tejer el arte. Luego de confeccionar la red es preferible proceder a su entintadura, no recomendándose que la haga el pescador a causa de las dificultades que presenta la regulación de la temperatura. El "terileno" se usa con éxito en muchas partes del mundo, principalmente para capturar peces "duros" como el salmón y el bacalao, pero no ha sido aceptado del todo para las especies "blandas" como el arenque, a causa del daño que produce al pescado cuando se recogen las redes. No obstante, ha tenido éxito en la construcción de artes de arrastre, por haber resistido durante las pruebas nueve vez de una marea-que dura el material corriente. El costo relativamente alto del "terileno" se compensa, en parte, con su mayor duración.

GENERAL INTRODUCTION

TERYLENE polyester fibre is a new synthetic fibre which has already made a considerable impact on the textile industry and has significantly affected certain fields which have hitherto been dominated by natural fibres. Apart from its merits in the manufacture of wearing apparel and for industrial use, the special properties of Terylene make it suitable for employment in the fishing industry. It has been used not only for netting twines, ropes and lines, but also for lifeboat and hatch covers, sails and tarpaulins.

The fibre is a British discovery made by J. R. Whinfield and J. T. Dickson in the Laboratories of the Calico Printers' Association Ltd., between 1939 and 1941. Later the world patent rights, with the exception of the USA were acquired by ICI Ltd., and the name "Terylene" became a registered trade mark, the property of ICI Ltd. Recently several European companies have been licensed to manufacture the fibre under their own trade names, and it is also being made in Canada by Canadian Industries Ltd.

A new factory at Wilton, Middlesbrough, Yorkshire, produces over 25 million pounds per annum, and larger outputs are envisaged.

TYPES OF YARN

Both continuous filament yarn and staple fibre are manufactured. The continuous yarn can be divided into two categories. The first is a yarn with a tenacity of 6 to 7 grams per denier and a corresponding extension at break of 12½ to 7½ per cent. This yarn, which is intended primarily for industrial uses, is being manufactured currently in 125 denier/24 filaments and 250 denier/48 filaments. It enables very fine and strong twines to be produced. The development of a high tenacity extra heavy denier yarn is under way which will enable heavier nets,

TABLE I

Physical Properties of Fishnet Twines—Natural Fibres

		Hemp		*Flax*			*Cotton*		
	Construction	7·8s/3	6·3s/3	6·9s/3	10s/3	13·2s/3	8·8s/3/3	30s/7/3	29s/5/3
	Count	2·6	2·1	2·6	3·35	4·4	1·1	1·4	1·96
	Twist t.p.i. twine	—	—	—	—	—	5·5 Z	8·3 S	8·6 S
	strand	5·7	6·0	3·7 Z	6·6 S	3·9 Z	18·7 S	9·5 Z	12·4 Z
	yarn	5·7	6·0 S	6·0 S	6·7 Z	6·2 S	1·1 Z	1·4 Z	1·9 Z
	Runnage (yd./lb.)	780	630	780	1006	1318	922	1170	1646
DRY	Breaking Load (lb.)	38·3	37·8	28·3	27·8	23·8	14·8	15·0	10·5
	Extension (%)	4·6	5·8	6·5	6·25	5·4	16·0	11·5	14·2
	Tenacity (g.p.d.)	3·0	2·4	2·3	2·8	3·2	1·4	1·8	1·8
WET	Breaking Load (lb.)	44·8	49·4	45·5	36·8	29·4	19·9	19·1	13·1
	Extension (%)	8·9	10·0	9·7	7·8	9·1	24·2	27·8	27·2
	Tenacity (g.p.d.)	3·6	3·2	3·6	3·8	3·9	1·9	2·3	2·2
DRY	Knot B/L (lb.)	15·7	22·2	19	14·8	12·0	8·21	8·5	5·5
	Extension (%)	11·5	8·4	9·0	10·0	10·0	17·0	10·1	13·0
	Tenacity (g.p.d.)	1·2	1·4	1·5	1·5	1·6	0·77	1·0	0·92
WET	Knot B/L (lb.)	19·5	18·2	19·1	12·8	13·0	12·6	11·9	8·3
	Extension (%)	22·4	15·5	10·0	8·1	10·0	24·1	28·9	24·5
	Tenacity (g.p.d.)	1·6	1·1	1·5	1·3	1·7	1·1	1·4	1·4
	Abrasion dry revs.	48	54	124	60	71	1195	898	1183
	„ wet revs.	178	201	125	123	158	208	169	154

TABLE I (continued)

Physical Properties of Fishnet Twines—Synthetic Fibres

		Terylene			*Amilan*			*Nylon*		
	Construction	250/8/3	250/6/3	250/4/3	210/8/3	210/6/3	210/5/3	210/8/3	210/6/3	210/4/3
	Denier	6662	4980	3342	5247	4034	3323	5547	4160	2784
	Twist t.p.i. strand	6·3 Z	5·4 Z	7·1 Z	5·8 Z	6·0 Z	6·5 Z	4·6 Z	5·1 Z	7·0 Z
	yarn	10·7 S	12·2 S	14·9 S	10·6 S	11·5 S	11·7 S	11·8 S	12·2 S	15·0 S
	Runnage (yds./lb.)	672	896	1336	850	1106	1343	805	1073	1603
DRY	Breaking Load (lb.)	78·0	58·5	38·3	50·7	39·3	31·7	63·8	52·8	33·8
	Extension (%)	31·1	29·4	27·5	56·0	47·6	45·0	45·0	42·6	41·1
	Tenacity (g.p.d.)	5·3	5·33	5·2	4·4	4·4	4·3	5·2	5·8	5·5
WET	Breaking Load (lb.)	78·4	58·9	38·1	45·9	31·0	29·0	60·9	45·2	27·1
	Extension (%)	30·9	27·6	20·5	55·7	48·9	46·2	47·2	43·7	41·8
	Tenacity (g.p.d.)	5·3	5·4	5·2	4·0	3·5	4·0	5·0	4·9	4·4
DRY	Knot B/L (lb.)	27·0	17·6	12·2	26·4	18·3	16·6	26·8	21·4	11·6
	Extension (%)	11·1	9·1	9·2	24·6	24·3	23·3	18·7	17·9	17·6
	Tenacity (g.p.d.)	1·8	1·6	1·7	2·3	2·1	2·3	2·2	2·3	1·9
WET	Knot B/L (lb.)	26·0	20·8	14·3	21·7	16·4	13·1	20·3	17·9	12·1
	Extension (%)	9·6	9·6	10·5	26·7	25·2	22·5	24·7	21·7	21·4
	Tenacity (g.p.d.)	1·8	1·9	1·9	1·9	1·8	1·8	1·7	1·9	2·0
	Abrasion dry revs.	1412	1921	2090	5949	8093	10024	3277	6817	8974
	„ wet revs.	1098	1429	1785	1891	1095	1561	1649	1968	2622

e.g. trawls, to be produced more economically. All the high tenacity yarns are bright.

The second category comprises a yarn with a tenacity of 4½ to 5½ grams per denier and a corresponding extension at break of 25 to 15 per cent. It is intended mainly for wearing apparel and is produced in deniers ranging from 25 to 150, most of which can be obtained in either bright or delustred forms.

A staple fibre, with a tenacity of 3½ to 4 grams per denier and a corresponding extension at break of 40 to 25 per cent., is currently being manufactured, ranging in staple length from 1½ to 6 in. and from 1½ to 6 denier (that is 1½ in. staple, 1½ denier) for processing on the cotton system, up to 6 in. staple, 6 denier for processing on the flax system. All staple fibre has a heat stabilized crimp and is available with a dull-lustre. Filament yarn is twisted to three-quarters of a turn per inch and supplied to the trade on bobbins.

The fibre is made from polyethylene terephthalate, a condensation product of terephthalic acid and ethylene glycol, both of which are derived through various chemical processes from the products of mineral oil cracking. The polymer is chipped, and the fibre produced by a melt spinning process. Molten polymer is pumped through a spinneret and the spun yarn is subsequently mechanically stretched to develop fibre-like properties. The filament yarn has been exported overseas to be made into twines and nets. In certain countries, where limited doubling facilities are available, twines have been exported by manufacturers in the United Kingdom. Complete nets have also been supplied in certain instances.

The fishing industry is mainly interested in the high tenacity filament yarn on the grounds of high strength and low extensibility, although the staple fibre is used for specialized purposes, such as net mounting ropes.

PHYSICAL PROPERTIES

The most important physical properties which this yarn can offer for use as twines or netting are:

(i) High tensile strength which is unaffected by wetting. In particular, it has a high wet knot strength.
(ii) Low extensibility and high modulus.
(iii) Rot proof and not weakened by mildew.
(iv) Good resistance to sunlight.
(v) Stability on water immersion coupled with low moisture absorption.
(vi) Good resistance to abrasion under wet conditions.
(vii) The smooth nature and transparency of the material.

Other fibres mainly used for netting twines are cotton, flax, manila, sisal and polyvinyl alcohol such as Kuralon, and the polyamides Perlon and Nylon. The general physical properties of a range of Terylene fishnet twines in comparison with twines made from the fibres mentioned above are given in Table I.

A study of this table demonstrates the advantages which the fibre has to offer. A loss in strength on knotting is common to all fibres, and synthetic fibres may lose relatively more strength on knotting than natural fibres, such as cotton and linen, but as the initial strength of Terylene is very much higher, its actual knotting strength remains above the level of natural fibres.

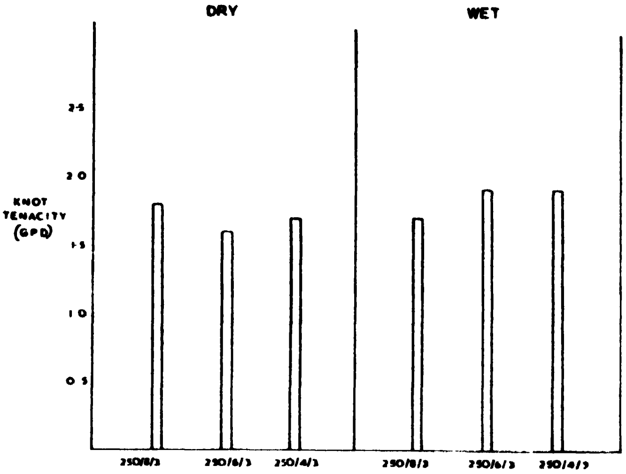


Fig. 1
Single Knot Tenacity of Terylene Twines.

In the dry state the twines may have a slightly lower dry knot tenacity than comparable nylon twines. The wet knot tenacities of the two are not significantly different (see figs. 1 and 2). The wet knot strength of a fishnet twine is obviously of more importance than its dry knot strength. The strength of a twine depends not only on the fibre from which it is made, but also on its construction (twist, number of strands, etc.). The tables also show the low extensibility of Terylene and its resistance to stretch. This facilitates the manufacture of nets with mesh sizes which conform to the required specification and which resist distortion in use.

Terylene twines do not shrink when immersed in water at ambient temperature, but they will shrink at elevated temperatures. If the nets are to be subjected to various heat treatments, e.g. dyeing, prior to use, and the mesh size is critical, an allowance should be made for shrinkage.

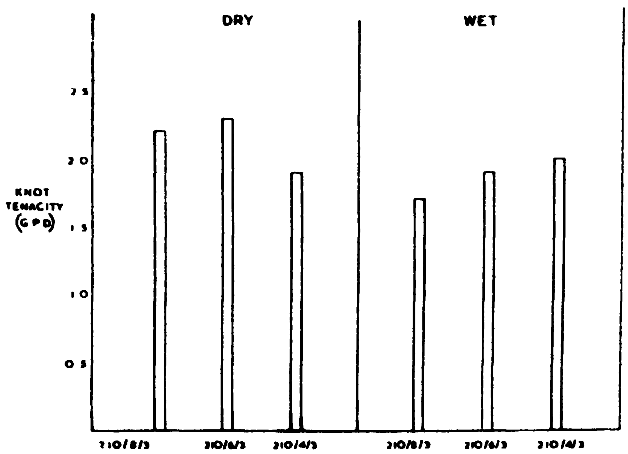


Fig. 2
Single Knot Tenacity of Nylon Twines.

The abrasion resistance of the twines is superior to those made from cotton and flax. Unlike most synthetic fibres, its abrasion resistance is not appreciably different under wet conditions. The data above were obtained by rubbing both wet and dry twines over a 3 mm. thick hardened carbide steel bar. The abrasion resistance of nylon twines is significantly better than that of Terylene twines, but the difference under wet conditions is not nearly so marked. In practice Terylene fishnets can be expected to show good wearing qualities because of their good wet abrasion resistance. Mention has already been made of the low moisture absorption of the fibre (Table I) and this is clearly shown in the graph (fig. 3). This means that on immersion in water the twines do not swell, the mesh sizes of the nets remain intact, little change in effective net weight occurs, and the twines dry quickly.

The smoothness, fineness and transparency of the material eliminate air bubbles and contribute to a low order of visibility.

The fibre has very good resistance to chemical attack, in particular to acids and oxidizing agents. It is thus resistant to sea water attack and unaffected by contact with oils, cutch and tar. This has been demonstrated in certain areas where traditional nets were affected by chemical contamination which had no effect on Terylene nets.

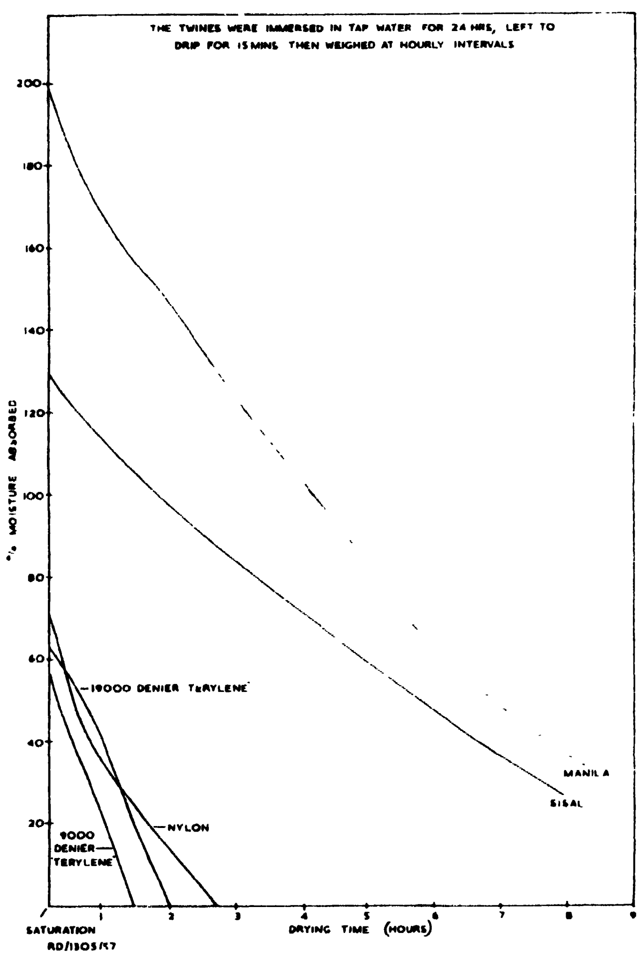


Fig. 3

The rate of drying of Manila, Sisal, Nylon and Terylene Twines.

In connection with the use of Terylene in twines and nets, the following points are worthy of mention:

KNOT SLIPPAGE

In the manufacture of fishing nets, two types of knots are commonly used, the single sheet bend (single weaver's knot) and double sheet bend (double weaver's knot). The latter type does not slip during use and double knotted twines have a knot strength about 10 per cent. higher than single knotted twines. Both Terylene and nylon single knotted nets are prone to knot slippage, but the tendency is less with Terylene. Tests carried out on samples of Terylene, nylon, cotton and linen single knotted gillnets showed that three out of every four knots slipped in the case of nylon when dry and one in four when wet. One out of every four Terylene knots slipped when dry, but none when wet. No knot slippage occurred with the cotton net and only occasionally with the linen net. However, the resistance of Terylene to single knot slippage is not considered to be good enough and as more single knotted fish netting is produced than any other, knot slippage constitutes a problem. It is said that the somewhat slow rate of production of double knotting machines has been improved and is now about the same as the single knotting machine.

Knot slippage is a result of the smoothness of synthetic filament yarns, and an obvious answer is to increase the coefficient of friction of the twines by the application of a surface coating. The anti-slip agent may be applied to the twine during manufacture of the net, or to the finished net to fix the knots. Some net manufacturers consider both pre- and post-treatments are necessary. The general view seems to be that the nets should be made from bonded twines to enable an undistorted net to be taken off the machine and safely transported to a stretching frame to tighten and fix the knots. In certain cases it is possible to avoid the use of prebonding agents by the application of very high tensions at the back of the loom. These consolidate the knots sufficiently for net handling prior to the stretching treatment.

The bonding agents recommended for Terylene fishnet twine are Colophony resin and Bedesol 76. Colophony resin is applied from a solution in methylated spirits or aqueous ammonia. Bedesol 76 is applied from a solution in 64 deg. over proof methylated spirits. Both bonding agents can be applied either by single-end gumming at a speed of 100 to 150 yards per minute, or by hank dipping for 15 minutes, draining, and, in the case of the ammonia solution of Colophony resin, drying for one hour at 80 deg. C. The percentage solids of resin required on the twines depend on the net making machine used. For a Seriville machine, the required pick-ups of Colophony resin and Bedesol 76 are 1·0 per cent. and 2·5 to 3·5 per cent. respectively. The former is achieved using a 5 per cent. solution and the latter a 6 per cent. solution. For the Zang machine the respective pick-ups are 2 to 3 per cent. and 5 to 7 per cent. In the first case a 7 to 8 per cent. solution is required and in the latter a 12 to

15 per cent. solution. As twines bonded from methylated spirit solution may be slightly sticky and as the solvent is inflammable, bonding from aqueous ammonia should be followed by drying at 80 deg. C. It also has the advantage of keying the resin to the fibre. The differences in optimum pick-up of the bonding agent for the Zang and Seriville machines are a feature of the more critical operating conditions for the Seriville machine.

As already mentioned, the net itself can be treated with bonding agents to prevent knot slippage. Both Colophony resin and Bedesol 76 have been satisfactorily used in concentrations akin to those for bonding twines. The net is opened out as much as possible to ensure that all of it comes into contact with the solutions. It is immersed for a minimum period of 10 minutes, with stirring or agitation to ensure an even application of solids. The net is then removed and dried. A more even application of the solids is obtained if the net is centrifuged to remove surplus solution before drying. Drying at a temperature of 80 deg. C. is preferable to drying in air at room temperature, since the latter process is very much slower, and leaves a net slightly sticky. About 4 per cent. allowance should be made for the shrinkage in drying at 80 deg. C.

During manufacture of the net it is important to ensure that the tensions applied to the twine are sufficient to pull the knots tight. In addition to being stretched, nets can also be given a steam or hot air treatment to consolidate the knots. Steaming the nets on a frame at 150 deg. C. for 15 minutes has been found to be most satisfactory.

As an alternative method P.V.C bonded twines have been used (about 5 per cent. pick up). The success of nets produced from such twines has been reported from Sweden. As a means of avoiding the use of bonding agents, Terylene/cotton and Terylene/spun acetate mixture twines have been produced. Single knots produced from such twines do not slip. It is also noteworthy that Terylene staple twines can be single knotted without slippage occurring.

DYEING

In many instances dyeing has been shown to give increased catches (e.g. blue-grey nets for Norwegian lake trout), but whether this applies generally to dyed synthetic nets has yet to be confirmed. However, fishermen usually demand nets dyed to a wide variety of shades, from reddish-brown to green and blue, and in many cases they prefer to dye their own nets.

No difficulties are to be expected in nets made from dyed Terylene twines. The twist set yarns may be dyed by using the appropriate equipment under normal dyeing techniques, i.e. with disperse dyestuffs for 90 minutes at the boil (with or without carrier), or at higher temperatures under superatmospheric pressures. If, however, the fisherman wishes to dye his own nets the matter is not so simple, because the necessary equipment is often not available for dyeing at the boil, although suitable dyestuff packages are available to enable the fisherman to dye his nets satisfactorily to a variety of shades. As mentioned previously, an allowance for shrinkage must be made if the mesh size of the net is critical.

Tinting of bonded twines at ambient temperature has been successfully carried out and it is possible also to tint

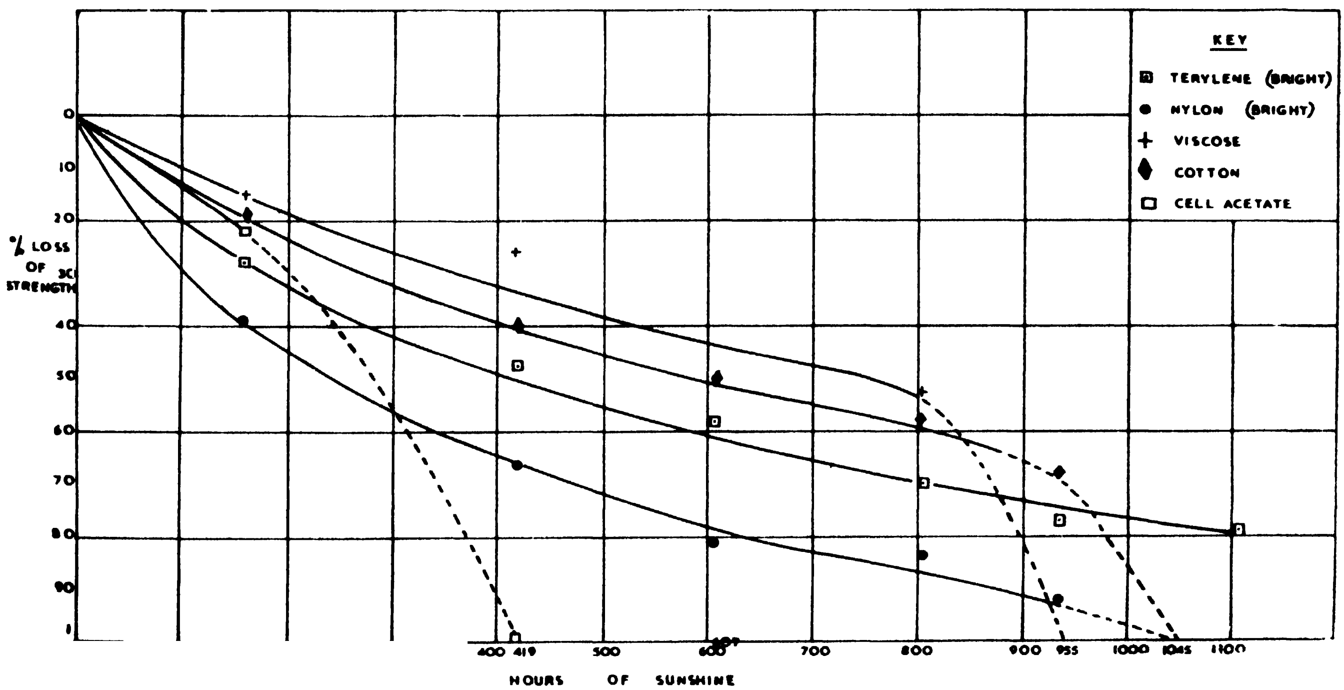


Fig. 4. Weather Tendering of Terylene and other fibres.

TABLE II

Average variation from nominal mesh size of different nets when tested dry and after immersion in water for 15 minutes and 24 hours

	Dry	*After immersion for 15 minutes*	*After immersion for 24 hours*
Linen . .	−1·92% to +1·92%	−2·88% to 0·96%	2·88% to 0·96%
Cotton . .	−1·16% to +1·16%	−3·53% to Nominal	−4·05% to Nominal
Nylon . .	2·35% to +2·59%	−2·22% to +2·00%	−2·06% to +2·34%
Terylene . .	−1·16% to +0·58%	−1·16% to +2·32%	−0·58% to +2·32%

(Data supplied by Dominium Textile Company Limited prepared for Canadian Government Specification Board).

the unbonded twine or net at ambient temperature by using disperse dyestuffs dissolved in chlorinated hydro carbons, but some shrinkage of the net may occur. Asphalt based solution can be used to stain and stiffen the net if required.

MESH RETENTION

Some tests have been carried out on the mesh stability of various types of net. The mesh was measured dry at room temperature, before being immersed in water, and also after the nets had been immersed for 15 minutes and 24 hours respectively. A summary of the results is given in Table II, and the superiority of the fibre in respect of mesh size retention is clearly illustrated. It is interesting to note that after immersion for 24 hours cotton shows the greatest variation with an average shrinkage of 4·05 per cent., followed by linen, nylon and Terylene in that order. It is submitted that a tolerance of 3 per cent. above or below the nominal mesh size is a realistic approach. This excellent mesh size retention of Terylene is of obvious importance with respect to gill-netting.

SUNLIGHT EXPOSURE

The fibre has about the same resistance to daylight and weather as the best of the natural fibres (see fig. 4), but because it has a higher strength premium and is rot proof it has a longer useful life. Trials have been carried out with Terylene and nylon twines exposed to daylight and weather in the United Kingdom, and the results are given in Table III and fig. 5. Even though the overall time of exposure is comparatively short the superiority of Terylene is clearly demonstrated. Terylene nets and others made from natural and synthetic fibres are now being exposed in several countries, such as Canada, Kenya, India and Scandinavia, but it is too early to draw conclusions from these tests.

DURABILITY

The general toughness of the fibre, its very good mechanical properties, complete resistance to rotting and good resistance to sunlight and weather, ensure a long life for Terylene nets.

TABLE III

Comparison of Terylene and Nylon Twines after Weather Exposure taken at Monthly Intervals

Constructional details of Twines

Terylene .	Resultant denier 4,190	Structure 250/5/3
Nylon .	Resultant denier 3,570	Structure 210/5/3

Exposure Dates	*Sun Hours*	*Total Sun Hours*	*TERYLENE* Breaking Load (lb.)	*TERYLENE* Extension %	*TERYLENE* Tenacity (gm./d.)	*TERYLENE* % loss in Bk. Load	*NYLON* Breaking Load (lb.)	*NYLON* Extension %	*NYLON* Tenacity (gm./d.)	*NYLON* % loss in Bk. Load
Control	—		47·7	23·6	5·2	—	42·5	30·6	5·4	—
1st July —31st July	137·63	137·63	37·4	18·0	4·1	21·6	33·3	27·4	4·2	21·6
1st Aug. —31st Aug.	117·2	254·83	32·0	15·9	3·5	33·2	28·4	24·8	3·6	33·2
1st Sept. —30th Sept.	108·7	363·53	29·6	14·9	3·2	37·9	24·1	22·5	3·1	43·2
1st Oct. —31st Oct.	127·9	491·13	29·7	18·6	3·2	37·7	22·6	21·6	2·9	46·8
1st Nov. —30th Nov.	55·6	547·03	27·0	14·0	2·9	43·4	22·1	21·3	2·8	48·0
1st Dec. —31st Dec.	13·1	560·13	26·0	15·0	2·8	45·8	16·2	19·8	2·1	61·9
1st Jan. —31st Jan.	30·69	590·82	26·4	14·9	2·9	44·6	18·7	21·1	2·4	56·0
1st Feb. —28th Feb.	73·3	664·12	27·0	14·7	2·9	43·4	17·0	18·6	2·2	60·0
1st Mar. —31st Mar.	80·2	744·32	27·1	16·5	2·9	43·2	14·8	19·5	1·9	68·2
1st April —30th April	133·0	877·32	25·7	16·9	2·8	46·1	15·3	22·1	1·9	64·0

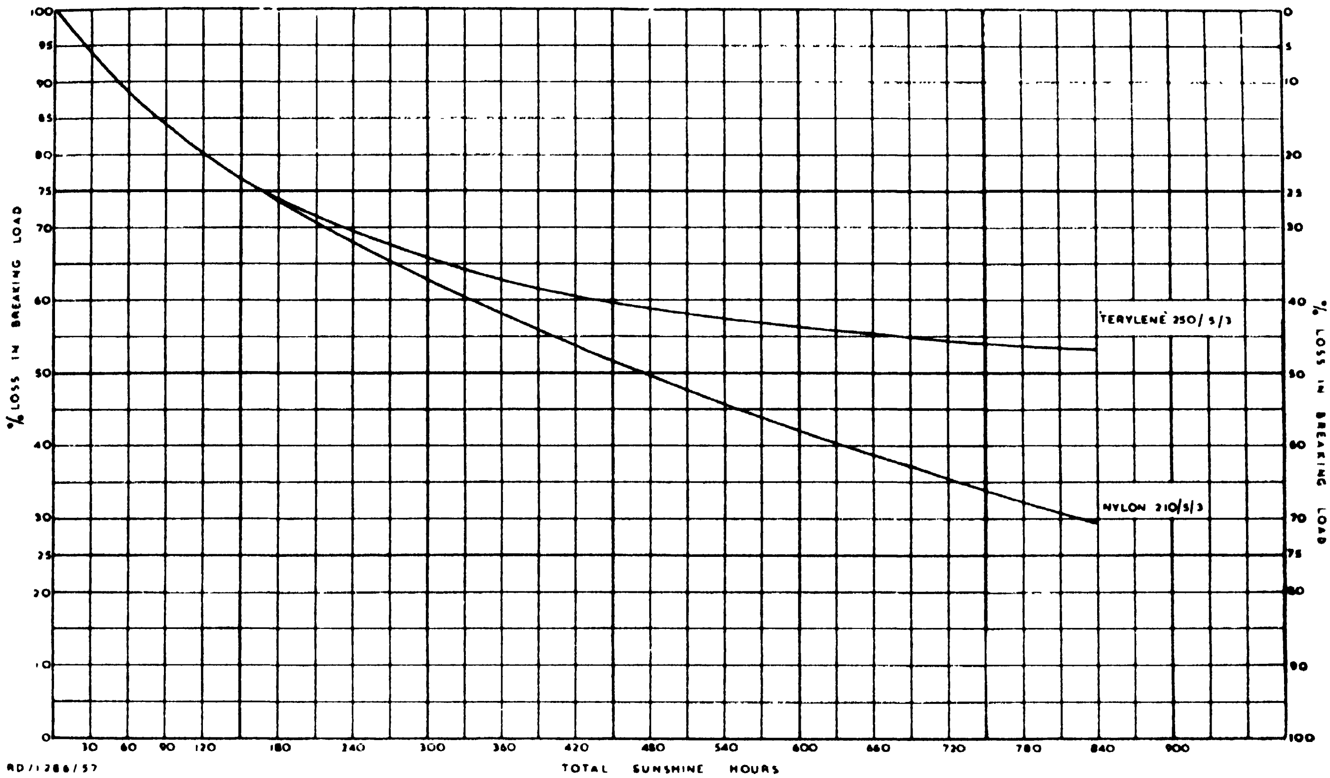


Fig 5. Comparison of 250/5/3 Terylene and 210/5/3 Nylon Twines after Exposure

EASE OF HANDLING

Nets made of the fibre are easy to handle because thinner twines can be used to give lighter nets. Trawl nets, for example, can be towed more easily. This weight saving factor makes it possible to use larger nets or, alternatively, a small vessel can be used to handle a net. The low moisture uptake means little effective change in weight, and the net is less prone to freeze under icy conditions. The somewhat high specific gravity of the fibre permits a net to sink more rapidly, while the high resistance to stretch is favourable to easy hauling.

COST

The nets are more expensive than natural fibre nets but they provide considerable savings on a price/life basis. In fairness it must be pointed out that the initial cost of the netting is sometimes very considerable and may be more than some fishermen can afford. The risk of accidental damage and loss must also be borne in mind. The difference in price between Terylene and the natural fibres becomes less marked in nets because twines of greater runnage can be used. The price of Terylene compares favourably with that of nylon in terms of pence per pound, but, because of its greater specific gravity, the twines have less runnage than nylon twines of equal thickness. Weight for weight, however, the twines have identical runnage.

CONSTRUCTION:

Cords and Twines

The fishnet twines are normally produced from 125 and 250 denier high tenacity filament yarn with plied and cabled constructions. In general, twist is inserted in the singles yarns in twines having plied constructions. The ply twist required to produce a "balanced" twine can be obtained from the formula:

$$\text{t.p.i. strand} = \frac{-\text{ t.p.i. singles}}{\sqrt{\text{No. of strands}}}$$

The negative sign indicates opposite twist. No twist is inserted in the singles yarn of twines having cable constructions. The twine twist required to produce a balanced cord is given by the formula:

$$\text{t.p.i. twine} = \frac{-\text{ t.p.i. strands}}{\sqrt{\text{No. of twines}}}$$

The amount of twist inserted at each stage in the production of the fishnet twines depends on the hardness of "handle" required and most manufacturers have certain twist factors which enable them to calculate the twist required. In order to produce a twine from Terylene filament yarn which has a balanced construction and a good yarn to twine strength conversion efficiency, twist factors in the range 3·6 to 4·6 are suggested.

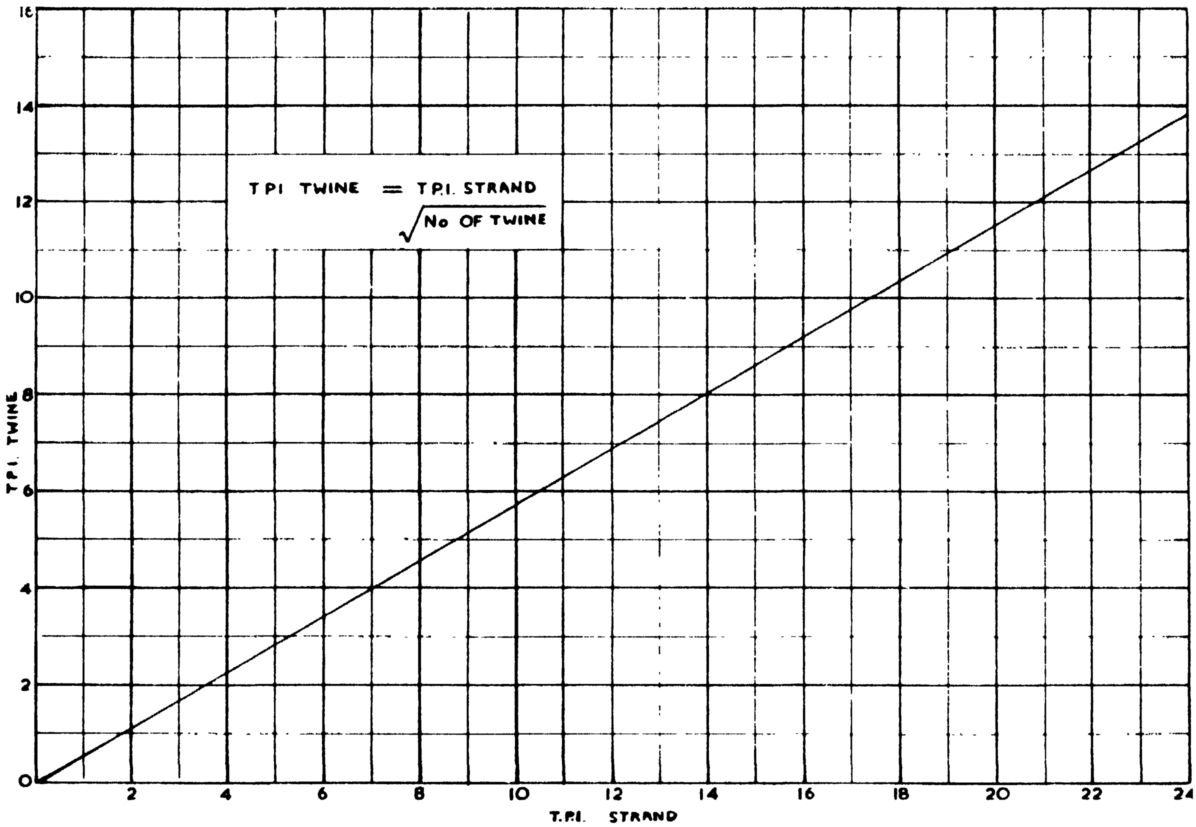


Fig. 6. T.P.I. Strand.

Note: Twist factor $= \frac{\text{t.p.i.} \times \sqrt{\text{denier}}}{73}$

The construction for a range of the filament twines are given in Table IV.

The information given in this table has been interpreted graphically (see figs. 6 and 7) and from these the twist required for the production of a range of twines having stranded constructions may be obtained. The use of balanced twists gives twines which are completely dead,

TABLE IV. Terylene Fish-Net Twine Constructions

Construction	Breaking load (lb.)	Twist Factor 3·6 (t.p.i.) Strand Twist	Twist Factor 3·6 (t.p.i.) Twine Twist	Twist Factor 4·0 (t.p.i.) Strand Twist	Twist Factor 4·0 (t.p.i.) Twine Twist	Twist Factor 4·6 (t.p.i.) Strand Twist	Twist Factor 4·6 (t.p.i.) Twine Twist
125/2/3	10·0	16·5	9·5	18·2	10·5	21·0	12·2
125/3/3	15·0	14·0	8·1	16·8	9·75	18·0	10·4
125/4/3	19·8	11·5	6·7	13·0	7·5	14·7	8·5
125/5/3	24·4	10·5	6·1	11·9	6·9	13·5	7·8
125/6/3	29·7	9·5	5·5	10·75	6·2	12·1	7·0
125/7/3	35·0	9·0	5·2	9·9	5·7	11·4	6·6
125/8/3	39·6	8·5	4·8	9·1	5·25	10·7	6·2
125/9/3	44·5	8·3	4·6	8·7	5·0	10·2	5·9
125/10/3	49·5	7·8	4·3	8·25	4·75	9·5	5·5
250/2/3	19·8	11·5	6·7	13·0	7·5	14·7	8·5
250/3/3	29·7	9·5	5·5	10·75	6·2	12·1	7·0
250/4/3	39·6	8·5	4·8	9·1	5·25	10·7	6·2
250/5/3	49·5	7·8	4·3	8·25	4·75	9·5	5·5
250/6/3	59·5	6·9	3·9	7·5	4·3	8·7	5·0
250/7/3	69·3	6·3	3·7	7·0	4·0	8·1	4·7
250/8/3	79·3	6·0	3·4	6·5	3·75	7·4	4·3
250/9/3	89·0	5·7	3·2	6·25	3·6	7·1	4·1
250/10/3	99·0	5·3	3·0	5·9	3·4	6·6	3·8

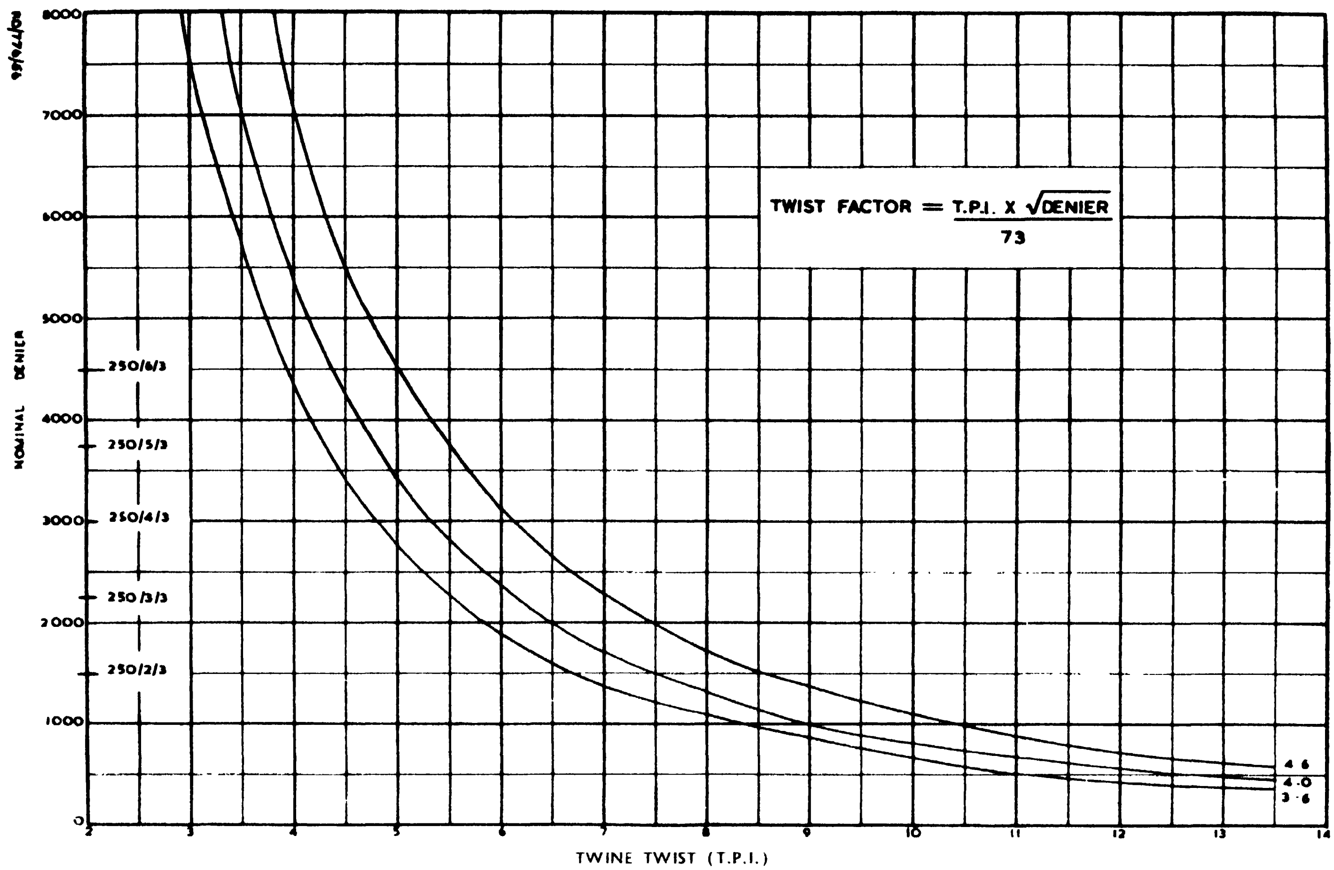


Fig. 7. Twine Twists for Twines with Twist Factors of 4·6, 4·0, 3·6.

Table V. Terylene/Filament Acetate Twines

	No. 1	*No. 2*	*No. 3a*	*No. 3b*	*No. 4*	*No. 5*	*No. 6*	*No. 7*
Construction	5/3	6/3	6/3	6/3	10/3	7/3	3/3	4/3
	3 × 250 T 2 × 200 Ac	4 × 250 T 2 × 200 Ac	3 × 250 T 3 × 200 Ac	3 × 250 T 3 × 200 Ac	3 × 250 T 4 × 200 Ac	4 × 250 T 3 × 200 Ac	2 × 250 T 1 × 200 Ac	2 × 250 T 2 × 200 Ac
Nominal denier	3450	3700	4050	4050	6900	4800	2100	2700
Resultant denier	3574	4380	4216	4368	7348	5066	3172	2801
T.p.i. "S" strand	8·0	7·5	7·1	6·7	6·7	6·9	9·7	8·2
"Z" twine	3·5	2·5	2·2	6·0	2·5	2·8	4·5	3·3
Strength	33·5	44·2	35·4	35·2	64·0	44·9	23·0	23·8
Extension	15·0	15·8	16·0	17·0	25·1	22·6	14·7	15·6
Tenacity	4·25	4·58	3·81	3·65	3·9	4·0	4·8	3·8
Knot Strength	16·8	20·6	19·4	18·0	33·2	23·4	10·8	12·4
Extension	9·1	8·3	9·1	10·0	10·9	8·8	7·3	9·1
Tenacity	2·13	2·14	2·08	1·87	2·1	2·1	2·3	2·0
Wet Strength	34·4	44·0	34·2	33·0	64·8	44·8	21·9	21·9
Extension	14·6	15·4	15·0	16·8	24·4	15·4	14·7	14·5
Tenacity	4·37	4·56	3·68	3·43	4·0	4·0	4·6	3·5
Wet Knot Strength	16·4	19·1	17·2	15·9	31·7	20·6	9·9	12·1
Extension	11·3	8·8	10·3	12·0	12·7	10·7	9·3	10·3
Tenacity	2·08	1·98	1·85	1·65	1·9	1·8	2·1	2·0
Dry Knot Slippage	None	None	None	1 in 5	None	None	None	None
Wet ,, ,,	2 in 5	None	None	None	None	None	1 in 5	None

show no tendency to snarl and have maximum strength. Some net manufacturers prefer to use twines with unbalanced twists and these must be twist set before net manufacture to consolidate the twist and prevent twine liveliness. The twist setting process is, in essence, one of free shrinkage and as such the properties of the twine alter. The general effect is to increase the denier and extension at break and to decrease tenacity, shrinkage potential and initial modulus of elasticity, the breaking load remaining unchanged. Such changes may detract from the performance of the netting.

Webbing

Terylene filament twines can be handled on traditional net making machines and the nets are said to be easier to make than those of other synthetic fibres, because of the twine's high resistance to stretch. The twines have been processed satisfactorily on single knot machines, such as the Zang and the rather more critical Seriville machine. In using bonded twines care must be taken to ensure that the correct percentage pick-up of bonding agents has been achieved so that the net making machine may function at optimum efficiency. Certain machine adjustments are also necessary to take this into account. In particular, it has been found advantageous to alter the number of turns of twine round the emery beam and also round the drag rod on the shuttle holder. Terylene twines have been used successfully on double knotting machines.

NETS:

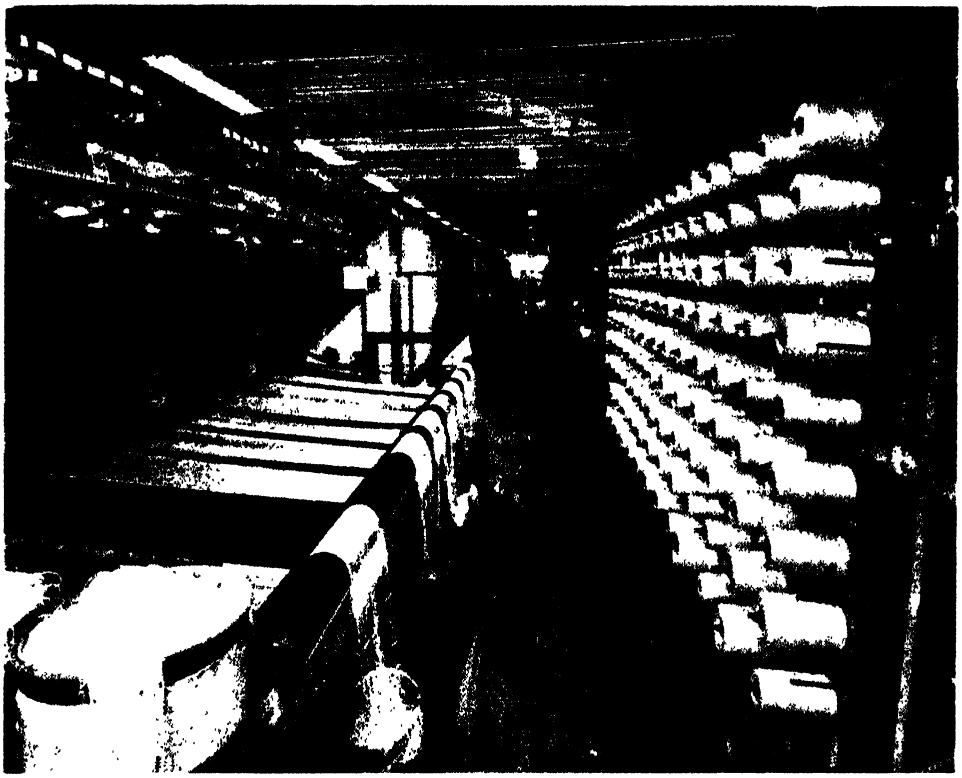
Gillnets

The gillnet market overseas is at present the largest consumer of synthetic twines and Terylene gillnetting has been used successfully in many parts of the world,

Skill and care are concentrated on this stage in the manufacture of Terylene gillnets.

TABLE VI. "Terylene"/Acetate Spun Twines

	No. 2	*No.* 3	*No.* 4	*No.* 5
Construction	6/3	6/3	10/3	7/3
	4 × 250 Terylene	3 × 250 Terylene	6 × 250 Terylene	4 × 250 Terylene
	2 × 1/22's Acetate	3 × 1/22's Acetate	4 × 1/22's Acetate	3 × 1/22's Acetate
Nominal denier	4346	4419	7392	5169
Resultant denier	4678	4492	7732	5329
T.p.i. yarns Acetate	12·5	13·0	12·0	12·0
strand "S"	5·8	5·4	6·9	5·5
twine "Z"	5·3	4·1	3·1	3·7
Strength (lbs.)	43·8	36·9	66·4	46·9
Extension (%)	16·0	16·7	23·9	16·0
Tenacity (g.p.d.)	4·25	3·73	3·90	4·0
Knot strength	16·7	16·8	29·8	20·8
Knot extension	10·3	10·0	12·9	14·0
Knot tenacity	1·62	1·70	1·75	1·77
Wet strength	45·5	36·3	65·1	46·4
Wet extension	15·7	15·2	22·3	15·2
Wet tenacity	4·41	3·67	3·82	3·95
Wet knot strength	19·6	18·0	30·0	21·8
Wet knot extension	10·6	10·0	12·6	10·0
Wet knot tenacity	1·90	1·82	1·81	1·86
Knot slippage	None	None	None	None



Here is shown a stage in the manufacture of Terylene gillnets.

principally for catching salmon and cod. It has been used in Canada for fishing salmon off the West Coast, the nets showing up to particular advantage in fast moving water or ocean currents, where lively fish can dive straight through a net or, when caught by the gills, escape by expanding the net mesh. The small diameter of the twines may lead to lower visibility, but it is thought that this very good performance can be attributed essentially to the high resistance to stretch.

In certain types of synthetic fibre gillnetting it is now becoming customary to pull out the fish head foremost which is speedier than the normal practice, i.e. compressing the gills and pulling the fish out backwards. In such cases the high resistance to stretch is somewhat of a disadvantage, as it is not always possible to clear the nets in such a manner.

The gillnets have been used successfully in Kenya lakes for fishing borus and tilapia, while cod gillnets have been very successfully used in Scandinavian waters. The gillnets are being increasingly used in India.

Such gillnets have to date been found more suitable for catching hard rather than soft fish. The twines used have been fine and hard and have cut into soft fish, such as herrings, to such an extent that the fish have become bruised and damaged. When removed from the net by shaking the fish may be decapitated. Chiefly for this reason, Terylene has not yet been extensively used for British home water drift netting. However, such drift netting is being developed and twine constructions have been revised to give thicker and more suitable twines. Further trials are in progress to develop this market.

A mixed high tenacity Terylene filament/spun acetate netting twine is being developed, principally for pilchard nets. It will not bruise or damage the fish and will not slip when single knotted. Tables V and VI give the principal physical properties of such twines. The use of Terylene core spun cotton yarns is also being considered for similar reasons, but, because of the cotton present, it could not be expected to be so rot resistant as a mixed filament/spun acetate yarn.

Trawl Nets

The filament twine has been used with success for bottom trawls. Trials were carried out some time ago, principally for the codend, because of the shortage of twine, although some complete trawls were also made up. These nets were made by the Great Grimsby Coal, Salt and Tanning Co. Ltd., of Grimsby, and the tests were carried out by distant water trawlers on various fishing grounds. It was found that each trawl net lasted on average about 9 trips and, in one case, 15 trips were made before the net was lost. The normal trawl net is generally good for an average of one trip. It was noted that the Terylene nets had good mesh stability and their resistance to abrasion reduced any chance of the codend bursting as it was hauled in. The nets were much easier to tow through the water and being completely rot-proof, drying was unnecessary. It is understood that cleaner catches were obtained. The ship's crew reported that the nets were more pleasant to handle than the usual nets. The lower moisture uptake was particularly advantageous in the icy operating conditions in Northern waters. Another advantage was that unloading of the codend was sometimes done in fewer operations because of its greater strength.

Risk of loss or accidental damage of the net is now being greatly reduced by introduction of Decca equipment, which is of special advantage when expensive trawls are used. The longer life and greater security offered by such nets outweigh the occasional losses. Already a number of trawler companies have started their own trials for near, middle and distant water fishing with Terylene trawl nets.

There is perhaps a need for the use of thinner twines to reduce the price of the net and without doubt the introduction of an extra heavy denier yarn will enable nets to be produced more economically.

Appreciable quantities of the fibre are now being used in Sweden for mid-water trawls and trials with such trawls are also being conducted in the United Kingdom by the Ministry of Agriculture, Fisheries and Food

Purse Seine Nets

Until comparatively recently, little has been done with Terylene purse seine nets, principally because of their cost, which may be as much as £5,000.

Trials have been carried out in Canada with drum seines near Deep Water Bay off the West Coast. The netting, whilst only about a quarter of the weight of corresponding tarred cotton netting and with twines a third as fine, was about 10 per cent. stronger in the wet mesh. This means that smaller vessels can be used or alternatively outsize seines can be carried by vessels which normally work with the smaller seine nets.

The nets wound easily on to the drum, but some difficulty was experienced in playing out, the loose bights of netting tending to get entrapped. The bunt end of the seine was said to be easily held. There was less drag on the net so that it could be closed much more quickly than can normal purse seines. This is a real asset, ensuring a quicker and more efficient fishing operation. The nets were held more easily against the tide, which means, firstly, they can be used in faster waters, thus enabling fishermen to operate in more fishing grounds and, secondly, fishing time can be extended. The nets tended to become entangled, when fish could only be extracted with difficulty, a disadvantage arising from their high order of flexibility. This could be overcome by using coarser twines or applying suitable coating agents.

Despite the disadvantages the preliminary results were most encouraging and, with the suggested modifications, it should be possible to use such purse seines with great profit. It is worthy of note that the somewhat higher specific gravity of the fibre compared with other synthetic fibres was an advantage, since it enabled the net to sink more easily. The lightness in weight of the netting is particularly useful for table seines.

More extensive trials of these purse seines nets are now being made.

Purse/Lampara Nets

Many standard purse/lampara seine nets used in Walvis Bay, South West Africa, have failed prematurely, due it is thought, to chemical contamination, but a preliminary test of Terylene netting for use in these waters has proved most encouraging. Detailed trials are now in progress.

Seine Nets

Trials with Terylene seine nets are to be carried out shortly in the United Kingdom.

OTHER APPLICATIONS

Other applications include lines and snoods. A fairly substantial market is developing in Norway, where the use of the twines has resulted in increased catches. The high resistance to stretch facilitates pulling in the line and it is easier to tell when the fish are hooked as a more definite response is obtained. Strength stability on wetting and the quick drying properties are also important. The lines are slightly more expensive but this is offset by fishing performance.

The twines are being tried for lobster pots in the United Kingdom, chiefly because of their rot resistance and general toughness.

Fishnet mounting ropes of spun Terylene (flax system) cordage, which are used for supporting the nets, have been tried. The staple yarn is preferred to the continuous filament yarn because its hairy nature minimises slippage of the net and corks. Headlines of the fibre are also being tested.

TEVIRON FISHING NETS

by

THE TEIKOKU RAYON CO. LTD.

Edobori—Minamidori, Nishiku, Osaka, Japan

Abstract

The Teikoku Rayon Co. Ltd. introduced in October 1956 the new synthetic fibre Teviron, made from polyvinyl chloride, which can be obtained either as filament or staple fibre, the former having a silk-like appearance, the latter resembling wool.

This paper deals with the use of this material in the manufacturing of fishing gear and it is pointed out that, in competition with other yarns, it ranks next to cotton in price. Other advantages are explained and tests have shown that Teviron can compete with Nylon in the Salmon and Trout fisheries, although Nylon has long been rated the best material for those fisheries.

Filets de pêche en Teviron

Résumé

The Teikoku Rayon Co., Edobori—Minamidori, Nishiku, Osaka, Japon, a mis sur le marché en octobre 1956 une nouvelle fibre synthétique, le Teviron, obtenue à partie du chlorure de polyvinyle qui se présente sous l'aspect soit de filaments soyeux, soit de fibres ressemblant à la laine.

Ce document est consacré à l'utilisation de ce matérial pour la fabrication d'engins de pêche et on fait remarquer que, par comparaison avec d'autres filets, son prix le place juste après le coton. D'autres avantages de cette fibre sont énumérés et des essais ont montré que le teviron peut rivaliser avec le nylon pour la pêche au saumon et à la truite, alsor qu'on a longtemps considéré que le nylon était le meilleur matériel dans ce cas.

Redes de pesca de Teviron

Extracto

En octubre de 1956 la "Teikoku Rayon Co. Ltd.," Edobori-Minamidori, Nishiku-Osaka, Japón, lanzó al mercado una nueva fibra sintética llamada "teviron", hecha a base de cloruro de polivinilo, la cual puede obtenerse en forma de hilo continuo o como fibra para hilar. El primero tiene el aspecto de seda y la segunda de lana.

Este trabajo se refiere al uso del "teviron" en la tejeduría de artes de pesca, señalándose que, en competencia de precio con otras fibras, figura a continuación del algodón. También se dan a conocer otras ventajas, demostrando las pruebas efectuadas que puede competir con el nylón en las pesquerías de salmón y trucha, no obstante considerarse desde hace tiempo que este último material es el más apropiado para la pesca de dichas especies.

CHARACTERISTICS OF TEVIRON

TEVIRON, a polyvinyl chloride synthetic fibre first introduced in October 1956, is produced by Teikoku Rayon. The yarn is available both as filament and as a staple fibre: the former has a silk-like appearance and touch, while the latter resembles wool.

This fibre is suitable for making fishing nets and rope.

	Filament	*Staple Fibre*
Denier	300 den. (20-60 fil.)	2-15 den.
Specific Gravity	1·39	1·39
Normal Strength	3·0-3·7 g/den.	2·0-3·0 g/den.
Extensibility (unknotted) (independent of humidity)	14-25%	50-75%
Knot strength	2·0-2·7 g/den.	1·5-2·5 g/den..
Extensibility (knotted)	9-17%	50-70%
Ratio of Knot Strength to Normal Strength	70-75%	80-85%
Young's Modulus	800-900 kg./sq. mm.	200-300 kg./sq. mm
Elasticity at 3%	80-85%	80-85%
Temperature at beginning of Shrinkage	60-70 deg. C.	100 deg. C.
Resistance to friction	Great (esp. in water)	Great
Resistance to Acid and Alkali	Great	Great
Resistance to sunlight	very great	very great

TEVIRON FISHING NETS

Cost

A Teviron net costs less than a net of any other synthetic fibre yarn, and is only 30 per cent. more than a cotton net.

Ease of handling

(a) Owing to the great resistance to rot (see figs. 1 and 2), little work is needed for drying or re-dyeing Teviron nets or for other maintenance services.

(b) As the net does not absorb water, it is very light and can be handled by a smaller crew.

The table below gives the results of an investigation into labour and time factors. The comparison was made between two large fixed nets of approximately similar size, one of Teviron, the other of manila:

	Number of Workers	*Time required for pulling up the net completely from the sea (Minutes)*
Teviron net	44	25
Manila net	60	45

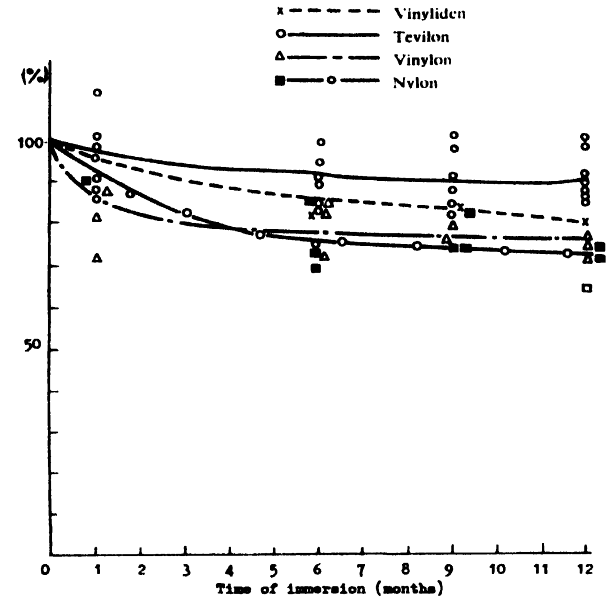


Fig. 1. Results obtained from immersion in sea-water.

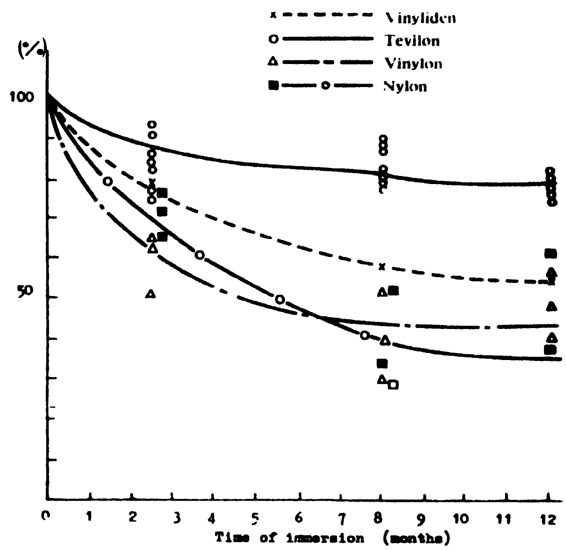


Fig. 2. Results obtained from outdoor exposure.

The Teviron net could be pulled up when the current was rapid; the manila net could not be moved.

Suitability for various gear

(a) *Gillnets:* Teviron twine is flexible, and a minimum of shrinkage assures stability of mesh size. A test of Teviron and nylon drift nets for salmon and trout in northern seas showed that the Teviron net is not inferior to nylon net:

Average number of fish caught for each operation

Teviron net	2·27
Nylon net	2·22

(b) *Purse seine nets:* Teviron needs no drying, and little repair and other maintenance work, allowing more fishing time per day, and longer trips. More fish can be caught because the net sinks rapidly.

(c) *Fixed nets:* The fibre does not decay even in the warmest season of the year, and has proved a strong and reliable material in rough water.

Repairing drift nets in Ceylon. Photo FAO.

KREHALON FISHING NETS AND ROPES

by

KUREHA KASEI CO. LTD.

Tokyo, Japan

Abstract

Krehalon is a vinylidene chloride filament which has a higher specific gravity (1·7) than other synthetic fibres. It is less affected by currents, sinks faster and drains water faster. The pliability of the fibre gives more strength to the knots and resistance to impact and friction. These characteristics make it particularly suitable for setnets. Big setnets of Krehalon have been in use since 1952 and are said to show no signs of wear.

Krehalon is also used for stick-held dipnets, surrounding nets, gillnets, longlines and trawlnets. It is available both as monofilament and continuous-multifilament yarn; nets are either knotless or made with English knot. Lines and ropes are also made of Krehalon. This fibre is sensitive to heating and should be kept off sandy beaches or cobblestones in midsummer.

Filets de pêche et cordages en Krehalon

Résumé

Le Krehalon est un filament de chlorure de vinylidène, qui possède un poids spécifique plus élevé (1,7) que les autres fibres synthétiques. Il est moins affecté par les courants, plonge plus rapidement et l'eau s'en égoutte plus vite. La souplesse de la fibre donne plus de résistance aux noeuds, augmente la résistance aux impacts et au frottement. Ces caractéristiques le font convenir particulièrement bien pour les filets fixes. Depuis 1952 on utilise des grands filets fixes de Krehalon et on déclare qu'ils ne montrent pas de signes d'usure.

On utilise aussi le Krehalon pour les carrelets montés sur des perches, les filets-parcs, les filets maillants, les palangres et les chaluts. Le Krehalon est produit en fil monofilament et en fil multi-filaments continus; les filets sont soit sans noeuds, soit noués. On fait aussi des lignes et des cordages de Krehalon. Cette fibre est sensible à la chaleur et doit être maintenue à l'écart des plages de sable ou des galets pendant la saison chaude.

Redes de y cuerdas de "Krehalon"

Extracto

Desde 1952 se han comenzado a utilizar grandes artes de "krehalon" filamento de cloruro de vinilideno. Este material tiene mayor peso específico (1,7) que el resto de las fibras sintéticas y sufre en menor grado la influencia de la corriente; además se hunde y deja escurrir el agua con mayor rapidez. La flexibilidad de las fibras imparte una mayor firmeza a los nudos a la vez que ofrece más resistencia al impacto y a la fricción, haciéndolo especialmente apropiado para la fabricación de redes fijas.

Esta fibra también se usa para salabardos provistos de mango, artes de enmalle y arrastre, palangres y espineles.

Las redes de este material pueden fabricarse sin nudos o empleando el nudo de tejedor. El "krehalon" también sirve para fabricar cabos y cuerdas, pero es muy sensible al calentamiento y no debe extenderse sobre piedras o playas de arena durante el verano.

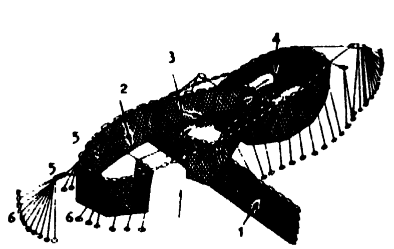
GENERAL

THIS vinylidene chloride filament has the greatest specific gravity (1·7) of any synthetic fibre. It is less water absorbent and drains water faster. Nets made with this fibre are pliable and strong and retain their shape even in turbulent waters. They sink quickly. The tensile strength of the fibre is 120 to 130 per cent. higher than that of comparable cotton yarn. The flexibility of the fibre gives higher knot strength and greater resistance to impact and friction.

The fibre is particularly suitable for constructing setnets, as fish of any size are unlikely to be injured when trapped because of the pliability of the fibre. Some setnets made of Krehalon (see fig. 1) have been in use since 1952 and show no signs of wear (1957). Fishermen say they can withstand the buffeting of the severest typhoons. Stick-held dipnets (see fig. 2), surrounding nets, gillnets, longlines and trawlnets made of this fibre show similar durability.

The mesh size of Krehalon nets is usually made slightly smaller than that of nets of natural fibres as it does not shrink in usage. The fibres can be dyed freely in any colour.

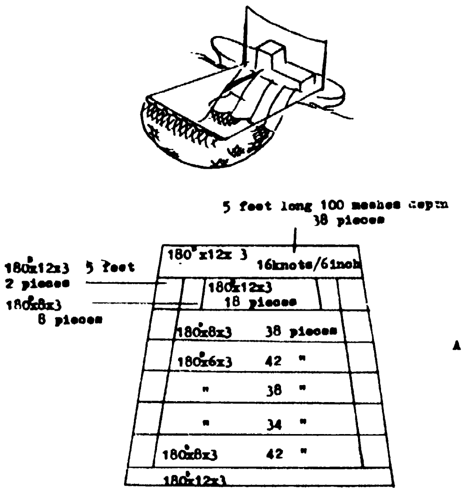
Sizes: In multi-filament twines several 180 denier filaments are usually put together to form yarn, twine or line. Mono-filaments are composed of one large



Large setnet made of Krehalon

1. leader net
2. ante-chamber
3. funnel
4. bag
5. floats
6. anchoring stones or sand bags

Fig. 1.



A stick-held dipnet made of Krehalon

Fig. 2.

filament (i.e. as 1,000 denier). 360 denier is equivalent to cotton yarn of count 20's. Thickness and tensile strength have been taken into consideration. Multi-filament nets are more pliable than mono-filament nets.

Nets: The nets are of the same specifications as the conventional cotton yarn or manila twine nets available in knotless or English knot. Smallest are 720 D × 3, mesh size 25 knots per 6 inches.

Ropes: Ropes, lead line, twisted twines, longlines, cord, etc., are manufactured according to specifications.

Cautions regarding use: Long exposure to high temperature can cause a chemical change in the filament. For this reason, a sandy beach or cobblestones are best avoided in midsummer.

Tarring: Krehalon nets do not normally require tarring, but, if necessary, put one part of refined tar into two parts of 5 per cent. solution of neutral soap. Tar at a temperature less than 40 deg. C.

Use a hot iron knife when cutting a filament. This obviates the danger of fraying.

Liftnet fishing in Jakarta harbour. Photo FAO

SOME PHYSICAL PROPERTIES OF MANILA ROPE

by

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Abstract

Very little has been published to date on the properties of rope, in spite of its vast importance to the fishing industries of the world. People have learned about rope by experience but definite conclusions based on exact and concrete data are not always available. In this paper the author attempts to bring out some of the properties of hard-laid, medium-laid and soft-laid ropes and tables showing the physical characteristics in both the wet and dry state are given.

Quelques propriétés physiques des cordes de Manille

Résumé

Jusqu'à présent très peu d'articles ont été publiés au sujet des propriétés des cordes malgré leur grande importance pour les industries des pêches dans le monde. On a appris empiriquement à connaître les cordes mais on ne dispose pas toujours de conclusions définitives basées sur des données exactes et concrètes. Dans cet article, l'auteur essaie de faire ressortir quelques-unes des propriétés des cordes commises lâche, moyennement et serré, et donne des tableaux montrant les caractéristiques physiques à l'état sec et à l'état mouillé.

Algunas propiedades físicas de la cuerda de abacá

Extracto

Se ha publicado muy poca información sobre las propiedades de las cuerdas de abacá o manila no obstante la gran importancia que tienen en la industria pesquera de todo el mundo. Se sabe mucho acerca de cuerdas por experiencia, pero no siempre se dispone de conclusiones definitivas basadas en datos exactos y concretos. En este trabajo el autor trata de dar a conocer algunas características de las cuerdas poco, medianamente o muy retorcidas, e incluye tablas con las propiedades físicas de ellas tanto húmedas como secas.

KNOWLEDGE of the various intrinsic properties of ropes is indispensable for the right choice and economic use of them. Although experience has resulted in some general knowledge, no definite conclusions based on exact and concrete data are available and very little has been published on this matter. The following article is an effort to contribute some information for fishermen on this subject.

Influence of basic manufacturing procedures

During the process the fibres are twisted successively in opposite directions into yarns, strands, ropes and cable. This results in a decrease in breaking load. A remarkable fact is that even when the same basic fibre material is used, the breaking strength of "Z" yarn is different from that of "S" yarn. It is obvious, therefore, that the actual twisting process itself exercises a very considerable influence on the breaking strength.

Trial I—Influence of the means of manufacture

Rope was formerly made exclusively on the rope walk but the process has now been mechanized. Theoretically, it makes no difference how rope is made, although the finger-tips of an experienced ropemaker possess certain qualities which cannot, except with great difficulty, be duplicated in a machine.

To obtain more concrete information on this aspect, a ropemaker was found who agreed to make rope in three different types of machine. He was requested to use different ways from a given yarn, viz. on the rope walk and on two different types of machine. He was requested to do his utmost to ensure that the ropes were as identical as possible. Little difference was apparent in the three ropes at first sight, yet very marked dissimilarities were disclosed by investigation (see Table I). These differences were not apparent from the slight variations in circumference, which is generally assumed to be an indication

TABLE I

Rope

Rope closing method	*Average[1] weight of 1 metre of rope in grammes*	*Total number of turns per strand per metre*	*Average[2] circumference in mm.*	*Average[1] breaking strength in kg.*	*Breaking length in km.*
Rope walk	90	25·0	38·6	1284	14·27
Machine 1	95	27·3	38·8	929	9.78
Machine 2	95	26·0	37·7	1028	10·82

[1] Average for 16 determinations.
[2] Average for 80 determinations.

of strength when comparing ropes made of the same material.

This should not be interpreted as an endeavour to expound a theory that rope made on the rope walk is "good" and machine-made rope "bad". Such a sweeping statement could never be made on the basis of a single trial; the only purpose was to prove that the way in which a rope is made can result in significant differences in the breaking strength even when the same fibre gradings are used.

Trial II—Influence of the lay

Procedure. Three types of rope were made on the rope walk. The conditions, i.e. basic material, equipment, etc., under which the experiments were carried out were identical in all cases. The only intentional deviation was that a number of different lays was selected, so as to produce ropes of hard, medium and soft lay. This was done not only to ascertain possible modifications in the properties of the rope, attributable to the different lays, but also because these modifications are important in some instances in commercial fishing.

The three different ropes were all based on 20 yarns per strand, made from the same fibre mixture.

Test Methods. During the closing of the rope, 20 bobbins (⅓rd of the total number used) were marked. The yarn was subsequently examined to establish its various properties. Five lengths were cut off simultaneously from the rope to be tested for breaking strength, etc. The first and third lengths (3·5 metres long) were examined dry, the second and fourth (4 metres long) were examined wet, while the fifth (1 metre long) was untwisted to enable the yarns to be examined dry.

The lengths intended for use in testing the breaking strength at the splice, with overhand knot and as a sling, were then cut off successively.

Breaking strength tests were carried out on a hydraulic breaking-strength machine fitted with clamps. The distance between clamps was 150 cm. and the rate of movement of the straining head approximately 12½ cm. per minute.

The ropes examined "wet" were immersed in fresh water for at least 16 hours. Their weight was determined after all non-absorbed water had run off for 30 minutes. The yarn tensile strength test was carried out with 100 cm. between clamps, the rate of movement of the straining head being approximately 25 cm./min.

Results. In the following the results of this experiment

TABLE II
Soft-laid Rope

Experiment	*dry*	%	*wet*	%
Type	3-strand, plain-laid		3-strand, plain-laid	
Total number of yarns	3×20—60		3×20=60	
Weight per metre in grammes	322·4	100	521·5	161·7
Average number of turns per strand per metre	13·78	100	13·86	100·6
Average circumference in mm.	74·85	100	84·70	113·2
Average breaking strength in kg.	4930	100	5205	105·6
Average breaking length in km. (based on dry weight)	15·30	100	16·14	105·5
Average breaking length in km. (based on wet weight)	—		9·98	65
Average duration of test, after application of initial load	6·425×½ min.	100	8·125×½ min.	126·5
Breaking strength short splice in kg.	4295	87·1	4389	84·3
Breaking strength with overhand knot in kg.	2033	41·2	2333	47·3
Breaking strength with sling around rods 10 cm. in diameter	7344	149	—	—

TABLE III
Normal-Laid Rope

Experiment	*dry*			
Type	3-strand, plain-laid		3-strand, plain-laid	
Total number of yarns	3×20 −60		3×20 60	
Weight per metre in grammes	333·3	100	494·2	148·3
Average number of turns per strand per metre	15·15	100	15·02	99·1
Average circumference in mm.	72·45	100	80·1	110·6
Average breaking strength in kg.	4513	100	4357	96·5
Average breaking length in km. (based on dry weight)	13·54	100	13·06	96·5
Average breaking length in km. (based on wet weight)	—		8·82	65·1
Average duration of test, after application of initial load	6·75×½ min.	100	8·05×½ min.	119·3
Breaking strength short splice in kg.	3652	80·9	3700	94·9
Breaking strength with overhand knot in kg.	1978	43·8	2322	51·5
Breaking strength with sling around rods 10 cm. in diameter	6789	150·4	—	—

are interpreted according to a system developed at the Nederlandsche Visscherij-Proefstation.

(a) Dry Rope

The increase of number of turns per unit length (lay) results in :

(1) increase of weight per unit length (see below)

	relation of weight per unit length		
	yarns (not twisted)		*rope*
Soft laid . . .	1	:	1·256
Medium laid . .	1	:	1·298
Hard laid . . .	1	:	1·332

(2) decrease in diameter (that means more material per unit diameter)

(3) decrease in breaking strength (that means more material for unit breaking strength)

In the present example the remaining breaking strength of one yarn in the rope in the three different types (1/60 × rope strength) is:

In soft laid rope .	82·17 kg.	(62·6%)
In medium laid rope	75·22 kg.	(57·34%)
In hard laid rope .	56·67 kg.	(43·20%)

The breaking strength of the yarn, prior to closing the rope, was 131·18 kg. (100 per cent.) (see Table V).

(4) This means that the breaking length, the only accurate tensile strength criterion for rope, cannot be used for the comparison of ropes of different lays.

(5) increase in knot strength.

(6) increase in strength of a loop.

The total extension at break is maximal in normal and less in hard and soft laid ropes (see Table VI).

(b) Wet Rope

Increase in number of turns per unit length (lay) results in:

(1) less water absorption (less increase in weight).

(2) less increase of diameter due to water absorption.

Contrary to the dry rope, the total extension at break of the wet rope is higher with hard and soft lay than with normal lay (see Table VI). With a tension of 2,000 kg. or less the soft laid rope has the highest extension and the hard laid rope the lowest. Immersion has no remarkable influence on the number of turns per unit length. There is a certain influence of immersion on the breaking strength but the results available at present are not sufficient to draw reliable conclusions.

(c) Influence of rope manufacturing on the yarns

In order to examine the effect of manufacturing, samples of the three types of rope were untwisted and the single yarns tested. It was found that whilst soft and normal lay has only very little influence (loss) on the breaking strength of the single yarn, hard lay results in a certain decrease (see Table V).

TABLE IV

Hard-laid Rope

Experiment	*dry*	%	*wet*	%
Type . . .	3-strand, plain-laid		3-strand, plain-laid	
Total number of yarns	3×20=60		3×20=60	
Weight per metre in grammes .	340·5	100	473·7	139·1
Average number of turns per strand per metre	16·81	100	16·71	99·4
Average circumference in mm. .	65·8	100	69·9	106·2
Average breaking strength in kg. .	3484	100	3284	94·3
Average breaking length in km. (based on dry weight) . .	10·22	100	9·65	94·4
Average breaking length in km. (based on wet weight) .	·		6·94	67·9
Average duration of test, after application of initial load .	5·85 × ½ min.	100	6·70 × ½ min.	114·5
Breaking strength short splice in kg. .	3407	97·7	2944	89·6
Breaking strength with overhand knot in kg.	1778	51·0	1878	53·9
Breaking strength with sling around rods 10 cm. in diameter .	5878	168·7	—	·

TABLE V

Yarn

	Before closing	*Untwisted from soft-laid rope*	*Untwisted from normal-laid rope*	*Untwisted from hard-laid rope*
Average breaking strength in kg. .	131·18	130·76	128·38	121·11
No. of determinations	200	100	100	100
Average weight per 100 metres in grammes	428	434·5	427·4	424·7
Average breaking length in km. .	30·65	30·09	30·10	28·45
Percentage of breaking length . .	100	98·2	98·2	92·8

TABLE VI

Total Extension

Tension	*soft rope*		*normal rope*		*hard rope*	
kg.	dry	wet	dry	wet	dry	wet
250	*%	10·8%	5·3%	7·9%	4·0%	6·4%
500	*	13·8	7·4	11	5·6	9·8
1000	10·9	15·8	11·1	13·5	8·4	13·0
2000	13·2	18·0	14·8	16·1	12·8	16·8
3000	14·8	19·6	16·7	17·8	15·0	18
4000	16·1	20·8	17·7	19·2	16·2	0

* Not determined.

THE MANUFACTURE AND TESTING OF SYNTHETIC YARNS AND FIBRES USED IN JAPANESE FISHING GEAR

by

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Abstract

Synthetic fibre has been used for fishing gear in Japan since 1932 when it was tried out as fishing gut, and after 1948 an effort was made to increase its use, and now all kinds of nets and gear are made from synthetic materials. This paper gives in tabular form the physical properties and uses of the various fibres and also the quantity of nets and lines manufactured from both natural and synthetic fibres in 1956. The weight of nets exported is also given. Then follow the rules which have been designed to standardize the testing of spun vinylon, filament nylon, filament vinylidene chloride and filament vinyl chloride.

Fabrication et essai des fils et fibres synthétiques entrant dans la construction des engins de pêche japonais

Résumé

Les fibres synthétiques sont utilisées au Japon pour la confection des engins de pêche depuis 1932, époque à laquelle elles ont été essayées en remplacement du crin, et l'on s'efforce depuis 1948 de développer leur emploi en sorte qu'actuellement les filets et engins de tous types sont confectionnés en matériaux synthétiques. Ce document donne sous forme de tableaux les propriétés physiques et les applications des différentes fibres ainsi que les quantités de filets et de lignes fabriquées d'une part en fibres naturelles, et de l'autre en fibres synthétiques en 1956. Le poids des filets exportés est également indiqué suivant les règles adoptées pour la normalisation des essais des fils de brins de vinylon ainsi que des filaments de nylon, de chlorure de vinylidène et de chlorure de vinyl.

La manufactura y ensayo de las fibras e hilos sintéticos usados en los artes de pesca japoneses

Extracto

A partir de 1932 la industria pesquera japonesa comenzó a usar fibras sintéticas en los artes de pesca cuando las ensayó como sedales, pero sólo después de 1948 se hicieron esfuerzos para aumentar su uso y, en la actualidad, todos los tipos de redes y artes son confeccionados con este material. En el trabajo materia de este extracto se compendian en tablas las propiedades físicas y usos de las diversas fibras, asi como las cantidades de redes, palangres, etc. fabricados con fibras naturales y sintéticas. También se incluye el peso de las redes exportadas y las disposiciones que se proyectaron para normalizar los ensayos de vinilón hilado, nylón y cloruros de vinilideno y de vinilo en hilos de una sola hebra.

SYNTHETIC fibre was first used for fishing in Japan in 1932, as fishing gut. Since about 1948 experiments have been carried out on the adaptability of synthetic fibre for fishing gear through co-operation of the Fisheries Agency, Fisheries College, Fisheries Research Institute, fibre makers, fishing net makers, fishermen, etc.

As a result of improvement in quality, advance in net-making techniques and the reduction in cost by mass production in 1953, the demand for synthetic fibre has considerably increased for seine and setnets, and salmon and trout gillnets (see Tables I, II, III).

The export of fishing nets has gradually increased since 1951, about 1·2 million lbs. being exported in 1956.

TABLE I

Production of Synthetic Fibre Nets by Netting Types for 1956

Unit: Pounds

Fibre	Type: *English Knot*	*Reef Knot*	*Knotless Net*	*Moji Net*	*Total*
Nylon	4,489,213	50	82,287	—	4,571,550
Vinylon	1,893,088	3,028,940	810,478	183,394	5,915,900
Polyvinylidene Chloride Fibre	598,034	6,454	1,546,712	—	2,151,200
Polyvinyl Chloride Fibre	70,619	—	104,181	—	174,800
Two Fibres Plied	631,900	—	—	—	631,900
Total	7,682,854	3,035,444	2,543,658	183,394	13,445,350

TABLE II

Production of Fishing Nets and Lines in 1956 (or 1957)

Unit: 1,000 Pounds

Type	Month 1	2	3	4	5	6	7	8	9	10	11	12	Total	1955
Fishing Nets														
Cotton	1,152	1,478	1,215	915	730	641	586	731	774	702	708	673	10,305	14,845
Silk	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Manila Hemp	81	117	71	71	43	53	60	111	168	108	115	112	1,110	1,273
Other Hard Fibres	3	23	19	18	11	11	49	3	3	2	2	3	147	437
Synthetic Fibres	713	1,082	1,120	1,090	920	783	829	898	969	1,290	1,101	1,095	11,890	6,923
Sub-Total	1,949	2,700	2,425	2,094	1,704	1,488	1,524	1,743	1,914	2,102	1,926	1,883	23,452	23,490
Fishing Lines														
Cotton	826	991	895	888	805	885	703	844	833	775	797	863	10,105	12,092
Silk	0	0	0	0	0	0	0	0	0	0	2	0	2	5
Manila Hemp	13	8	17	13	15	7	0	9	17	12	17	13	141	51
Other Hard Fibres	3	7	4	7	3	2	7	1	0	0	0	0	34	146
Synthetic Fibres	152	229	287	274	234	275	289	373	330	422	427	498	3,790	1,511
Sub-Total	994	1,235	1,203	1,182	1,057	1,169	999	1,227	1,180	1,209	1,243	1,374	14,072	13,805
Total	2,943	3,935	3,628	3,276	2,761	2,657	2,523	2,970	3,094	3,311	3,169	3,257	37,524	37,295

TABLE III

Production Capacity of Fishing Nets and Lines in 1956 (or 1957)

		*Machines Operable**	*Machines for Synthetic Fibres*	*Machines Operated**	*Monthly Capacity per Machine*
Hand Machine	Reef knot	8,258	6,437	3,898	150 lbs.
	English knot	74	—	62	
	Moji net	6	-	2	
Power Machine	Reef knot	87	42	51	370
	English knot	2,199	2,469	1,398	540
	Moji net	426	—	181	
	Knotless net	57	56	44	2,940
Twister	Hari twister	48,038	n. a.	35,835	
	Ring twister	181,522	„	163,889	
Companies concerned		111	64	101	

* Machines for natural fibre nets and lines included.

Owing to the rapid development of different synthetic fishing gears, efforts are being made to determine suitable testing methods for synthetic yarns.

The following methods and standards are proposed.

Method of Testing Twines for Fishing Nets

A—Spun Vinylon. B—Filament Nylon.
C—Filament Vinylidene Chloride and Filament Vinyl Chloride.

In the following text, the materials to which each paragraph refers are shown by the letters A, B and C.

1. Scope

These standards shall cover the methods of testing twines of the materials shown above.

2. Definition

2-1. *Standard Condition in Testing Room* (A. B. C.) Temperature at 20 ± 2 deg. C., and relative humidity at 65 ± 2 per cent.
Remark: For determining temperature and humidity, the Assman's Aspiration Psychrometer shall be employed, and the relative humidity obtained from the humidity table by Sprung's formula.

2-2. *Standard Condition of Test Sample* (A. B. C.)—is when the sample left in a testing room under standard conditions (2-1) has reached moisture equilibrium (2-3).

2-3. *Moisture Equilibrium.* (A. B.) After pre-drying a test sample at a temperature of 40 to 50 deg. C.

it is left in the laboratory under standard conditions. When the sample has been brought to the constant weight (2-5), being steady and uniform in hygroscopic state, it shall be considered to be in moisture equilibrium.

2-3. *Constant Weight* (C.) Weigh the test sample twice successively at intervals of one hour or more at the time of drying. The constant weight shall be considered as that when the difference between the two weighings is under 0·03 per cent.

2-4. *Absolute Dry Condition* (A. B.) Is reached when the weight of a test sample becomes constant (2-5) due to being left in a drying oven at 105 to 110 deg. C.

2-4. *Absolute Dry Weight* (C.) Is the weight under standard conditions of test sample, also called the bone weight.

Remark: Moisture regain under standard conditions is almost nil.

2-5. *Constant Weight* (A. B.) Weigh the test sample at intervals of one hour or more for the moisture equilibrium, and at 10 minutes or more for the absolute dry condition. Constant weight is reached when the difference is within 0·05 per cent. of the last respective weights.

2-6. *Commercial Moisture Regain.* (A.) 5 per cent. of the absolute dry weight (B.) 4·5 per cent. (C.) 0 per cent.

2-7. *Denier* (A. B. C.) Denier is a unit of fineness, the yarn having a weight* of 0·05 gr. per 450 metre length. The denier is equal numerically to the number of grams per 9,000 metres.

2-8. *Yarn Count* (A). Yarn count to be expressed by the number of hanks (One hank = 840 yards) per pound in weight*.

2-9. *Indication of Yarn Count* (A.)
Yarn count to be expressed as follows:

Single Yarn 20 yarn count . . . . 20^s
Twine 20 yarn count 2 ply . . . . . $20/2^s$
3 strands of 20 yarn count 2 ply $20/2/3^s$

2-9. *Indication of Denier* (B.)
Denier to be expressed as follows:

Twine 3 strands of 15 filament 210 denier 5 ply . . .
$210^D/15f \times 5 \times 3$

2-9. *Indication of Denier* (C.)
Denier to be expressed as follows:

Twine 3 strands of 1 filament 1000 denier 8 ply . . . .
$1000^D/1f \times 8 \times 3$
3 strands of 10 filament 1500 denier 6 ply . . .
$1500^D/10f \times 6 \times 3$

2-10. *Indication for Direction of Twist* (A. B. C.)
The direction of twist to be expressed by S and Z as shown in fig. 1:

Fig. 1.

The direction of upper twist, middle twist and lower twist to be expressed as follows:

UPPER TWIST DIRECTION · MIDDLE TWIST DIRECTION LOWER TWIST DIRECTION.

* The weight includes the commercial moisture regain.

TABLE IV

Export of Natural and Synthetic Fibre Fishing Gear in 1956 (or 1957)

Unit: Pound

	Month												
Type	1	2	3	4	5	6	7	8	9	10	11	12	Total
Natural Fibres													
Cotton	363,037	532,585	528,811	448,219	494,895	401,129	412,297	361,712	424,347	426,674	351,561	473,724	5,218,991
Silk	—	20	159	31	—	—	2	—	5	99	4	—	320
Manila Hemp	18,706	13,345	42,629	2,507	14,170	40,159	9,164	894	21,434	10,445	91,330	194,436	459,319
Sisal	—	32,894	55,099	15,815	47,146	25,187	54,945	—	29,710	44,826	—	20,867	326,489
Flax		1,230	2,110		1,183	1,933	749	375		285	2,363	595	10,823
Ramie		10	2,000		—	825	—		207		440	5	3,487
Coil Yarn	—					7,572							7,572
Sub-Total	381,743	580,084	630,808	466,572	557,394	476,805	477,157	362,981	475,703	482,329	445,698	689,627	6,026,901
Synthetic Fibres													
Nylon	17,140	36,570	49,072	63,955	62,795	65,009	38,818	55,464	59,264	67,519	74,017	93,309	682,932
Vinylon	4,797	6,877	14,148	8,776	8,217	12,789	4,060	16,938	17,616	12,696	97,335	17,195	221,444
Polyvinylidene Chloride Fibre				720	992	16,047	19	951	261	254	44,034	316	63,594
Polyvinyl Chloride Fibre			2,672			—		—	—	7		442	3,121
Two Fibres Plied	18,841	850	6,373	8,692	622	6,698	9,004	13,872	16,871	24,050	27,624	31,534	165,031
Sub-Total	40,778	44,297	72,265	82,143	72,626	100,543	51,901	87,225	94,012	104,526	243,010	142,796	1,136,122
Total	422,521	624,381	703,073	548,715	630,020	577,348	529,058	450,206	569,715	586,855	688,708	832,423	7,163,023

2-11. *Indication for Number of Twist* (A. B. C.)
The number of twist will be indicated by the numerical value of turns per metre (t./m.) or turns per inch (t./in.). In the case of twine the number of upper twist, middle twist and lower twist to be indicated as follows:

LOWER TWIST NUMBER × MIDDLE TWIST NUMBER × UPPER TWIST NUMBER.

Example: Upper twist Z 120 turns per metre, middle twist S 5 turns per inch and lower twist Z 10 turns per inch—Z 10 t./in. × S 5 t./in. × Z 120 t./m.

2-12. *Standard Initial Tension* (A.)
Standard initial tension is the first tension in which the yarn is suspended without any extension. In cases where tension affects mean "thickness", "ply number", "apparent yarn count", "twist", "tensile strength and extensibility", "knot strength", "elastic recovery" and "shrinkage in water", the initial tension is given to a yarn of 20^s with a load of 5 grams. An initial tension other than the standard one shall be indicated.

2-12. *Standard Initial Tension* (B. C.)
In cases where tension affects mean "thickness", "ply number and filament denier", "denier", "twist", "tensile strength and extensibility", "knot strength", "elastic recovery" and "shrinkage in boiling water" the initial tension used is 1/30 g. of the nominal denier (filament denier × ply number). An initial tension other than the standard one shall be noted.

3. Sampling and Preparation (A. B. C.)

The test sample is taken by cutting off 5 m. from the end of the yarn. Care must be exercised to prevent change in twist, and no tension given. In case of testing for "knot strength" and "elastic recovery", the test sample will be left in the testing room under ordinary conditions until it reaches the constant weight. When the testing room cannot be kept in standard condition, the test sample will be put in a closed vessel (of 36 per cent. sulphuric acid) and the temperature be kept at the constant degree (20 deg. C.).

4. Test Items (A. B. C.)

(1) Corrected weight
(2) Moisture regain
(3) Standard weight
(4) Thickness
(5) Ply number
(6) Yarn count or denier
(7) Twist
  1. Upper twist number
  2. Middle twist number
  3. Lower twist number
  4. Twist shrinkage
(8) Twist setting
(9) Tensile strength and extensibility
  1. Dry tensile strength and extensibility
  2. Wet tensile strength and extensibility
(10) Knot strength
  1. Wet strength of reef knot
  2. Wet strength of English knot
(11) Elastic recovery
(12) (a) Shrinkage in cold water; (b) in boiling water
(13) Moisture absorption
(14) Sinking speed
(15) Weathering resistance

5. Methods of Testing

The test of "standard weight", "tensile strength and extensibility", "knot strength" and "elastic recovery", will be carried out in a testing room under standard conditions. When the testing room cannot be kept at the standard temperature, the temperature at the time of the test will be noted.

5-1. *Corrected Weight*
Find out the weight of gross and tare of two samples and get the corrected weight from the following formula and indicate the average number.

$$\text{Corrected weight} = W \times \frac{100 + R_c}{100 + R}$$

where: W = weight of the test sample (gross weight − tare weight)
R = moisture regain measured (per cent.)
R_c = commercial moisture regain (A = 5 per cent., B = 4.5 per cent., C = 0 per cent.)

5-2. *Moisture Regain* (A. B.) or *Absorbed Moisture* (C)
Weigh two test samples both before and after absolute dry condition. The average moisture regain is obtained from the following formula to (one place of decimal):

$$\text{Moisture Regain (per cent.)} = \frac{W - Wd}{Wd} \times 100$$

where: W = weight before drying the test sample.
Wd = weight of absolute dry test sample.

5-3. *Standard Weight* (A. B. C.)
Suspend a test sample 2 m. or more in length in a perpendicular position. Then find out the weight of a standard length and indicate the average weight.

5-4. *Thickness* (A. B. C.)
Take five test samples and wind them 20 times closely, parallel to each other, and with a standard initial tension, around a cylinder about 5 cm. in diameter. Measure the breadth and divide by 20. The average number is indicated in millimetres (to one place of decimal) as shown in fig. 2.

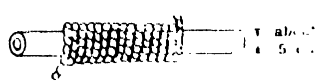

Fig. 2.

5-5. *Ply Number* (A.) *Ply Number and Filament Denier* (B. C.)
After untwisting the twine the ply number and filament denier are measured.

5-6. *Yarn Count* (A.) or *Denier* (A. B. C.)
Give the testing sample the standard initial tension and cut it into ten lengths of 30 to 90 cm. After weighting the yarn count or denier is obtained from the following formula:

$$\text{Yarn count (s)} = 0{\cdot}5906 \times \frac{L}{W}$$

$$\text{Denier (D)} = 9000 \times \frac{W}{L} = \frac{5315}{s}$$

where: W — weight of test sample (g.)
L — total length of the test sample (m.)

Remark: The corrected denier shall be calculated by the following formula:

$$\text{Corrected denier (B)} = D \times \frac{100 + 4{\cdot}5}{100 + R}\ ;\ (C) = D \times \frac{100}{100 + R}$$

where: D — denier measured
R — moisture regain measured (per cent.)

5-7. *Twist* (A. B. C.)
Apply a standard initial tension to the yarn, with 25 cm. (10 inches) between the clamps, with a yarn twist tester, and test for twist as follows, taking an average of ten or more tests

5-7·1 *Twist Direction* (A. B. C.)
After untwisting the test sample, the twist directions are examined from upper twist, middle twist, and lower twist.

5-7·2 *Upper Twist Number* (A. B. C.)
Untwisting the upper twist thoroughly, the untwisted number is converted into the number corresponding to one meter or one inch, and this figure is indicated as the upper twist number.

5-7·3 *Middle Twist Number* (A. B. C.)
All but one strand of the thoroughly untwisted strands of the upper twist are cut out, and then untwisted. This untwisted number is converted into the number corresponding to one metre or one inch, and this figure is indicated as the middle twist number.

5-7·4 *Lower Twist Number* (A. B. C.)
All but one yarn of the thoroughly untwisted strand of middle twist are cut out, and then untwisted. This untwisted number is converted into the number corresponding to one metre or one inch, and this figure is indicated as the lower twist number.

5-7·5 *Twisting Shrinkage* (A. B. C.)
After untwisting the test sample, measure the length of the yarn. The shrinkage percentage is measured from the following formula:

$$\text{Twisting Shrinkage (per cent.)} = \frac{L^1 - L}{L} \times 100$$

where: L — Length of the test sample
L^1 — Length after untwisting

5-8 *Twist Setting* (A. B. C.)
Take ten pieces of any test specimen each one metre long, pick up both ends and put them together and count their twisting number.

5-9 *Tensile Strength and Extensibility*

5-9·1 *Dry Tensile Strength and Extensibility* (A. B. C.)
Employing a suitable "Tensile Strength Tester", and exercising care not to untwist the test specimen, grip one end in the upper clamp, and after applying a standard initial tension, grip the other end in the lower clamp, the clamps being 25 cm. apart, and tension speed being 30 cm./min. Then measure the tensile strength and extensibility (kg. and per cent.) at the time of breaking. Take the mean of ten or more tests. (Carry to three figures.)

5-9·2 *Wet Tensile Strength and Extensibility* (A. B. C.)
The test specimen is immersed in water at room temperature,* and after it has thoroughly absorbed water, the wet tensile strength and extensibility is measured in a similar manner as described in 5 — 9·1.

5-10 *Knot Strength*

5-10·1 *Reef Knot —Wet* (A. B. C.)
The standard initial tension is applied to the test specimen, and a reef knot is made as shown in figure 3. Then it is immersed*. After the test specimen has thoroughly absorbed water, it is gripped in the clamps, keeping the knot in the middle, and the wet strength (kg.) is measured as in 5 to 9·1.
The average of ten tests is taken.

5-10·2 *English Knot—Wet* (A. B. C.)
A standard initial tension is applied to the test specimen and an English knot breaking strength is measured as in 5 — 10·1. The average of ten tests is taken.


Fig. 3.


Fig. 4.

5-11 *Elastic Recovery* (A. B. C.)
Employing a suitable "Tensile Strength Tester", the test specimen is extended to 12·5 mm. (5 per cent. of the original length). Then the load is removed for two minutes, and again the standard initial tension is applied and the remaining elongation is measured. The elastic recovery is measured from the following formula:

$$\text{Elastic recovery (per cent.)} = \frac{12{\cdot}5 - L}{12{\cdot}5} \times 100$$

Where: L — remaining elongation (mm.)

The average of ten tests or more is taken.

5-12 *Shrinkage in Water* (A.)
A standard initial tension is applied to the test specimen, and a section one meter long is marked. Then a loop is made by tying both ends together outside the marks. Immerse as for 5 — 9·2 and after the specimen has thoroughly

* The time for immersion is twelve hours.
Remark: Tests in which the specimens break at the clamp should be rejected.

TABLE V

Synthetic Fibres Produced and Used for Fishing Gear in Japan *June, 1957*

		Vinylon Staple		*Nylon Filament*		*Vinylidene Filament*	*Polyvinyl Chloride Fibre Filament*
		Regular	*High Tenacity*	*Regular*	*High Tenacity*		
Tensile Strength (gram per den.)	Std.	4·2 to 6·0	6·5 to 7·0	5·0 to 6·0	6·4 to 7·7	1·5 to 2·6	2·7 to 3·7
	Wet	3·2 to 4·8	5·2 to 5·8	4·2 to 5·0	5·4 to 6·7	1·5 to 2·6	2·7 to 3·7
	Std. Loop	1·5 to 2·6	3·0 to 3·4	4·7 to 5·5	5·4 to 6·5	1·0 to 2·0	
	Std. Knot	2·5 to 4·0	4·0 to 4·5	4·5 to 5·4	5·0 to 6·3	1·0 to 2·0	1·8 to 2·7
Elongation (%)	Std.	17 to 26	14 to 18	23 to 36	18 to 24	18 to 33	13 to 30
	Wet	19 to 30	15 to 19	38 to 48	21 to 28	18 to 33	13 to 30
Elastic Recovery (%)		75 to 88 at 2% 60 to 70 at 5%	Up to 81 at 2% 65 to 70 at 5%	98 at 3%		98 to 100 at 5%	80 to 85 at 3%
Specific Gravity		1·26 to 1·30		1·14		1·70	1·39
Moisture Regain		5·0% at standard condition		4·5% at standard condition		None	None
Moisture Absorption		12·0% at 95% R.H.		8·5% at 95% R.H.		0·1% at 95% R.H.	0·1% at 95% R.H.
Effect of Heat		Softens at 220 to 225 deg. C. Shrinkage starts at about 200 deg. C.		Softens at 180 deg. C. melts at 215 deg. C. Yellows slightly at 150 deg. when held for 5 hours.		Softens at 140 to 160 deg. C. Self-extinguishing.	Softens at 110 to 120 deg. C. Shrinkage starts at 60 to 70 deg. C.
Effects of Acids		Concentrated sulphuric, hydrochloric, formic acids decompose or swell.		Hydrochloric and Sulphuric acids cause degradation. Benzoic and Oxalic acids will cause loss in tenacity and elongation depending upon time and concentrations.		Unaffected by most acids including aqua regia.	Unaffected by most acids including aqua regia.
Effect of Alkalis		Strong alkalis cause yellowing but not affect strength.		Substantially inert.		Unaffected by most alkalis with the exception of concentrated ammonium hydroxide and sodium hydroxide.	Not affected by concentrated alkalis.
Effect of Organic Solvents		Good resistance.		Generally insoluble, soluble in some phenolic compounds and in concentrated formic acid.		Substantially inert.	Dissolves or swells in some aromatics, chlorinated hydrocarbons, ketones, esters.
Effect of Other Chemicals		Soluble in hot pyridine phenol, cresol. Resistant to oils.		Generally good resistance.		Generally good resistance.	Generally good resistance
Effect of Sunlight		Loses tensile strength after prolonged exposure.		Loses strength on prolonged exposure. No discoloration. Bright yarn is more resistant than semi-dull.		Darkens slightly after prolonged exposure.	Substantially unaffected after prolonged exposure.
Remarks		Vinylon is the generic term of polyvinylalcohol fibres.				Vinylidene is an abbreviation of Vinyl-chloride-Vinylidene-chloride copolymer fibres in Japan.	
Producers and Trade Names		Kurashiki Rayon Co. Ltd. "Kuralon" Dainippon Boseki Co. Ltd. "Mewlon" Kanegafuchi Boseki Co. Ltd. "Kanebian"		Toyo Rayon Co. Ltd. "Amilan" Nippon Rayon Co. Ltd. "Grilon"		Asahi-Dow Ltd. "Saran" Kureha Kasei Co. Ltd. "Krehalon"	Teikoku Rayon Co. Ltd. "Teviron" Toyo Kagaku Co. Ltd. "Envilon"
End Use		Seine net Longline Lift net	Setnet Trawl net	Gillnet	Seine net	Setnet Seine net Trawl net	Setnet Trawl net

Notes: For making fishing gears, these fibres are used generally in filaments, excepting vinylon which is not produced in filament form. In vinylon the high tenacity staple is employed for this purpose.

absorbed water, dry it in the air. Apply an initial tension again and then measure the length of the marked section. The shrinkage in water is obtained from the following formula (to one decimal):

$$\text{Shrinkage (per cent.)} = \frac{1000 - L}{1000} \times 100$$

where: L = length (mm.) of the air dry test specimen after treatment.

5-12 *Shrinkage in Boiling Water* (B.)
Take the test sample of 1 m. or more in length, fix both ends of the yarn together to overlap two-fold, and then measure a length of 50 cm., marking the two end points. Apply the weight to give the standard initial tension. Remove the weight, immerse the test specimen in boiling water for 30 minutes, and then take out of water to allow to dry in the air. Applying the same weight again, measure the length of the air dried sample. Calculate the shrinkage according to the following formula and take mean value of 5 tests or more (to one place of decimal).

$$\text{Shrinkage in boiling water (per cent.)} = \frac{500 - L}{500} \times 100$$

where: L = length of air-dried test specimen after immersion (mm.)

5-13 *Moisture Absorption* (A. B. C.)
Take about 2 m. length (if this wejghs less than 2 g., take about 2 g.) of the test specimen, and after measuring the weight in air dry condition, immerse it in water at room temperature*. Then take the specimen out of the water and allow the water to drip for two minutes; take the weight, and calculate the moisture absorption from the following formula:

$$\text{Water absorption (per cent.)} = \frac{W^1 - W}{W} \times 100$$

where: W = air dry weight of test specimen
W^1 = water absorption weight of test specimen

5-14 *Sinking Speed* (A. B. C.)
Take a piece of twine of 2 cm. in length with a knot in the middle, let it sink from the surface of water at 20 deg. ± 5 deg. C. contained in a glass beaker (see fig. 5). Measure the speed per second from AB to CD, a distance of 50 cm. The test specimen should be previously de-aerated and immersed in clear water*. Take the average of three or more tests.

Remark: Tests in which the specimen sank in a diagonal way or sank close to the wall of the vessel should be rejected.

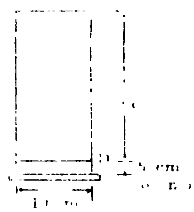

Fig. 5.

5-15 *Weathering Resistance* (A. B. C.)
Take two test specimens at random, fix them to a textile testing board, and measure their strength (ten times × 2) by exposing them under the condition mentioned below for 20 hours with the weathering resistance tester made in the form of the weather-O-meter. This strength is compared with that of the control sample and the average value is taken in per cent.

Arc 130 to 145 V. 50 to 60 c/s 15 to 17A to 2 sets
Carbon for Arc " 70 (Solid) and " 20 (Core), or other corresponding types.

Temperature in the tester	40 to 50° C.
Revolving Speed	once per min.
Exposing time	102 min.
Spraying time	18 min.
Pressure of spraying water	25 to 30 lbs./in.^{2}
Water requirement for spraying	20 to 30 gal./hr.

* The time for immersion is twelve hours.

Remark: Tests in which the specimens break at the clamp should be rejected.

Brailing herring from a purse seine on the West Coast of Canada. **Photo Inf. Serv. Dept., Fish., Ottawa.**

THE PHYSICAL PROPERTIES OF NETTING AND TWINES SUITABLE FOR USE IN COMMERCIAL FISHING GEAR

by

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Abstract

Many new materials have recently been introduced into commercial fishing gear, but many other useful materials have been rejected because they have not been tried to the best advantage. Often the tensile strength of the dry, straight twine is used as the basis for the substitution of new materials for more conventional ones, but this basis can result in serious error because the twines are invariably knotted and wet while fishing, and knotting and wetting affect different materials in different ways. Because pertinent, reliable and comparable data are often not available for new materials, original tests have had to be made, and the results thereof are presented herewith.

The materials tested, in forms generally suitable for use on the coast of British Columbia, include cotton, linen, ramie, hemp, Manryo, nylon and Terylene.

The test procedures used to measure net weight in water, change in length due to wetting, linear twine density, twine diameter, twine stretch under load, and tensile strength are briefly described.

The properties of the twine and netting are divided into two groups. The first group includes the "parameters" (properties which have the same numerical value for all twine sizes of the same material and style), and, where available, quantitative data for these properties are reported in tabular form. The second group includes properties whose values vary with and are dependent on the twine size, and formulas are presented for estimating values of this second group of properties from data for the first. Definitions and unit equivalents for all properties are quoted.

Propriétés physiques de filet et des fils pouvant être utilisés dans les engins de pêche commerciaux

Résumé

On a récemment adopté pour la fabrication des engins de pêche commerciaux un grand nombre de matériaux nouveaux mais beaucoup d'autres matériaux utiles ont été rejetés simplement parce qu'ils n'ont pas été essayés dans les meilleures conditions. On manque très souvent pour les nouveaux matériaux de données pertinentes, dignes de foi et comparables, et il a fallu faire des essais originaux dont y on trouvera les résultats ci-dessous.

Les matériaux, essayés sous des formes convenant généralement à l'utilisation sur la côte de la Colombie britannique, comprennent le lin, la ramie, le chanvre, le manryo, le nylon et le térylène. On trouvera une brève description des techniques utilisées pour ces essais qui consistaient à mesurer le poids net dans l'eau, les variations de longueur subies par le fil mouillé, la densité linéaire du fil, le diamètre du fil, l'allongement du fil sous l'influence d'un poids et la résistance à la rupture. On a réparti les propriétés des fils en deux catégories, les "paramètres" (propriétés ayant la même valeur numérique pour toutes les dimensions du fil fabriqué avec le meme materiel et de même façon) et les propriétés dont les valeurs sont fonction de la dimension du fil et on trouvera des formules pour calculer la valeur des propriétés de cette seconde catégorie à partir des données relatives à la première. On donne des définitions et des équivalents unitaires pour toutes les propriétés.

Propiedades físicas de las redes e hilos adecuados para artes de pesca comercial

Extracto

Recientemente ha comenzado a usarse gran número de nuevos materiales en las artes de pesca comercial, pero también se han rechazado muchos útiles a causa de no haber sido ensayados de manera que puedan utilizarse con ventaja. Como a menudo no se dispone de datos seguros que permitan comprobar nuevos productos textiles, en este trabajo se dan a conocer las pruebas originales que debieron hacerse para este objeto, así como los resultados obtenidos.

Los materiales ensayados en las formas como generalmente se usan a lo largo de la costa de Colombia Británica incluyen: algodón, lino, ramio, cáñamo, "manryo" ("vinylon"), "nylon" y "terylene". En el trabajo también se describen, en forma sucinta, los procedimientos usados en las pruebas de materiales para medir su peso neto en el agua, cambio de longitud al humedecerlo, peso lineal y diámetro, alargamiento del hilo con el peso y resistencia a la tensión.

Las propiedades de los hilos y de las redes se dividen en dos grupos: los "parametros" (propiedades con el mismo valor numérico para los hilos del mismo tipo y material) y las propiedades cuyos valores varian y dependen del diámetro del hilo. También se dan fórmulas para estimar los valores de este segundo grupo de propiedades basándose en datos del primero, definiciones y equivalencias para todas las propiedades.

INTRODUCTION

DURING the past decade, many new materials, particularly synthetic fibres, have been introduced into commercial fishing, usually being presented as substitutes for other materials. If these new materials are to be substituted rationally, certain physical properties should be determined quantitatively *a priori*, although the data describing the new and the conventional materials need only be relative. But where these materials are to be used in new applications, then the physical properties should be fully described. It is the author's opinion that many new materials have been rejected as unsatisfactory, through improper use of the material during initial trials, a result of complete neglect of quantitative test data or because only irrelevant physical properties have been considered.

The misuse of test results has been illustrated in the selection of twine sizes for salmon gillnets. Because fish must be caught from water, wet strength is more important than dry strength even though, for convenience, many people measure only the latter. At one time all salmon gillnets on the British Columbia coast were made of premium-grade linen which increases about 50 per cent. in strength when wet. In contrast, nylon loses about 15 per cent. strength in water. Therefore, if a nylon twine is chosen to give the same dry strength as the linen it is to replace, the wet strength of the nylon net will be little more than half that of the linen net.

The manufacturers of nylon gillnets were aware of this and, for the first experimental nets, selected twine sizes of sufficient wet strength to carry normal fishing loads. The results were satisfactory. Nevertheless some net men and fishermen still select their nylon gillnets on the basis of hand tests applied to dry netting, with the result that nets are chosen too light for their loads. They are torn more easily, and their owners erroneously claim that the quality of nylon is becoming poorer. Because wetting affects the strength of different materials in different ways, wet strength tests are much more significant to fishing gear design than are dry strength tests.

Another example of the improper use of test results is in the choice of the physical property which the test evaluates. Because twine must be knotted to form netting the strength of the knot or the mesh is more important than the strength of the straight twine. Soon after the introduction of nylon 66 multifilament gillnets into the British Columbia salmon fishery, nylon 6 multifilament gillnets began to appear. On one occasion at least, the tensile strength of twine from the latter nets was found to be about 40 per cent. weaker than nylon 66 twine of the same weight, and nylon 6 was rejected as being unsatisfactory for salmon gillnets. However, because these two nylons react differently to knotting, the mesh of a nylon 6 is only about 20 per cent. weaker than that of a nylon 66 net of the same weight. Considering their lower price nylon 6 nets do have a place in the British Columbia salmon fishery in competition with the nylon 66 nets. Because knotting affects the strength of different materials in different ways, knot strength or mesh strength tests are much more significant to fishing gear design than are tensile tests on the straight twine.

Many new materials have been made available, unaccompanied by specific test data describing their physical properties. Inquiries addressed to the suppliers often elicit no further information, or bring data which have little significance to fishing gear applications. It has therefore been necessary for the Fisheries Research Board of Canada to perform its own tests prior to recommending how these materials may be used to greatest advantage. Obtaining our own test data has the threefold advantage that: (1) pertinent properties may be measured; (2) the test data are reliable to the best of our ability; and (3) by using consistent test procedures, data on all materials, both conventional and new, may be compared.

This paper presents the results of our many tests on seven different fibres in eighteen different forms suitable for use in commercial gear for the British Columbia fishery. Because different materials were designed for different applications, not all properties of all materials were measured, and the accompanying table is not complete. However, except for the mesh strength of hemp and medium-laid cotton, test procedures were consistent throughout and the test data presented are comparable between different materials. All test results have been reduced to "parametric" form, that is, to properties which are reasonably constant over the complete twine-size range of a given material and style. Sometimes corresponding materials from different manufacturers have properties in which measured differences are statistically significant, but these have been grouped into the overall averages presented in Table I.

MATERIALS TESTED

The cotton netting and twine, the Manryo twine, and the twisted, spun, nylon 66 twine, were of "cable" construction: i.e., the twine contains three or four plies and each ply contains several yarns. The yarn style is identified by the British system of hanks (1 hank = 840 yards = 768 metres) per pound (453·6 grams). The twine size is identified by two numbers, the first being the number of yarns per ply and the second the number of plies in the twine. The total number of yarns in the twine is the product of these two numbers. In the medium-laid twines the helix angle of the plies was about 54 deg., in the soft-laid twines about 28 deg., and in the extra-soft-laid twines about 22 deg.

The linen, ramie, and hemp twines were of plied construction, i.e., the yarns were doubled directly into the twine. The linen yarn is identified according to an arbitrary commercial numbering system, but the approximate number of leas (1 lea = 300 yards = 274·3 metres) per pound (453·6 grams) is quoted in parenthesis. The ramie yarn is identified according to this same leas-per-pound system, and the hemp yarn is identified by the number of pounds (1 pound = 453·6 grams) per spindle (14,400 yards = 13,167 metres). In all cases the twine size is identified by the number of yarns which have been twisted into the twine.

The monofilament twine is identified by its nominal diameter.

The continuous multifilament yarns (nylon and Terylene) are identified both as to weight or total denier per yarn and as to the number of filaments per yarn. The twisted twines were of "cable" construction and are described by two numbers in the same way as are the cotton twines.

The braided twines are described by the total number of yarns in the braid.

PROPERTIES AND TEST PROCEDURES

The nett weight (gravitational force less buoyant force) of the netting in the water is an important factor in determining how it will lie or move in the water and how much lead and what float capacity is required for a given piece of equipment. For example, the low density of nylon contributes toward the fishing efficiency of

Material	*Cotton Medium Lay*	*Cotton Medium Lay*	*Cotton Soft Lay*	*Cotton Extra Soft Lay*	*Linen 'Salmon' Lay*	*Linen 'Salmon' Lay*	*Ramie 'Salmon' Lay*	*Ramie 'Salmon' Lay*	*Hemp*	*Manryo Medium Lay*	*Manryo Soft Lay*	*Nylon 6 Monofil*	*Nylon 6 Multifil*	*Nylon 66 Hi-Ten Multifil*	*Nylon 66 Spun Soft Lay*	*Nylon 66 Multifil Braided*	*Nylon 66 Spun Braided*	*Terylene (Dacron) Hi-Ten Multifil*
Yarn Style	10-hank	8-hank	10-hank	10-hank	#50 (22 lea)	#40 (20 lea)	20 lea	17 lea	25 lb/sp	20-hank	20-hank	0·25 mm. diameter	210 den. 15 fil.	210 den. 34 fil.	10-hank	5 × 210 den.	15-hank	250 den.
Twine Size Range	2/3 to 18/3	20/3 to 36/3	3/4 to 12/4	4/4 to 8/4	4-ply to 10-ply	4-ply to 12-ply	5-ply to 6-ply	5-ply	3-ply	3/3 to 10/3	8/4 to 18/4		3/3 to 10/3	2/3 to 12/3	4/3 to 9/3	12 to 16 yarn	24 to 32 yarn	3/3 to 12/3
1. Weight (%) in Water	35½	35½	35½	35½	33½	33½	34	34	32½	18½	18½	12½	12½	12½	12½	12½	12½	27½
2. Specific Gravity	1·55	1·55	1·55	1·55	1·50	1·50	1·51	1·51	1·48	1·23	1·23	1·14	1·14	1·14	1·14	1·14	1·14	1·38
3. Change in Length (%) to Wetting	−9·8	−9·8			−1·4	−1·4	−1·4	−1·2	−5·4			+2·5	−2·0	+0·5				+1·5
4. Linear Density (kyd./lb.) per yarn	6·73	5·39	7·16	7·30	6·65	5·85	5·91	4·93	1·65	14·1	14·6	7·95	20·5	19·2	7·13	4·35	12	15·8
5. Effective Cross-section Area (circular mils) per Yarn	215	300	220	200	130	160	120	150	1130	105	115	110	56½	57½	205	250	100	80
6. Total extension (%) at break of:																		
Twine, Straight, Dry	18				3·5	3·5				21	23	22½	21	25	40+	33½	40+	16½
Wet	33				6	6				26	30½	22	21	24	(More	40+	40+	17
Single Knot, Dry	14									12	14½		14	16½	than	24	37	10½
Wet	31									19	23½		14	16½	40%)	29	34	10½
Double Knot, Dry					2·5	2·4							16	18½		23	37	10½
Wet					4·5	4·3							15	18		33	38	10½
Mesh, Single Knot, Dry	13											12	14½	18				9½
Wet	28											10	14½	18				9½
Double Knot, Dry					2·4	2·4							15	18½				10½
Wet					4·5	4·5							15	18				10½
7. Specific Strength (kyd.) of:																		
Twine, Straight, Dry	13·1	13·6	14·8	14·5	44·0	43·2	33·1	32·1		33·2	35·2	44·5	39·1	63·7	27·4	53	31	48·6
Wet	14·4	15·0	16·5	17·0	58·8	58·5	54·0	42·0		24·8	25·2	35·8	35·2	56·0	25·9	43	27	50·2
Single Knot, Dry	9·4		9·1	9·6						12·1	13·5		23·2	25·6	21·1	27	23	22·8
Wet	12·6		11·9	13·4						10·4	11·3		20·3	22·5	18·6	23	19	24·2
Double Knot, Dry					22·5	20·3							29·1	34·0		30	24	23·1
Wet					32·0	29·2							23·1	28·2		25	21	22·7
Mesh, Single Knot, Dry	8·2	8·6							19·3			22·4	24·4	30·8				20·0
Wet	9·6	10·0							19·1			17·5	22·0	28·1				20·7
Double Knot, Dry					19·9	19·7	15·9	15·6					26·6	34·3				24·1
Wet					31·6	30·9	26·3	27·9					23·1	29·9				23·5
8. Strength Change (%) to Wetting of:																		
Twine, Straight	+10	+10	+12	+17	+34	−35	−34	+31		−25	−28	−20	−10	−12	−5	−19	−13	−3
Single Knot	+34		+31	−40						−14	16		−12	−12	−12	−15	−17	−6
Double Knot					+42	−44							−21	−17		−17	−12	−2
Mesh, Single Knot	+17	−16							1			−22	10	−9				+3
Double Knot					+59	+57	−66	+79					13	−13				−2
9. Strength Efficiency (%) of:																		
Twine, Single Knot, Dry	72		61	66						36	38		59	40	77	51	74	47
Wet	88		72	79						42	45		58	40	72	53	70	48
Double Knot, Dry					51	47							74	53		57	77	48
Wet					54	50							66	50		58	78	45
Mesh, Single Knot, Dry	63	63										50	62	48				41
Wet	67	67										49	62	50				41
Double Knot, Dry					45	46	48	49					68	54				50
Wet					54	53	60	66					66	53				47
10. Toughness Index (kyd.-lb./lb.) of:																		
Twine, Straight, Dry	1·18				0·77	0·76				3·5	4·0	5·0	4·1	8·0	5·5+	8·9	6·2+	4·0
Wet	2·38				1·76	1·76				3·2	3·8	3·9	3·7	6·7	5·2+	8·6+	5·4+	4·3
Single Knot, Dry	0·66									0·7	1·0		1·6	2·1	4·2+	3·2	4·3	1·2
Wet	1·95									1·0	1·3		1·4	1·9	3·7+	3·3	3·2	1·3
Double Knot, Dry					0·28	0·24							2·3	3·1		3·5	4·4	1·2
Wet					0·72	0·63							1·7	2·5		4·1	4·0	1·2
Mesh, Single Knot, Dry	0·53											1·3	1·8	2·8				1·0
Wet	1·34											0·9	1·6	2·5				1·0
Double Knot, Dry					0·24	0·24							2·0	3·2				1·3
Wet					0·71	0·70							1·7	2·7				1·2

nylon gillnets but creates handling problems in nylon purse seines. The nett weight was measured by weighing an air-dry sample of netting in the air, by soaking the sample overnight in distilled water at 70 deg. F. (21·1 deg. C.) and then reweighing while still immersed in the water. The weight in water was then expressed as a per cent. of the air-dry weight. This weight per cent. is numerically equal to the weight in water in pounds (or kilograms) per hundred pounds (or kilograms) air-dry in air. The specific gravity was calculated from the weight per cent. in water. The nett weight (per cent.) of the netting in salt water or in fresh water and at any temperature may be estimated by the relation:

$$\left.\begin{array}{l}\text{Weight (\%)}\\ \text{in sea water}\end{array}\right\} = \left[1 - \frac{\text{specific gravity of sea water}}{\text{specific gravity of material}}\right] \times 100$$

The change in length due to wetting must be known where the mesh length is specified only for dry netting. In many types of fishing gear, such as gillnets and trawls, the mesh length of the web in the water is an important factor in determining the fishing efficiency of the gear or in releasing under-size fish for conservation purposes. Different materials react differently to wetting, e.g., most natural fibres shrink and most synthetic fibres extend, so that a quantitative measure of this reaction is needed before dry mesh length can be properly specified for a given application. The change in length (per cent.) due to wetting was determined by measuring the length of meshes in the sample when air-dry, by soaking the sample overnight in cold tap water, by measuring the length of meshes in the same sample while wet, and by expressing the change in mesh length which occurred during wetting as a per cent. of the average mesh length of the dry sample. Shrinkages are prefixed by the negative (—) sign and extensions are prefixed by the positive (+).

The linear density is a convenient measure of the size of the twine. Often twine must be purchased by weight but is required for use by length. A knowledge of linear density therefore permits estimation of the quantity (weight) of twine required to construct a given piece of equipment. In keeping with common Canadian practice, the indirect system (length per unit weight) is used. Ten one-yard (1 yard = 0·9144 metres) pieces of air-dry twine were cut under four ounces (113·4 grams) tension and were weighed collectively to the nearest milligram. The linear density of the twine (1 yard per pound = 2·016 metres per kilogram) was calculated by dividing the weight of the ten-yard sample in grams into 4536. The effective linear density per yarn was then calculated by multiplying the linear density of the twine by the total number of yarns in the twine. Further division by 1,000 reduced the number of integers required for the table and changed the length unit from yards to kiloyards (1 kiloyard = 1,000 yards = 914·4 metres).

The diameter of the twine is a major factor in determining how strongly moving water pulls the netting, how easily swimming fish can move the netting, and what power is required or speed attained while towing a given piece of equipment. The diameter was measured by placing four parallel strands of air-dry twine under the 1·25 inch (3·15 centimetres) diameter circular foot of a dial gauge. The total force exerted diametrically on the twine by the foot during measurement was 6 ounces (170·1 grams). The separation of the foot from the supporting anvil caused by the interposed twine was indicated by the dial gauge in mils (1 mil = 0·001 inches = 0·0254 millimetres) and was reported as the twine diameter. This method of measurement has certain defects when used to determine the diameter of twine for fishing gear. Twines made from staple fibres have loops and fibre ends protruding from the twine which increase the resistance to movement of the twine through water but which are easily pressed to the twine during diameter-measurement; and soft-laid twines are pressed out of round by the measuring device more than are harder laid twines. However, when interpreted in the light of these effects, twine diameters measured in this way can be useful.

The effective cross-section area per yarn was calculated as a dimension which is a function of the diameter and yet is reasonably constant over all twine sizes for each yarn style and twist hardness. The effective cross-section area of the twine in circular mils (1 circular mil = 0·0005067 square millimetres) is the square of the twine diameter in mils (1 mil = 0·001 inches = 0·0254 millimetres). Further division by the total number of yarns in the twine gives the effective cross-section area of each yarn. The diameter of any size twine of the same style may then be estimated by multiplying the effective yarn area by the number of yarns in the twine and by deriving the square root of this product.

Total extension and breaking load of twines were measured simultaneously on a Scott Model J2 recording tester of 100 pounds and 400 pounds maximum capacities, using type X-1 clamps. The tester was set so that 10 inches (25·4 centimetres) of untensioned twine lay between the nips of the clamps prior to test. For knot strength tests, the twine was cut and the appropriate knot, single weavers' knot or double weavers' knot, was tied in the twine by hand.

For testing the mesh strength of netting for seines and trawls (medium-laid cotton and hemp), small panels of netting were cut from the sample, all the meshes along two opposite sides of the panel were threaded respectively onto ¼ inch (6·35 millimetres) diameter rods on the tester, and the sample was stressed to rupture through separation of the rods by the tester. The mesh strength was then calculated by dividing the panel strength by the number of meshes in the width of the panel. The netting was tested in both directions relative to the selvedge and the overall average is reflected in the data quoted here. Netting in seines and trawls is stressed in use over several meshes at a time rather than on single meshes; therefore, by testing panels as above, irregularities in the physical dimensions of the netting result in lowered mesh strength as is experienced in use. Netting in gillnets is more commonly stressed on individual meshes so that these materials (linen, ramie, nylon, and Terylene) were tested one mesh at a time. The mesh was placed around two one-inch-diameter (2·54 centimetres) drums so that no knots touched either drum, and the drums were separated by the tester until the mesh broke. For dry strength, the materials were tested in their natural, air-dry state, and for wet strength, the materials were soaked overnight in cold tap water.

Specific strength is dimensionally identical with tenacity, the only difference being in the units employed. Arithmetically it is the test strength per twine (i.e., twine strength, knot strength, or half the mesh strength) in pounds (1 pound = 453·6 grams) multiplied by the linear density of the air-dry twine in kiloyards per pound (1 kiloyard = 1,000 yards = 914·4 metres). This specific strength may be converted into tenacity in grams per denier by further multiplying by 0·1016. For specific strength units, the weight or gravitational force was cancelled against the strength or breaking force, leaving length as the unit for specific strength. This permits an easier understanding of the physical significance of specific strength or tenacity than is possible with the metric units, grams per denier. Specific strength (and tenacity) is the length of twine the weight of which equals the breaking strength of that same twine. For the same strength-quality, an increase in weight per unit length causes an identical increase in strength, leaving the specific strength (and tenacity), which could well be called breaking length, constant. For a given material of a given quality the specific strength is reasonably constant over all twine sizes; and the breaking strength of a particular twine may be estimated from the specific strength by dividing this latter by the linear density of the twine. Specific strength figures may be used directly to compare the strength of different materials on an equal weight basis, e.g., high tenacity nylon 66 when wet is seen to be slightly weaker than wet linen, a relation often obscured by the fact that nylon 66 and linen twines are not made in identical weights. Specific strength may also be used as a measure of strength-quality, the specific strength of different specimens being directly comparable even though the yarns may be spun to slightly different weights. Finally, the tensile strength (breaking force per unit area normal to the direction of the force) of the fibre itself is related to the specific strength through the fibre density so that the usable tensile strength of the fibre in pounds per square inch (1 pound per square inch = 70·307 grams per square centimetre) may be estimated from the relation:

Tensile Strength = 1,300 × Specific Gravity × Specific Strength. Comparison of this usable tensile strength with data available elsewhere for the virgin fibre gives an idea of the manufacturing and geometrical efficiencies realised in these fishing gear materials.

The load extension characteristics on initial loading of each twine, both dry and wet, were drawn autographically by the Scott tensile tester. The average of ten replicate test plots was redrawn showing the per cent. extension (increase in length under load expressed as a per cent. of the unstressed length) as a function of specific load. Specific load, analogous to specific strength, is the actual load in pounds (a pound = 453·6 grams) multiplied by the linear density of the air-dry twine in kiloyards per pound (1 kiloyard = 1,000 yards = 914·4 metres). All these average curves for all twine sizes of a given material and style were drawn against the same reference axes and an average of the curves was then drawn. The stretch data given in Table I were read from this last average plot against the corresponding specific strengths of each material in each state. These data do not include elongations consequent upon tightening of knots, which are functions of the initial knot tightness; but they do include irreversible elongations in the twine itself. Undoubtedly, the load–extension characteristics under cyclic loading are more significant to fishing gear design than are initial loading characteristics, but the former cannot be obtained with our Scott tensile tester.

Data describing the tensile strength of the dry, straight twine often have little application to fishing gear design; in fact, they can lead to serious error. Even so, such data are frequently all that are available. The change (increase or decrease) in tensile strength which results from wetting the materials is reported as a per cent. of the dry strength to assist in estimating the strength in water where only dry strength data are available. Similarly, the per cent. of the twine strength which is retained in knotted structures is reported to assist in estimating the knot or mesh strengths where only twine strength data are available. These per cent. changes in strength to wetting and per cent. strength efficiencies of knots and meshes were calculated from the specific strength data.

The tensile strength of the fibrous materials used in fishing gear can be measured relatively easily, so this property is often the only one evaluated, and is sometimes blindly adopted as the only measure of quality and performance. Where the material is to be subjected only to dead loads, tensile strength is an adequate measure of quality. However, fighting fish are not dead loads, and it is more important that the material be able to absorb the energy inflicted on it by the fish than merely carry the weight of the fish. A dramatic illustration of this is that nylon gillnets for salmon need not be so strong as linen gillnets to hold the same fish, because the greater elastic extension of the nylon imparts greater ability to absorb the energy expended by the salmon. The "toughness" used here is a rough measure of the energy required per unit length of twine to break that twine, whether it be straight, knotted, or in a mesh. Arithmetically it is one-half the product of the breaking load and the fractional extension from unstressed length to rupture. This estimate is in error to the extent that the load–extension curve is assumed to be linear; but, whereas most fishing gear materials deviate from linearity toward the extension axis, the error is in the same direction in most cases and the figures are reasonably comparable. A further loss of correlation between this calculated "toughness" and performance toughness originates from use of the load-extension relation under initial load—permanent elongation is included. However, despite approximations in its estimation, "toughness" is more important in the design of some types of fishing gear than is tensile strength. "Toughness" is reduced to the parametric form, viz., toughness index, by multiplying it by the linear density of the air-dry twine. This toughness index is thus the energy required per unit weight of twine to break that twine, and is reasonably constant for all twine sizes of the same material in the same style.

DEFINITIONS AND DIMENSIONS

A. Parametric properties, quantitatively reported in the table, which are reasonably constant for all twine sizes of the same material and style.

1. Weight (per cent.) in water is the nett weight (gravitational force less buoyancy) of the material when immersed in distilled water at 70 deg. F. (21·1 deg. C.), expressed as a per cent. of the air-dry weight.

$$\text{Weight (\%) in water} = \frac{\text{Nett weight in water}}{\text{Air-dry weight in air}} \times 100$$

2. Specific gravity is the density of the material relative to the density of pure water at 4 deg. C. 39·2 deg. F.).

$$\text{Specific gravity} = \frac{0{\cdot}998}{1 - 0{\cdot}01 \text{ (weight (\%) in water)}}$$

3. Change in length (per cent.) to wetting is the increase (+) or the decrease (−) in length caused by soaking the material in water, expressed as a per cent. of the air-dry length.

$$\text{Change in length (\%) to wetting} = \frac{\text{Wet length} - \text{Dry length}}{\text{Dry length}} \times 100$$

4. Linear density is the length per unit weight (indirect system).

$$\text{Linear density per yarn (kyd./lb.)} = \frac{1}{1000} \times \text{Linear density of twine (yd./lb.)} \times \text{Total number of yarns in the twine}$$

1 yd./lb. = 2·016 m./kg.
1 kyd./lb. = 1000 yd./lb.
= 2·016 m./g.

5. Effective cross-section area is the area of the circle whose diameter equals the measured diameter of the twine.

$$\text{Effective cross-section area per yarn (circular mils)} = \frac{(\text{Twine diameter (mils)})^2}{\text{Number of yarns in twine}}$$

1 circular mil = area of circle 1 mil (0·001 in. 0·0254 mm.) in diameter.
= 0·0005067 sq. mm.

6. Total extension (per cent.) at break is the increase in the length of the twine caused by the load required to break the twine (straight, knotted, or mesh) expressed as a per cent. of the unstressed length.

$$\text{Total extension at break} = \frac{\text{Twine length at break} - \text{Unstressed length}}{\text{Unstressed length}} \times 100$$

7. Specific strength (kyd.) is the effective tenacity.

$$\text{Specific strength (kyd.)} = \frac{1}{1000} \times \text{Linear density of air dry twine (yd./lb.)} \times \text{Measured strength (lb.)}$$

1 kyd. = 1000 yd.
= 0·1016 g./den.

8. Strength change (per cent.) to wetting in the increase (+) or decrease (−) in tensile strength caused by soaking the material in water, expressed as a per cent. of the dry strength.

$$\text{Change in strength to wetting} = \frac{\text{Wet strength} - \text{Dry strength}}{\text{Dry strength}} \times 100$$

9. Strength efficiency (per cent.) is the per cent. of the straight twine strength which is retained in knotted structures.

$$\text{Strength efficiency of Knotted twine} = \frac{\text{Knot strength}}{\text{Straight twine strength}} \times 100$$

$$\text{Strength efficiency of mesh} = \frac{\text{Mesh strength}}{\text{2x Straight twine strength}} \times 100$$

10. Toughness index (kyd. lb./lb.) is an approximate estimate of the energy per unit weight of twine required to break the twine.

$$\text{Toughness index} = \frac{1}{2} \times \frac{\text{Total extension (\%) at break}}{100} \times \text{Specific strength (kyd.)}$$

1 kyd. - lb./lb. = 3000 ft. - lb./lb.
= 91440 g. - cm./g.

B. Specific properties, variable with twine size, which may be estimated from the values of the parametric properties given in the table.

1. $$\text{Twine weight (yd./lb.)} = 1000 \times \frac{\text{Linear density per yarn}}{\text{Number of yarns per twine}}$$

1 yd./lb. = 2·016 m./kg.

2. $$\text{Twine diameter (mils)} = \left(\text{Effective cross-section area per yarn} \times \text{Number of yarns per twine}\right)^{\frac{1}{2}}$$

1 mil. = 0·001 in.
= 0·0254 mm.

3. $$\text{Twine strength (lb.)} = \frac{\text{Specific strength of twine} \times \text{no. of yarns}}{\text{Linear density per yarn}}$$

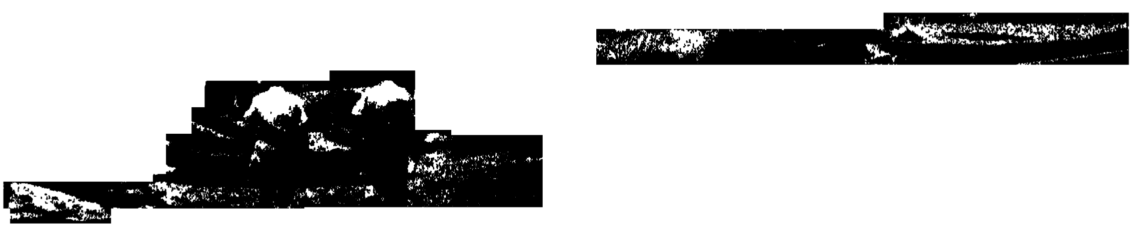
1 lb. = 453·6 g.

4. $$\text{Mesh strength (lb.)} = \frac{\text{2x Specific strength of mesh} \times \text{no. of yarns}}{\text{Linear density per yarn}}$$

1 lb. = 453·6 g.

5. $$\text{Toughness (ft.-lb./ft.)} = \frac{\text{Toughness index} \times \text{Number of yarns}}{\text{Linear density per yarn}}$$

1 ft.-lb./ft. = 453·6 g.—cm./g.



Log-rafts returning from drift net fishing, Ceylon. Photo FAO.

TESTING METHODS FOR NET TWINES AND NETS, ESPECIALLY THOSE MANUFACTURED FROM SYNTHETIC MATERIALS

by

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Abstract

This paper describes a number of tests for yarns and cords used in the fishing industry, and the author points out that, as a certain amount of standardization has already been achieved in the textile industry, the International Fishing Gear Congress can help in fostering a uniformity of measuring methods in the various branches of the fishing gear industry.

He recommends that "TEX", the unit for yarn numbering, representing the mass in grams per kilometre of yarn, be used for net yarns and cords, and further that "twist", indicated by Z or S according to the direction of the turn, should be expressed as the number of turns per metre (t/m).

The methods for testing for stretching, shrinkage and stiffness of yarns and cords are fully described, and the question of knot-strength is dealt with in detail. He discusses the different ways in which a knot can break down when tested in the clamps of a dynamometer, such as tip-over, breaking before and after slip and breaking after tip-over, etc., and then he tests for the "opening-up" of knots in synthetic materials, by putting knotted cords in a container revolving at 60 r.p.m. and finding the number of revolutions necessary to loosen the knots. Finally, the methods used for testing knots are applied to the testing of meshes, and mesh-strength, i.e. the load at which a mesh breaks, is surely one of the most important factors affecting the performance of a fishing net.

Méthodes d'essai pour les cordes des filets et les filets, en particulier pour les articles fabriqués à partir de fibres synthétiques

Résumé

L'industrie textile étant déjà arrivée à un certain degré de normalisation, le Congrès international des engins de pêche peut contribuer à l'adoption de méthodes uniformes de mesure dans les diverses branches de l'industrie des engins de pêche. L'auteur recommande d'utiliser pour les filets et les cordes destinés aux filets, le "TEX" unité pour le numérotage des fils représentant la masse en grammes par kilomètre de fil et de plus d'exprimer la torsion, indiquée par Z ou S selon le sens, en nombre de tours par mètre (t/m).

Les méthodes servant à déterminer l'extension, le raccourcissement et la rigidité des filés et des cordes sont décrites en détail, de même que la question de la résistance des noeuds. L'auteur examine les différentes manières dont un noeud peut se rompre au cours d'essai au dynamomètre, et il vérifie l'ouverture des noeuds des matériaux synthétiques en plaçant des cordes nouées un récipient tournant à 60 t/m et en cherchant le nombre de révolutions nécessaires pour relâcher les noeuds. Enfin, les méthodes utilisées pour vérifier les noeuds sont appliquées à la vérification des mailles et la résistance des mailles.

Métodos para ensayar cordajes y redes, especialmente de fibras sintéticas

Extracto

Como ya se ha logrado cierto grado de normalización en la industria textil, el Congreso Internacional de Artes de Pesca podría ayudar a uniformar los métodos de medida en las diversas ramas de la industria de artes de pesca. El autor recomienda el uso de la unidad "TEX" para numerar los hilos, que representa el peso en gramos por kilómetro de kilo o cordaje empleados en la fabricación de redes, e insinúa expresar la "torsión" o colchadura, indicada per Z o S según el sentido en que se practique, en número de vueltas por metro (v x m).

También describe, en detalle, los métodos usados para determinar el alargamiento, encogimiento y flexibilidad de los hilos y cordeles, así como el problema de la resistencia de los nudos. Además analiza las diversas maneras en que puede romperse un nudo al probarlo con las pinzas de un dinamómetro, como la rotura antes y después de correrse, etc. y las pruebas para determinar su aflojamiento cuando se usan materiales sintéticos, poniendo las cuerdas anudadas en un recipiente que gira a 60 r.p.m. a fin de encontrar el número de revoluciones necesarias para que se aflojen dichos nudos. Por último, los métodos usados en las pruebas de nudos se han aplicado a los ensayos de las mallas y a su resistencia.

1. INTRODUCTION

THE use of synthetic yarns during the last few years as material for nets has caused a growing interest in testing methods for twines and nets. This is expressed by more exact measuring and by development of new measuring methods to deal with the special problems which have arisen.

The "Bureau International pour la Standardisation de la Rayonne et des Fibres Synthétiques" (BISFA) with a membership of all the main North and West European producers of man-made fibres, and connected with the International Organisation of Standardisation (ISO), is engaged in standardizing the different testing methods for textile and tyre yarns, and for this purpose publishes the "BISFA-rules". In the USA similar work is done by the American Society for Testing Materials (ASTM).

This contribution discusses various testing methods for net yarns and twines, and nets. Some of these methods are already known in the textile industry, some, of specific interest to the fishing industry, relate to testing methods developed in our own laboratories. The BISFA rules are quoted with regard to the first group, but proposals are made for the second primarily from the point of view of the yarn producer.

The term "yarn" is understood to mean a continuous strand of fibres and/or filaments, from which twist, if any, can be removed in one operation; strand is the product obtained by twisting together two or more twisted yarns, twine is the product obtained by twisting two or more strands together.

2. METHODS OF TESTING YARNS AND TWINES

2·1 Yarn Number

Several units are used for the numbering of net yarns and twines. The ISO Conference, May 1956, recommended the use of the combination of grammes per kilometre of yarn, called "tex", as a unit for yarn numbering and we strongly advocated the use of the same unit for net yarns and twines. Table I shows the numbers in tex, denier and m/kg. for some yarns.

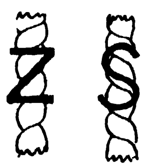
TABLE I

m/kg.	100	500	1,000	5,000	10,000	50,000	1,000,000
Td (g./9000 m.)	90,000	18,000	9,000	18,000	900	180	90
Tex (g./1000 m.)	10,000	2,000	1,000	200	100	20	10

2·2 Twist

Since the determination of the twist of net yarns and twines is the same as that of textile yarns only a few points will be mentioned. The direction of twist is normally indicated by the letters Z or S, as shown in fig. 1. In order to maintain the metric system we recommend that the twist shall be expressed as the number of turns per metre of twisted yarn or twine (t/m.).

Below is illustrated the indication of the twist construction of a twine:



Z-twist S-twist

Fig. 1. Indication of the twist direction.

100 tex Z 400 × 2 S 300 × 3 Z 100 means a twine composed of 6 yarns: every yarn is first twisted to 400 t/m. in Z-direction, then two of these twisted yarns are twisted together to 300 t/m. in S-direction, and finally 3 of these strands are twisted in Z-direction to 100 t/m.

2·3 Strength and Extensibility

The stress-strain curve, and the strength and total extension at break, are determined by the load-extension tester or dynamometer. The many types of dynamometer can be classified according to the time conditions under which the determination of strength and extension are performed. The time factor plays an important part in this determination for the materials used in fishing nets. The velocity and the way of increasing the strain have an influence on the shape of the stress-strain curve and the values of strength and extension at break. Efforts have been made to realise one of the following principles in making the dynamometers:

1. the length of the test object increases in proportion to the time; thus the rate of extension is constant;
2. the force on the test object increases in proportion to time; constant rating of loading.

The electronic recording dynamometers which are characterized by their stability, accuracy and versatility, are of recent design.

One clamp is moved at constant speed while the force is measured by the other clamp, connected with an electric element for measuring the force (fig. 2).

These meters have some specific properties, viz., the possibility of recording both a decrease and an increase in stress, and the many and wide measuring ranges that can be covered by a single instrument. These make them particularly suitable for testing twines and nets.

In practice, the wet strength and total extension at the breaking point of the twines are of primary importance. As regards modern, synthetic materials, such as e.g. nylon 6, nylon 66 and polyesters, the wet stress-strain properties do not differ very much from those measured in dry condition, so it suffices to determine the latter only for routine measurement.

The BISFA rules describe the measuring conditions as "the length of the test specimen between the jaws shall be 50 cm., and the mean time to break shall be 20 ± 2

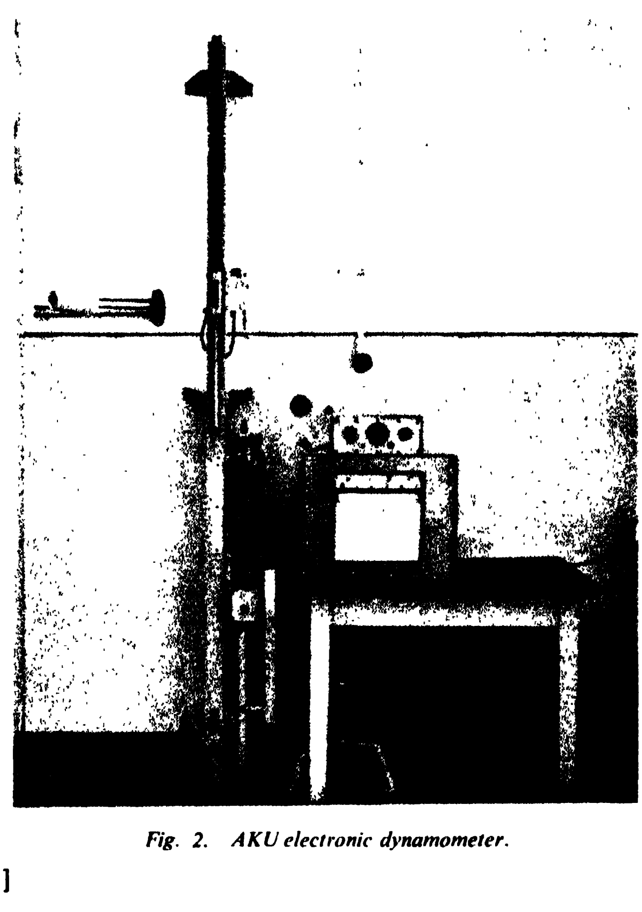
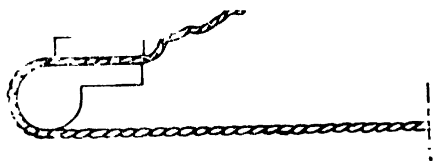


Fig. 2. AKU electronic dynamometer.

seconds". From a scientific point of view this may not be the best possibility, but this prescription of the time was the only solution, owing to the many different working principles of the dynamometers which are in use in the various laboratories.

In consequence of the growing use of the electronic dynamometer, however, more and more laboratories have begun to apply a constant rate of extension, generally 1 per cent. of the original length between the clamps per second.

To avoid slipping or breaking of the test specimen in the clamps, it is advisable to use clamps of such a shape that a very sharp kink is avoided (fig. 3). Usually only



Callaway clamp.

the strength and total extension at break are given of the stress-strain properties. In practice, the shape of the stress-strain curve, or the modulus, can, however, be of great importance to the behaviour of the twine. It is therefore advisable to determine some points on this curve, for example, the extension at 25 per cent. of the breaking load.

2·4 Shrinkage

The amount of shrinkage, either in hot or in cold water, can be important as it may effect a change in size of the mesh when the nets receive a final treatment in hot water or when they are dyed.

The method we have used is as follows: 5 knots were laid in a twine at distances of about 1 m., these distances being measured to an accuracy of 1 mm. (l_0) on an apparatus as shown in fig. 4. The pre-tensions were taken

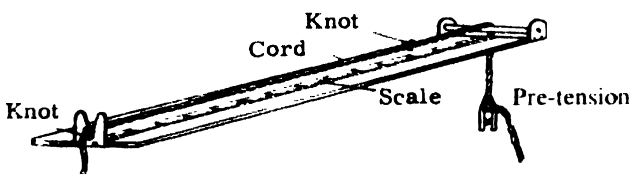


Fig. 4. Apparatus for measuring the shrinkage.

according to the BISFA rules. The sample was then placed in cold (20 deg. C.) or in boiling water, after which the distance between the knots was measured again (l_1), wet or after conditioning in a standard atmosphere according to the BISFA rules: temperature 20 deg. ± 2 deg. C., relative humidity 65 per cent. and to the ASTM standards

70 deg. ± 2 F., 65 per cent. The value $\frac{l_0 - l_1}{l_0} \times 100$ then gives the shrinkage in per cent.

In this way we can determine 4 values of the test sample:.

(a) cold water shrinkage, measured in wet condition.
(b) cold water shrinkage, measured after conditioning.
(c) hot water shrinkage, measured in wet condition.
(d) hot water shrinkage, measured after conditioning.

In figs. 5 and 6, these 4 values are given for some twine samples of synthetic material as a function of the immersion time in water (t).

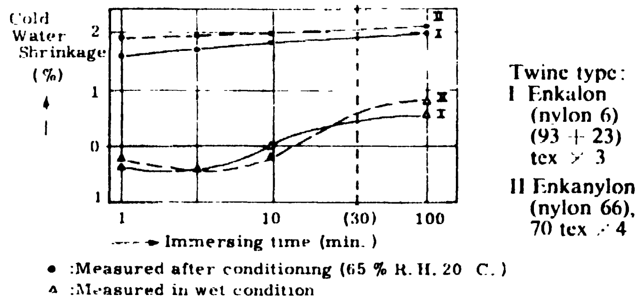


Fig. 5. Influence of the immersing time on the cold water shrinkage.

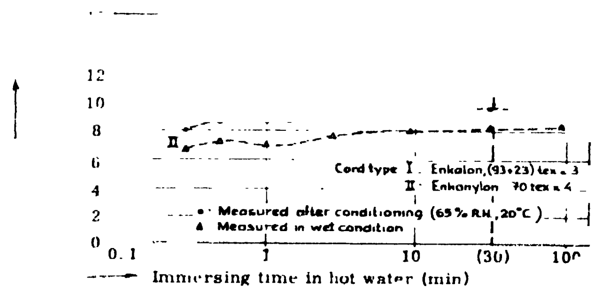


Fig. 6. Influence of the immersing time on the hot water shrinkage.

It can be seen that especially in the first minute of t. the shrinkage strongly increases, and that for t.=30 min. a nearly constant value is reached for all the samples. An immersing time of 30 min. should be accepted as the standard immersing time for routine measurements.

2·5 Stiffness

For measuring the stiffness of twines we used the following method:

Around a rod, 4 cm. in diameter, we wound 20 turns of the twine close to each other, held together by a narrow strip of adhesive tape at the turns. The coil thus formed is taken off the rod (fig. 7a).

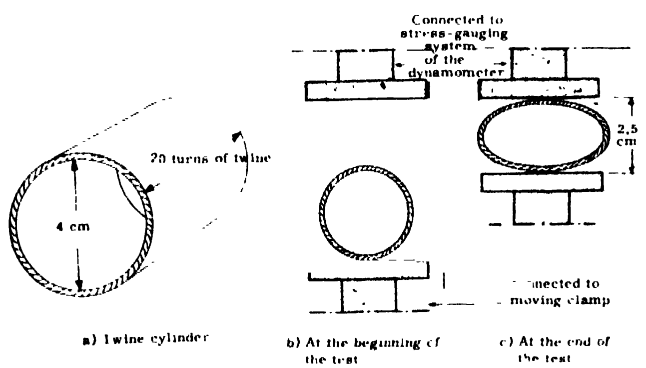


Fig. 7. Stiffness test of twines.

Two flat plates of about 10 cm. diameter are attached to the clamps of the electronic dynamometer, the distance between the two plates in the highest position of the moving clamp, being 2·5 cm. The moving clamp is not lowered a few centimetres and the cord cylinder is placed on the lower flat plate (fig. 7b). The lower clamp is then moved upwards until the extreme position is reached (fig. 7c), when the cylinder becomes an ellipse with a short axis of 2·5 cm. The force needed for this is taken as a measure of the stiffness.

3. METHODS OF TESTING KNOTS

3·1 General

The different methods of test on knots, dealt with further on, refer to the single-knot, as drawn in fig. 8. In

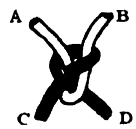


Fig. 8. Single knot.

the following the knot-ends will be as indicated according to the letters given in this figure.

There are various methods of loading a knot according to the twine ends which are clamped on the dynamometer. Table II gives these different possibilities of clamping, with the results obtained on loading the knots with an increasing force.

TABLE II

Clamped Twine-ends	*Result*	*Clamped Twine-ends*	*Result*
A and B	tip-over of the knot	A and C+D	slip of AB through CD or knot breakage
A and C	knot breakage, in some cases after slip	B and C+D	,,
A and D	,,	C and A+B	knot breakage
B and C	,,	D and A+B	,,
B and D	knot breakage		
C and D	knot breakage in some cases after tip-over of the knot.		

3·2 Knot Strength

The knot strength, and especially the wet knot strength determines the strength of the nets. The twine ends B and D are clamped in on the dynamometer to determine the knot strength (fig. 9).

The stress at which the knot breaks—expressed in kg. or in per cent. of the breaking load of the twine—is called the (wet or dry) knot strength.

We investigated the influence of:

(a) the load with which the knots were tightened initially (in the range from 30 per cent. to 60 per cent. of the twine strength).

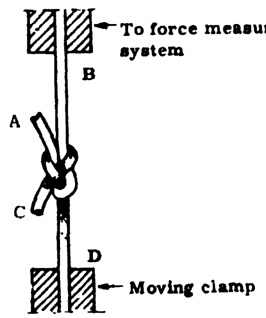


Fig. 9. Determination of the knot strength.

(b) the velocity of the moving clamp (range: 1 per cent. to 4 per cent. rate of elongation).

(c) the waiting time, i.e. the time between the tightening of the knots and the beginning of the test (range: 6 seconds to 24 hours).

The factors were not found to influence significantly the knot strength.

To find agreement between the values for the knot strength, an exact description of the circumstances under which the test is performed is therefore unnecessary.

3·3 Tip-Over Resistance

Generally, there are two causes of changes in the size of the meshes, viz. the tip-over, and the slip of the knots. In the tip-over the structure of the knot changes, after which the twine AB can easily shift through the knot.

The testing method is performed as follows (fig. 10):

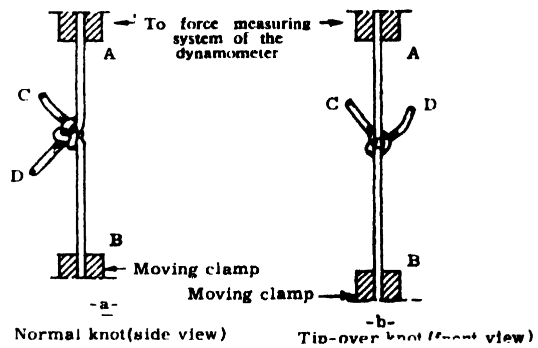


Fig. 10. Determination of the tip-over resistance.

the twine ends A and B are clamped on the dynamometer and the force at which the tip-over of the knot takes place is determined. This force, in kg. or in per cent. of the knot strength, is called the tip-over resistance.

When the tip-over begins, the stress-strain curve mostly shows that for a short time the force is constant or decreases somewhat.

In some cases, e.g. in research on bonded twines, it can be of importance to the producer to determine the tip-over resistance of the knots without making a net. The knots must be tied manually and tightened in accordance with what happens on the stretching apparatus. Subsequently, whether or not after fixation, the knots are measured. In fig. 11 a, b and c the tip-over resistance is given as a function of the three above-

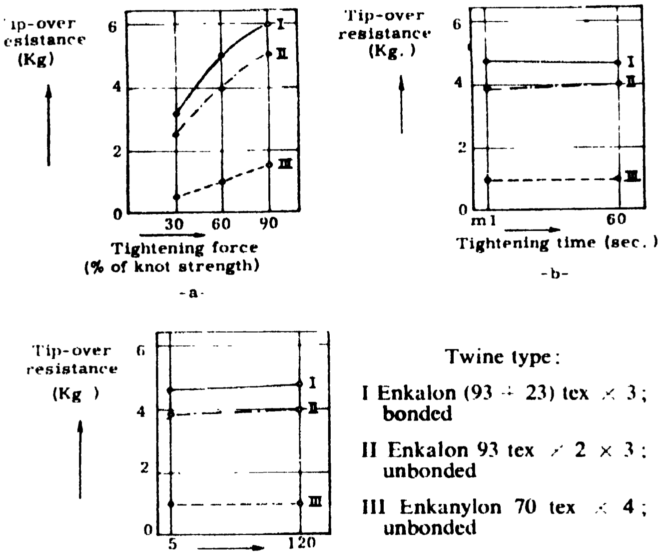


Fig. 11. Influence of (a) tightening force, range 30-90 per cent. of the knot strength; (b) tightening time, range 1-60 seconds (c) waiting time, range 5-120 min. on the tip-over resistance.

mentioned factors, and the analysis of variance is given in Table III for twine sample II.

TABLE III

Source of variation	*Sum of squares*	*Degrees of freedom*	*Mean square*	*Variance ratio*
	Main Effect :			
A (tightening force)	1334	2	667·00	154
B (tightening time)	12	1	12·00	2·76
C (waiting time)	9	1	9·00	2·07
	Interaction :			
AB	2	2	1·00	0·23
AC	21	2	10·50	2·42
BC	1	1	1·00	0·23
ABC	3	2	1·50	0·34
Residual	469	108	4·34	—
Total	1851	119		

It appears that in the applied ranges of the factors only the tightening force has a significant influence.

We have chosen for the tightening force a fairly arbitrary value, viz. 20 per cent. of the knot strength. For the rest the standard conditions were:

rate of extension : 1 per cent. per second
tightening time: 10 sec.
waiting time: 5 min.

As a chemical preparation is applied to synthetic materials to prevent the knots slipping, it is advisable to determine both the wet and the dry tip-over resistance.

3·4 Knot-Slip Resistance

The slippage of the knots, while retaining the knot structure also causes a change in mesh size.

To determine the resistance to this slippage, the knots are clamped as drawn in fig. 12. The force, in kg. or in

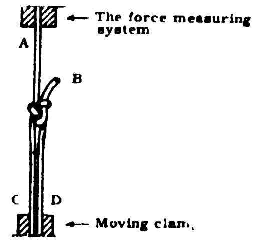


Fig. 12. Determination of the knot-slip resistance.

per cent. of the knot-strength, at which the slip begins is a measure of knot-slip resistance. The slippage can occur either suddenly or gradually, depending on the specimen type. Fig. 13 shows the stress-strain curve which can be obtained, where S in the knot-slip resistance.

Curves a, b and c show a sort of slip-stick effect, curve d shows the slippage which takes place gradually. Sometimes only a slight slippage occurs (see arrows in fig. 13, c and d). In this connection we decided to

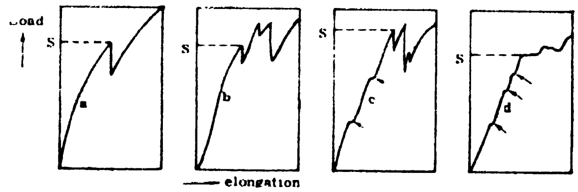


Fig. 13. Stress-strain curves which can be obtained with the determination of the knot-slip resistance.

take only that force as knot-slip resistance, in which the slippage occurs for longer than 1 second under the measuring conditions mentioned below.

We investigated the influence of various factors on the knot-slip resistance. First the influence of the angle (α), under which the twine ends c and d can be clamped. We determined the knot-slip resistance at α=0 deg., 60 deg. and 120 deg. In all cases it was lowest at α=0 deg. Further, just as for the tip-over resistance (see 3·3), the influence of tightening force, tightening time and waiting time were investigated. The results are shown in fig. 14, and

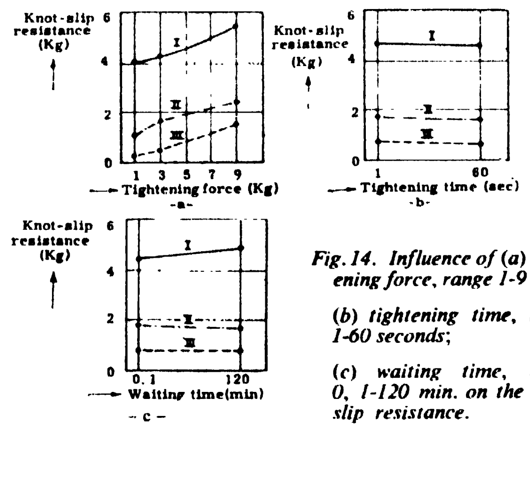


Fig. 14. Influence of (a) tightening force, range 1-9 kg.

(b) tightening time, range 1-60 seconds;

(c) waiting time, range 0, 1-120 min. on the knot-slip resistance.

the analysis of variance is given for one of the samples in Table IV.

TABLE IV

Source of variation	*Sum of squares*	*Degrees of freedom*	*Mean square*	*Variance*
		Main Effect :		
A (tightening force)	. 37773	2	18886	176
B (tightening time)	. 2	1	2·00	0·02
C (waiting time)	. 4	1	4·00	0·02
		Interaction :		
AB .	. 22	2	11·00	0·10
AC .	. 401	2	200·50	1·87
BC .	. 154	1	154·00	1·44
ABC .	. 384	2	192·00	1·79
Residual .	. 11571	108	107·14	
Total .	50311	119		

In all cases the influence of the tightening force is significant, and that of the tightening time is not. In the range investigated, the influence of waiting time is only significant for some samples (see e.g. sample I, fig. 14, c), so the influence of this factor was investigated on a somewhat larger scale. The results are shown in fig. 15,

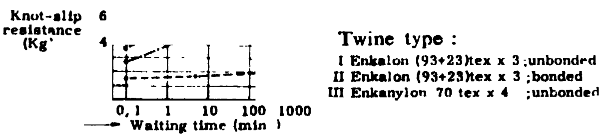


Fig. 15. Influence of the waiting time on the knot-slip resistance range 0, 1-1440.

from which it appears that for a waiting time exceeding 5 min. there is no further influence on the knot-slip resistance.

On the basis of the above-mentioned results, we have chosen the following standard conditions for routine measurements:

angle between the clamped specimen ends C and D: 0 deg.;

rate of elongation: 1 per cent. per second,

and, if the knots are tied manually:

tightening force: 20 per cent. of the knot-strength
tightening time: 10 seconds
waiting time: 5 minutes

For some twine types the knot slip resistance appears to be higher and for other types lower than the tip-over resistance. Hence, for a complete evaluation of a twine, both measurements must be carried out.

3·5 Open-Up Resistance

In the use of synthetic materials, one difficulty which may arise is that the knots loosen just after they have been made on the netting machine. To evaluate a net twine in this respect, the following testing method has been developed: in two twines (length about 20 cm.) a knot is tied and just tightened. Two of the twine ends are brought together and a weight is attached to them. The knots are then tightened by dropping the weight over a distance of about 20 cm. The weight is taken according to the yarn number and amounts to about 1 g. per 5 tex.

Five knots are tested with an apparatus as shown in fig. 16. The knots are placed in a wooden box, which is rotated with a velocity of 60 r.p.m.

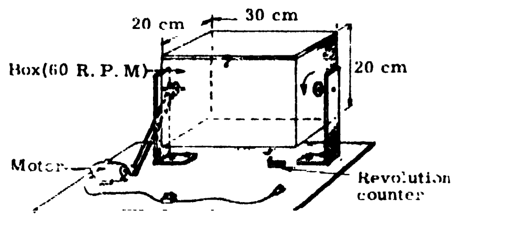


Fig. 16. Apparatus for determining the open-up resistance.

This process is regularly interrupted to check on how many, if any, of the knots have loosened.

From the values found, i.e. the number of revolutions after which each of the knots had loosened, we deduced that the frequency distributions of these values approximately correspond to those given in fig. 17.

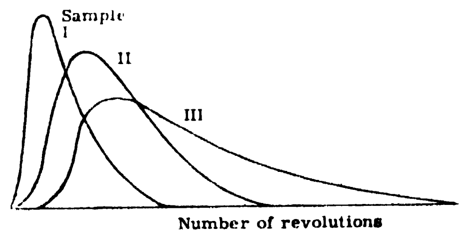


Fig. 17. Frequency distribution of the number of revolutions after which the knots have loosened.

In such a frequency distribution, the most characteristic value when taking a random sample is the middle or so-called median value. In this case, for example, if the number of revolutions at which the five knots loosen, is arranged in order of size: X_1, X_2, X_3, X_4 and X_5, then X_3 is taken as the determining value, called the open-up resistance. Generally, the measurements are repeated several times to find an average value of X_3, ($\bar{X}_3$), and a measure of the spread (standard deviation s_{x_3}).

In fig. 18 the $\bar{X}_3$-values are given for some samples of

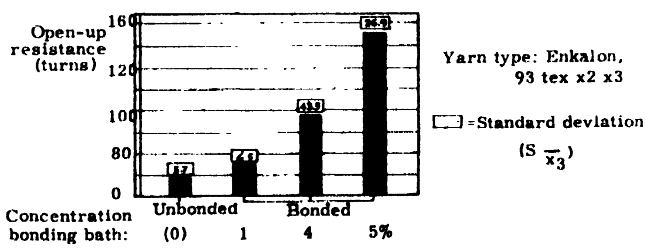


Fig. 18. Some values obtained with measurements of the open-up resistance.

the same twine, each dipped into a bath of different concentration and containing a bonding preparation. Tests were made of 6 × 5 knots of each sample. It appears

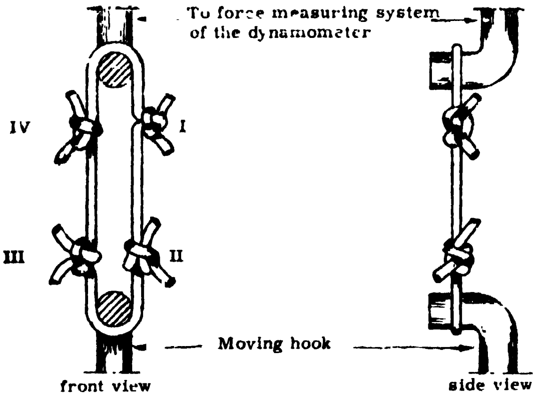


Fig. 19. Determination of the mesh strength.

that the difference between the X_3 values are relatively large as compared with the spread s_{X_3}.

4. METHODS OF TESTING MESHES

4·1 General

In principle, some of the methods mentioned above for testing knots can be applied also to testing the meshes for mesh strength and tip-over resistance of the mesh. As the remarks, made in 3·2, and 3·3 also apply partly to these two qualities, only a few points of the testing methods will be dealt with.

4·2 Mesh Strength

The meshes are clamped as shown in fig. 19. The load at which the mesh breaks is called the mesh strength, and is given in kg. or in per cent. of twice the twine strength (because, apart from the four knots, there are two ends between the clamps). It appears that mostly knot II or III (fig. 19) breaks, and sometimes knot IV. As the weakest of these 3 knots will determine the mesh strength, the latter will be somewhat lower than twice the knot strength.

4·3 Tip-Over Resistance in the Mesh

For determining tip-over resistance the mesh is clamped as in the mesh strength measurement (fig. 19). There is usually a tip-over of knot I (fig. 19) before the mesh breaks. The load at which this happens is called the tip-over resistance of the mesh and is given in kg. or in per cent. of the mesh strength. The value is about twice as high as the corresponding tip-over resistance of the knot.

5. CONCLUSION

We have not, of course, given a complete survey of testing methods for yarns, twines, cords, knots and nets, but have only recorded some of the experience gained with the various testing methods normally used in our laboratory for evaluating yarns and net twines.

Hand hauling a Marlon pursed lampara seine in South Africa. Photo FAO.

TESTING OF MATERIALS USED IN FISHING

by

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Abstract

This paper points out the necessity for testing under fishing conditions materials used for fishing, i.e. in the wet state instead of the dry. It shows how it is possible to be misled by taking only dry breaking strength as a criterion instead of testing materials wet and knotted. In the case of hemp, it was found that the lower grades yarn, i.e. those with low dry breaking length, possessed a superior wet, knotted breaking strength. Tables showing the characteristics of hemp, cotton (Egyptian and American), silk and synthetic fibres are included.

Essais de filet et de fil à filet

Résumé

Cette communication fait ressortir la nécessité d'essayar les matériaux utilisés pour la pêche dans les conditions d'emploi, c'est-à-dire mouillés au lieu de secs. Elle montre comment il est possible de se tromper en prenant comme seul critère la résistance à la rupture à l'état sec au lieu d'essayer les matériaux mouillés et noués. On a trouvé, dans le cas du chanvre, que les fils de basse qualité, c'est-à-dire à faible résistance à la rupture à sec, avaient une plus forte résistance à la rupture quand ils étaient mouillés et noués. Des tableaux donnent les caractéristiques des fibres de chanvre, de coton (égyptien et américain), de soie et synthétiques.

Ensayo de redes e hilos empleados en su fabricación

Extracto

En este trabajo se expone la necesidad de ensayar los materiales de pesca en las condiciones como trabajan, e.i. húmedos en vez de secos. Se ha demostrado que es posible incurrir en equivocaciones utilizando como criterio de comparación la resistencia a la tracción del material seco, en vez de húmedo y anudado. En el caso del cáñamo, se encontró que los hilos de material de calidad inferior, o sea aquéllos con un bajo módulo de ruptura cuando están secos, presentan una resistencia a la rotura muy superior cuando se hallan húmedos y anudados. Se incluyen tablas con las características de las fibras de cáñamo, algodón (egipcio y americano), seda y materiales sintéticos.

IN most places where twine is bought or sold for making webbing and nets, an attempt is invariably made to appraise the quality. This is done in many ways, and attempts are usually made to define the various properties possessed by the material, but there is one property that is invariably assessed, viz. the strength of the twine. The average fisherman tests the strength by trying to break the twine with his hands; the more well-to-do arrange for it to be examined at a research laboratory under ideal test conditions (20 deg. C. ± 2 deg. and 65 per cent. relative humidity).

The greatest value is attached to the breaking strength and it is taken for granted that strong twine makes strong webbing. When various twines are to be compared qualitatively, this same criterion is adopted, so that the prospective purchaser inevitably assumes that the strongest twine is most advantageous.

A fundamental misconception underlies this appraisal method which frequently leads to faulty conclusions, with all the attendant disadvantages to the fisherman, because the strongest twine is not always synonymous to the strongest net.

Twine intended to be worked up into webbing is usually tested dry to determine its tensile strength. The way in which this is actually done is of secondary importance, as the process is used simply to obtain data on the dry breaking strength or dry breaking length of the twine. But the only correct basis for examining a twine's properties is to test it under wet conditions, i.e. wet and knotted, since it will be used in wet condition, and the properties when wet are decisive when it comes to comparing various twines for webbing.

It would be of great help if both national and international standards of testing could be established and the results passed on to the fishermen; this would be of practical value to them when buying materials.

As a supplement, a list of tests are given here which have been carried out at the Netherlands Fishery Experimental Laboratory as a routine investigation of the qualities of the materials bought and for comparing properties of materials. It is not considered that these are the only suitable tests, but they are based on experience and have met requirements so far.

The figures quoted for the breaking strength are the mean averages of 10 test samples, as customary in routine investigations. The usual sample lengths and rates of traverse were adopted. The material for the "wet" tests was previously immersed in water for at least 12 hours.

EXAMINATION OF HEMP TWINE

The tests were carried out in accordance with the normal textile method (Table I). The only possible conclusion under these conditions was that Quotation I

TABLE I

Hemp Net Twine

Quotation No.	*Analysis No.*	*Make lays (1)*	*Theoretical No. of metres per kg.*	*Theoretical weight in gr. per m.*	*Actual No. of metres per kg.*	*Actual weight in gr. per m.*	*Dry breaking strength of twine*	*Breaking length in km. (2)*
I	24	100	340	2·941	309	3·240	65·2	20·6
I	23	130	442	2·262	412	2·427	53·6	22·1
I	22	150	510	1·961	478	2·090	58·0	27·3
I	21	180	612	1·634	512	1·952	51·2	26·2
II	25	100	340	2·941	378	2·646	59·8	22·6
II	26	130	442	2·262	357	2·801	52·5	18·7
II	27	150	510	1·961	467	2·141	48·1	22·5
II	28	180	612	1·634	526	1·901	42·9	22·6

(1) Lay – No. of 1·70 m lengths together weighing exactly 500 grammes.
(2) Dry breaking strength divided by dry weight per metre.

TABLE II

Hemp Net Twine

Quotation No.	*Analysis No.*	*Wet yarn breaking strength*	*With overhand knot, breaking strength (wet)*	*With overhand knot, in % of dry yarn (wet)*	*With overhand knot breaking strength in km. (wet)* *
1	24	66·8	39·4	58·9	12·2
1	23	46·2	23·2	50·2	9·6
1	22	53·6	26·8	51·3	12·8
1	21	53·2	28·8	54·0	14·7
2	25	53·1	44·4	76·1	15·27
2	26	47·7	41·9	87·8	14·96
2	27	39·1	36·9	94·4	17·46
2	28	38·4	33·2	86·5	16·67

* Breaking strength (wet) divided by dry weight per metre.

was the best, as the breaking length of this material was considerably superior to that of Quotation II.

As a considerable quantity of sample material remained unused at the end of the tests, curiosity prompted us to carry out the same breaking strength tests, using wet twine instead, incorporating an overhand knot.

The results were surprising for we suddenly found ourselves confronted with the fact that this "fishery method" (wet, knotted breaking strength) yielded results diametrically opposed to those obtained by the textile method. Quotation II was now found to be the best (Table II).

When the data in Tables I and II are compared, a striking fact emerges in connection with these hemp twines, which were of special hard twist, viz. the wet, knotted breaking strength of the "higher grade" twines deteriorates by a much greater percentage than that of the "lower grade" twines.

The wet, knotted breaking length leaves no doubt that one type of twine was far superior to the other, and that there was thus every justification for purchasing the twine which would inevitably have been rejected, had the dry evaluation method been employed.

As the hemp samples (both hard twisted) came from different manufacturers, samples (normal twist) from yet another manufacturer were tested. The results of this third series of tests confirmed our findings in the two previous tests (Table III). Here, too, it was found that:

1. twines characterized by a good *dry* breaking length were considerably inferior in *wet, knotted* breaking strength (webbing as used under fishing conditions), and that lower grade twines (low dry breaking length) possess a superior wet, knotted breaking strength.
2. as this transition is fairly rapid (between 3/36 and 3/30), it cannot be attributed to the twist or diameter of the twine, but to the intrinsic properties of the raw material itself.

A happy coincidence also made it possible to carry out this series of tests with twines made of spun yarns. As they were not the same as the net twines originally tested, the results do not correspond exactly, but the general principles, defined in 1 and 2 above, still hold good.

TABLE III

Hemp Net Twine

Analysis No.	*Make of product*	*Actual No. of metres per kg.*	*Dry breaking strength in kg.*	%	*Dry breaking in km.*	*Wet breaking strength in kg.*	%	*With overhand, knot breaking strength in kg. (wet)*	
36	3/60	1990	8·6	100	17·1	12·1	140	10·7	130
37	3/42	1263	15·1	100	19·1	20·7	136	16·7	110
38	3/36	1101	16·0	100	17·6	23·8	149	19·3	120
39	3/30	964	22·9	100	22·1	27·0	118	19·7	88
40	3/24	755	31·2	100	23·5	32·9	106	27·9	89
41	3/18	766	33·5	100	25·6	36·6	109	28·6	86
42	3/15	553	41·1	100	22·7	45·3	110	35·1	86
43	3/12	371	66·1	100	24·5	59·0	89	47·9	73

TABLE IIIA

Make	*A*	*B*
Our mark	21 blue	22 blue
Runnage (metres/kg.)	385·0	383·0
Breaking strength in kg.		
dry	45·2 (100%)	37·8 (83·5%)
wet	45·6	35·9
wet overhand knot	38·6	34·6
Breaking length in km.	17·44 (100%)	14·74 (84·3%)
Wet overhand knot breaking length in km.	14·82 (100%)	13·32 (90%)
Breaking strength in grammes per tex		
dry	17·48 (100%)	14·47 (82·8%
wet	17·56	13·75 (78·9%
wet overhand knot	14·82	13·25 (89·4%

A preliminary investigation indicated that in the case of flax, made from fibres of various lengths, the results differ to a certain extent, depending on whether the textile or fishery test method was used.

The long staple fibres of this material were separated from their short counterparts and both were used to produce the same type of netting twine with precisely the same lay and twist.

The results are summarized in Table IIIA.

Considered from the *dry* breaking length point of view, it appears that sample A was the best, the ratio being 100 : 84·5 on the basis of breaking length. When the *wet*, knotted breaking length is taken as criterion, the corresponding ratio is 100 : 90.

Here, too, there is yet another indication that the "poorer" yarn (shorter fibres) stands up better to knotting.

TESTING OF COTTON NETTING

The same characteristic deviations between the *dry* twine and the *wet* knotted breaking length are also found in the case of cotton twines.

To ascertain whether these data could be used as quality indications, the figures of the wet breaking strength were measured at the mesh, the results being expressed in the number of grams breaking strength per fibre quantity employed. An abbreviation, "tex" was used for this latter unit (1 tex = the quantity of material involved when 1,000 m. weigh exactly 1 g.).

When the quality of the various net samples is evaluated by this method (see Table IV), it will be found that:

1. the unit "g. tex" provides a serviceable standard for comparing the strength of different net twines.
2. webbing made from Egyptian cottons is less strong than that made from American cottons.
3. the breaking length of dry twine is not a suitable criterion for evaluating the strength of wet netting. The dry twine breaking length of sample *b*, for example, is very low, whereas calculated on the basis of g./tex, based on the wet mesh breaking strength, this sample is the strongest. The dry breaking lengths of twine samples *b*, *d* and *f* are almost identical, yet they show a difference in the number of g./tex calculated on the basis of the wet mesh breaking strength.
4. Twine sample *c* is stronger than *a* and *b*; the dry breaking length is also better. On the basis of g./tex, however, calculated from the wet mesh strength, *a* and *b* are stronger than *c*.

TESTING OF SILK YARNS

Similar deviations in results when both the textile and fishery methods were employed are also found when silk yarns were tested to ascertain the number of grammes wet, knotted breaking strength per unit of weight The unit of weight "denier" was adopted (1 denier = the quantity involved when 9,000m. of yarn weighs exactly 1 g.).

Two different lots of material were tested, and here again it was very obvious that this "fishery test" method brought to light qualities which would not have been

TABLE IV
Cotton Webbing

				d	*e*	*f*
Type	30/12 *carded American cotton*	30/12 *carded American cotton*	30/12 *carded American cotton*	30/12 *carded Egyptian cotton*	36/12 *carded American cotton*	36/12 *carded Egyptian cotton*
Ply	4 × 3 = 12	4 × 3 = 12	4 × 3 = 12	4 × 3 = 12	4 × 3 = 12	4 × 3 = 12
Twist direction	ZZS	ZZS	ZZS	ZZS	ZZS	ZZS
Runnage (m./kg.)	3851	3824	3943	3935	4796	4570
Breaking strength (dry)	5·21	5·15	5·94	4·84	4·48	4·19
Percentage	100	100	100	100	100	100
Breaking length	20·06	19·69	23·42	19·05	21·49	19·15
Breaking strength (wet)	5·70	5·73	6·81	5·60	5·18	4·46
Percentage (in terms of dry twine)	109	111	115	116	116	106
Breaking strength at mesh, dry	7·20	7·60	7·29	6·64	5·93	5·70
Percentage (in terms of dry twine)	138	148	123	137	132	136
Breaking strength at mesh, wet	8·15	8·68	8·00	7·59	7·10	6·24
Percentage (in terms of dry twine)	156	169	135	157	158	149
Wet breaking strength at mesh, grammes/tex.	31·382	33·257	31·152	28·870	34·053	28·519

TABLE V
Silk Net Twine

Supplier						
No.	80/3 × 3	80/3 × 3	80/3 × 4	80/3 × 5	80/3 × 6	80/3 × 8
Runnage (m./kg.)	8237	8177	5783	5015	4139	3247
Total denier	1012·5	1012·5	1350·0	1687·5	2025·0	2700·0
Dry breaking strength (kg.)	3·58	3·29	4·60	5·93	7·35	8·76
Breaking length (dry)	29·49	26·90	26·61	29·74	30·42	28·44
Dry breaking strength (g./denier)	3·538	3·259	3·407	3·514	3·620	3·244
Wet breaking strength (kg.)	2·64	2·44	3·47	4·37	5·37	6·61
Wet breaking strength (g./denier)	2·607	2·410	2·570	2·548	2·652	2·448
Wet breaking strength, with overhand knot (kg.)	1·57	1·70	2·09	2·70	3·45	4·30
Wet breaking strength, with overhand knot (g./denier)	1·551	1·679	1·548	1·600	1·709	1·593

shown by the dry test method. As this material is intended solely for use as wet webbing, the number of g./denier calculated on the basis of the wet, knotted breaking strength, is the only correct criterion to adopt when evaluating the quality of the yarns for fishery purposes (Table V).

The breaking strength in g. denier, calculated on the basis of the dry yarn breaking strength, runs parallel with the dry breaking length, as this is, in point of fact, the same unit expressed in different terms. When the breaking strength of wet, knotted yarn, is determined, the data in respect of the various yarns will be found to differ entirely.

TESTING SYNTHETIC FIBRE WEBBING

The term "g./denier" is very frequently used to express the breaking strength of synthetic twines. This, however, invariably refers to dry twines. The current trend is more and more in favour of the wet breaking strength. The fact that some manufacturers of synthetic fibre twines regularly indicate the wet, knotted breaking strength, is certainly a step in the right direction.

Net manufacturers treat the twines (continuous filaments) which have previously been worked up into webbing, in various ways in order to "fix" the knots. The determination of the breaking strength in g./denier, calculated on the basis of the wet, mesh breaking strength, also enables the investigator to ascertain whether this treatment has damaged the twine in the knot. This determination is far more logical than simply testing the twine prior to the knot being fixed.

Table VI summarizes certain data in respect of various samples, all expressed in terms of the wet, knotted breaking strengths of both twines and webbing.

One cannot help being amazed by the great changes which nylon 6 undergoes (I was unable to examine any webbing made from nylon 66), when made into webbing with specially treated knots.

TABLE VI
Synthetic Net Twine and Webbing

Denier	726	10425	2520	4788	6300	5670	5760	6930	10080
Material	nylon 6	nylon 6	nylon 6	poly-phenyl alcohol	nylon 6	nylon 6	nylon 6	nylon 6	
Filament	contin-uous	contin-uous	contin-uous	fibre	contin-uous	contin-uous	contin-uous	contin-uous	contin-uous
Product	new twine	new twine	new twine	new twine	new webbing	new webbing	new webbing	new webbing	new webbing
Dry breaking strength (kg.)	4·78	69·0	9·41	19·2	43·06	33·14	30·86	41·4	52·8
Dry breaking strength (g./denier)	6·579	6·610	3·734	4·008	6·835	5·845	5·445	5·973	5·23
Wet breaking strength (kg.)	4·27	59·2	8·30	14·6	39·95	29·67	27·35	30·30	42·5
Wet breaking strength (g./denier)	5·851	5·679	3·532	3·048	6·341	5·233	4·824	4·372	4·216
Wet breaking strength, with overhand knot (kg.)	2·62	25·6	5·80	6·70					
Wet breaking strength, with overhand knot (g./denier)	3·607	2·456	2·302						

In the case of a polyalcohol yarn, the dry breaking strength or other evaluation figures based on such a test would prove misleading as a basis for the comparison.

This fact has quite rightly been publicized by the manufacturers, and it is indeed encouraging to note that the wet, knotted breaking strength of this twine is now being advocated as a quality criterion.

TESTING OF TRAWL TWINE

A single test was carried out with trawl twine, and here, too, differences came to light in respect of the wet, knotted breaking strength, despite the fact that the manila twines were of the same runnage. This was fully in accordance with the results of our investigations on other yarns.

The investigation had to be interrupted, however, as it proved impossible to resolve the problem of the manila fibre gradings employed.

CONCLUSIONS

1. The most widespread method in use at present for the comparison of net twines of different quality is the dry breaking strength or other criteria based on it, e.g. breaking length or tenacity (the breaking strength in denier or tex).
2. As the twine is used wet and knotted in the form of webbing, it is more logical to employ an evaluation standard based on the wet, knotted condition of the twine.
3. The wet, breaking strength of knotted twine, or the wet mesh breaking strength, is therefore the most appropriate criterion. Evaluation figures, derived from the wet, knotted, breaking length or the wet, knotted breaking strength in denier or tex, can also be used for this purpose.
4. The evaluation figures, calculated according to 1 and 3 above, do not yield parallel results. In fact, in some cases, they are diametrically opposed, as a higher dry breaking length, for instance, is attended by a lower wet, knotted breaking strength. Thus, some twines, otherwise very strong, are found to be highly sensitive to strong flexion, while less strong twines suffer to a smaller degree when wet and flexed, i.e., knotted.
5. For webbing, the wet mesh breaking strength is the only logical strength criterion, because it corresponds more accurately with the conditions under which the webbing is used, and permits a more accurate comparison to be made of the various materials used.

A canoe fisherman mending his net on the Indian Malabar coast. Photo FAO.

LATERAL STRENGTH AND KNOT-FIRMNESS OF SYNTHETIC TWINES FOR FISHING PURPOSES

by

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Abstract

The author describes tests for determining lateral strength and knot-firmness of netting twines and shows how knot-firmness can be improved by treating the twines with bonding agents. The paper is illustrated by numerous tables and diagrams.

Résistance aux efforts latéraux et tenue des noeuds des fils synthétiques pour la pêche

Résumé

L'auteur décrit les essais pour la détermination de la résistance aux efforts latéraux et la tenue des noeuds des fils à filets. Il montre comment on peut améliorer la tenue des noeuds en traitant les fils par imprégnation de divers produits. L'article est illustré par de nombreux tableaux et diagrammes.

Resistencia lateral y firmeza de los nudos de hilos sintéticos empleados en los artes de pesca

Extracto

El autor describe los ensayos hechos para determinar la resistencia lateral y la firmeza de los nudos hechos con hilos de fibras sintéticas, y la manera cómo esta última puede aumentar tratando el material con fijativos. El trabajo también contiene numerosas tablas y esquemas.

IN spite of all well-known test results published on the subject of general, physical and chemical properties of synthetic fibres, time and again two problems emerge which cause a certain amount of trouble in the manufacture and use of nets, twines and cordage: "lateral strength" and "knot-firmness".

Lateral strength means the resistance which the material offers to any stress differing from the normal tensile stress operating in the longitudinal direction of the fibre axis. Well-known examples are the strength in a knot and loop, alternating bending strength, etc. Since in these cases there is an additional stress on the material the normal tensile strength is, as a rule, thereby reduced. Various materials react to this additional stress in very different ways and, in this connection, the type of material (e.g. Perlon or hemp), its special properties (depending on the type), the structure of the yarn or twine and other factors often play an important part.

Knot-firmness concerns the reaction of a knot to forces which cause shifting or loosening and thereby a change in the size of mesh.

TESTING METHODS

Our investigations were limited to the two synthetic fibres which are at present most important for the fishing industry, at least in Europe: polyamides (Perlon, nylon) and polyesters (Terylene, Trevira, Dacron). The material was tested in many different forms: filament yarns, staple fibre yarns, twisted twines, and braided twine.

The object of the investigations was to find ways and means of reducing the loss in tenacity caused by knotting and to improve the firmness of knots, particularly in very smooth materials made from continuous filament.

These efforts were successful, at least in the laboratory but the results will, of course, have to be confirmed in

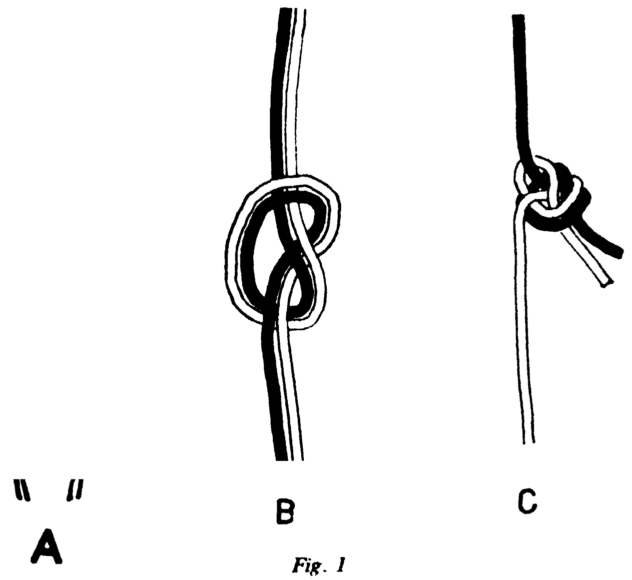


Fig. 1

Types of knots used in the tests.

A =Fishermen's knot; B – Overhand knot; C – Double overhand knot

Fig. 2
Apparatus used for testing knot-firmness.

practice. In our experiments, we determined the lateral strength of the various materials and structures examined by testing the strength of normal knots and customary net knots both in dry and wet conditions (see fig. 1).

Knot-firmness is more difficult to determine by tests. Here we also tried two ways which, although not corresponding exactly to the stress on the knot of the net in use, nevertheless allowed a comparison of the knot firmness. Since the problem of maximum resistance in a knot to displacement is obviously closely connected with maximum roughness of the surface of filaments, yarns and twines, we first tested the yarns in "loop knot" or "double overhand knot" forms (see fig. 1, C) in a normal tensile strength testing device. The knot was tightened by means of a constant weight. When a load was applied to the knotted yarn, the knot loosened (meaning poor firmness), or held fast while the yarn or twine broke in the knot or in some other place.

In the second method, we desisted from any tensile stress on the knotted yarns since in the net the knots will, as a rule, shift only when they are not loaded. Instead, we placed a number of short pieces of twine connected by the fishermen's knot (fig. 1, A) in a rubber-lined box (fig. 2). A rubber roller was also put in the box. The closed box was rotated for 30 minutes at about 60 r.p.m., i.e., a total of about 1,800 revolutions. During this process, a number of knots will loosen, depending on material and previous treatment. This number is expressed as percentage. By this method, which corresponds approximately to the I.C.I. pilling tester, we were able to find very marked differences.

TENSILE STRENGTH, LOAD-EXTENSION

Before giving the results of the investigations, let us refer again to the influence of the raw materials on the lateral strength of the net twines. The main facts can be seen in the load-extension-diagrams (fig. 3). This shows a comparison between the two materials, Perlon and

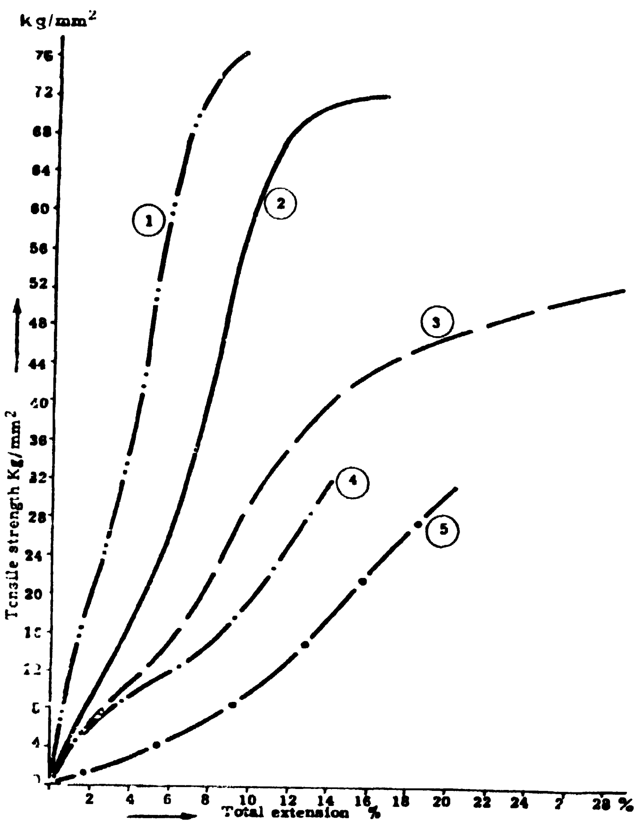


Fig. 3
Load-extension properties of different materials (dry).

1. *TREVIRA 840 den. (10,300 m/kg.)*
2. *PERLON 840 den. high tenacity (10,550 m/kg.).*
3. *PERLON 1,150 den. (8,080 m/kg.).*
4. *TREVIRA Nm 20 (19,680 m/kg.).*
5. *PERLON Nm 20 (19,500 m/kg.).*

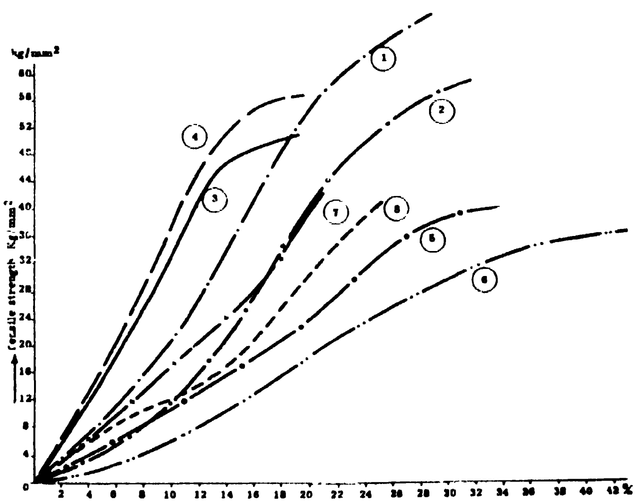


Fig. 4
Load-extension properties of different twines (dry and wet).

1. *PERLON 840 - 3 den. (3,160 m/kg.) dry*
2. *" " " " wet*
3. *TREVIRA 840 - 3 den. (3,000 m/kg.) dry*
4. *" " " " wet*
5. *PERLON Nm 20/2/3 (3,110 m/kg.) dry*
6. *" " " " wet*
7. *TREVIRA Nm 20/2/3 (3,040 m/kg.) dry*
8. *" " " " wet*

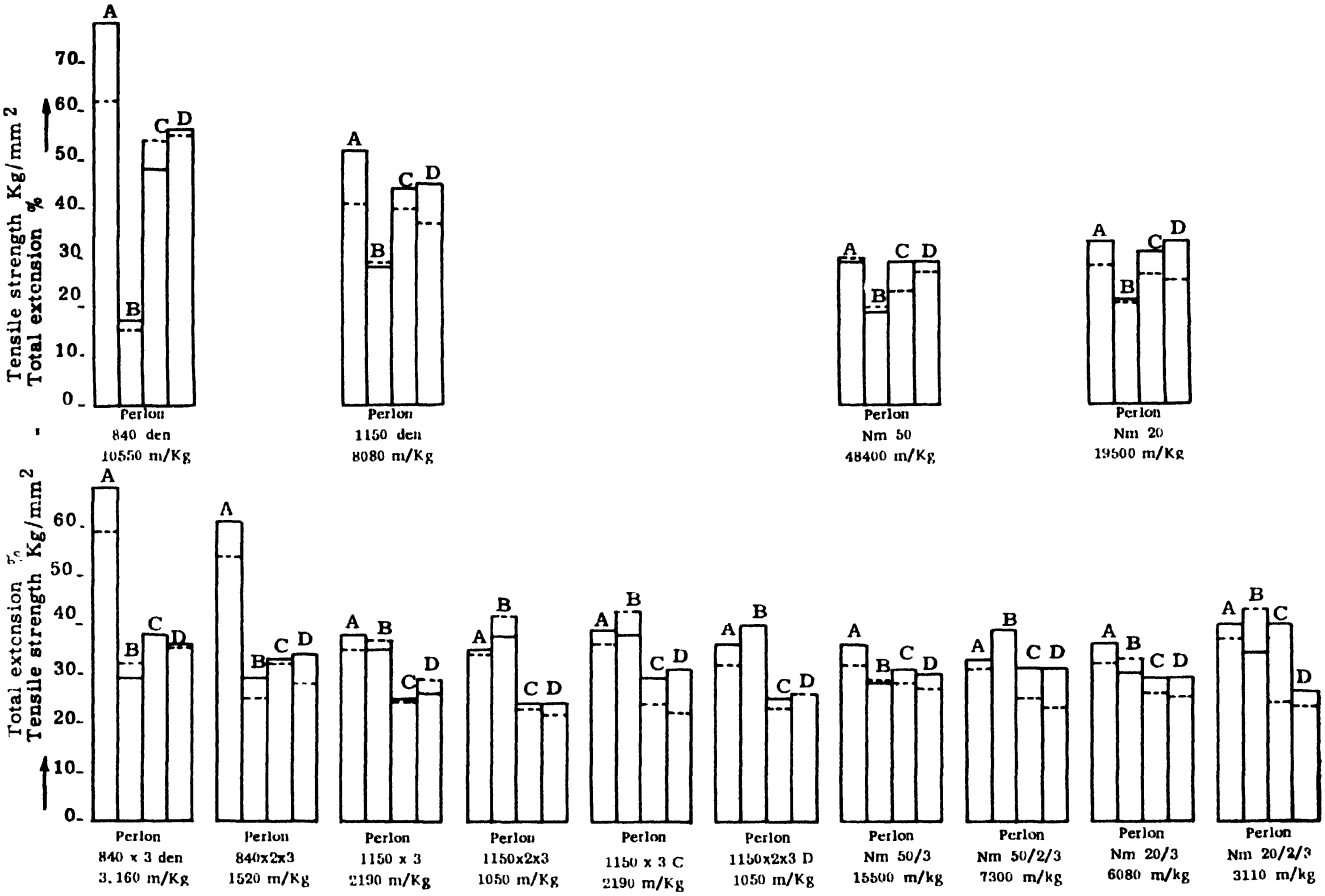


Fig. 5

Comparison of the relative knot strength of different yarns and of twines made thereof. A – tensile strength, B total extension, C – kno strength with overhand knot, D – knot strength with fishermen's knot. - - ——dry, ... wet.

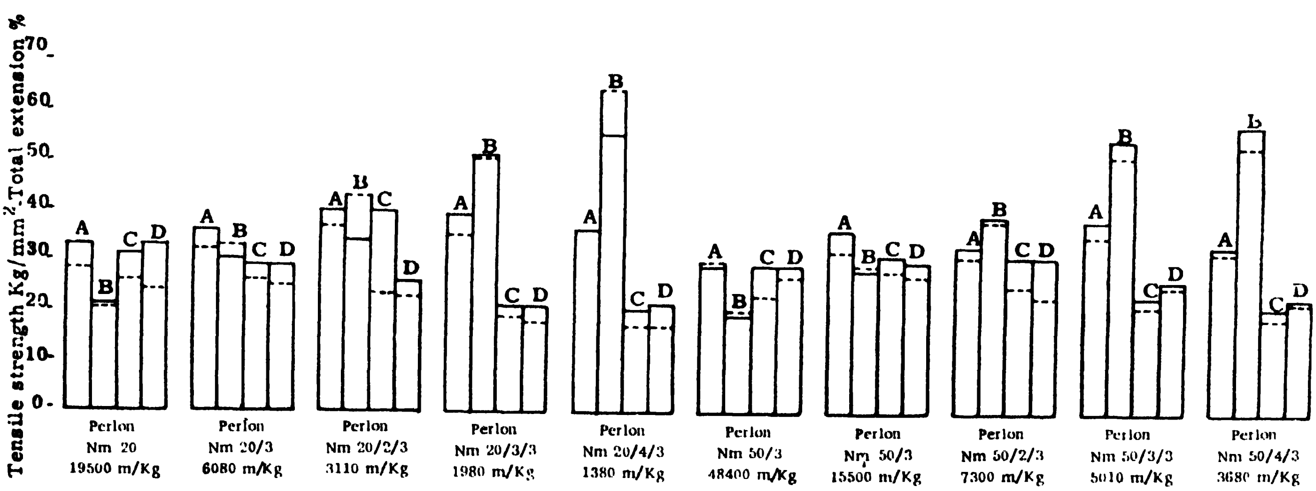


Fig. 6

Relative knot strength of Perlon staple twines. A – tensile strength, B = total extension, C – knot strength with overhand knot, D – knot strength with fishermen's knot. ———= *dry*, ... = *wet*.

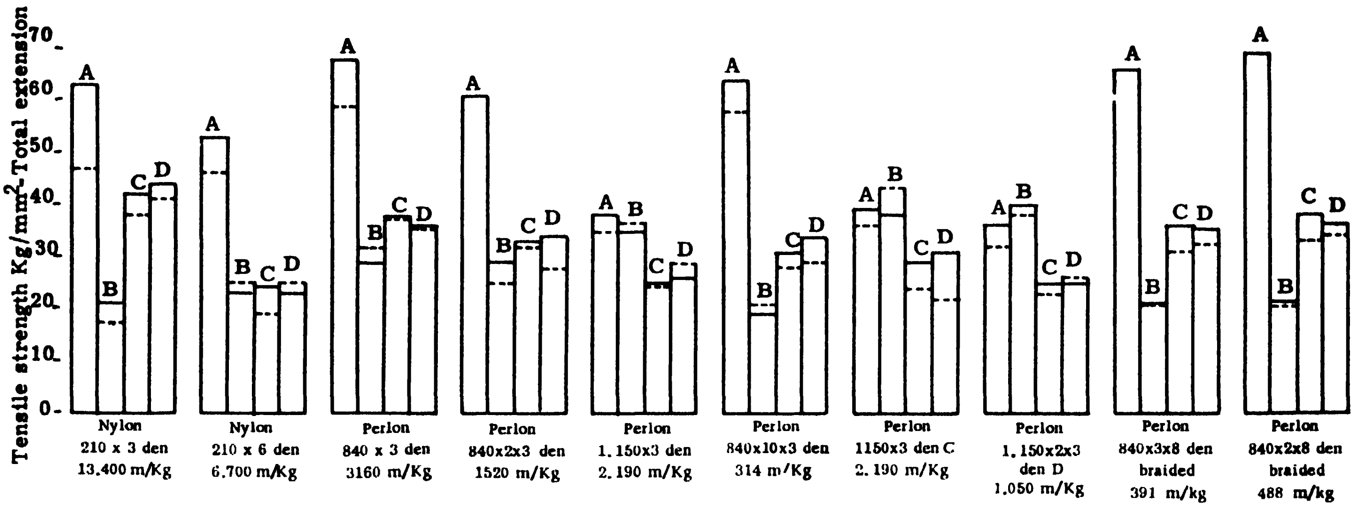


Fig. 7

Relative knot strength of Perlon continuous filament twines. A = tensile strength, B = total extension, C = knot strength with overhand knot, D = knot strength with fishermen's knot. —— = dry, ... = wet.

Trevira, in their various forms, i.e., as *continuous filaments* and as *spun yarn*. The different values for breaking strength and extension are clearly seen as well as the very different behaviour under small to medium loads, i.e., the most important in practical use.

The polyester yarns are distinguished by a curve which is relatively steep at small loads. Their extension is thus relatively small in this region, which is advantageous in nets. This material, when twisted, often shows very different characteristics, depending both on the material used and on the structure.

Dr. Klust shows in his comprehensive report "Perlon Twines", the important influence of doubling, twisting, braiding, etc., on the physical properties of net twines, so that it is enough to mention this in passing. For instance, Perlon twines made of continuous filament usually have higher tenacity and lower extension than those made of spun yarn.

In net twines *wet tenacity* is of particular interest. Fig. 4 shows some comparisons between Perlon and Trevira (Terylene), the twines being of similar thickness, although some are of filament and others of spun yarns. Trevira is distinguished by a very good wet tenacity.

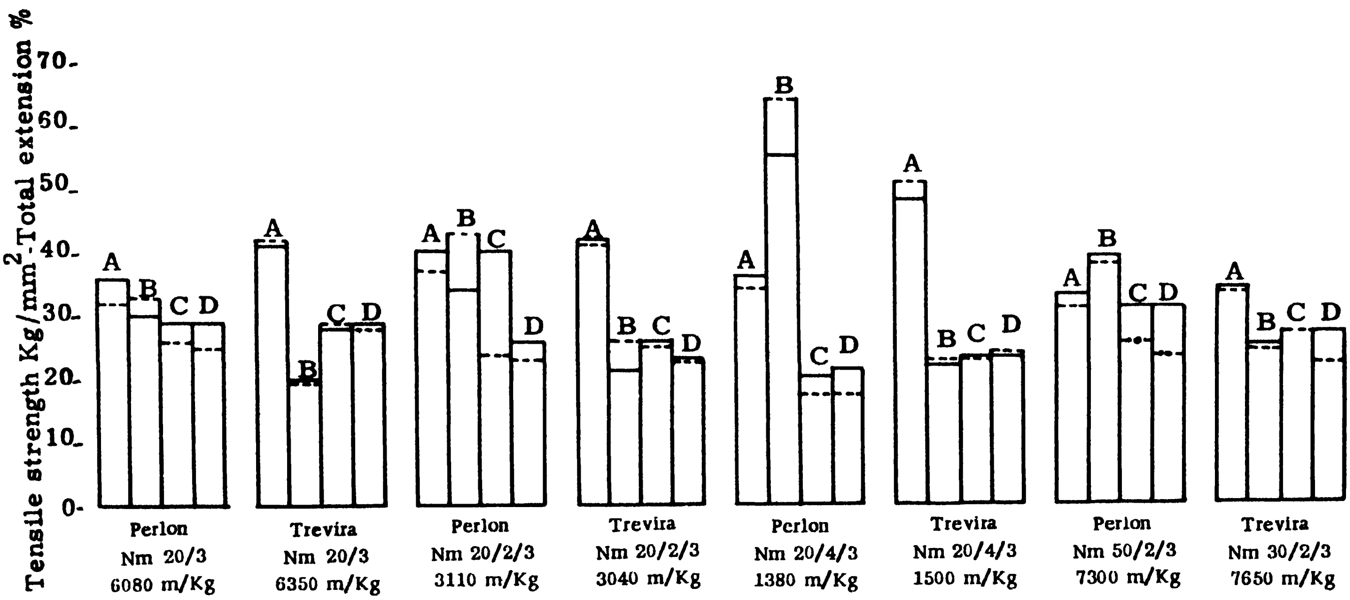


Fig. 8

Comparison of Perlon and Trevira staple twines in regard to their tensile strength (A), total extension (B) and knot strength with overhand knot (C) and fishermen's knot (D). ——— = dry, ... = wet.

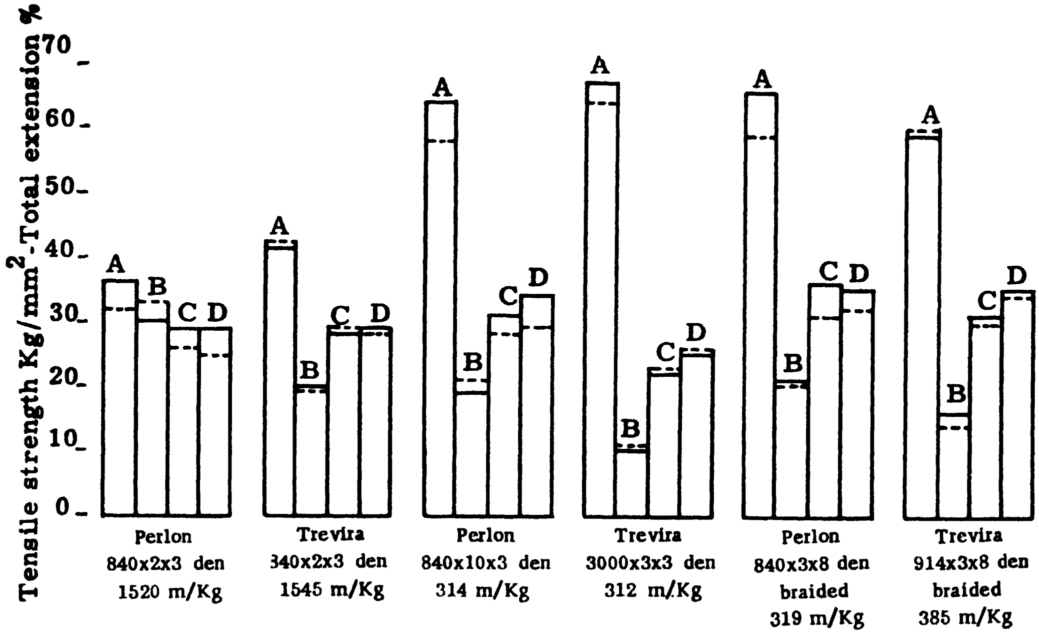


Fig. 9

Comparison of Perlon and Trevira continuous filament twines in regard to their tensile strength (A), total extension (B), knot strength with overhand knot (C) and fishermen's knot (D). ——— = dry, ... = wet.

KNOT STRENGTH

Wet tenacity, and above all, knot strength is decisive in judging the usefulness of the material in nets and of course knot strength in a wet condition is of special interest.

It becomes obvious that high normal *tensile strength*, does not indicate equally good *knot strength.* Fig. 5 shows these values for Perlon filament, staple fibre yarns and twines of different structures. The higher tensile strength of the continuous material can be clearly seen along with its higher sensitivity to knotting and plying. The initial differences in the knots still exist, though no longer in the same relation. In multiple twists, the *knot strength* of the continuous material is, under certain circumstances equal to, or below, that of twines of spun material. Braided twines, however, usually show a better result.

This fact does not question the other advantages of twines of continuous material as far as smoothness, lower thickness, lower towing drag, etc., are concerned. Trevira gives slightly better results, especially in regard to the wet *knot strength* of spun material.

Twines made of Perlon (spun yarn as well as filament) of various structures are compared in figs. 6 and 7 where the influence of the structure emerges clearly. It is well

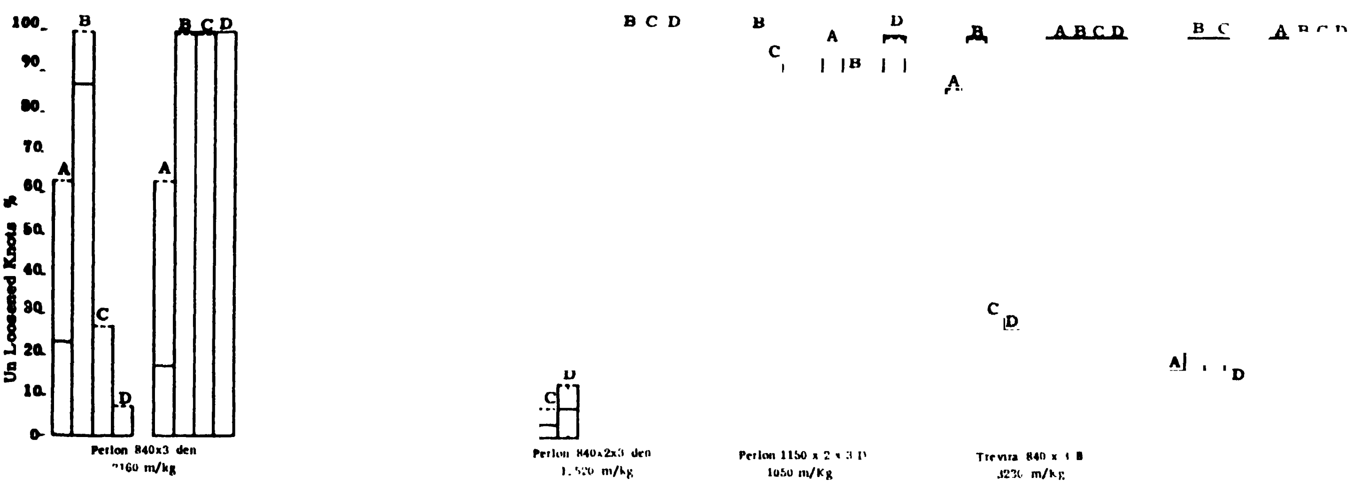


Fig. 10

Knot firmness of different Perlon and Trevira staple twines according to I double overhand knot and II fishermen's knot testing method. A = untreated, B = treatment x, C = treatment y, D = treatment z. Results given in per cent. loosened knots. ——— = dry, ... = wet.

known that the "critical twist" in continuous filament twines is reached much earlier than in spun material. This is also true of corresponding twist structures made of Trevira. In this case, too, the lower extension and the universally high wet strength are evident.

In figs. 8 and 9 you see pairs of twines, each of which contains a strand made of Perlon and the other of Trevira, directly comparable or, at least, very similar in their total thickness (length per weight). It is tempting in this comparison to examine in detail the influence of the twist, but Dr. Klust has dealt with this subject very extensively in his above mentioned report.

The purpose of this comparison-test was merely to point out the chances open to the processors in selecting *material* and structure and to warn against jumping to quick conclusions regarding the suitability of a particular material before all factors have been taken into account.

KNOT FIRMNESS

The next point concerns the problem of *knot firmness*. It is well known, and seems to be confirmed in practice, that net twines of spun yarn show sufficient firmness of knots. This is probably directly connected with the considerably rougher surface produced by the many projecting fibre ends and the position of the capillary fibres. This fact is also very clearly reflected by the values found by means of the two test methods already described. Furthermore, it was found that untreated twines, wetted for 24 hours and then dried, had a better knot firmness than unwetted twines.

Subsequently, we tried to improve the knot firmness by treating the twines with various agents. The results obtained with three different products are given below:

- X means an adhesive which is almost water-insoluble and was dissolved in a solvent;
- Y is a product on polyvinyl acetate basis, likewise almost water-insoluble;
- Z is a product on silicate basis, likewise having a roughening effect on the surface.

The influence of these agents on the firmness of the knots is shown by both test methods so that the stability in twines of spun yarns may be considered to be practically 100 per cent. there being only slight differences between the various products.

The result of the treatment of twines of *continuous* filaments is, of course, clearer (fig. 10). Although the various materials and structures show different reactions to the agents, the knot firmness of the Terylene is striking.

In fig. 11 the results of a braided twine of Perlon and of Terylene compared with Perlon monofilament are shown. The braided twines are distinguished because of their structure by a better knot firmness. The results have been further improved by the above mentioned treatment. The position of monofilaments is somewhat different. Although knot firmness was improved, too, by the treatment, the results were not uniform. However, certain other possibilities are emerging for monofilaments, but it would be premature to report on them now.

In conclusion, it must be pointed out that the examination of this very interesting subject, has by no means been concluded. Further tests, as well as a free exchange of experience between all concerned, will have to follow if optimum results are to be achieved.

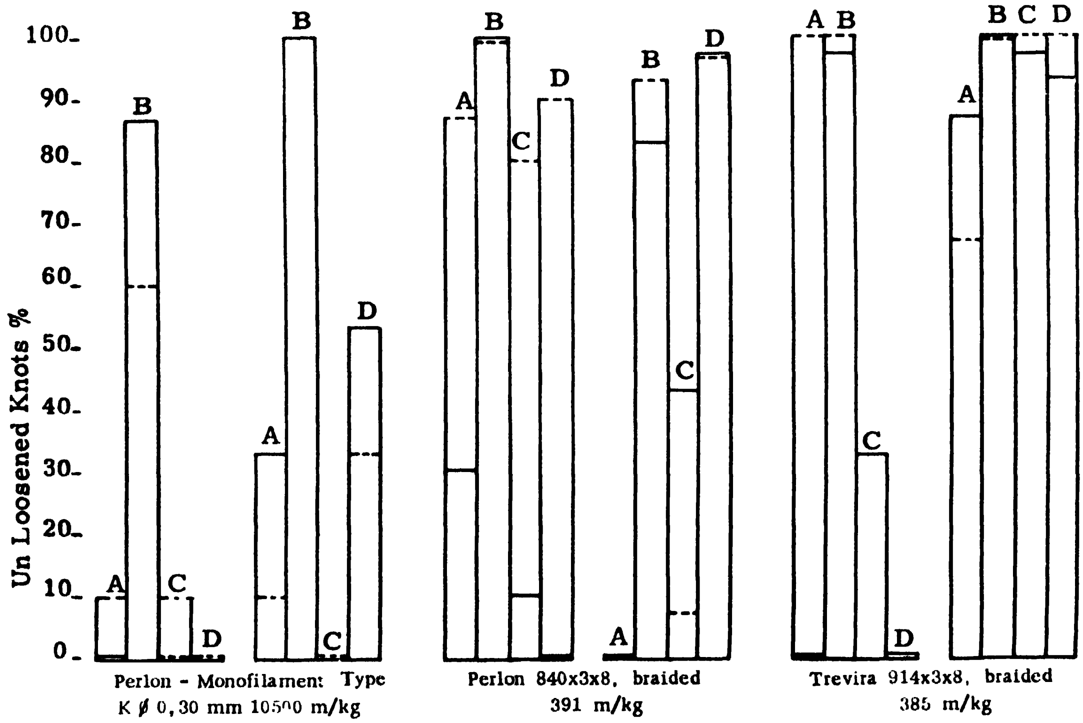


Fig. 11

Knot firmness of Perlon monofilament and Perlon and Trevira braided twines according to I. double overhand knot and II. Fishermen's knot testing method. A = untreated, B = treatment x, C = treatment y, D = treatment z. Results given in per cent. unloosened knot. ——— dry, ... wet.

DISCUSSION ON THE PROPERTIES OF TWINES AND TESTING METHODS

Dr. G. Klust (Germany) Rapporteur: This subject may be divided into two sections: Testing Methods and the Properties of Twines. Among testing methods, those of prime importance here refer to twines, nets or ropes.

Reuter, Shimozaki and Arzano list tests for net twines. These tests take into account: Construction of the twine; thickness of twine, dry and wet; weight in air and in water; length-weight unit; sinking speed; shrinkage; breaking strength, dry and wet; breaking length; breaking strength per weight unit (tenacity); knot strength; breaking extension; load-extension curve; elastic extension and permanent elongation; toughness or the ability to absorb work; abrasion resistance; resistance to light, weathering and to water; stiffness or handiness; knot-slippage or knot firmness; resistance to bacteria, mildew and insects.

These tests were carried out under conditions as close as possible to those of actual fishing, therefore they will not always correspond with the methods generally used by textile industries.

Different methods often give different values and van Wijngaarden in his paper urged that there should be a certain uniformity in the measuring methods and the conditions under which they are performed; this, I believe, is necessary. This Congress will of course not be able to engage in such special problems, but it would be a considerable practical success if the papers and discussions helped promote closer co-operation between those who make such tests.

Of the testing methods specified in these papers, a few, which are not very well known at present, may be cited.

Japan Chemical Fibres Association gives a simple method of measuring the thickness of twines. Pieces of test samples are wound twenty times closely in parallel around a cylinder of about 5 cm. in diameter with a standard initial tension. Then the breadth is measured and divided by twenty. The average number is indicated in millimetres.

A method of testing the sinking speed is given in the same paper. A cylindrical glass vessel is used, having two marks at a distance of 50 cm. A piece of twine, 2 cm. long, with a knot in the middle, is put into the glass filled with water, and the time taken by the twine to sink from the top to the bottom mark is recorded.

There is no need to mention such important testing methods as those for breaking strength and extension because they are very well known and are dependent on the machines at the disposal of the examiner. In these tests too there should of course, be conformity in the methods in order to produce comparable results.

Knot slippage or knot firmness has become of great importance. We know that the smooth surface of continuous filament twines does not assure absolutely slip-proof knots. Van Wijngaarden and Stutz describe methods for determining the resistance of knots to slippage. The load-extension curves of knotted twines are drawn by a tensile tester. When the knot is slipping, the arc of the curve is interrupted by the appearance of jags or teeth. Slippage can occur suddenly or gradually. The force in kilograms or per centage of the knot strength at which the slip begins is the measure of the resistance.

Knots in smooth twines often shift without a load. To find differences in the behaviour of twines made of different fibres, Stutz placed a number of short pieces of yarn, connected by the usual net knots, in a rubber-lined box. A rubber roller was also put into the box which was then rotated for 30 minutes. During this process a larger or smaller number of knots will loosen, depending on material and previous treatment. The number is expressed as a percentage. A similar method is described by van Wijngaarden.

Van Wijngaarden also determines the moment when the loaded knot is changing its structure so that the twine slips through the knot. The force in kg. or percentage of the knot strength at which this takes place is called the "tip-over resistance."

For measuring the stiffness of twines, van Wijngaarden winds 20 turns of the twine round a rod 4 cm. in diameter. The coil is taken off the rod and placed between one of the scales of a balance and a fixed metal plate. Weights are added to the other scale-pan until the coil is in the form of an ellipse, the short axis of which is 2·5 cm.

In this connection there is von Brandt's method, described in his book "Arbeitsmethoden der Netzforschung".

As expected, nearly all papers deal with synthetic fibres. They are now of great importance in most of the leading fishing countries and are more and more replacing natural fibres.

Needham states in his publication on the use of nylon in the fishing industry: "They bring to one of man's oldest occupations the miracle of science and, in doing so, provide easier living for the fisherman." For instance, the miracle can be noted in the rot-proof quality of the synthetic fibres. I remember the great astonishment and the scepticism of our inland fishermen when they first received gear made of PeCe. This rot-proof quality is most important in fishing gear as it ensures greater durability and eliminates the work and expense of preservation. It also enables the gear to remain in water for an unlimited time and eliminates the need to dry it.

This rot-proof quality is now taken for granted, and the developments in synthetic fibres have considerably increased the demand by fishermen or these materials.

Lonsdale outlines the desired properties of the ideal fibre for use in fishing gear, but adds that this fibre, of course, does not exist.

Teviron seems to be the cheapest of synthetic fibres, and the price of Teviron fishing net is only 30 per cent. higher than that of cotton. Its resistance to weathering is very high. The same holds true for Rhovyl and PCU.

Polyethylene fibres have the lowest density of synthetic fibres, lower than that of water, therefore ropes made of this fibre will float and, in trawling, the upper net will tend to rise of its own buoyancy.

The fibres with the greatest specific gravity are those made of polyvinylidene chloride, e.g., Krehalon. This property enables the nets to sink faster. It makes the fibre particularly suitable for setnets.

Terylene has a high tensile strength which is unaffected by wetting. The most important characteristic seems to be its very low extensibility. Gillnets of Terylene have been used successfully, principally for catching salmon and cod, but not herring. This soft fish becomes damaged by the fine twine. Trawls made of Terylene have proved very successful.

The most important characteristic of the polyacrylonitrile fibres is a very good resistance of weathering, but the fibre does not seem to be used in fishery and none of the papers mention it as a net material.

Twines made of polyamide filament or staple fibre have a relatively low resistance to weathering, less than that of cotton. This refers especially to types of polyamides which have been delustred, and which are not suitable for use in the fishing industry. For most fishing gear this sensitivity to light is not, however, an important disadvantage. Practical experience gained by Swedish freshwater fishermen has proved that nylon nets discarded after 3 to 4 years have become unserviceable because of damage by tearing and not because of the effect of sunlight.

In Portugal, purse seine nets made of perlon staple, not dyed or prepared in any way, have been in use 1,300 fishing days and are still effective. Cotton nets frequently treated with preservatives, have a durability of 400 to 500 fishing days. The excellent physical properties of polyamide twines are of much greater importance than their resistance to light.

But there are cases where the resistance to light will be insufficient, as, for example, when part of the fishing gear remains above the water level. Colouring the net may help, or twines made of polyester, polyvinyl chloride, polyvinylonitrile or Saran may be used. Terylene polyester fibre has a better resistance to light and weathering than the polyamides and is equal to the best of the natural fibres, such as cotton, although the polyvinyl alcohol fibres are better. These fibres, such as the polyacrylonitrile (Orlon, Dralon and PAN) and especially the unchlorinated polyvinyl chloride (Rhovyl, PCU and probably the new Japanese fibre Teviron) have the highest resistance to weathering.

Resistance to abrasion is very important but we do not know exactly the abrasion resistance of nets made of different types of fibres. Test methods never give absolute values, but only relative ones. They are in a high degree dependent on the method employed.

A few papers give examples for assessing the abrasion resistance. Shimozaki has chafed twined across an oil stone and a figure shows that the resistance of non-treated twines increases in the following order: Saran, Krehalon, Teviron, Cotton, Kyokurin (a mixed twine made of Amilan and Saran), Kuralon and polyamide Amilan. In tests made by Imperial Chemical Industries Ltd. twines were abrazed over a hardened carbide steel bar. The abrasion resistance of Terylene twines was superior to that of cotton and flax, but less than that of nylon twines. There is a good conformity between these data and those of Klust. Examples of the wet abrasion resistance of Perlon filament tissue in comparison with those of hemp and manila are to be found in the Perlon-Warenzeichenverband paper.

It seems certain that the polyamides have an especially high abrasion resistance, not equalled by any other fibre. The durability of fishing gear made of such fibres, such as trawl nets, is probably primarily due to their abrasion resistance.

What types of fishing gear ought to be made of fibre of the highest strength? First, those subjected to the heaviest stress and strain, such as trawl nets, expecially those used by large fishing boats. But it is also profitable to use strong fibres for fine gillnets. The stronger the fibre the finer the twine and the finer the twine the greater the quantity of fish caught.

The test records given in the papers show that two types of synthetic fibres are superior to others; polyamide and polyester. But here we have to distinguish between fibres of normal or ordinary tenacity and fibres of high tenacity. The factor which determines the strength of synthetic fibres is the degree to which they have been drawn out during manufacture. A high degree of drawing or pre-stretching results in a considerable increase in tensile strength, which is connected with a reduced breaking extension. But high tenacity leads to loss in lateral strength. It is important to know the decrease in strength caused by knotting and by high tenacity. Tests of knot strength are much more significant than those of the straight twine. In this connection it is interesting to note the physical properties of twines in Japanese knotless nets.

Twine and knot strengths of polyamide fibres are dependent on the degree of stretching, not on the type of fibre. In principle nylon and Perlon, for example, do not differ in strength when they are made with the same degree of drawing. (That may be seen in the paper by Arzano). Carrothers has tested twines of nylon 66 and nylon 6 or Perlon. The twine made of the latter was found to be about 40 per cent. weaker than nylon 66 of the same weight, but the two twines reacted differently to knotting. The mesh of nylon 6 or Perlon was only about 20 per cent. weaker than the mesh of nylon 66 and not 40 per cent. weaker as in the case of the twine. Carrothers has not, I think, compared twines with the same degree of tenacity, but a twine made of a highly drawn nylon with a twine made of normal Perlon. Lonsdale has found that every type of knot has a different knotting efficiency. A decrease in the angle through which the loop is formed weakens the strength. If the number of loops in a knot increases, the knot strength increases too.

As Carrothers states, tensile strength is often adopted as the only measure of quality because it can be measured relatively easily. But it is important, too, that the material is able to absorb kinetic energy. The degree of extension (elastic and permanent) is sometimes of the same or of a greater importance than tensile strength. Statements of breaking extension of the twine, mostly given by manufacturers, do not provide possibilities of evaluation. In synthetic nets, the meshes of which are formed by knots, knot-strength reaches only about 50 to 60 per cent. of the breaking load. Breaking extension of twines made of different fibres may be similar, but the shape of the load-extension curves may be different. This can be of great importance to the behaviour of the twine under working conditions. Van Wijngaarden proposes to determine extension under lower load, for example, extension at 25 per cent. of the breaking load.

Net twine has a great capacity for working if total and elastic extensions are great. It will be able to absorb kinetic energy and will stand shock loads better than twine of lower extensibility. The demands on net materials differ very much between different types of gear, but for all gear it is advantageous to use fibres of high tensile strength. On the other hand, one type of gear may require a low extension while another may require a higher extension. It is always an advantage for a fibre to possess a high degree of elasticity which guarantees a good consistency of mesh size. There is no ideal fibre for fishing gear, but the various types of synthetic fibres each having different properties, provide a range of choice from which to select the best for each type of gear. So we can say with Amano "Modern fishing means the use of synthetic fibre nets".

Mr. J. E. Lonsdale (U.K.). One problem before synthetic fibre makers is to determine the exact properties required in a fishing net fibre and on this point fibre producers can learn a great deal from the fishermen and from the fisheries technologists. As synthetic fibres are man-made, they can be tailored to produce the required properties but until the manufacturers know what the fishermen want, they cannot produce the best possible fibre. Even for a material such as nylon, which has been in existence for some twenty years, there is great room for exact assessment of the properties required by the fishermen. One major complication is to differentiate between the properties required in different types of fishing and different types of nets in different parts of the world.

There has so far been no real attempt to try to rationalize these properties but once this has been done, and an attempt is made to find out exactly what the fishermen want, advances will be made in the properties of man-made fibres.

Dr. Avon Brandt (Germany) (Chairman). The polyester and polyamide fibres are used mainly in Europe and in America. The group of polyvinyl alcohol fibres is most important in Japan.

Mr. P. J. G. Carrothers (Canada). The results of my tests on Manryo were published in the Progress Report of the Fisheries Research Board of Canada, and copies may be obtained from the Vancouver Technological Station.

Manryo twine is similar to cotton in general appearance. Generally speaking, we found the properties of the new Manryo (dry twine) to be considerably better than cotton, but when knotted and wetted, the properties of both twines were similar.

So many of the tests have been on the dry twine, but wet mesh and wet knot tests are of far greater importance than a straight, dry twine test.

I would also like to say a word about the need for standardization of test procedures. So far, these have been primarily developed from the manufacturers' point of view, but nets are used to catch fish, so the test methods are better designed from the fisherman's rather than from the manufacturers' point of view. Pertinent properties which relate to the fishing function should be measured, such as handling characteristics, the wet mesh strength, probably also toughness, etc.

Test procedures in most countries are fairly well standardized up to the stage of the dry twine, i.e., the ASTM in the States. Could not this Congress try to encourage some of these groups to consider also standard tests for netting? Many of the methods available have been developed solely for research purposes. There is a need to develop these methods further so that they can also be used for routine control purposes. It would then be possible for netting manufacturers to state how strong their netting is without fear of, say, a government laboratory or standards laboratory testing the netting by another procedure, and saying that the nets are not what they are claimed to be.

Mr. B. F. Wolmarans (Union of South Africa). About 2 years ago, the first blend of Japanese synthetic netting was put into use in South Africa. We find this is vastly superior to straightforward synthetics. Other types have been imported from U.K., Germany and Holland, but we find Marlon very much more resistant to the peculiar water and weather conditions we have in South West Africa. Firstly, nets manufactured of this material are reputed to sink very much faster; they are abrasion-resistant to a very great degree. The price factor also comes into consideration. After much experimentation our industry has concentrated on Marlon particularly in the Walvis Bay area where conditions are very bad. Kuralon is unsatisfactory, although it has been put into use in the areas further south where the water is clearer and where damage is not so noticeable.

Mr. R. S. Rack (Northern Rhodesia). A very few years ago our local fishermen were taking motor car tyres to pieces, in order to get threads for their fishing nets. Subsequently they have come to use nylon, which has superseded cotton. They are very simple people; they know cotton and nylon; it might be a blow to their vanity if I say they know very little of any other. In fact, I believe that if I were to say "this is not nylon, this is Marlon", they would say "yes, you mean Marlon-nylon." There is a danger in this wide use of trade names which are being interpreted as common names. A worthless fishing twine may be sold under a high sounding name. I would therefore suggest that the trade name always be accompanied by a specification of performance. I would also suggest that the testing methods be brought under two headings: Practical forms of test which could be carried out on behalf of the fishermen to ensure that the nets sold are adequate, and more exhaustive tests which could be carried out for the satisfaction of the industry.

Could not this matter be referred to the various standard institutions who, in cooperation with users and manufacturers, might be able to provide tests of this nature?

With regard to the value of synthetic fibres under tropical conditions in my part of the world we use practically all nylon. Our primary aim is to reduce the cost as much as possible. Many of our fishermen make their own nets, and therefore a nylon which is non-slipping and which could be knotted with a single knot, would be of great advantage. Abrasion is also a problem. However, the physical characteristics are not so vitally important to us. When I tell you that we lose a good many nets to crocodiles you will understand this point of view!

Mr. T. D. Iles (Nyasaland). I am concerned more with the biological side, the fisheries research in general, rather than with test of net characteristics, but I have had an opportunity on Lake Nyasa, where we are investigating a deep water gillnet fishery, in comparing cotton, flax and nylon nets. Under our local conditions, the physical characteristics of the nets such as tensile strength, do not give such a great advantage as far as the fishermen are concerned. A problem in this particular fishery concerns a fresh water crab, which causes a great amount of physical damage and, in fact, whereas a flax net will give up to 25 sets, a nylon net may only give up to 40, despite the fact that the tensile strength of the nylon is very high, far higher than is really needed for the fish that are being caught. Such problems, under these conditions at least, are far more important than physical characteristics of the net.

Mr. C. P. Halain (Belgian Congo). Nylon fishing twine —to some extent imposed upon us, owing to difficulties in finding fishing twines—was first used in the Belgian Congo in 1943. The fishermen now use nylon almost solely and cotton or linen yarn is seldom sold, but we are still looking for a better synthetic fibre.

Incidentally, some 80,000 to 100,000 tons of river and lake fish are marketed in the Congo every year.

Mr. M. K. Kramer (Israel). We have carried out three experiments with synthetic fibres. The first, with trawling, was unsuccessful, and we are now waiting for other and better fibres. Good results were obtained, however, with the fibre net in Lake Tiberias. It was found that a white fibre net doubled catches and these were tripled last year by using a red fibre net. Today there is not one gillnet in the Lake which is not of synthetic fibre.

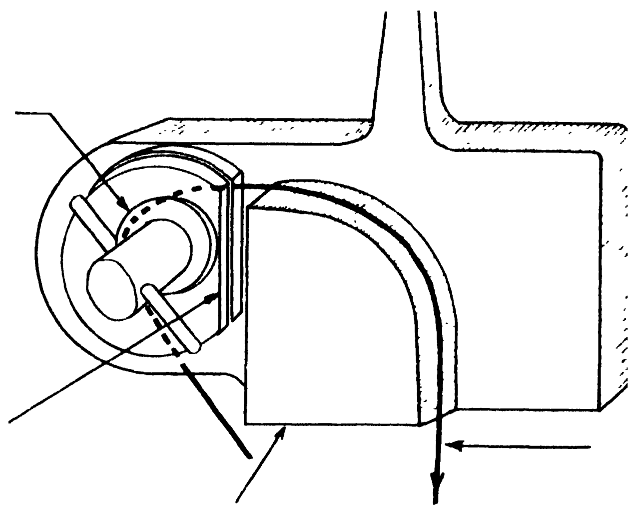
We have now begun experiments for the change-over of sea purse-seine nets. We have begun by using fibres from various countries—three kinds from Germany, two from the U.K., and two from Japan. In 1958 we hope to experiment with Italian fibres also, and so arrive at some final result.

Dr. W. Einsele (Austria). Monofilament nets have revolutionized our fisheries. There is very little plankton in our lakes and the light penetrates very deeply. Catches were exceedingly low, especially in the summer, not because there were no fish but because we were unable to catch them. This has changed entirely since the introduction of monofil nets and this summer, for the first time, enough fish has been caught to supply the hotels, restaurants and villages in the Lake region.

Mr. E. F. Gundry (U.K.). There is a tendency, especially at the government fishery officer level, to assume that man-made fibres make the best nets to have. The biggest production of nets today is still from the orthodox vegetable fibres, and therefore the advantages of the "old-fashioned" material must not be overlooked. The great advantage of sisal or cotton over other fibres, is their lower cost, and, in an industry such as fishing, which is having economic difficulties, the lower the cost of the nets, the more attractive they are. The advantages of the man-made fibre will increase as their price decrease. Another characteristic of cotton nets is in the extensibility of the material. Herring constitutes a very big part of the fishing catch both for man and for animal feeding stuff, and there are many types of herring nets and herring gillnets. The man-made fibre herring gillnets are not entirely successful, the fish becoming so deeply enmeshed, that the catch can be extracted only with a great amount of labour and the fish often being damaged. Also in the trawler field the advantages of synthetic nets are not so apparent, because the physical conditions under which the net is operated do not permit it to last as long as their qualities might promise. The rock or the wreck on the bottom of the sea is capable of tearing and pulling loose an expensive synthetic net as easily as the one made of the less expensive natural fibre. It would be a mistake to think that there is no future for the orthodox vegetable fibre materials and those in authority and responsible for advising fishermen should inform them that good service can be obtained from the vegetable fibres as long as the nets are kept clean and maintenance is good.

Dr. J. Reuter (Holland). When a fisherman has to make his choice of material, the more figures he sees the less able he is to make his choice. This information about testing was started by scientists. Fishermen are not scientifically trained, so we should adopt test methods that are scientifically correct and at the same time be easily understood by the fishermen. Take for example the breaking strength of twine; every textile man has this as his main goal, because the stronger the twine the better it is, but he forgets that the fisherman tests his net wet by pulling on the mesh and not the straight twine. There are fibres that are strong in the dry condition but become weak when they are wet and knotted.

Messrs. G. A. Hayhurst and A. Robinson (U.K.) in a written statement: When checking twines for breaking strength and extension it is essential to avoid distorting them. If simply secured between two grips there may be a severe bend in the twine which, when subjected to the test force, will cause a stress concentration and give a most unreliable result. It is therefore recommended that quarter-circle bollards be used to lead the twine to the grip, as shown in the sketch.



When checking extension under load, the test sample must be pre-tensioned to a slight but known extent. We always make such measurements at 1 per cent. of breaking stress.

Mr. E. A. Nilssen (Norway). Synthetic fibres were introduced about three years ago in Norway. I think that at present only synthetic fibres are used for the gillnets. Such nets bring in bigger catches, they are stronger, easier to handle, lighter, need not be dried and need no preservation. The fishermen in Norway use sisal and manila for the mounting, but they would also prefer synthetics in the mounting as they could then just leave the nets without any drying. We are now trying to find the right material for these mounting lines. We have tried monofilament nets, but without much success. This is rather astonishing, when one thinks of Sweden, where they are using so many of these nets. As for the breaking strength, we use single-knot and double-knot nets. The double-knot nets were the best at the beginning because there was no knot slippage, but the single-knot nets have improved much in the last two years. The double-knot nets give somewhat higher strength. In Norway there is a State import monopoly for nets and raw materials; the Government also uses test machines. As most Norwegian manufacturers send the nets, the twine, etc. to this laboratory, tests are therefore uniform. The most important test is that of the knot strength. The fishermen normally pull the net in a wet and in a dry condition, we must find a twine that gives good results in both conditions. Synthetic fibre has also been tried for the big purse seines (about 180 fathoms long) in Norway. This has resulted in an increasing demand for the nets. As soon as the price of synthetic fibres comes down more or less to the level of cotton and hemp, it is possible that only synthetic fibres will be used.

Mr. R. Ocran (Ghana). In Ghana, we are trying to develop line fishing. We catch heavy fish and the breaking strength of cotton and hemp cord is not strong enough. How can synthetic fibre be applied to line fishing?

Dr. H. A. Thomas (U.K.). Some of the first trials with Courlene (a polyethylene material) were in fact with line fishing using a large number of snoods in the Irish Sea from Fleetwood, and remarkable catches were achieved. The fishermen spoke very highly of the knot strength at the point where the hooks were running out on the snood from the main line. Some purse seine nets of this yarn were then produced, in cooperation with the Fleetwood fishermen. It was found that the knot with the polyethylene yarn—Courlene—did not have to be heat-sealed; if they were tied with the right technique, they obtained satisfactory results. We have a large number of individual reports on these fishing trials, which we shall be pleased to give in detail to anyone who is interested.

It has not been possible at this Conference to include a full-size paper dealing with materials suitable for protective clothing for fishermen. I would, however, suggest that perhaps at another Conference it might be possible to include one session on the clothing and protective equipment.

The last pages in Dr. Arzano's paper give some details of the use of man-made fibres in protective equipment. There is a development which started in Norway, namely the string vest. The object of this vest is to maintain a layer of air next to the skin to prevent clothing from becoming moist from perspiration, this also being a very good heat insulant and thereby adding to the warmth of the body. The older established man-made fibres (blend or a mixture of viscose staple and acetate staple) can be used for the string vest. To maintain the warmth of the feet it is of advantage to have an insole or interlining between the feet and the rubber boot or the gumboot. For gloves, blends of viscose staple with nylon staple and with wool seem to achieve the best results. Viscose staple and filament coated with polyvinylchloride or with linseed oil and rubber are used for such things as aprons, gumboots, overcoats and sou'westers.

Mr. A. Robinson (U.K.). We have some experience with long-line fishing and particularly with snoods of nylon yarn. These have been found to be very successful indeed in various respects, not only as to durability but also for increasing the catch.

Where the speed of replacing snoods is of great importance, nylon snoods have been particularly advantageous. Very few snoods indeed have broken when the fish has been ripped from the hook, and very little time has been lost in repairs. The line itself is usually made of staple nylon in order that the snoods can be attached to it securely and do not slide on the line. The life of the staple nylon longline is very good but, of course, the price is high.

Mr. S. Springer (United States of America). In the Gulf of Mexico longline tuna fishery, we have been making use of synthetic lines—both mainlines and branch lines. Here, the advantage of the synthetic fibre is in its great strength—possibly double that of the natural fibre lines. The nylon line that has been most successful in this fishery is a heat-stabilized line, which has less tendency to twist.

Mr. K. J. Westrop (U.K.). There is a need for standardization of testing methods. Different methods lead to different actual figures, which do however serve usefully for purely relative testing of the fibres. For instance, the abrasing resistance described by Dr. Klust shows the superiority of the polyamide and the polyester fibres over the natural fibres, though just what these relative figures would mean when you are concerned with the actual nets, of course, is another story. As yarn producers, we can evaluate our yarn as a textile material, but the fisherman himself must obviously be the man to decide what is required of a net. A practical trial, to be valid, must be made with many nets to cover the whole range of different types and the different conditions under which the nets are used.

Presumably something will come out of the Congress and these discussions as to what should be done about surveying such testing methods. I would like to add that the Imperial Chemical Industries could probably contribute to any future conference if a paper of this sort is required.

Dr. A. von Brandt (Germany). I would propose that, in addition to the Working Party on Terminology and Numbering Systems, we form a Working Party on Testing Methods*, and that the following gentlemen be appointed as members: Mr. Reuter (Netherlands); Mr. Carrothers (Canada); Mr. Takayama (Japan); Mr. Percier (France). The standardization of testing methods should be considered from the fisherman's point of view, and not from that of the textile industry.

Dr. G. Klust (Germany) Rapporteur. I should like to give a brief summary of what has been said during the discussion. Synthetic fibres have given good results from northern waters to the tropics. For instance, in the Belgian Congo, the inland fishermen almost exclusively fish with nylon nets. Several speakers stressed the extremely good results that had been obtained with monofilament nets. Mr. Gundry defended natural fibres, especially cotton which still is being used extensively in the fishing industry, the lower price being a very important factor.

The necessity of uniformity in methods of testing net materials has been stressed. These test methods, it was pointed out, must be brought into relation with experience gained in practical fishing. A close relationship between the manufacturers of synthetic fibres and the fishing industry could give extraordinarily good results, because synthetic fibres could be produced in such a way as to meet the requirements of the consumers.

If the manufacturers know the requirements of the fishing industry they are in a better position to manufacture what is actually wanted.

* *Editor's note.*—This Working Party has been active since the Congress. Under Dr. von Brandt's leadership, considerable progress has been made towards reaching an agreement on uniform standard testing methods. (*See preliminary report on pages 98 and 99.*)

REPORT OF THE WORKING GROUPS ON "TERMINOLOGY AND NUMBERING SYSTEMS" AND "TESTING THE PROPERTIES OF TWINES"

Prof. von Brandt (Germany)*: The two working parties have met and started to deal with the problem of standardization. Due to the little spare time left by the packed programme of the Congress, no definite results can be expected yet. The difficulties which such an attempt of standardization meets have been discussed and are well known by everybody working in this field. The quality of twines for the fishery or particularly the standardization of their denotation depends not only on the basic material which is presently often camouflaged under a big number of trade names, and the manufacture of this material into fibres but also on the way how the fibres are processed to the twine. The final goal of the Working Party for Standardization of the Numbering System dealing with these questions is to find out and establish a simple and unmistakable system for defining the twines used in fishery. This system is meant to enable the fishermen all over the world to know what really is offered to them and what will best suit their purpose when substituting one twine or material for another. The Working Group consists of fibre producers, twine makers and net makers. Mr. J. E. Lonsdale, U.K., has been appointed chairman. After having discussed the matter repeatedly also with many people at this Congress, the present situation is characterized as follows:

1. The presently used numbering systems are too complicated and too confusing for use in the fishery.
2. The numbering complications are caused mainly by the twine and net makers who often create own systems.
3. It is necessary for the fishing industry to use always a common numbering system at least in addition to the national or manufacturers' systems. It may in time replace those.
4. As basic units for this common system either Denier or Tex are suggested. The former is a non-decimal unit generally used in the textile industry and already introduced to a certain extent into the fishery. The latter one is a newer decimal system which is strongly recommended for international use.

The Working Party, having accepted English as working language, is undertaking to survey the numbering systems currently used throughout the world for fisheries purposes, devise methods of unification and make recommendations. In addition to the inquiries to be made to this effect, everybody who wishes to bring his view to the attention of this Working Party is requested to write to Mr. J. E. Lonsdale of the British Nylon Spinners, Ltd., Pontypool, England.

Editor's Note.—This report was given on the last day of the Congress.

It is the intention of this Working Party, while endeavouring to bring order in the systems of counts and numbering, to take into account what has been customary in the fishing industry as to date, and the specific demands of this industry. The future count system, therefore, should at the same time indicate the main qualities important for the various fishing purposes. The following list of twine and net qualities has been set up and may be useful as a base for discussion

(a) tensile strength
(b) knot strength
(c) knot slippage
(d) mesh size
(e) permanent elongation
(f) elastic extension
(g) softness
(h) resistance to abrasion
(i) weight
(j) water absorption
(k) resistance to rotting
(l) resistance to weathering
(m) resistance to chemicals

If applicable, these qualities should be tested in wet conditions. For nets the knot strength of the twine is of more importance than the unknotted tensile strength. The mesh size often has to be considered in regard to economic and biological problems as marketing and overfishing. The permanent elongation may be of significance for the proper mesh size. Elastic extension or elasticity may be very effective when dealing with shock loads. Softness comes in particularly with gillnets. Abrasion may be caused in different ways during handling or when towing a trawl net over the sea bed. The weight is always considered as the weight in water not only for easy handling but also in regard to operation performance for instance in bottom trawls when a good and continuous contact with the bottom is wanted or in purse seining where the sinking speed can be of great importance. Water absorption has an obvious relation to these weight problems. Resistance to rotting is such a general problem in fisheries that no further comments are needed. Resistance to weathering is of particular importance in tropical areas with bright sunlight. The means of improving the insufficient resistance to weathering of certain synthetic materials have been discussed. They lead to the question of resistance to chemicals of which the different dying materials consist.

The proper selection of the optimal material for the fishing purpose in question is strongly affected by the mutual interference between these qualities. With a stronger material, for instance, the twine diameter can be reduced saving twine, and towing or current resistance. But, with thinner material there might be more abrasion or, in gillnetting, the fish might be damaged, or it might be inconvenient to handle. The choice, therefore, must be based on the main qualities required for the particular purpose. This working party has been limited to manufacturers of twine and webbing because they are closest to the practical fishermen.

It is the intention to submit the information compiled and the conclusions drawn in the form of a report to FAO next year. FAO will then distribute this report to all people interested in this matter. The collaboration which is hoped to be created hereby, and the comments and discussions resulting, are expected to finally result in terms and a system of numbering and defining twine and net qualities which is acceptable and most suitable for all concerned with the fishing industry.

To be comparable, the qualities listed above must, of course, not only have uniform units but must also be determined in a uniform way. The standardization of the testing methods is the subject of the second working party having been established at the beginning of this Congress. These methods also must apply to the demands of the fishing industry rather than to the textile industry, which mainly is concerned with clothing, stockings, etc. In the short time available this working party has prepared the following short report.

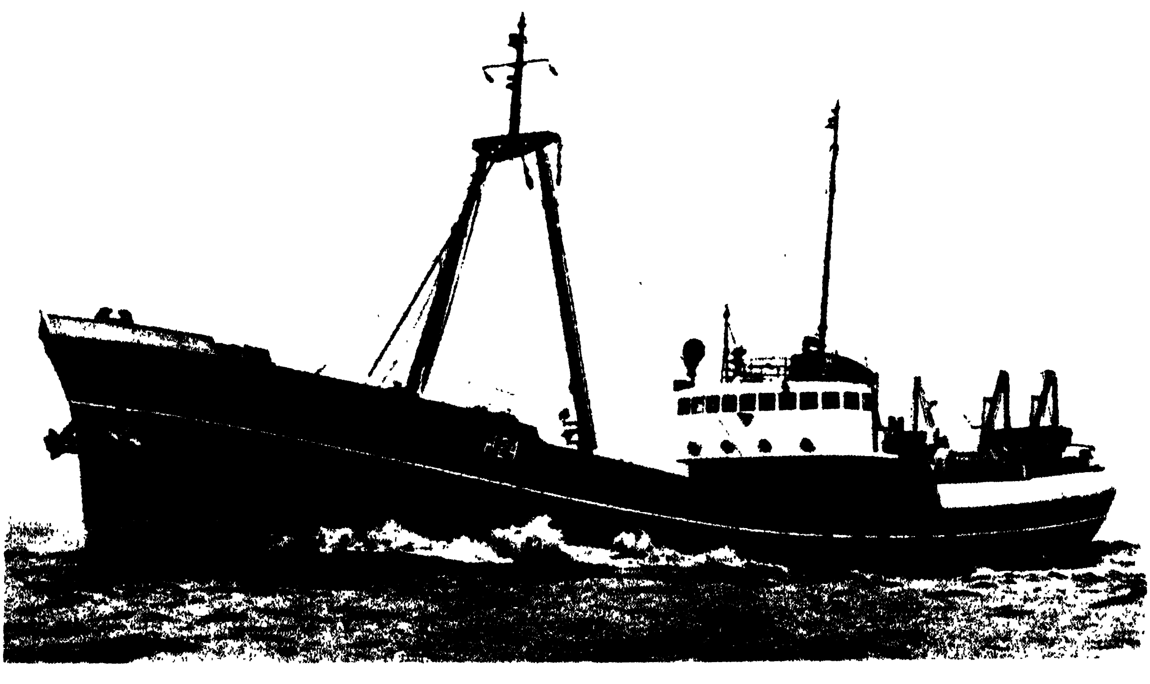
"The working group was formed to find a common agreement on test methods which will be adapted to test material under similar conditions as it is used in practice. The group has appointed Prof. A. von Brandt as Chairman. The various testing methods were discussed and a preliminary division agreed upon:

(1) Test methods outside the scope of the working group, such as determination of the specific gravity of fibres, etc. which are not entirely adapted to fishing conditions but absolutely necessary for manufacture and research.

(2) Test methods which have already been accepted and standardised nationally or internationally, as for instance French elongation test etc. These test methods are also not entirely adapted to fishing conditions but absolutely necessary.

(3) Test methods of particular interest for fishery purposes on which a common agreement has still to be found—for instance, sinking speed of the net, visibility in the water, mesh knot and mesh breaking strength etc. The last group of test methods will be the main task of the working group. Prof. A. von Brandt will write to people interested in the subject who he thinks can contribute to the unification of this subject. He will be glad to receive contributions from any participant to the present Congress. A full report will be written next year."

The working party has decided to compile the existing results of tests, discuss and evaluate them, after which a programme of work will be set up. Testing results often depend on the type of test carried out, and we must determine how we can work in agreement since so many people throughout the world are carrying out tests, there is need for some unity in this field. FAO has also emphasized to the different governments that they should help in this matter.



The 883 tons distant-water trawler Portia *of Hull. Her diesel-electric engines, which can be controlled directly from the bridge, give her a speed of nearly 16 knots.*

PRACTICAL CONSIDERATIONS OF THE USE OF SYNTHETIC FIBRES IN TWINES AND NETS

by

G. A. HAYHURST and A. ROBINSON

William Kenyon and Sons Ltd., Dukinfield, Cheshire, U.K.

Abstract

From the twine-maker's point of view the characteristics of synthetic fibres are discussed and a comparison made of the results obtained from nylon nets with those from cotton nets. The heat-setting of nylon twine is discussed, and also the question of the use of bonded twines for single knot nets. Brief notes are given on testing methods for twines.

Considérations pratiques sur l'utilisation des fibres synthétiques dans les fils et filets

Résumé

Cette étude est écrite du point de vue du fabricant de fil de pêche. Les auteurs examinent les caractéristiques des fibres synthétiques et comparent les résultats obtenus avec des filets de nylon et des filets de coton. La stabilisation à chaud du fil de nylon est étudiée ainsi que la question de l'emploi de fils imprégnés pour les filets à noeuds simples. Les méthodes d'essai des fils sont exposées brièvement.

Consideraciones prácticas sobre el uso de fibras sintéticas en los hilos y redes de pesca

Extracto

Desde el punto de vista del fabricante de hilos se analizan y comparan los resultados obtenidos con redes de nylón y de algodón. También se consideran el tratamiento térmico de los hilos de nylón para disminuir el resbalamiento de los nudos y el problema de la fijación de los hilos en redes de nudos simples. El trabajo también contiene breves descripciones de los métodos usados en los ensayos de los hilos

CONTINUOUS filament yarns of nylon and Terylene are extremely "lively" when twisted so that when twine is cut the yarns promptly untwist. Heat setting of the twine during manufacture reduces this liveliness by altering the linear molecular structure of the fibre. If this process is carried out when the twine is in relaxed state contraction takes place, and influences the length/weight ratio and the extensibility. The extent of the contraction depends upon the temperature and time the twine is heated. The nylon and Terylene twines are treated at or below 100 deg. C. for up to 10 minutes.

If the twine is permitted to contract during this process a greater length will be necessary to make any particular specification of net and the raw material cost is therefore increased. The elasticity of the twine is affected and if it were allowed to contract during the heat setting process, extension under load would be increased; much depends on the temperature and time. For this reason the Kenlon brand twines are heat-set by methods, devised and developed within the Organization and contraction during heat-setting is avoided so that the length/weight ratio is improved. These twines show about 18 per cent. up to 25 per cent. extension at break whereas twines which have been heat-set in a relaxed state show about 21 per cent. up to 30 per cent. extension at break. The difference in length/weight ratio may be anything from 5 per cent. up to 10 per cent. in the case of nylon 66 of 210 denier.

IMPREGNATION

The low coefficient of friction against itself caused some difficulty when synthetic fibre nets were first introduced and necessitated the use of double knots to prevent knot slippage. If suitable impregnating materials and methods are employed, it is possible to increase the coefficient of friction so that secure single knots may be achieved with both machine-made or hand-made nets. It goes without saying that coating of the twine with materials which are incompatible with nylon or Terylene does not give satisfactory results. Reasonable resistance to flaking off during rubbing or surface abrasion and rapid leaching out in water are two of the points to be considered in this respect.

KNOTS

Where double knots are made, satisfactory results may be obtained with thermoset type twines, but where single knots are made it is advisable to use bonded type twines.

In either case heat setting of the net is usual and this must be done at a temperature higher than that used for the heat setting of the twine. It is therefore an advantage if the twine is heat set at a temperature less than 100 deg. C., so that boiling water or low pressure steam may be used for heat setting the net. Where possible, the net should be kept on tension during heat setting, otherwise some contraction will take place, thus affecting mesh size.

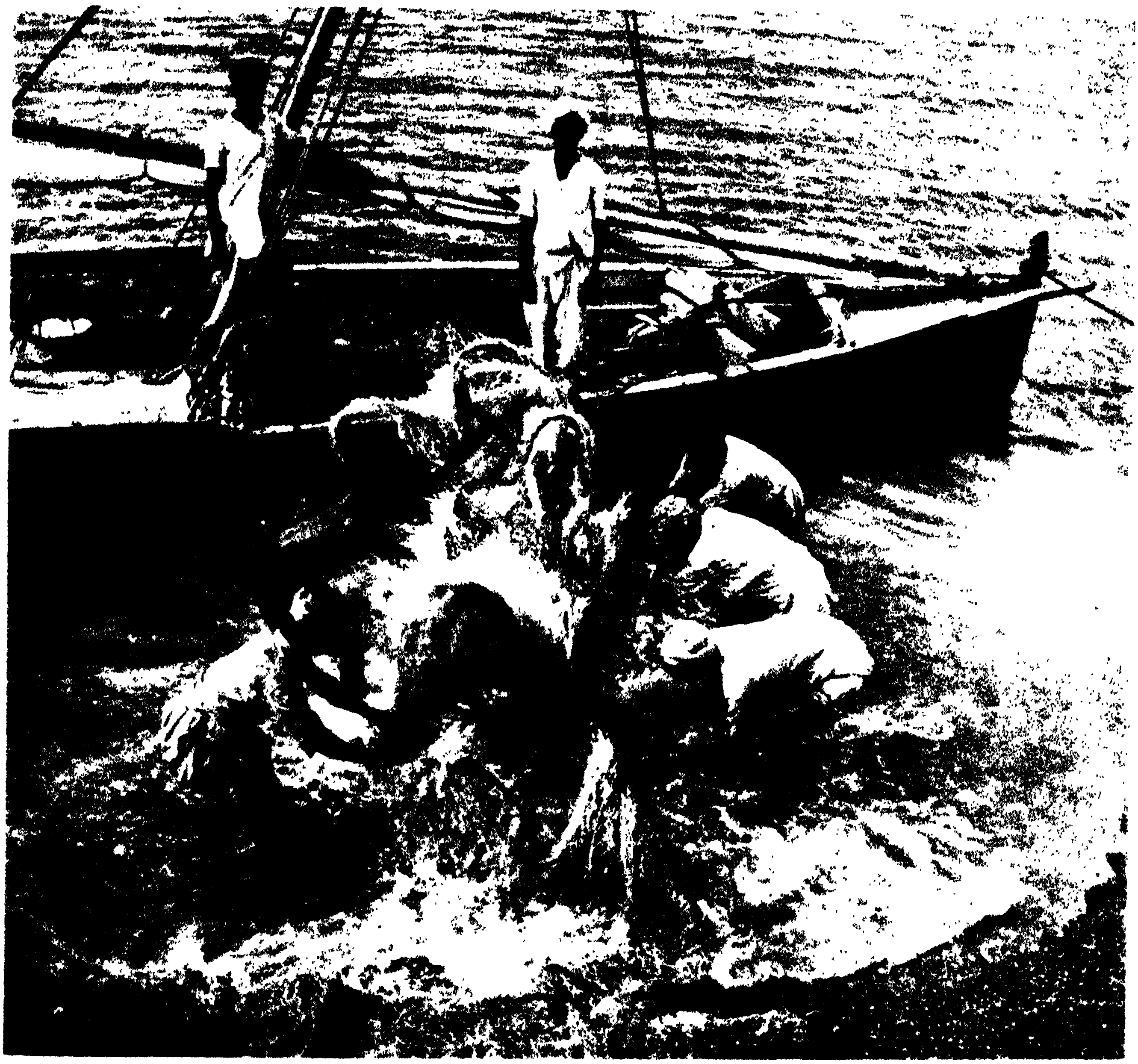
To further avoid knot slippage the net can be impregnated with suitable materials. When nets are so treated with a recent development of our own it is practically impossible to move the knot in any way, under any conditions, wet or dry.

SHRINKAGE IN WATER

Where an exact match of mesh size is required a check should be made when both natural fibre and synthetic fibre nets are saturated in water. This is necessary because of the different water absorption characteristics.

ROPES

From the remarks above regarding rot-proofing, it will be obvious that, in order to gain the maximum advantage, synthetic fibre mounting ropes should be used where possible. It is sometimes found that ropes made from staple fibre yarns (instead of continuous filament yarns) are the most suitable as this avoids any possibility of the tying cords gliding on the head rope. On the other hand, ropes made from continuous filament yarn are much stronger and this consideration may have a bearing on the size of rope required and therefore on the cost.



Washing fishing nets in Pakistan. Photo FAO

SOME CONSIDERATIONS ON NETMAKING

by

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Abstract

When designing a new net the netmaker endeavours to obtain the largest catching potential for the smallest cost in material and the least power output. He has to take into account many factors whose effect only become apparent when the gear is in action, a condition he cannot observe and has to guess at. In most cases, however, they produce deformation of meshes in the netting or leave other signs which become apparent during operation or when the net has been used for some time. The stress-strain reaction in webbing is dealt with and it is pointed out that very often a stress can be neutralised by adjusting the hanging at the stress point. The effect on the net of hanging coefficients, webbing joints and tailoring are also discussed.

Quelques Considerations sur la Fabrication des filets

Résumé

Quand il dessine un nouveau filet, le fabricant de filets s'efforce d'obtenir la plus grande puissance de capture pour le coût le plus bas de matière et la moindre puissance mise en jeu. Il doit tenir compte de beaucoup de facteurs dont les effets se manifestent seulement quand l'engin est en action, une condition qu'il ne peut pas observer et qu'il faut qu'il suppose. Cependant, il se produit des déformations des mailles dans le filet qui a été utilisé pendant quelque temps. L'auteur traite de la réaction à l'effort de tension dans le filet et il fait ressortir que très souvent un effort peut etre neutralisé en ajustant le montage au point soumis à l'effort. Il examine aussi l'effet sur le filet des coeffcients de montage, des assemblages des parties et de la coupe.

Consideraciones sobre la Fabricacion de redes

Extracto

Al proyectar una nueva red el fabricante trata de darle el mayor potencial de pesca posible con el menor costo de material y el consumo de fuerza motriz más pequeño. Ha de tomar en consideración muchos factores cuyo efecto no se hace evidente hasta que el arte está en funcionamiento, situación que, por no poder observarla, ha de tratar de adivinarla. Pero en la mayoria de los casos esos factores causan deformaciones de las mallas de los paños o dejan otras señales que sólo se hacen evidentes cuando el arte está trabajando o cuando se ha usado la red durante aigún tiempo. Trata el autor de la reacción a la tensión y tracción a que está sometida la red y subraya que, con mucha frecuencia, una tensión puede neutralizarse ajustando el montaje en el punto donde ocurre. Menciona también el efecto que el coeficiente de colgadura, las costuras de los paños y la manera de cortarlos ejercen en el arte.

A FEW decades ago the construction of fishing nets, from the braiding of the webbing to the assembly of the whole gear was the task of the fishermen themselves. The boat owner was only interested in the cost and, in many cases, the fishermen had to help pay for the gear or even owned a part of it. In the driftnet and line fisheries, for instance, each fisherman owned a certain number of the nets that went to make up the set. The cost of materials was high in relation to earnings from the catch and very often more consideration was given to the price and durability of the material than to its catchability and efficiency as a part of the gear.

The operating range of the vessels was small and the nets used were largely the same for each home port as the gear was adjusted to the fishing conditions prevailing on the grounds within reach of that port. Large differences were, however, to be noted between different fishing areas, in boats, in gear and even in the type of operation.

The use of larger vessels, engine power and better material has brought many changes; fishing gear is now constructed to give a high degree of efficiency in a certain fishing method over a much greater range of grounds. Higher speeds of operation, with resulting higher strains on the nets, and the use of new materials and improved methods of netmaking, have brought changes to net manufacture. While the cost of material in relation to returns from the catch has decreased, the cost of labour has increased and the new non-rotting fibres have made preservative treatment practically unnecessary, so that the conditions governing the cost of fishing gear are now totally different. Today the nets are increasingly planned and constructed ashore and the fishermen are relying more and more on the netmaker to make and improve his gear.

Although some observations of gear in action have been made by frogmen and results are being obtained by underwater television, the netmaker himself does not normally see how the net he has made, functions. He still has to evaluate the performance of the net by interpreting various telltale signs which are only apparent when the net is back on board, such as localized tightening of knots, deformation of meshes, gilling of fish, wear on knots, etc. Many of these signs only become apparent after some time so that the fisherman must still, as of old, keep his gear under close observation. His criticisms and suggestions, based on such observations, are of the greatest help to the netmaker.

GENERAL

When making a new design, the aim of the netmaker is to produce a net which will give the largest catching potential for the smallest cost in materials and the least energy output. Depending on the type of gear, many different factors have to be taken into account, such as resilience of webbing, strength and elasticity, resistance to flow of water, weight and bulk, speed of operation, cost of materials, condition of fishing ground, etc. However, in most cases, the most important factor is the shape the completed net will take when in action.

Gillnets and trammel nets need no fashioning as their shape in operation is determined by the looseness given to the webbing when it is hung between the float- and leadlines. This not only determines the opening of the meshes but also the resilience and the bulge the webbing can take during certain types of operation. The amount of resilience given to these nets differs according to the type of operation, the net height and fish species to be caught. It is regulated by the amount of, and relation, between, the buoyancy and weight of floats and sinkers.

A certain amount of shaping is necessary during the construction of roundhaul nets to give the webbing its bulge during operation and to take up the various strains on the webbing during shooting and hauling. This is achieved partly by using the appropriate hang-in coefficient but mainly by adjustment of take-up and/or tuck-in between the strips of webbing that go to compose the complete net. With trawl nets and other types of bagnets, the netmaker has to tailor the webbing to make individual net sections fit the curve of the lines to which they are hung and to obtain the required bagshape. The problem here is made more difficult by the fact that in some cases the operational conditions are liable to change; variation in resistance, or drag due to change in the flow of water through the net, influence the performance of the whole gear. Points and direction of forces acting on the net may change, with a resulting change in the shape of the net in operation.

The strains on the net must be spread as evenly as possible and, in general, should be across the knots. The twine must everywhere be strong enough to withstand the strains acting upon it, yet, on the other hand, its weight, resistance to flow of water and cost have to be taken into account.

In the case of gillnets, the mesh size must be appropriate for gilling and/or entangling the particular fish species caught; with other nets, it must prevent such gilling. When deciding on the mesh size for bagnets, the netmaker has to take into consideration, apart from the resistance, the water release so as prevent "whirling" or backwash within the net.

Apart from the above considerations, which are connected with the catchability of the net, the netmaker has to give thought to the handling of the net during the shooting and hauling operations. For instance, very fine twines may make hauling difficult and too much loose webbing may slow down the speed of operation as in the case of roundhaul nets.

There is no such thing as an ideal net. All nets are a compromise to fit a certain set or collection of fishing conditions; all are subject to controversy, being praised by some fishermen and condemned by others. Much depends, of course, on how the net is used, both as to assembly of the net to other gear parts and the skill with which it is operated. A well constructed net may give unsatisfactory results because of defective auxiliary gear, such as floats and kites, sinkers and anchors, trawl boards, etc. All such gear must be of the right type and fitted in the correct position; they help the net to take its correct shape in operation and are therefore as important as the net itself. The fisherman must realize that he can only get maximum efficiency from a given net if he uses it under the conditions and in the manner for which it was constructed. Finally, much can be done to adapt a net to the conditions prevailing, if the netmaker is made aware of those conditions.

STRAINS AND STRESSES

Although certain studies have been made on the forces acting on the webbing of a net, most netmakers still use empirical values when planning and constructing new nets. There is a complex stress-strain reaction in webbing, very much like that in an elastic fabric, i.e. it elongates in the direction and at the point of stress, while contracting in the lateral direction. In fact, the webbing takes up a part of the stress by yielding to it.

The deformation of webbing due to a stress acting on it depends on the position of the stress point in relation to the whole net and the magnitude and the direction of the stress. Normally the stress acts "across the knots" and in that direction a small strain will be taken up completely by the partial closing of the meshes directly below the point of stress. Larger stresses will cause an increased strain reaction along the "halvers" until the selvedge is reached. Further increase of strain will result in a lateral closing of the webbing section.

The amount of reaction to a given stress in influenced by the hang-in coefficient and the mesh size, increasing as these values increase. In general, individual stresses cause positive strain reaction in the area of webbing enclosed by those halvers which run out from the point of stress; the meshes along these lines are opened and the knots tend to slip, while directly under the point of stress the meshes are closed and elongated. Above the "halver" lines, the webbing is loose and the area of loose webbing is in proportion to half the area under stress.

When considering the effect of the direction of strains

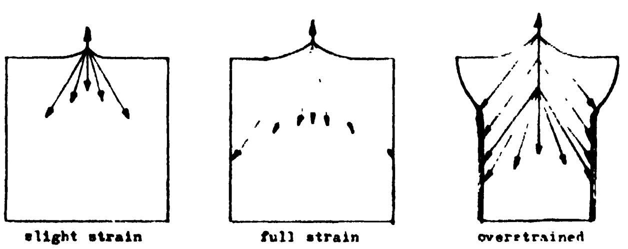

Fig. 1. Effect of stress on webbing.

and forces acting on webbing, it can be said that the more the strain acts out of the vertical (across the knots), the easier the webbing will give to the strain, but the more deformation it will cause. The only remedy for diagonal stresses is the use of tension lines to take up the strain. An important fact is that, by proper adjustment of the hanging in stress points, the stress can be neutralized to a certain extent. This is done by allowing the meshes to elongate by close hanging at the point of stress, thereby spreading the strain.

For the rational design of fishing nets and, in particular, of trawl nets, more accurate knowledge of the stress-strain behaviour in webbing is needed to counteract the deformation it causes to the shape of the net and weaknesses which arises from it. This could well be a subject of practical research at one of the Research Institutes.

Because of this yielding characteristic of webbing it is difficult to foresee the actual shape of a new designed net. However, to the experienced netmaker, the condition of a used net gives much indication on its behaviour in operation; the tightening of knots below stress points, the swelling of twine in slack parts, the deformation of meshes, accumulation of scrap, wear on the knots, etc., all help to form a picture of the net's performance and its shape in action.

HANGING OF WEBBING

The correct hanging of the webbing to the framing or supporting lines is an important factor in all nets. At present there are two methods in use for expressing the hanging coefficient and this causes confusion when constructing nets from a plan. The first is to express the length of the line, to which the webbing is hung, in a percentage of the total stretched webbing:

$$\frac{\text{length of line} \quad 100}{\text{length of stretched webbing}} = \text{per cent. of hanging}$$

The second method is to express the amount of excess or loose webbing (total webbing minus line length) as a percentage of the total webbing:

$$\frac{\text{excess webbing} \times 100}{\text{total webbing}} = \text{per cent. of hang-in}$$

Both are reciprocal values, but as the second expression gives a direct proportion of the looseness or resilience in the net, this would appear to be the most logical for expressing the hanging coefficient of nets. Taking the stretched mesh as unity, the following table gives the theoretical data on the meshes for different hang-in coefficients. It is clear that the mesh height, for instance, will depend to a certain extent on the strains acting on the webbing.

The resilience of a section of webbing is determined by the forces acting on it. With low strains, however, the hang-in coefficient has a big influence so that when hung squared, webbing has its greatest area but least flexibility. With increasing hang-in, it becomes looser in the lateral direction, whereas with less than 28 per cent. of hang-in the webbing has a certain vertical springiness.

In gillnets and entangle nets the hang-in determines the looseness of the net, true gillnets being usually hung somewhat tighter than entangle nets. The resilience

Hang-in or Looseness per cent.	*Ratio of line to webbing per cent.*	*Angle of mesh*	*Height of mesh*	*Width of mesh*	*Filtering coefficient (area of mesh)*
10	90	128 20′	0·436	0·90	0·785
12	88	123 20′	0·475	0·88	0·836
14	86	118 40′	0·510	0·86	0·877
16	84	114 20′	0·542	0·84	0·911
18	82	110 10′	0·572	0·82	0·938
20	80	106 20′	0·599	0·80	0·958
22	78	102 40′	0·626	0·78	0·975
24	76	99 - -	0·649	0·76	0·986
26	74	95 30′	0·672	0·74	0·991
28	72	92 10′	0·693	0·72	0·998
30	70	89 —	0·713	0·70	0·998
32	68	85 40′	0·733	0·68	0·997
34	66	82 40′	0·751	0·66	0·991
36	64	79 30′	0·768	0·64	0·983
38	62	76 40′	0·784	0·62	0·972
40	60	73 40	0·801	0·60	0·961
42	58	70 50′	0·815	0·58	0·945
44	56	66 10′	0·829	0·56	0·928
46	54	65 20′	0·842	0·54	0·909
48	52	62 40′	0·854	0·52	0·888
50	50	60 —	0·866	0·50	0·866
52	48	57 20′	0·877	0·48	0 842
54	46	54 50′	0·888	0·46	0·817
56	44	52 10′	0·898	0 44	0·790
58	42	49 40′	0·907	0·42	0·762
60	40	47 10′	0·916	0·40	0·733
62	38	44 40′	0·925	0·38	0·703
64	36	42 10′	0·933	0·36	0·672
66	34	39 50′	0·940	0·34	0·639
68	32	37 20′	0·947	0·32	0·606
70	30	34 50′	0·954	0·30	0·572

and fishing height of these nets is, of course, largely influenced by the amount of sinker weight on buoyed-up nets, and the amount of buoyancy on bottom operating nets, which produces the strain in the webbing.

In roundhaul nets, the hang-in is adjusted to give depth and bulge during operation; in the wings, however, it is often curtailed as too much webbing affects the speed of operation.

With trawl nets, the hang-in to be given to wings, quarters and bosom, depends on the general shape and the cut of the sections of the net. It is difficult to determine accurately, and is usually based on previous experience and experimenting. It is, therefore, most important that the amount of hang-in on wings, quarters and bosom is denoted on trawlnet plans.

The fastening of the webbing to the lines is done in different ways according to the gear. The main requirement is to ensure that the hanging cannot shift over the line or become loose once the net is hung. The net-line hitch and rolling hitch are about the best knots to use when making hangings to carry two or more meshes. The clove hitch is to be discouraged unless locked by an additional half hitch, as it tends to become loose. In most cases, it is better to use a rather heavy twine for the hangings as it reduces wear on, and cutting of, the selvedge meshes. When the nets are hauled mechanically, it is best to keep the hangings rather short to avoid snagging while in operation.

The backhand marline hitch is still the most secure for rigid fixing of the webbing to the lines, but is also the most time-consuming to make. It has the further disadvantage of requiring renewal every time the selvedge meshes need repairing.

JOINING OF WEBBING

When sections of webbing of the same width are joined together, the angle of the meshes in both sections is the same. When the width of the sections differs, the angle of the meshes in the widest section will be smaller, so that this piece will have more hang-in and, by the same token, less lateral strain. Several combinations are possible and each is applied according to the purpose of the joint:

(a) the sections have the same width but different mesh size

(b) the sections have the same mesh size but differ in width

(c) the sections differ both in width and mesh size.

The first is a simple joint between sections of different mesh size and the take-up meshes are inserted at suitable intervals. It is, however, advisable to allow the large strip a little extra width to enable it to expand fully during operation.

In the cases of (b) and (c) the greater width of one of the sections is given to allow the webbing freedom to bulge out laterally, as in the case of roundhaul nets and some types of bagnets. Under (c) is included the special case where, although both width and mesh size differ, the sections are joined mesh to mesh, which is very common in trawl nets. It must be borne in mind that in the above case the effect is more a narrowing of the wide section instead of bulging. It results in the wider webbing section reacting as if it were baited at a faster rate; this, at the same time, helps to shift the stress towards the side or selvedge of the complete section.

In small-mesh webbing, it is better to make the take-ups by creases rather than by baitings, especially in the case of joining two sections of equal width, as the baitings tend to form a contraction in the row they are made, which causes slipping of knots.

Where a tuck-in is needed in the lacing of vertical strips of webbing because of difference in depth or mesh size, the tucks should be made by half meshes or legs, rather than by full meshes. Full mesh tucks form strain points in the webbing, which soon become holes.

In calculating the width of the sections to be joined, the take-up or tuck-in rate should be rounded off to allow for an easy sequence. This not only facilitates the actual work of joining but allows the sequence to be expressed in a simple fraction form such as 5/6, for example, meaning 6 meshes are joined to 5, or one take-up every fifth mesh. Simple take-up sequences are, furthermore, easy to replace in mending and when new webbing sections have to be inserted during overhauling of nets.

TAILORING OF WEBBING

All bagnets need fashioning, either by braiding them in the round, with baitings inserted at appropriate intervals, or by assembly of shaped webbing sections. With the latter method, the sections can be braided to shape or they can be cut to shape from machine-made strips of webbing. Theoretically, it is possible to cut or braid webbing to any shape; in practice, however, all shapes are obtained by decreasing the width of sections at certain baiting rates, as curves give rise to many difficulties both in construction and in mounting the webbing to its supporting lines. Curves, therefore, are always made by a series of straight lines, each at a different angle to the vertical or "across the knots" direction.

When drawing plans of nets, it is best to use a "1 to 2" ratio, i.e. all width measurements are drawn in as half values while heights are drawn to full value. It would be helpful when comparing net designs, if such a ratio could be adopted by all netmakers, as a comparable picture of the general net shape would then be apparent at a glance. Apart from representing a fair mesh opening, 53 degrees or about 56 per cent. hang-in, this ratio gives a fair picture of the net shape and has the advantage of being easy to work with on the drawing board. Furthermore, with this ratio the baiting rates can be taken directly from the drawings as they are equivalent to the cotangents of their angle of slope to the vertical. The angle of these slopes increases with the baiting ratio and fig. 2 shows the slopes of the most frequently used baiting ratios and illustrates the equivalent cutting rates.

In some net sections, a faster slope is necessary to fit the slope of curving supporting lines as, for instance, at the quarterpoints where the wings join the bosom in trawlnets. In such cases, the slope can be increased by inserting baitings under the selvedge of the wing which, by reason of its fly meshes, already has a slope of 1 : 2.

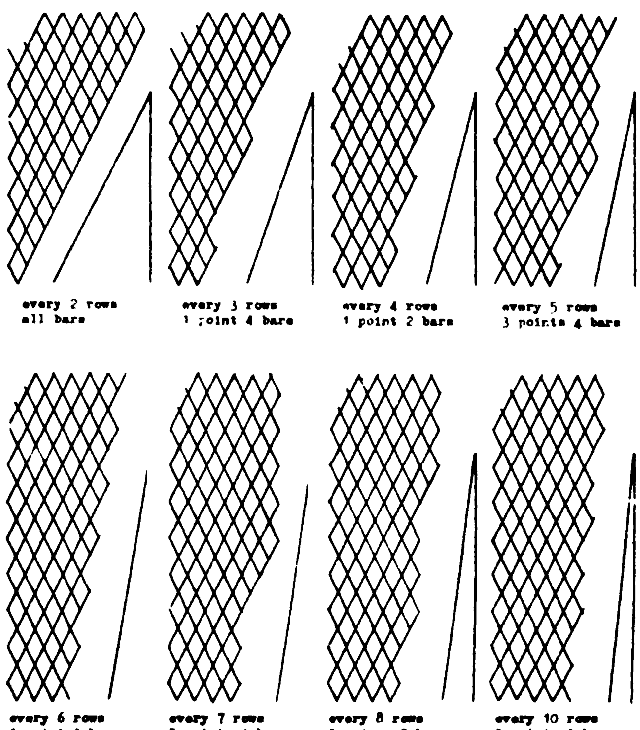

Fig. 2. Slope and cutting ratios of most frequently used baiting rates.

The additional baitings cause a localized closing of the meshes and a consequently greater height, which allows the selvedge to stand further off.

Where desired, the meshes can be kept lower down at the normal opening by inserting creases to equalize the number of meshes.

When considering the dimensions of new nets, it is always better to overestimate the width the net will have in action; this is especially true of all types of trawl nets. Too high assessment of the opening width of a trawlnet may result in the use of too much webbing, but the net will still operate properly and catch fish. Underestimating the width at the trawl mouth, however, will cause a change in the whole shape of the net. When the wings are pulled further open than calculated, the bosom is pulled forward while the sideseams fall back; this causes a contraction in the webbing of the throat with resultant bad water release. It may even lead to the cod-end turning over.

This desirability to over- rather than under-estimate net width does not mean that it is better to choose a bigger net, but that careful consideration should be given to the amount of webbing to be allowed to a headline. Indeed, where it is a question of the *size* of net to be used by a certain vessel the contrary is true: it is always better to under-estimate.

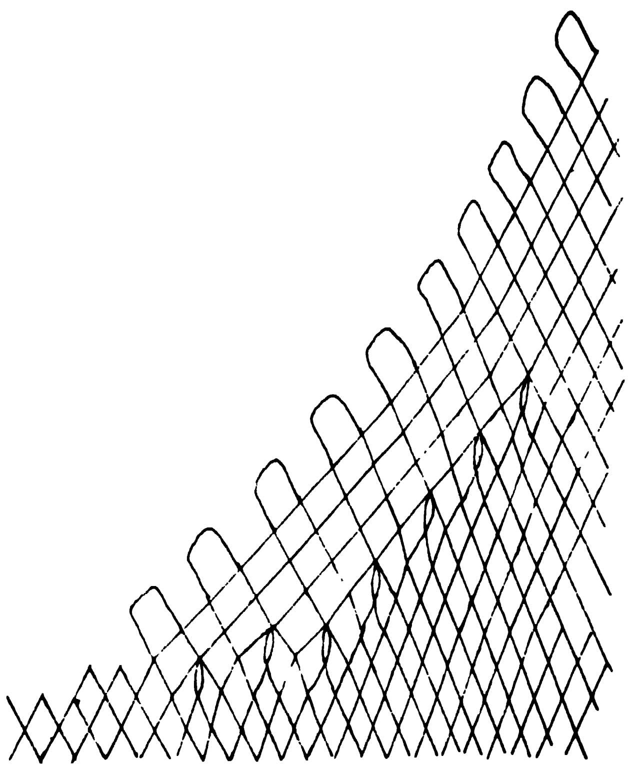

Fig. 3. Double baiting at the quarterpoints.

Net sections being braided by hand.

THE KNOTLESS NET

by

THE NIPPON SEIMO CO. LTD.

Tokyo, Japan

Abstract

This method of making nets was invented in 1922 by the Nippon Seimo Co. Ltd., in Japan and it is becoming increasingly popular in the fisheries of that country. It has many advantages; the meshes are not distorted under strain, and because of the absence of knots, less material is needed with a consequent saving of weight and bulk.

The paper describes the manufacture of these nets and shows how easily they can be repaired.

Le filet sans noeuds

Résumé

Cette ingénieuse méthode de fabrication des filets a été inventée en 1922 par la Nippon Seimo Co. Ltd., au Japon, et ce filet connait une vogue de plus en plus grande dans les pêches de ce pays. Il comporte de nombreux avantages; les mailles ne se déforment pas sous la tension et, du fait de l'absence de noeuds, la fabrication exige moins de matière première, d'où économie de poids et moindre encombrement.

L'article décrit la fabrication de ces filets et montre combien leur réparation est facile.

La red sin nudos

Extracto

En las pesquerias del Japón va aumentando la popularidad de un ingenioso método para fabricar redes, ideado en 1922 por la Nippon Seimo Co. Ltd., de ese país. Entre las diversas ventajas de este procedimiento figuran el hecho de que las mallas no se deforman con la tensión y la ausencia de nudos; además, se utiliza menos material con la consiguiente economía de peso y volumen.

En el trabajo original se describe la fabricación de estras redes y demuestra la facilidad con que pueden repararse.

THE knotless net was invented in 1922 by the Nippon Seimo Co. Ltd. (Japan Fishing Net Manufacturing Co.). In this type of webbing the twines are joined at the mesh corners by an interlacing of the two twine strands. Knotless nets did not come into general use while only natural fibres were available, but followed with the development of rotproof synthetic fibres and their increased use for fishing nets. Now this type of webbing is rapidly becoming popular for several kinds of nets.

SPECIAL ADVANTAGES

The rapid change-over to knotless nets in Japan is chiefly due to the following special features, of which the most important are:

Less weight and bulk

Less twine is used to make the meshes which, in some cases, can mean a saving of as much as 50 per cent. of the raw material. As there are no knots, the bulk of the net is greatly reduced.

Higher strength

When knotted, twines of natural fibres lose about 18 to 20 per cent. in strength. The loss is often higher with synthetic fibres and may reach 30 to 40 per cent.

As the fibres undergo practically no sharp bending in knotless nets, there is no reduction in strength so that a correspondingly lighter twine can be used.

Less resistance in water

The aggregate resistance of the knots in a traditional net is considerable and becomes an important factor in the use of nets which are towed or set in a current. The resistance of knotless nets is very much less.

Easier to handle—less friction

As there is no knot friction, the net can be hauled over the ship's side with less effort, so that the net can be lifted even during a change of current without danger of becoming fouled. During shooting, the net runs out much smoother as there is no inter-knot friction.

Less labour and smaller tackle required

As the whole net is lighter and less bulky, time and labour is saved and tackle can be lighter, factors leading to a saving in manpower.

No wearing away of knots

The damage caused by abrasion of knots in the belly of trawls, and other nets which are dragged over the sea bottom, is well known. In other types of nets the knots are worn away during operation by rubbing against the ship's side, net rollers or other gear parts.

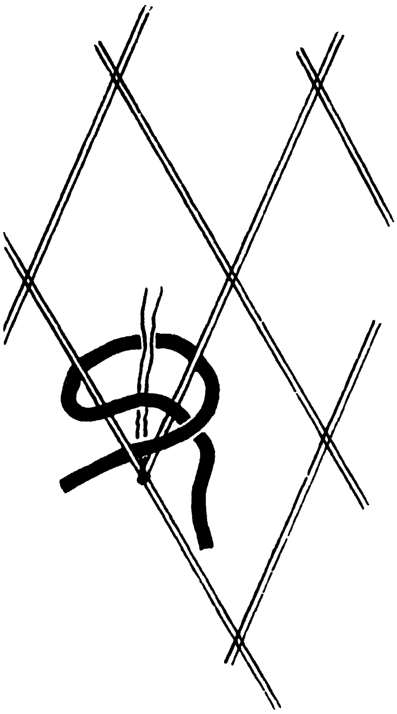

Fig. 1. Starting.

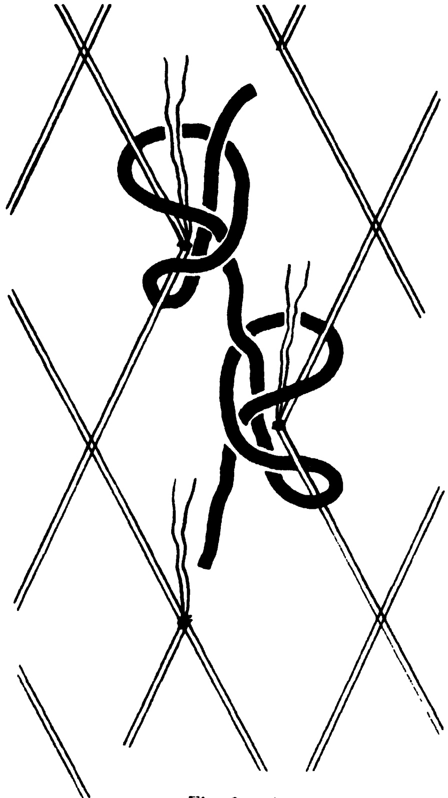

Fig. 2. Joining.

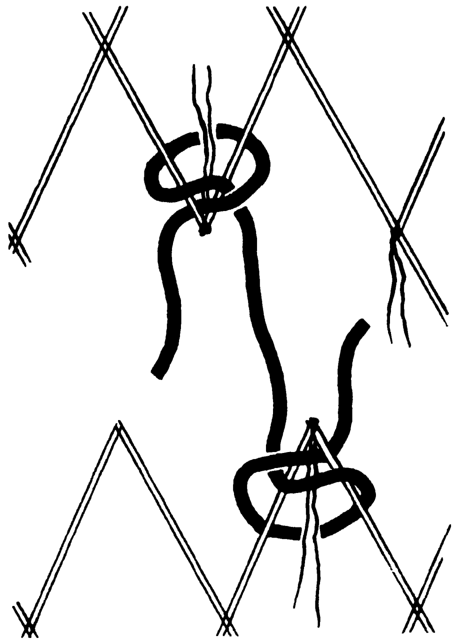

Fig. 3. Pick-up.

With synthetic fibres, which are rotproof, knotwear is very important as it shortens the useful life of the net.

Knotless nets, having no such "points" of wear, should last longer than knotted nets.

No damage to catch

When fish are collected in codends and bags of purse seines, many are damaged by rubbing and friction against the meshes. With knotless nets such damage is considerably reduced, which affects the quality of the catch.

Constant mesh size

Because there is no tightening of knots, as in knotted nets, the meshes undergo no change so that the mesh size of a knotless net is almost 100 per cent. constant throughout its life.

Easy to dye

Having no knots, the nets can be dyed more easily and completely. The absence of knots and the smaller bulk also means that less dyeing material is used and the nets dry quicker.

Less liable to fouling

There can be no deposit of dirt and micro-organisms between the interstices of knots, so that knotless nets are much less fouled and need less washing.

MENDING OF KNOTLESS NETS

When knotless nets were first introduced, the fishermen were anxious about the mending of them. In fact, torn parts are mended as easily as in knotted nets. The only difference is that, when starting, the mending twine should be attached from one mesh outside and all ends of torn meshes should be bent back within the mending knot, as shown in figs. 1, 2 and 3.

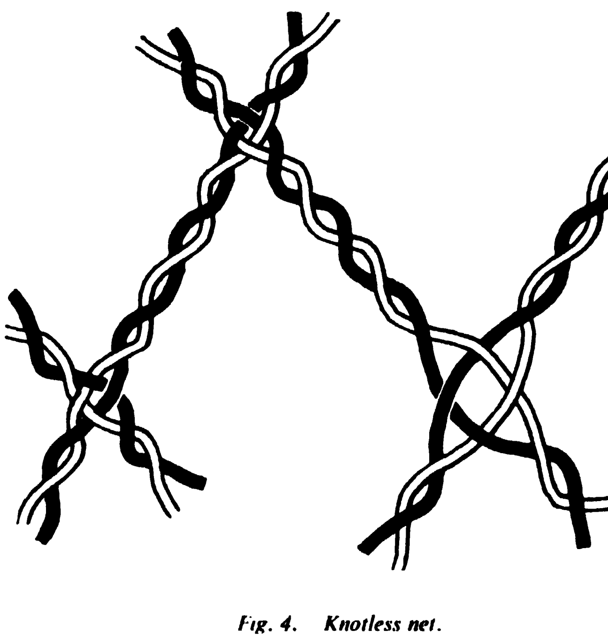

Fig. 4. Knotless net.

METHOD OF MANUFACTURE

The knotless net is manufactured in two stages. In the first stage the twine is prepared by doubling the appropriate number of single yarns together and then twisting two or more of such yarns into strands with a "Z" twist. The strand thus obtained is wound on the bobbins of the net making machine.

In the net making stage two such bobbins are attached to both sides of a special flat spindle. Turns of the spindle insert in the twine a second twisting operation in an "S" direction. When the necessary number of twists are made, the two bobbins move and exchange places with two neighbouring bobbins and the point of intersection of twine, which corresponds to a "knot" in the knotted net, is made accordingly.

The construction of a "knot" is shown in the diagram (fig. 4).

Strands of both twines run across and through each other, and are twisted in opposite directions as shown. Thus a "knot" or intersection is made.

The twine in the knotless net has an "S" twist of two strands.

The webbing is examined, flaws and/or irregular twists are corrected and each web section is then completed by weaving on the top and bottom selvedges.

Any size of web section can be made to suit different types of gear.

The nets are heat-set so that the twist of the strands is fixed permanently. During this operation the tensile strength of the twine increases by about 15 per cent. By adjusting the process, the flexibility of the twines can be modified to suit particular purposes. Hard fibres can be made softer and soft fibres stiffened.

The heat setting process is necessary for nets of filament yarns such as nylon, Krehalon and Saran (vinylidene), Teviron (polyvinylchloride) and Kuralon 5 but not for cotton, Kuralon (vinylon) and the other spun yarns.

With the exception of materials belonging to the polyvinylchloride group, such as Krehalon and Saran, the nets made of nylon, Kuralon, etc. can be dyed with commercial dyes, pigment colours or coal tar. Heat setting is not generally required when coal tar is used.

Stacking a beach seine after a haul in Ceylon. Photo FAO.

DISCUSSION ON RATIONAL MANUFACTURING OF FISHING GEAR

Mr. H. Warncke (Germany)- Rapporteur: Our problem is now to produce machine-made webbing on a more rational basis and so reduce costs. This aim could be achieved by:

1. Greater uniformity and standardization of net types, and of the assembling components, which would gradually bring stock-carrying risks of manufacturers and dealers to a minimum;
2. A reasonable limitation of types of synthetic materials;
3. A general exchange of information on net-making problems.

Some progress has been achieved towards such a standardization by the fishermen and gear technicians. This is illustrated by Barraclough and Needler in their description of the construction of a midwater trawl for a 62 ft. 175 h.p. trawler equipped with typical British Columbia gear and deck layout, and by du Plessis who describes the South African Pursed Lampara. These two examples show that by careful consideration of the many factors, fishing nets can be restricted to a few types. Standardization must, however, be based on scientific study and practical experience.

The papers presented indicate that synthetic materials are becoming increasingly important to the fishing industry. It appears, however, that a fibre well suited for some types of net and gear lacks certain qualities for others. The net manufacturer must therefore produce and stock many types of gear in order to satisfy the requirements of the fishermen. A limitation in this ever increasing variety would enable the net manufacturer to reduce his stock-carrying overheads to a reasonable level, and so reduce production costs.

It was recommended that net manufacturers should exchange information so as to arrive at more rational production. However, owing to the big differences in production conditions between countries, created by subsidies, import rules, etc., most manufacturers would at present be reluctant to agree to such exchange as it would interfere with business competition.

It would seem, therefore, that the most likely methods of achieving rationalization are:

(a) Limitation of mesh-sizes to a standard set of sizes, together with a standard method of measurement. This would reduce the need for frequent adjustments to the net-making machines and allow for simplifications in their construction;

(b) limitation of sizes and twists of twines. For instance, the denier system counts that are at present in production, should be sufficient to supply all the required sizes of twines. The number of different twists and plies could probably be reduced without disadvantage to the fishing industry.

Such rationalization could be discussed by working groups formed of representatives of all parties concerned.

Problems of more general interest which might be considered are:

(a) Does dyeing really provide sufficient protection to the synthetic fibres against decay through exposure to ultra-violet rays, as seems to be widely accepted? Recommendations concerning the appropriate methods of dying synthetics are often difficult to interpret. Such recommendations should be consistent with the limited dyeing facilities of the fishermen.

(b) Which is the appropriate size of synthetic twines used in place of natural fibres? To replace 210/6 ply and coarser twines, synthetic fibres, 25 per cent. lighter in weight, are generally chosen. For finer twines, the criterion is the same running length as the natural fibre. This would mean that, in some cases, the main advantage of synthetics, i.e. their higher tensile strength, is not fully utilized and unnecessarily strong and heavy twines are used.

The Nippon Seimo Co. Ltd. deal with the construction of knotless nets designed and developed in Japan. They report that such nets, constructed of 2 strand twine, suffer no loss in strength, whereas natural fibres lose from 18 per cent. to 20 per cent. and synthetic fibres from 30 per cent. to 40 per cent. when knotted.

As the selvedges have to be woven separately, causing additional expense, it would be interesting to know if the initial financial advantage of lower weight is thus reduced? The relation between cost of production and price of material can perhaps explain why knotless webbing, which was not in demand when made of natural fibres, has increased in sales since it has been made of synthetic fibres.

Mr. D. McKee (Scotland): With regard to catering to the wishes of the fishermen, it is necessary for the manufacturers first to obtain, either from the fishermen or from fisheries management, information as to the thickness or weight by runnage of the twines or lines required.

A good illustration of this point is the fishing line situation. In inshore haddock line fishing, a man uses a line weighing approximately 1 lb./60 fm. Now he wants a synthetic line. We find the breaking strength of such a line in cotton or hemp is, say, 20 lb. The problem is—does he want a line of this strength or does he want the same thickness? Generally, in the case of light lines, the man wants the same body or feel in the new line, rather than the same strength. My firm which is mostly concerned with inshore herring fishing, gillnetting and that type of gear, has published a booklet for the industry, on the makeup of synthetic twines. This gives the dry and wet breaking strength of a cotton twine and recommended equivalent size in nylon or other synthetic twines in yds./lb., and m./kg. One omission is the breaking strength of knotted webbing, but information on this point can be obtained directly from our works. There is a certain risk in declaring breaking strengths and giving yardages as the figures depend on the testing method used. We, therefore, would claim at least 10 per cent. margin either way.

On the question of economy, I would like to quote an example. Recently, while abroad, I was confronted with general complaints about the economic failure of the fishing. Until a few years ago, the fishermen were using natural fibres and then changed to synthetics which cost double the price. When natural fibres were in use and the net got damaged, it was thrown overboard. I tried to find out how much more service they obtained from a synthetic net. I got the amazing answer—little, if any. It appeared that when the synthetic fibre net became damaged the same procedure was followed, and the net was thrown aside and not used again. It is not the part of the manufacturer to work down to economy level of that type, although successful manufacturing depends on the success of fishing.

There are many different types of mesh measurement. In Canada, for fine gillnets, you measure between knots; yet, in some parts of Canada, heavier nets are measured from the inside of one knot to the outside of another knot. The best suggestion I can make to the fisherman is to rely on the netting manufacturers, but to have a precise idea of requirements.

Mr. A. Robinson (U.K.): I fully agree with the comments made so far, particularly with those of Mr. McKee. Mr. Warncke also has made a very strong point regarding the difficulties which arise due to the large stocks which are necessary at present. My firm is essentially in the twine trade, but if the variety of sizes and special requirements can trouble us, how much more will they trouble the net manufacturer! Of course, these are difficulties inside the trade, perhaps not fully realised by the fishermen, but they have a very strong bearing indeed on the price that the fisherman is eventually asked to pay.

I also feel that the twine maker, and I am sure also the net maker, will, if only he is given full information, do all he can to help the fisherman. Net and twine factories get, daily, numerous inquiries and orders for materials, from which it is difficult to determine exactly what is required. Yet this is necessary because the customer does not have sufficient technical knowledge or information. However, if he states his problem exactly he will get reliable information in exchange.

With regard to the dyeing of synthetic fibres, nothing very definite has been proved so far as we are aware. Our tests have failed to prove that dyeing does give protection against deterioration due to sunlight.

Most firms would, I think, be willing to issue comparative lists showing the conversion from natural to synthetic fibres. We, ourselves, give such information quite freely and I believe the wet knot strength should be the criterion for such material. A comparison on any other basis, certainly so far as net twine is concerned, is apt to be misleading. At the same time, there are circumstances where other characteristics of synthetic fibres can be taken into consideration as, for instance, the greater elasticity which improves the energy absorption of the twine, quite apart from its merits as to breaking strength. It has been mentioned that synthetics may be as much as 25 per cent. lighter than natural fibres. On the basis of wet knot strength, and also taking into consideration the high tenacity yarns available today, a fairly reliable changeover to cotton can be made on the basis of a synthetic twine giving about 50 per cent. greater length per unit weight.

I would like to raise one further point, i.e. that of mutual understanding between fisheries workers all over the world. Apart from using the same standards and tests in our work, we should also be able to understand one another's writings Translation of fisheries literature is extremely difficult because of the different meanings given to the terms used in different countries and areas.

Dr. E. Hess (FAO): As you probably know, FAO has for the last 8 years been publishing the World Fisheries Abstracts in English, French and Spanish. We have, during these years accumulated quite a lot of terms and we are now in the process of preparing this material for publication as a dictionary in the three official FAO languages, English, French and Spanish, at least to begin with. The form of these dictionaries was agreed upon with UNESCO, who has done much work along similar lines.

The English dictionary will form the base and each term will have a definition. Each term is given a number and its meaning in another language can be found by simply referring to that same number in the other language part or book.

The whole field of fisheries technology will be covered, not just gear. The first section, on fish curing, is ready now The section on fishing gear and boats we hoped to have ready for this Congress, but I am sorry to say we did not get that far. We have another section on refrigeration also in an advanced stage. Before long, we hope to have this published, but will first issue a mimeographed draft and send it to as many people as we can think of in various countries for their comments. After study of these comments and necessary adjustments we will then publish in book form.

Mr. O. Aagaard (Norway): Much has been said about standardization as seen from the manufacturer's point of view. In Norway, a Standardization Committee was formed in 1930 at the request of the Fishermen's Organization. However, when the same fishermen discovered that standardization would mean that their individual taste and wishes as to twine and rope sizes, mesh sizes, etc. would be interfered with, the whole thing was dropped.

Before going over to any kind of standardization, it may be useful to hear the fishermen's opinion.

Prof. S. Takayama (Japan): About half the knotless nets used at present in Japan, i.e. 3 million lb. year, are made of synthetic fibres. All Japanese knotless nets are made of two strand twines*.

There are two types of nets based on practically the same system of connecting. In the first type the twines run diagonally through the webbing, whilst in the second type they run in a zigzag line. These different directions depend on how many times the two twines are threaded through each other

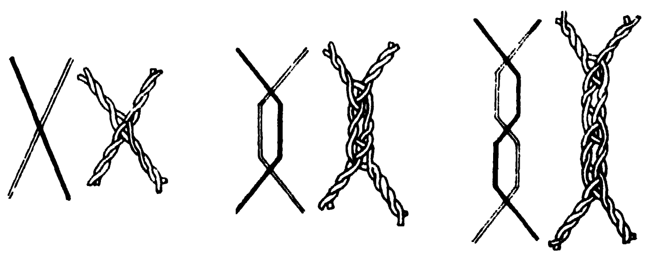

Fig. 1 Three types of joinings used in knotless nets.

* *Editor's note.* Knotless nets made of braided twine are now being manufactured and tested for instance in U.S.A. and Belgium

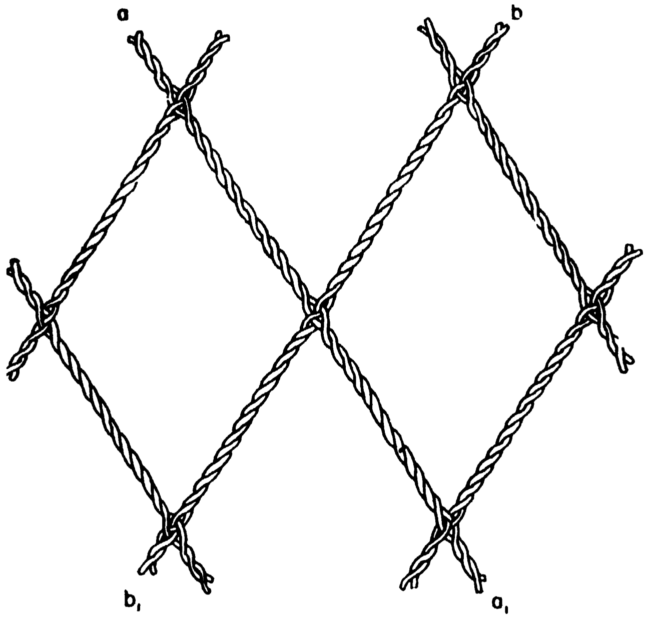

Fig. 2. Diagonally constructed knotless net.

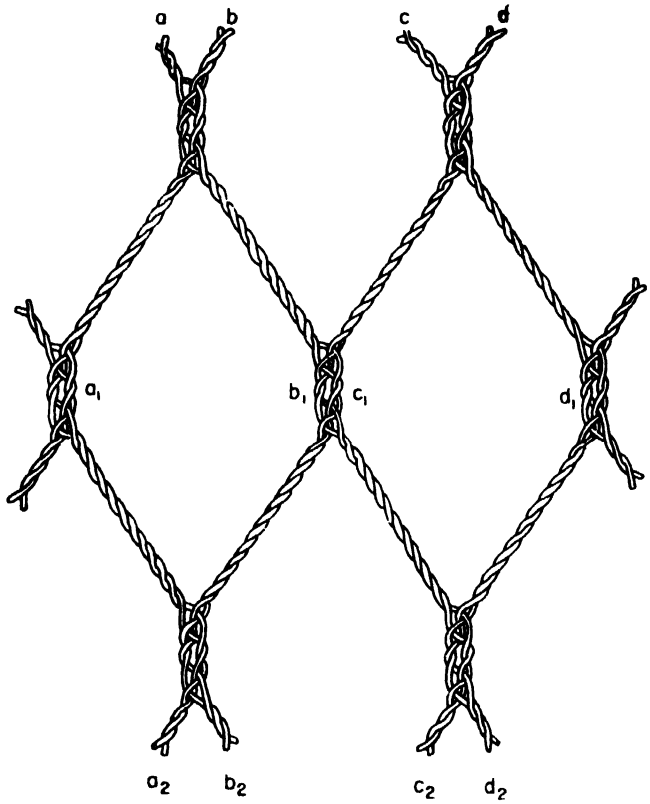

Fig. 3. Zigzag constructed knotless net.

If they pass through only once, the direction of the twines is diagonal; if they are threaded twice, the zigzag line is obtained; if they pass through three times, a diagonal is obtained, and four times again a zigzag, i.e. uneven numbers of interweaving results in diagonal twine direction and even numbers in zigzag. The number of the interweavings can be built up until a quite unusual mesh form results which could be called the tortoise type.

Knotless nets can be adapted for practically all types of gear, but until now, they are mainly used for big setnets, leader nets and gillnets.

Mr. H. Kobayashi (Japan). As regards mending tears or connecting pieces of webbing, there is no remarkable difference between knotted and knotless nets, and consequently, there are practically no additional costs with regard to selvedges. If double selvedges are needed, they must in any case be handbraided. Double selvedges can, however, be avoided simply by taking up two meshes instead of one, when hanging a net to lines. This is no longer a problem in the commercial fishery in Japan as the remarkable increase in the use of knotless nets shows.

Mr. J. Buchan (U.K.). It seems that there are two basic types of knotless nets, the "diagonal" and the "zigzag".

The twines in a webbing made with conventional double English knot, run in a zigzag line. There are two ways of testing this knot, either by pulling the two bars belonging to one continuing twine against the two bars belonging to the other twine, or by testing the two bars belonging to different twines against the opposite pair. The same two testing directions can be applied for both types of knotless net.

We have found that the conventional double English knot will give an efficiency of 54·6 per cent., that is the breaking load of the knot is 54 per cent. of the total breaking load of the two twines in the first direction, and 51 per cent. in the second. In the first type of knotless net, that is the straight cross, you get 75 per cent. and 57 per cent., but the knot will break at the weakest point, i.e. 57 per cent.

With the second type of knotless nets (that made by double inter-weaving of twine), we obtained 91 per cent. and 51 per cent., showing that the actual lowest efficiency of the knotless connection is not, in fact, better than the conventional double English knot.

Knotless nets are made in a two-fold construction, if one strand breaks, the twine can untwist, causing break in the net running, which will not happen with an ordinary webbing braided with double English knot.

Prof. A. von Brandt (Germany). The fact that not only Japan but also Russia use knotless nets to a large extent indicates to me that there must be considerable advantages. Furthermore, the gillnetting experiments we have carried out with Japanese nets in Germany gave good results. We had no difficulties with "knot" slippage and repair, for which our fishermen found an even simpler way than the one recommended by the Japanese.

In addition to what we have been told until now, I believe that knotless nets should have great value for trawl nets. The limiting factor for size of the gear or towing speed is the relation between towing power and gear resistance. Dr. Schärfe has shown how the towing resistance can be decreased by using hydrofoil otter boards and thinner synthetic twine. The smaller area of knotless nets should further decrease the towing resistance. This would be a valuable gain in addition to the savings in material resulting in lower weight.

DEVELOPMENT OF FISHING NET AND ROPE PRESERVATION IN JAPAN

by

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Abstract

This paper deals with the methods used in Japan for preserving different kinds of fishing gear. The methods which are described are as follows: (a) Sunlight disinfection; (b) Preservation by Copper Sulphate; (c) Copper Naphthenate preservation; (d) Tannin preservation; (e) Bichromate treatment after tannin; (f) Coal tar and (g) Preservation by Cyanoethylation. These processes are described in detail and a comparison of their relative efficiencies is shown in tabular form. The materials concerned in the investigation are Cotton and Abaca.

La préservation des cables et filets de pêche au Japon

Résumé

Les auteurs exposent les méthodes appliquées au Japon pour la préservation des différents types d'engins de pêche. Ces méthodes sont les suivantes: (a) desinfection par exposition aux rayons du soleil; (b) preservation par traitement au sulfate de cuivre; (c) préservation par traitement au naphténate de cuivre; (d) préservation par traitement au tanin; (e) traitement au bichromate après tannage; (e) traitement au goudron; et (g) traitement par cyanoéthylation. Les auteurs font une description détaillée de ces procédes et comparent sous forme de tableaux leurs efficacites respectives Les essais ont porté sur le coton et l'abaca.

Desarrollo de la red de arrastre y preservación de cuerdas en el Japón

Extracto

Este trabajo trata de los methodos usados en el Japón para preservar diversos tipos de artes de pesca, a saber: (a) desinfección con luz solar; (b) preservación con sulfato de cobre; (c) preservación con naftenato de cobre; (d) preservación con tanino; (e) tratamiento con dicromatos después de la entintadura mediante extractos curtientes: (f) alquitránde hulla, y (g) preservación mediante cianoetilación. Estos tratamimetos se describen en detalle y se compendia en tablas su eficacia relativa. En la investigación efectuada se estudiaron materiales de algodón y abaca

INTRODUCTION

THE various preservation methods of fishing nets and ropes may be grouped, according to their respective functions, into three categories:

1. Sterilization to destroy putrefactive bacteria, either by sunlight-drying after boiling, copper sulphate bathing, or copper naphthenate bathing.
2. Protection from bacterial putrefaction by coating the natural fibres with a film of either tannin, coal-tar or tannin and coal-tar.
3. Combination of these two methods, using copper naphthenate and coal-tar dyeing.

Most of these methods, while they are distinguished from the sun-drying in which no preservatives are used, allow the materials to be dried in the sunlight after treatment. However, the materials treated in copper sulphate bathing and the solution itself must not be exposed directly to the sunlight or air. The copper naphthenate treatment or its combination with coal-tar coating recently introduced in Japan is still in the experimental stage.

When a fisherman chooses one of these procedures, he has to consider not only the preserving effect which differs for each method but also the most suitable one for his particular type of fishing.

PRESERVATION BY STERILIZATION

Sunlight disinfection: Infectious micro-organisms cannot survive against heat or dryness, and sunlight disinfection of fishing nets, therefore, is practised all over the world, though only applicable as a supplementary method at certain intervals between fishing operations or seasons (Table 1).

Sunlight disinfection for non-dyed nets: Since colour is inseparable from dyeing for some fishing gear in Japan, non-dyed cotton nets are preferred i.e., the boat seine ("bacchi-ami") in Ise Bay, the purse seine for post larval anchovy, and the small trawl used from sailing boats ("utase-ami") in the Seto Inland Sea. The nets are simply dried in the sun or in the shade after every operation, mostly one-day trips. In addition, the nets are sterilized by periodic boiling. As this method is not very effective, the nets are liable to decay in a short period. The only alternative is to adopt white synthetic fibres and for these reasons Vinylon is now being used to some extent.

TABLE I

Specifications for Various Preservations of Fishing Nets and Ropes

Kind of preservation	*Type of gear*	*Kind of fibres*	*Formula of preservatives*	*Bath temperature (°C)*	*Time needed for bath*	*Redyeing during fishing season*	*Weight increase (%)*	*Life of nets treated (years)*
1. Copper sulphate	Small round hauls	Cotton	0·1% for dyeing bath (0·3% if sea water is used).	Normal	Several hrs.	Initial only		3-4
			0·01% for sterilizing bath (0·03% if sea water is used)	..	..	12 hrs. between trips	8	3-4
2. Copper naphthenate	Float lines, lead lines and ropes	Abaca	15·0% copper naphthenate 0·2% sterilizer 84% solvent 0·8% miscellaneous	..	10-15 min.	Once a season	12	1-2
3. Sunlight disinfection	Boat seines, and sailing trawl nets	Cotton	-	-	—	Between operations	0	
4. Tannin coating	Setnets	Cotton and abaca	3% cutch or tannin extract solution	Boiling for 2 hrs. then cooling for 12 hrs.		Once two weeks with weekly sun drying	3-5	2-3
	Round hauls and stick-held nets	Cotton	Same as above	For abaca, normally impregnate only 12 hours		Once two weeks with daily sun drying	3-5	2-3
5. Improved tannin coating	Setnets, round hauls and stick-held nets	Cotton and abaca	Apply No. 4, then fix in 1% $K_2Cr_2O_7$ or $Na_2Cr_2O_7$ bath	Normal	1-2 hrs.	Once 4 weeks for each with sun drying fortnightly	3-5	3-5
6. Coal tar coating	Trawl nets	Abaca	—	30°-40°C.	5-10 min.	Once three months	130	2
	Setnets	Cotton and abaca		30°-40°C.	5-10 min.	Once three months with sun drying monthly.	130	3-4
7. Tannin and coal tar coating	Setnets	..	Same as 4 plus 6	Same as 4 plus 6	Same as 4 plus 6	Once 5 months with tar dyeing	150	4-6
8. Resin and coal tar coating*	Setnets	..	After treating with a synthetic resin, treat with a specific coal tar	Normal	—	Same as above	150	5-6

* Commercial dye $H_1 + H_2$, for which see footnote of Table II.

Preservation by copper sulphate: In the Shizuoka and Wakayama Prefectures preservation of fishing nets by copper sulphate is more prevalent than in any other fishing community in Japan. With this treatment a life of three to four years is obtained. The nets are mostly made of cotton. They are used for sardine, anchovy, (and their post larvae called "shirasu"), mackerel and jack mackerel.

(1) **Dyeing bath:** Repeated treatment is necessary for sufficient preservation by copper sulphate solution. The dyeing bath needs the strongest concentration with 0·1 per cent. in the case of fresh water and 0·3 per cent. for sea water[1].

The net is soaked for several hours. In sea water, the copper sulphate turns to basic copper chloride. If left exposed long to the sunlight and air, this basic copper chloride would deteriorate the net. The net, therefore, has to be kept wet after the dyeing bath and put into use as soon as possible.

(2) **Sterilizing baths:** Following the dyeing bath, the net is sterilized after each fishing operation. The concentration should be 0·01 per cent. in fresh water and 0·03 per cent. in sea water. In practice, the solution for the sterilizing baths may be prepared by using the remaining solution of the dyeing bath. Copper sulphate is added according to the amount of water needed to replace that consumed. A simple method for determining the concentration of $CuSO_4$ in the serving solution has been established by Kanna and Matsumoto[2]. Soaking should last for at least several hours. The optimal length of time has not been ascertained.

(3) **Caution:** The net should always be kept wet. Do not heat the bath solution as in cutch dyeing. The solution can be prepared at ordinary temperatures in any season.

(4) **Storage:** Keep a treated net under sterilizing solution (0·005 to 0·001 per cent.) and cover it with a straw mat or canvas. When the net has to be stored in

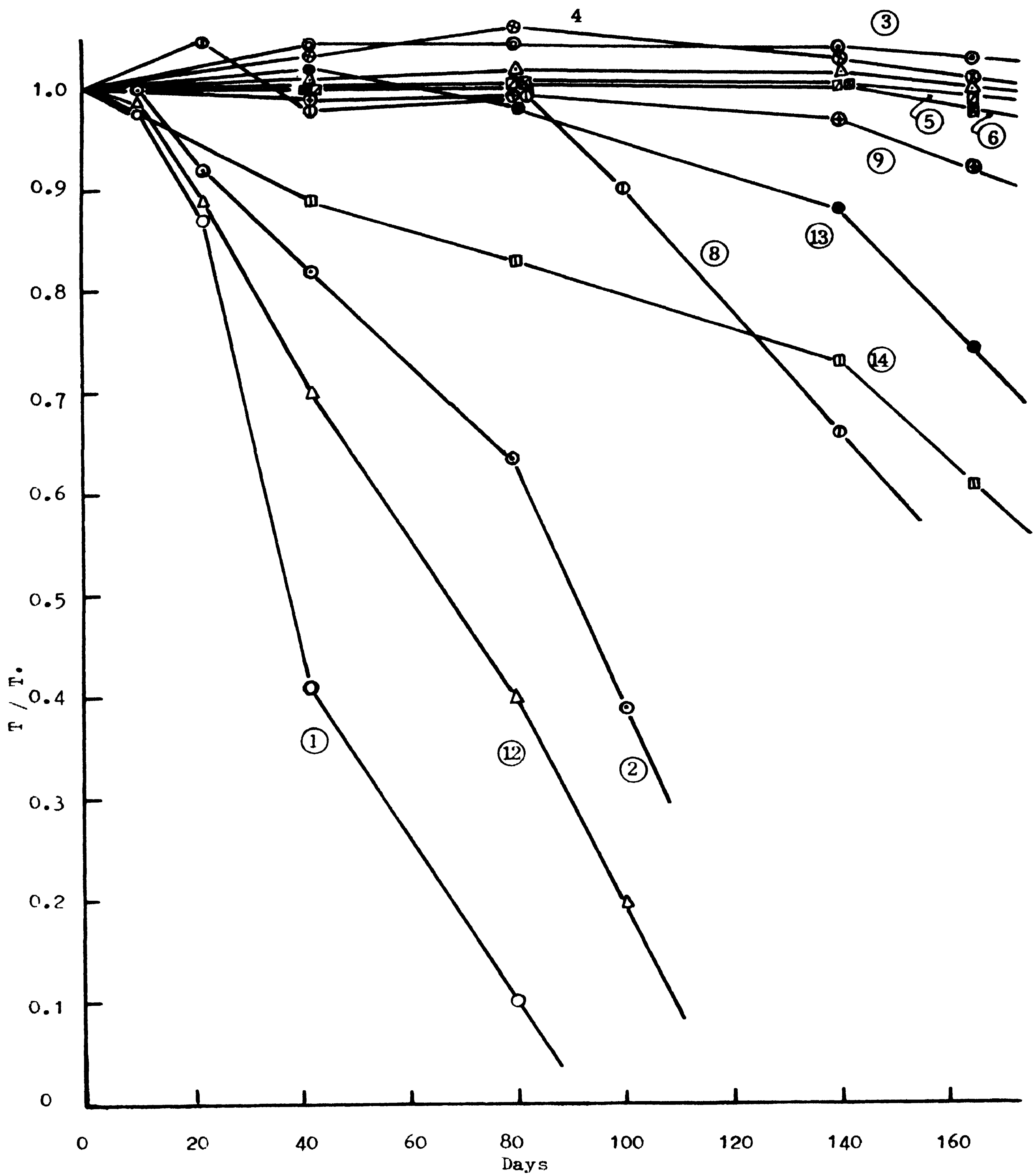

Fig. 1. Change in breaking strength of the cotton twines submerged in sea water. The test was commenced in December 1955.
T_0: Original breaking strength.
T: Breaking strength after submerging in the sea.

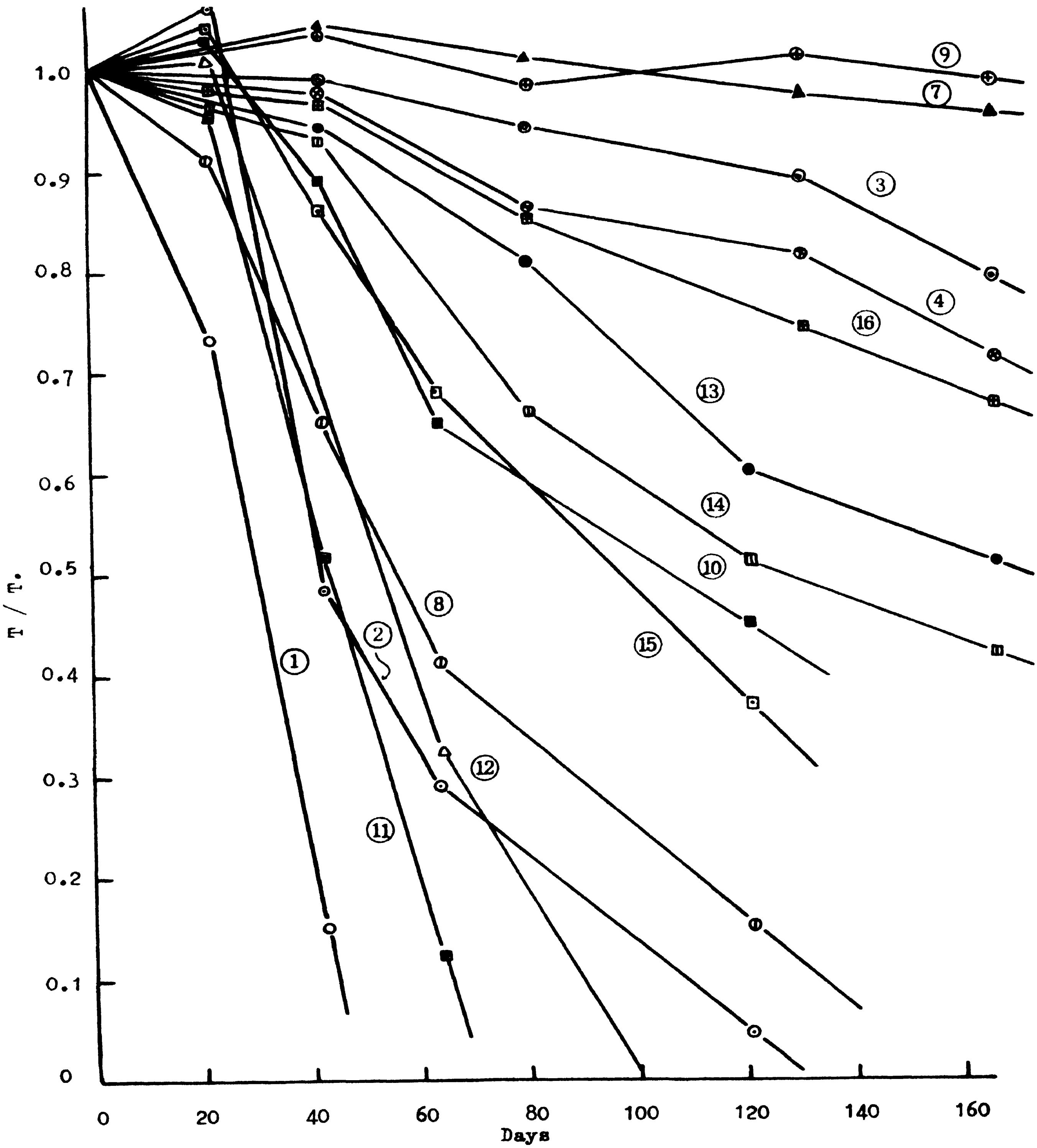

Fig. 2. Change in breaking strength of the manila twines submerged in sea water.
T.. Original breaking strength.
T. Breaking strength after submerging in the sea.

TABLE II

Specification of the Treatments shown in Figs. 1 and 2

No.	*First bath*	*Second bath*	*Third bath*
1	Cutch (3%)	—	—
2	,,	$K_2Cr_2O_7$ or $Na_2Cr_2O_7$ (1%)	—
3	,,	,, ,,	Coal Tar
4	,,	,, ,,	Coal tar (80%) Gasoline (20%
5	,,	Coal tar	
6	,,	Coal tar (80%) Gasoline (20%)	
7	H_1	H_2	
8	F_1	F_2	E_3
9	E_1		
10	B		
11	C		
12	H_1		
13	Coal tar		
14	Coal tar (80%) Gasoline (20%)		
15	D_1	D_2	
16	B	Coal tar	

H_1 contains melanin resin etc.; H_2 a kind of coal tar dye.
B contains copper naphthenate, synthetic disinfectant 3DM, etc., to be used in dyeing with vacuum compressors.
C has the same formula as B to be mixed with mineral oil when the twine is twisted.
D_1 mainly consists of cutch; and D_2, $CuSO_4$, alum, $K_2Cr_2O_7$, or $Na_2Cr_2O_7$, etc.
F_1 contains cutch, tannin, and persimmon tannin; F_2, $Na_2Cr_2O_7$, SiO_2, etc., E_3, coal tar and resins.
The trade names of commercial dyes produced by different companies. Their addresses are in possession of the authors

the air, wash out the dye residue with fresh water, if available, or otherwise with sea water. After drying in the shade, store it in a cool dark, airy place. The value of sprinkling malt over the net, as is sometimes done for storing, has not yet been confirmed.

(5) **Life of the treated net:** The net treated as above may last for more than three years, serving in every fishing season. However, one drawback is that the treatment is not applicable to those nets in continuous use in the sea or in high-sea operations.

(6) **Dyeing and preserving mechanisms:** It is understood that $CuSO_4$ in the net reacts to sea water on and between the net fibres. It first turns into a blue hydrophile colloid precipitation, viz., basic copper carbonate, which again reacting to sea water, gradually changes into basic copper chloride, a light-greenish hydrophobic crystal, which is precipitated on the fibres. Since the precipitation is not so effective against micro-organisms as $CuSO_4$, the net has to be subjected to the sterilizing bath immediately after every operation.

COPPER NAPHTHENATE PRESERVATION

Due to its high cost and the progress made in other types of dyestuffs, it was not until 1951 that copper naphthenate, as a preservative of fishing nets, attracted the attention of technologists and consumers in Japan. Excellent preserving qualities are obtained when copper naphthenate is mixed with some other sterilizers, at least in respect of abaca[3]. This dyestuff can be applied in a quick and simple way without affecting the properties of the treated net.

(1) **Treatment:** More than 90 per cent. of the copper naphthenate dye consumption in Japan consists of three different products—called A, B, C,* for the purposes of this paper.

Notwithstanding an inferior preserving effect upon cotton or ramie twines, they are used mostly in dyeing fishing ropes made of Manila and Sisal, such as float lines for driftnets. Three different treatments are used to apply these dyes for nets and ropes.

When a fisherman is about to dye his material with either A or B, the preservative is diluted at a normal temperature with kerosene, as specified for the product. After soaking for 15 to 20 minutes, the material is dried in the sun or in the shade.

In the case of net dyers and net makers, the material may be treated in an autoclave. After vacuumizing, the solution is put into the kettle, and the material is then treated at about 15 to 20 lb./sq. in. of pressure for a few minutes before being taken out for drying.

In a rope factory, copper naphthenate solution prepared as above with the mineral oil, is usually applied to the strands of twines or ropes, while they are being twisted; thus, the rope is dyed at the same time as it is manufactured.

(2) **Preserving effect:** Vacuum-compressing is likely to produce the best results of any of these methods (samples 10 and 11 in fig. 2). The first method is, however, as effective as the second, if the soaking time is more than five hours[4]. When compared with cutch treatment which is most commonly used in Japan, the effect of this preservative has been found superior, when applied to abaca, but inferior when applied to cotton or ramie (fig. 4).

(3) **Caution:** Since these preservatives are inflammable due to the kerosene used as the solvent, special care is needed. Such nets are, however, less likely to suffer damage by rats or animals during storage than nets dyed by other means. It is recommended that the concentration of the dye should secure more than 0·5 per cent. of copper to fix on the material.

(4) **Dyeing and preserving mechanisms:** In performing its function, copper naphthenate is not supposed to require chemical combination with any other element. Instead, it is precipitated on the surface of the fibres and penetrates between and inside them, destroying infectious microbes that are mainly on the surface of the material.

(5) **Trend in technological studies of the preservation:** Synthetic fibres, although used increasingly by Japanese fishermen, will not take the place of natural fibres for

* A: "Kanadem 42", composed of copper naphthenate, synthetic sterilizer, and synthetic resin acid.
B: "Ropelife", composed of copper naphthenate, organic preservative, and water-proofer.
C: "Shin Asanoha", mineral oil mixed with A or B.

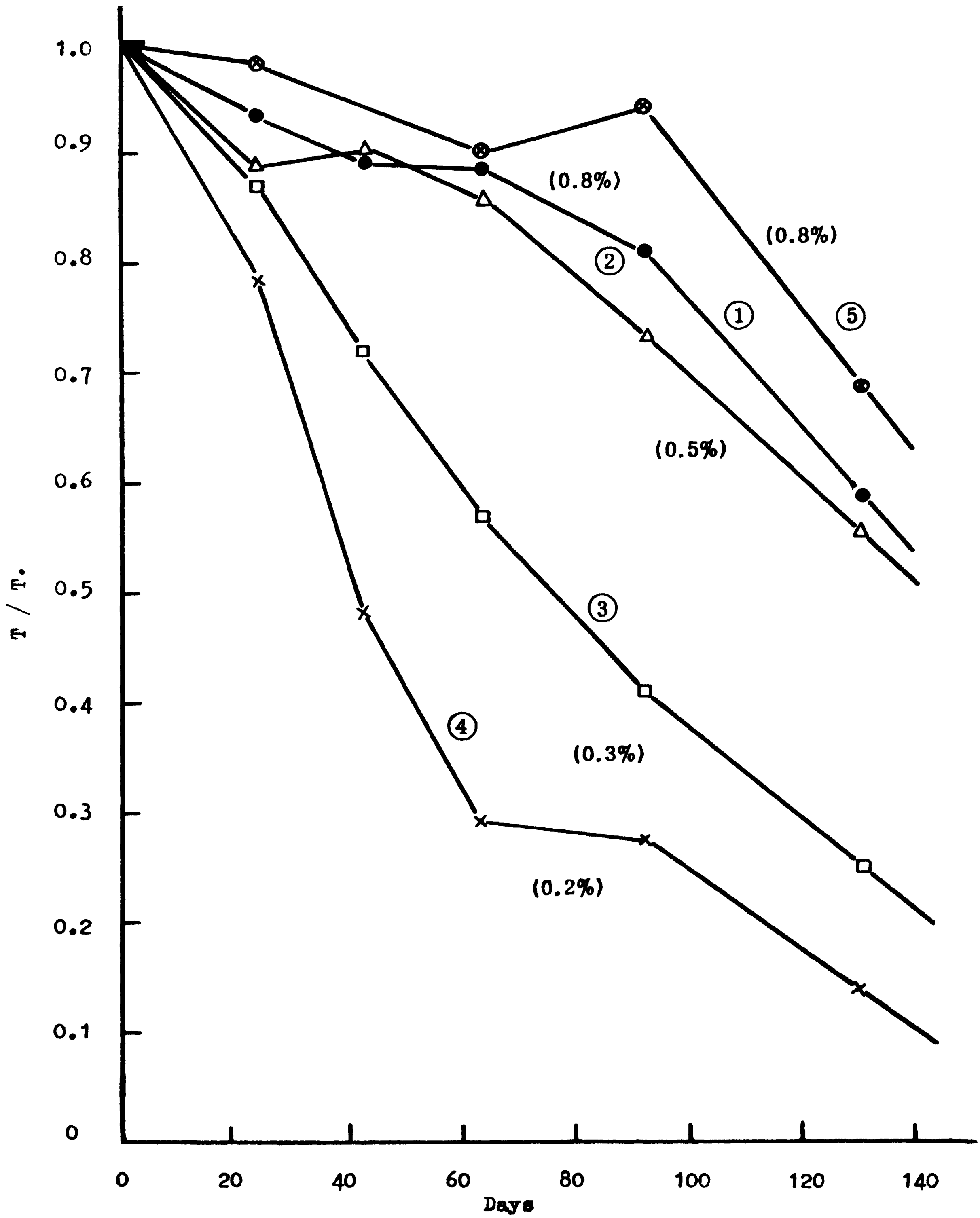

Fig. 3. Change in breaking strength of the manila twines treated with different concentrations of copper naphthenate.
T_o. Original breaking strength.
T. Breaking strength after submerging in the sea.

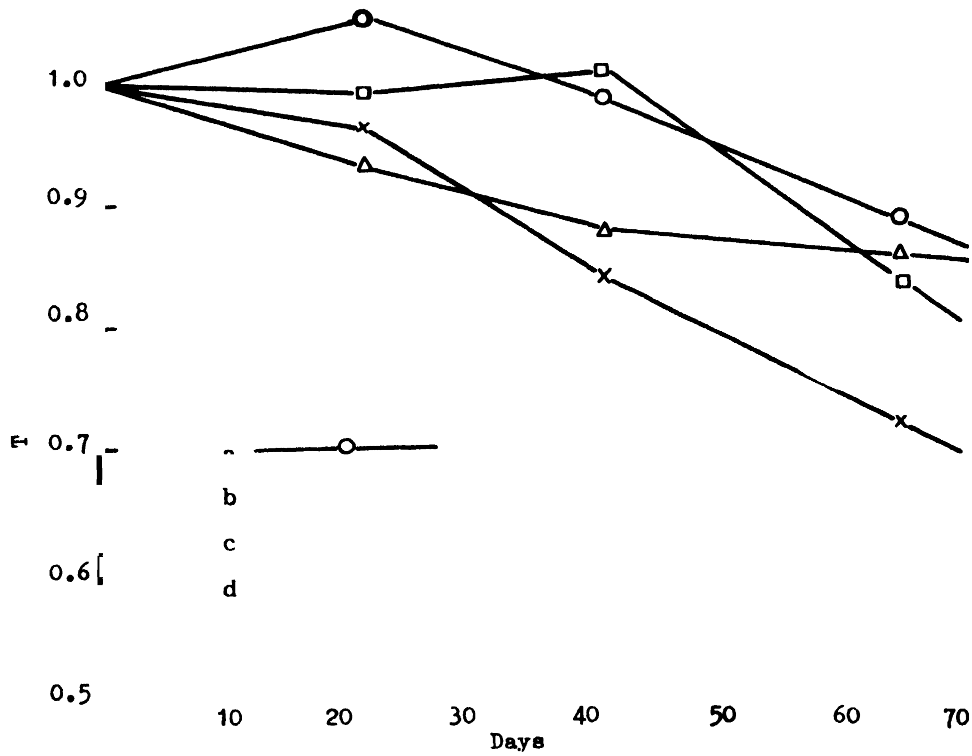

Fig. 4. Change in breaking strength of the manila twines treated with copper naphthenate dyes prepared from A each of which has different quantities of fungicidal agent.

T'. Original breaking strength.
T. Breaking strength after submerging in the sea.

some time, on account of the great difference in price, particularly between synthetic fibres and abaca, the material used for ropes and twines. For this reason, the adoption of synthetic fibres for fishing ropes has not yet made great progress. Further studies should be made on the technological aspects of copper naphthenate preservation, its application to abaca described above being an example of the work already done (samples 10, 11, figs. 2, 3 and 4).

In a recent study, twines treated in the various concentrations were submerged in sea water. The results revealed that the preserving effect depends on the concentrations as shown in fig. 3, in which the numerals enclosed in parentheses indicated the amount of precipitant, Cu.

Among the sample twines, each weighing approximately 48·7 g./m. 1, 2, and 3 were washed in running water for 5 hours, dried, then soaked for 12 hours in 40 per cent., 30 per cent. and 20 per cent. solutions of A respectively; sample 4, without washing, was soaked with 20 per cent. solution of A. The samples were then submerged in sea water for about 20 days before testing the remaining strength. As shown in fig. 3, the preservative has been found effective in the decreasing order of concentration of 40 per cent., 30 per cent., and 20 per cent. with the precipitant on the samples rating 0·8 per cent., 0·5 per cent., 0·3 per cent. and 0·2 per cent. of the copper. Certainly this is suggestive of correlationship between the concentrations and the amounts of the precipitant. Despite the same concentration 20 per cent. applied to both samples 3 and 4, the preserving effect was much greater in the washed sample 3 than in 4; while no appreciable difference was found in the effect between samples 1 and 3, sample 3 according to microscopy, had the dyeing solution soaked much deeper into the fibres than sample 4, which was most likely responsible for making sample 3 better than sample 4.

Experiments to establish an optimal mixing rate for securing the preserving at a reasonable cost by minimising the amount of expensive sterilizers to be mixed with copper naphthenate, were also conducted. Sample twines, each weighing approximately 48·7 g./m. washed in running water for 5 hours, were subjected for another 5 hours to copper naphthenate baths, which were prepared by mixing 48 per cent. copper naphthenate, less than 0·05 per cent. synthetic resin, and either 2, 1·5, 1, or 0 per cent. synthetic sterilizer 3 DM, and diluting to 30 per cent. with kerosene. The sample twines a, b, c, and d, were made to correspond to the different concentrations of the synthetic sterilizer in that order. After drying, the samples were submerged in sea water and the remaining breaking strength tested at intervals of about three weeks. Fig. 4 is indicative of efficiency of the synthetic sterilizer used, since all the samples but d had fairly good results. Comparing a, b, and c, one may notice that the first two with higher mixing rates were better than c until the 42nd day of the submergence, while little or no difference was apparent from the 67th day onward. In other words, after about 60 days of immersion, the precipitation of the synthetic sterilizer decreases nearly to the same extent among the three samples, and this in turn depletes their strength in the same degree. These findings may warrant the necessity of carrying out redyeing of fishing gear after about that period of use.

In respect of the relationship between the preserving effect and the length of time for immersion, preliminary experiments showed no discrepancies between sample ropes kept for various durations over five hours in the dyeing bath and those treated in the vacuum-compressor. More detailed experiments are under way.

TANNIN PRESERVATION

The commonest types of cutch used in Japan are distinguished from each other by their trade names, B, R, and T. In addition, considerable amounts of tannin products, such as wattle and quebracho extracts, are used, though, according to experiments by Kanna, there is little difference in the preserving effect[5].

(1) **Dyeing bath:** The cotton nets are first boiled for one to two hours, washed in fresh water and dried. They are then boiled with 3 to 4 per cent. solution of cutch in fresh or sea water for some 2 hours, left in the bath overnight for cooling, then dried in the sun or in the shade. Upon drying, the net is soaked once more in the same solution at ordinary temperature for one night. A 4 per cent. concentration of cutch solution is the best for net preservatives[6].

When dyeing hemp twine, the same procedure as for cotton materials can be employed, but heating should be avoided.

(2) **Redyeing for various nets:** The first dyeing bath described above is applicable to various small types of fishing nets. In the case of small-sized trap nets they are disinfected by sun-drying part by part after one week's use. In addition to that they are redyed with 3 per cent. solution every three weeks during the period in use.

For other types of net, such as small purse seines, stick-held dip-nets and beach seines, it is recommended that they receive sunlight disinfection after each day's use and redyeing at intervals of a week to ten days in 3 to 4 per cent. solution. The life of a small trap thus treated may be two or three years, and of the other nets, three or four years.

BICHROMATE TREATMENT OF TANNIN PRESERVATION

By impregnating with tannin products and consecutive sun-drying, a thin film of tannic acid is built up of the fibres. This film prevents infectious bacteria from getting into the fibres. Under conditions in the coastal waters of Japan, however, the acid film would remain on a net no longer than one week, if the net is in continuous use. Therefore, frequent re-dyeing is needed to maintain the strength of the net which otherwise would quickly deteriorate. Since one of the remedies, coal-tar coating, worked out in an attempt to prolong the life of big set-nets and such gear, has not yet been made free from certain disadvantages, another improvement has come into being in the form of either potassium bichromate or of sodium bichromate.

(1) **Treatment:** A net thoroughly impregnated with tannin solution in the same way as described above, is again soaked in 1 per cent. of solution potassium bichromate or sodium bichromate at ordinary temperature for one or two hours. The chemicals may be dissolved by heating, but the dyeing bath must not be heated. After the two-hour immersion and subsequent washing, the net is ready for use or it can be dried for storing[7].

A defect of this treatment is that it needs a considerable amount of labour, and is costly and time consuming, but this may be offset by the prolonged life of the net, as tannic acid fixed by the bichromate makes it possible for the net to be used for twice as long as a net dyed in a conventional tannin bath (samples 1 and 2, figs. 1 and 2).

(2) **Commercial dyes with tannin fixation:** Among several makes of commercial dyestuffs developed from the principle of tannin fixation, D* and E† showed the best results (samples 8 and 15, fig. 2).

The product D, good for preserving abaca materials, has been adopted with success for such gear as setnets which remain in the sea for prolonged periods. However, a net must be put into service soon after D treatment; if not, it is liable to suffer from the quantities of copper sulphate contained along with the sodium bichromate in the product. Product E, comprising fine grains of silicic acid in the fixative, gave excellent results, particularly when applied to cotton twine (footnote of Table II).

COAL-TAR DYEING AND ITS MODIFICATION

(1) **Evaluation:** Coal-tar treatment shows greater preservability than most of the other dyes reported above samples (13 and 14), fig. 1, due to the heavy coating on the fibre. A disadvantage is that the net becomes uncomfortably sticky and sometimes too heavy for efficient manipulation. In addition, this would often result in deteriorating the structure of fibre to a critical extent, and increasing the weight so much that nets such as setnets, run a risk of being lost in an abnormal current or rough sea.

(2) **Treatment:** Formerly coal-tar immersion was carried out at 100 deg. C. or higher for 5 to 10 minutes. However, recent experiments have established that the temperature need not be higher than about 60 deg. C. for cotton twine, or 30 to 40 deg. C. for abaca nets and ropes, the time required being around 10 minutes for both. The fractional distillation of coal tar can now be continued further than before, making possible the utilization of the resulting volatile preservatives; this would evaporate if heated to a higher temperature.

When either creosote or heavy oil is used as diluent to minimize the disadvantages, the former tends to acceler-

* "Horyo Senryo", requiring 3 per cent. cutch solution for the first bath, contains $K_2 Cr_2 O_7$ copper sulphate, and alum for the second bath.

† "Aritoku Tannin", requiring 3 per cent. cutch tannic acid solution for the first bath, contains $K_2 Cr_2 O_7$, silicic acid and tartar emetic for the second bath.

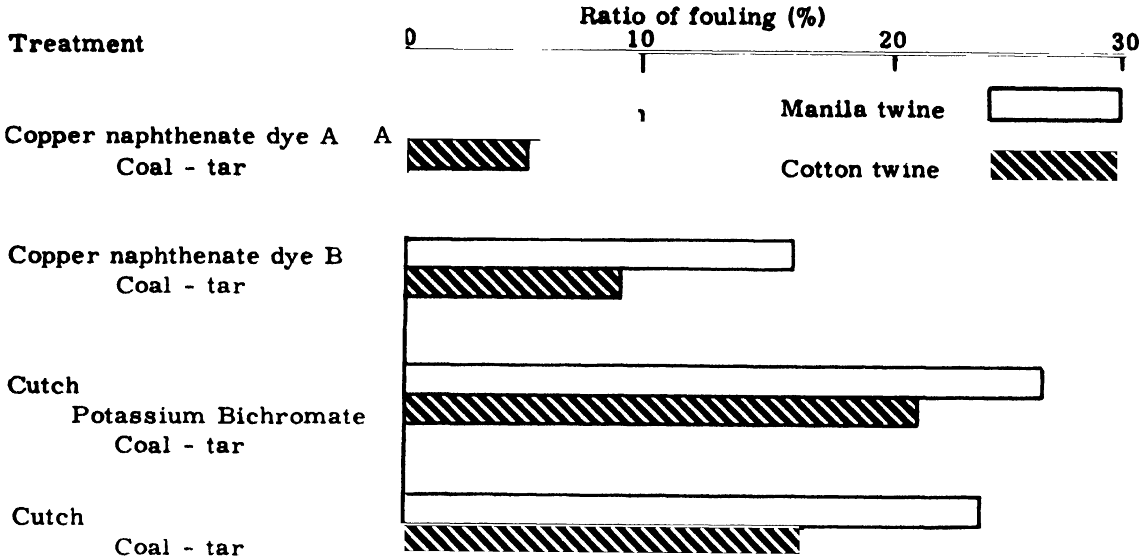

Fig. 5. Ratio of average weight of marine plants grown on the treated twines during 60 days' sea submerging to the weight of the new twines

ate the tar deterioration, while the latter would prevent the net from drying up.

(3) **Modified Coal-Tar Treatment:** Further experiments in coal-tar preservation showed that re-treatment of a cutch-dyed set net with coal-tar or diluted coal-tar could extend the life of the net from three to four years to four to six years (samples 3 to 7 and 16, figs. 1 and 2).

Commercial dyes D and E mentioned above, are successful applications born respectively from these ideas along with their special formulae. Tables I and II give the relative merits, as preservatives of coal-tar, diluted coal tar and some other dyes.

(4) **Maintenance:** Creosote or heavy-oil dilution containing 40 to 80 per cent. coal-tar is commonly used for the re-dyeing bath which a setnet, for instance, requires only every 80 days. Meanwhile, sunlight disinfection should be applied to the net two to three times between the baths. Re-dyeing for a trawl net is required after two or three operations covering 60 to 90 days; for round haul nets, it is only necessary after each fishing sesson.

The ideal storehouse for the treated net must have an elevated floor in order to secure enough ventilation with the lowest degree of humidity. Salt sprinkled between the layers of a folded net would partially check growth of micro-organisms and the deterioration by tar.

(5) **Trends in technological research:** Technological research in coal-tar preservation aims at development or improvement of (1) the diluted coal-tar treatment; (2) the protection of nets against foul organisms, and (3) a single dyeing bath treatment. In the case of cotton twine, experiments have shown more or less satisfactory results with regard to the first two questions. However, much remains to be learnt in connection with abaca material as well as the single dyeing bath[8] (Table II; samples 4, 6, 9, 16, figs. 1, 2; samples 5, fig. 3; fig. 5).

It has also been found that coal-tar treatment following the copper naphthenate bathing of cotton and abaca materials is effective against foul organisms. The twine samples were submerged in the sea and controls were carried out at 20-day intervals to dry and assess the amount of foul organisms, animals by number and plants by weight. Fig. 5 shows the average percentage increase of weight comparable by group of samples, on the basis of the total weight of plants found at the end of about a two-month period. The results obtained were nearly the same for both the plants and the animals. Although the treatment was also found effective for preserving the net (sample 16, fig. 2), further research is under way to obtain a similar result by a single bath instead of the double bath normally required.

These procedures are based on sterilization, and preclusion of micro-organisms and any technological advancement of fishing gear preservation is expected to proceed in these directions.

PRESERVATION BY CYANOETHYLATION

In regard to the preservation of salmon gillnets made of ramie, twine treated with acrylonitrile was compared to those treated with cutch and sodium bichromate, by submerging the samples in the sea for 50 days. The breaking strength, tested at 10-day intervals, proved that the former, although it had a lower initial strength because of cyanoethylizing, can be used for a much longer period (Table III).

Usually, the extent of cyanoethylation is indicated by the amount of nitrogen contained in the twine, though it is difficult to determine exactly to what extent it really is cyanoethylated.

If the nitrogen content is 2·5 per cent., as in the present experiment, the treatment would cost nearly twice as much as the cutch treatment or about 0·22$ U.S. 1 lb. of the material. However, treatment in bulk reduces the cost to a level within the means of the fishermen.

Caution: In using acrylonitrile, workers should be

TABLE III

Decrease in Breaking Strength of Ramie Thread (17 counts, 5 plies) (Submerged in the sea for 10 to 50 days)

Twine tested	Breaking strength (kg). assessed at 10 days intervals Initial	10 days	20 days	30 days	40 days	50 days
Non-treated	25·4	11·9	8·1	1·0	--	---
Treated with cyanoethylene	18·6	19·8	21·7	21·5	17·4	10·5
Treated with cutch 3 times, then with sodium bichromate	20·6	19·2	19·6	9·0	--	

protected from the hazards detrimental to their health.

SUMMARY

1. Disinfection by sun-drying and boiling is applied to certain types of nets which are used without dyeing because of reasons pertinent to their operation.

2. Preservation of nets and ropes by copper sulphate is recommended for fisheries using sardine purse seines and beach seines, which are based near the shore and the gear can therefore be retreated daily. The first dyeing bath requires several hours immersion in 0·1 per cent. copper sulphate solution in case of fresh water or 0·3 per cent. solution in case of sea water. After a day's operation, the net has to be sterilized in 0·01 per cent. solution (fresh water), or 0·03 per cent. solution (sea water). A suitable amount of the solution should be added to the re-dyeing bath from time to time to secure a constant concentration. In no case should a net treated with copper sulphate be exposed to the sunlight.

3. Copper naphthenate has a greater preserving effect when mixed with organic sterilizers and similar dyes. The dye is not so effective for cotton or ramie materials as for abaca. There should be more than 0·5 per cent. precipitation of copper on the materials in all cases.

4. The optional concentration of cutch is 3 to 4 per cent. Application of fixative such as $K_2Cr_2O_7$ or $Na_2Cr_2O_7$ can double the life of the cutch-treated materials. Among several commercial dyes produced on the principle of the tannin fixation bichromates, those containing copper sulphate as a fixative are good for preserving abaca materials, and those containing tartar emetic or silicic acid powder are suitable for cotton. No appreciable efficiency has been noticed with resin dyes.

5. Despite its remarkable qualities as a preservative, coal tar has the disadvantage of making nets sticky, heavy and fragile. Diluted coal-tar treatment, which could lessen these disadvantages, still needs to be improved. Experiments show that gasoline is a better diluent than creosote or heavy oil. The more coal tar is diluted, the lower its value as a preservative. However, pretreatment by formulae 1, 2, 8, or 12 in Table II has been found to improve greatly the preservation of a net when treated with diluted coal tar.

6. It is most important to preclude foul organisms, such as seaweeds and shells, from growing on setnets, etc. Nets treated first with copper naphthenate and then with coal tar were proved to be markedly free from infectious microbes and foul organisms. Research to secure a similar effect by a single dyeing bath is now under way.

7. Ramie netting twines treated with acrylonitrile agent and submerged in sea water indicated that the treatment made the material strongly resistant to micro-organisms, without affecting other properties required for fishing.

REFERENCES

[1] Matsumoto, J.: Unpublished.

[2] Migita, M., Matsumoto, J. and Kanna, K.: Studies on Fish Net Preservation by Copper Sulphate -I; A simple determination of Copper Sulphate. Bull. Japan. Soc. Sci. Fish., Vol. 18 No. 2 pp. 78-84 (1952).

[3] Shimozaki, Y.: On the Net Preservation and some Characteristics of Synthetic Netting Cords. "Teich" No. 10 (1956).

[4] Shimozaki, Y.: Unpublished.

[5] Kanna, K. and Migita, M.: Unpublished.

[6] Migita, M.: Fixing of Tanned Nets; Journal Fish. Exp St., No. 13, (1943).

[7] Migita, M.: Tanning Net in Sea Water; Bull. Japan Soc. Sci. Fish., Vol. 15, No. 12, pp. 781-786, (1950).

[8] Shimozaki, Y.: Unpublished.

ROT-RESISTANT FISHING NETS BY THE "ARIGAL" PROCESS

by

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Abstract

Micro-organisms living in water attack cellulose, which is the reason why unprotected cotton nets rot. Synthetic fibres are rot-proof, this being one of the reasons for their increasing use in net manufacture. Impregnation of nets as carried out by fishermen does not render them durably rot proof; the treatment has to be repeated frequently. In the U.S.A., processes have been worked out to produce rot-proof cotton by chemical treatments. Acetylated and cyanoethylated cotton are durably rot-proof, but the chemical treatments are complicated and costly. CIBA's Arigal proofing process is not based on chemical treatment, but on deposition of a synthetic resin in the fibre. The process consists of impregnation with an aqueous Arigal solution and fixation, without intermediate drying. The Arigal is not applied to the finished nets by the fishermen, but to the cotton yarn in a textile mill. The process is simple and gives a degree of conservation superior to that of the chemical treatments, and the properties of the fibre are not adversely affected. Cotton treated with Arigal exhibits outstanding weather resistance. It may thus be expected that the Arigal proofing process will find use in the field of net making, and that, in all respects, nets proofed by this process will meet the stringent requirements placed on them.

Des filets de pêche imputrescibles par le procédé "Arigal" de CIBA

Résumé

L'eau renferme des micro-organismes qui attaquent la cellulose; c'est pourquoi les filets de coton qui n'ont pas subi un traitement de protection, pourrissent. Les fibres synthétiques sont imputrescibles; c'est une des raisons pour lesquelles elles sont de plus en plus employées dans la fabrication des filets. L'imprégnation telle qu'elle est pratiquée par les pêcheurs ne confère pas aux filets une protection durable contre la pourriture, et doit être répétée fréquemment. On a mis au point aux Etats-Unis des traitements chimiques rendant le coton insensible à la pourriture. Le coton acétylé ou cyanoétylé est protégé d'une façon durable, mais les traitements chimiques sont complexes et coûteux. Le procédé Arigal de CIBA n'est pas un traitement chimique; il consiste à imprégner la fibre de résine synthétique au moyen d'une solution aqueuse d'Arigal et à la fixer sans séchage intermédiaire. L'Arigal n'est pas appliqué par les pêcheurs aux filets fabriqués, mais sur le fil de coton dans la filature. Le procédé est saimple et assure un degré de conservation supérieur à celui conféré par les traitements chimiques; en outre, il n'exerce pas d'effet nuisible sur les propriétés de la fibre. Le coton traité à l'Arigal possède une résistance remarquable aux conditions atmosphériques. On peut donc prévoir que le procédé Arigal sera adopté dans le domaine de la fabrication des filets et que les engins ainsi traités résisteront au dur service qui leur est imposé.

Redes de pesca resistentes a la pudrición mediante el procedimiento "Arigal" de CIBA

Extracto

La resistencia de las fibras sintéticas es una de las razones que han influído sobre la popularidad de us uso en la manufactua de artes de pesca, ya que los microorganismos presentes en el agua atacan a la celulosa causando la pudrición de las redes de algodón sin tratar. La entintadura hecha por los pescadoras impide el deterioro durante relativamente poco tiempo, debiendo repetirse con frecuencia.

En los E.U.A. se han ideado procedimientos químicos para obtener algodones, acetilados y cianoetilados, que resisten durante largo tiempo los efectos de las pudrición, pero tienan el inconveniente de ser complicados y caros. El métado "Arigal" ideado por CIBA, no se basa en la aplicación de un proceso químico, sino en el depósito de resinas sintéticas en las fibras impregnándolas con una solución acuosa de "Arigal" que se fija sin necesidad de recurrir a una desecación previa. Este procediminecto, además de ser secnillo, es aplicado en la hilandería a las fibras y no por el pescador, a las redes, da una preservación superior a la obenida con procesos químicos, no afecta adversamente a las propiedades de las fibreas y comunion al algodón gran resistencia a los agentes climáticos.

ALTHOUGH, in the main, fishing nets are still made from natural fibres, such as cotton, synthetic fibres have in recent years been used in increasing quantities. Synthetic fibres are very strong and light, absorb very little water, ase rot-proof and have good catching properties. Knot slippage and deterioration by weathering are for the present still disadvantageous but efforts are being made to counteract them.

The advantages of synthetic fibres greatly outweigh their disadvantages, as is shown by the enormous increase in use of synthetic fibres. According to Prof. von Brandt, more than nine million pounds of synthetic fibres, primarily vinylon, were used for net manufacture in Japan in 1955, compared with only 110,000 pounds used 5 years ago.

The high price of synthetic fibres is a drawback, but natural fibres, although cheaper, are not rot-proof, the cellulose being attacked by the micro-organisms living in water, so that they have to be protected. This protection increases costs, thus reducing the price advantage which cotton has over synthetics and, in some cases, making it quite illusory. Hitherto, preservation has been carried out by the fishermen who use copper preparations, chrome compounds, linseed oil, tar oils, etc., some treatments being carried out at the boil. None of these treatments is very durable and most have to be repeated periodically, which adversely affects the nets and causes shrinkage.

Methods for making cotton durably rot-proof have been studied very intensively in recent years in the U.S.A., the world's greatest producer of cotton, and considerable efforts have been made to produce a rot-resistant cellulose fibre. Theoretically, there are two ways of protecting the cotton fibre from micro-organisms. First, the fibre can be loaded with toxic substances which kill the organisms. This system of active preservation is used by fishermen e.g. when they impregnate their nets with copper compounds, but it does not offer durable preservation. In order to be effective, an active toxic agent should be able to penetrate into the interior of micro-organisms, and, to do this, it should be soluble to a certain degree. The drawback, is however, that even partly soluble substances, are eventually washed out by prolonged immersion in water. The second, and more promising method, is that of passive preservation, this being the method chosen by American research workers. Here the fibre is chemically converted into a cellulose derivative by esterification or etherification and thus made resistant to attack. The so-called chemical finishing of cotton by acetylation or cyanoethylation has been carried out on pilot plant scale in the U.S.A. and has been the subject of much discussion in recent years in interested circles.

The great disadvantage of chemical treatments is their complexity and high cost. Processes involving the use of volatile and, in some cases, toxic chemicals, necessitating the use of enclosed equipment made of acid-resistant material, can be neither simple nor cheap. It is therefore very doubtful whether chemically-treated cotton would offer an appreciable price advantage over synthetic fibres. This is the reason why the chemical finishing of cotton has not been able to stem the advance of the rot-proof synthetic fibres.

CIBA has attempted to solve the problem of rot-proof cotton by a different and considerably simpler means. By CIBA's Arigal process [see A. Ruperti, Mell. Textilberichte 37, 1419-1421 (1956)], passive protection is given by depositing a synthetic resin in the fibre, a process which gives permanent protection against attack.

The resin is fixed by a wet treatment which has been patented by CIBA. The Arigal is converted into a completely insoluble condensation product within the fibre, thus rendering the cotton rot-proof. This is achieved without any adverse affect on the mechanical properties of the fibre and without the fibre being degraded in any way whatever.

The method consists in impregnating the cotton with an aqueous solution of Arigal C in the presence of a catalyst (Arigal Catalyst C) and then fixing the preserving agent by a heat treatment, preferably under pressure, the material not being dried between impregnation and fixation. This process is simple and can be carried out in the conventional equipment available in the majority of textile works. It is only the wet fixation treatment which does not conform to the usual type of operation, since hitherto it has not been the practice to subject resin-treated goods to a heat treatment without previous drying. However, the wet fixation, too, can be carried out quite satisfactorily, using equipment generally to be found in dyeworks.

In order to ensure the maximum degree of preservation by this process it is essential that the Arigal be uniformly deposited throughout the material, the knots being adequately penetrated. The materials should therefore be treated at the textile mill, where best results are obtained by treating the untwisted yarn.

Calculated on the weight of the treated goods, 10 per cent. of Arigal C, when uniformly deposited, gives a very high degree of protection against micro-organisms. Cotton net thread treated with Arigal showed absolutely no reduction in tensile strength after two years immersion in a particularly muddy part of the Rhine.

Untreated cotton yarn immersed at the same place was completely destroyed in a matter of weeks.

Comparison of tests made with chemically treated cotton from America showed that the Arigal treatment gave greater durability (A. Ruperti loc. cit.). The Arigal cotton showed no reduction in tensile strength after a 4-week immersion in the Rhine followed by burial in compost earth for 24 weeks at 30 deg. C. The chemically treated cotton, on the other hand, was destroyed.

Cotton treated with Arigal is also very resistant to weathering. It is well known that the tensile strength of textile fibres is reduced by outdoor exposure. Cotton is one of the more resistant of the textile fibres in this respect, being far superior, for example, to nylon and Orlon 42. Chemical treatment reduces the weather resistance of cotton, whereas Arigal C treatment considerably increases this resistance. After a 12-month weathering test carried out at CIBA, a boiled out, untreated cotton fabric had retained 21·7 per cent. of its original tensile strength, and Dynel 23 per cent. The same quality cotton fabric proofed with 10 per cent. Arigal C retained 47·8 per cent. of its tensile strength, while Orlon 42 lost all strength after 12 months' exposure, and nylon after only 6 months.

Jute and ramie can also be treated by the Arigal C process with very good results. However, the degree of proofing obtained on hemp and linen leaves much to be desired, and treatment with Arigal alone cannot be recommended for these two fibres.

Nets made with Arigal treated cotton do not require the usual cutch treatment since such a treatment would not give added protection. However, if cutching should be desirable for colouring purposes, there is no reason why this should not be done. Even after prolonged immersion, cutch is not washed off Arigal treated nets and they do not have to be re-treated.

The Arigal process is still young and has yet to be proved in bulk application and practice before final judgment can be passed as to its possibilities. But even now its advantages are evident · the simplicity with which it can be applied, its relatively low cost, the complete absence of any fibre degradation, the improvement in the weather resistance of the cotton fibre and, finally, the outstanding durability of the rot-proofing itself.

Note:

Arigal—Trade-mark of CIBA Limited, Basle, Switzerland.
Dynel—Trade-mark of Carbide & Carbon Chemicals Co., U.S.A.
Orlon—Trade-mark of E. J. DuPont de Nemours & Co., U.S.A.

APPLICATION OF ACETYLATED CELLULOSE FOR FISHING GEAR

by

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Abstract

The partial acetylation of cotton, with an acetic acid content of 25-30 per cent. leaves the mechanical and technological properties of the yarn unaffected. There is no change in appearance or colour of the yarn and it is odourless, non-poisonous, and insoluble in water or solvents and, moreover, it has an extremely high resistance to micro-organisms. Besides cotton, fibres such as jute, hemp, linen, sisal, etc. can also be immunised to attack by bacteria without impairing their tensile strength. Tests on materials buried in compost with 30-40 per cent. humidity at 20-25 deg. C. showed that untreated cotton and jute yarns rotted away in 14 days while the acetylated yarns retained their original tensile strength after 6 months. Comparative tests in sea water showed that cotton lines were very weak after two months but the acetylated lines were still strong after seven months, and untreated sisal twine lost 50 per cent. of its tensile strength within one week, while acetylated sisal took nine weeks to lose the same amount. Lines, nets, and material for making sandbags are all improved by treatment and the fact that the present cost of manufacture is relatively high is offset to a large extent by the fact that partially acetylated cellulose fibres last 50-60 times longer than the untreated materials.

Application de la cellulose acétylée aux engins de pêche

Résumé

L'acétylation partielle du coton, avec une teneur de 25 à 30 pourcent d'acide acétique laisse intacte les propriétés mécaniques et chimiques du fil. Il ne se produit aucun changement de l'aspect ou de la couleur du fil; le produit est inodore, non toxique, insoluble dans l'eau et les solvants, et possède une résistance extrêmement élevée aux microorganismes. En dehors du coton, on peut immuniser d'autres fibres telles que le jute, le chanvre, le lin, le sisal, etc., contre l'attaque des bactéries sans affecter leur résistance à la traction. Des essais effectués sur des fils enfouis dans un compost renfermant 30 à 40 pourcent d'humidité et maintenu sà une température de 20 à 25 deg. C. ont montré que des fils de coton et de jute non traités pourrissaient complètement en 14 jours tandis que des fils acétylés conservaient leur résistance primitive à la traction au bout de 6 mois. Des essais comparatifs exécutés dans de l'eau de mer ont montré que les lignes de coton étaient devenues tres fragiles au bout de 2 mois, mais que les lignes acétylées étaient encore solides après sept mois; des fils de sisal ont perdu 50 pourcent de leur résistance en une semaine tandis qu'il a fallu neuf semaines aux fils de sisal acétylés pour arriver au même résultat. Les lignes, les filets et les matériaux utilisés a la confection des sacs de sable ont tous été améliorés par le traitement, et le coût relativement élevé de fabrication actuel est largement compensé par le fait que les fibres de cellulose partiellement acétylées durent 50 à 60 fois plus que les mêmes matériaux non traités.

Usos de la celulosa acetilada en los artes de pesca

Extracto

La acetilación del algodón con 25 – 30 per cent de ácido acético no afecta a las propiedades mecanicas y tecnologicas, ni produce cambios de aspecto o color en la fibra que es inodora, inocua e insoluble en agua o disolventes; además le comunica una gran resistancia a los microorganismos. Fuera de las fibras de algodón también es posible inmunizar las de yute, cáñamo, lino, sisal, etc. contra el ataque de las bacterias sin disminuir su resistencia a la tracción. Los ensayos de materiales enterrados en abono vegetal con 30 a 40 per cent. de humedad, cuya temperatura fluctuaba entre 20 deg. y 25 deg. C., demostraron que las fibras de yute y de algodón sin tratar se pudren en 14 días y las acetiladas conservan su resistencia a la traccion luego de 6 meses.

Los ensayos comparativos en agua salada permitieron observar que la resistencia de los hilos de algodón disminuye bastante después de 2 semanas, pero en los acetilados aumenta después de 7 meses. Los hilos de sisal pierden un 50 per cent. de su resistencia en 1 semana, mientras que en los acetilados esta misma disminución se logra al cabo de 9 meses. Los hilos, redes, y material para fabricar sacos de arena mejoran con este tratamiento y su costo de manufactura, relativamente elevado, se compensa en gran parte por el hecho de que las fibras parcialmente acetiladas duran unas 50 a 60 veces más que los materiales sin tratar.

HISTORY

IN 1920 C. Dorée (Biochem. J. *14*, 709-14 (1920)) mentioned for the first time the excellent resistance to micro-organisms of acetate silk and acetylated cotton (the latter without change of fibrous structure). A year later, a process of partial esterification of cotton fabrics to give resistance to bacterial attack was patented in U.S.A. by Wolcott and Jennison. (U.S.A. Patent 1.474.574).

In 1926 A. Rheiner (Sandoz Ltd., Basle, Switzerland), succeeded in developing a much improved method of partial acetylation of cellulose (ref. DRP 525'084 and 530'395 and A. Rheiner Angew. Ch. *46*, 675 (1933) "Ueber niedrig acetylierte Fasercellulosen") which made bulk production possible. The commercial production of partially acetylated cellulose without change of structure, according to this process, was taken up by Sandoz Ltd. in 1927 and by their affiliated company Cotopa Ltd. in Horsforth (England) in 1929 and the acetylated products have since been marketed under the registered trade marks "Passivgarn", "Kristallgarn", "Cotopa", "Crestol", "Crestine", "Crestic" and "Crestose".

After the second World War the Southern Utilization Research Branch, New Orleans (U.S. Department of Agriculture) carried out an extensive programme of research work in connection with partially acetylated cotton. Now, two U.S. firms are said to manufacture partially acetylated cotton in bulk.

PROPERTIES

For the production of cellulose derivatives, and in particular, cellulose esters, it is sufficient to modify only the amorphous part of the fibre to obtain the maximum resistance to micro-organisms. This corresponds on an average to the substitution of one hydroxyl group for one glucose anhydride unit. By this means, the swelling and water absorption capacity of the fibre are reduced to such an extent that bacteria and fungi have great difficulties in decomposing it. The crystalline part which has not been modified is not easily attacked by micro-organisms, as was proved by P. Karrer (Kolloid-Z., 52, 304 (1930)).

Practical experience has shown that for partial acetylation in bulk, an acetic acid content of 25 to 30 per cent. should be aimed at, to leave the physical properties of the yarn unaffected. A modified cellulose with an *extremely high resistance to micro-organisms* is obtained by this method.

The P.A. cotton does not show any change in appearance or colour. It is odourless, non-poisonous and insoluble in water or solvents. It can be knotted easily, causes no skin irritation or corrosion and shows considerably better resistance to heat than untreated material. Tensile strength remains the same, but it is not immune to attacks by termites.

Other fibres, such as jute, hemp, linen, sisal, ramie, etc., can be similarly immunised to micro-organisms. Acetylated bast fibres are of particular interest when the highest tensile strength is wanted. It is, however, questionable whether the higher priced cellulose fibres (such as ramie, which shows a better natural resistance to micro-organisms than cotton) can stand the price increase imposed by the acetylation process.

TENSILE STRENGTH AND COSTS

Acetylation increases the weight of material by 15 to 25 per cent., and this has to be considered in the total manufacturing costs. The absolute tensile strength remains unchanged or decreases only slightly (according to the yarn quality 0 to 7 per cent.), and the breaking length is reduced by 20 to 30 per cent. This may have to be taken into account by selecting suitable raw materials and by paying special attention to the spinning and twisting of the yarn.

A considerably increased tensile strength can be obtained by stretching acetylated yarn in superheated steam. Combinations of acetylated and synthetic fibres may be used. For instance, acetylated cotton is spun round polyamide filament or yarns made of polyester and acetylated fibres are twisted together, or synthetic staple fibres are spun with acetylated cotton fibres.

The partial acetylation of cellulose is dearer than most impregnation methods hitherto used to protect cellulose fibres against mildew, seawater and other forms of bacteria. It can only be used generally for this purpose if ways are found to reduce the manufacturing costs. But as the fibres last 50 to 60 times longer than untreated material there should be many possibilities for using them in spite of their relatively high price.

TEST REPORTS

The following reports give a vivid picture of the remarkable resistance of treated cotton to micro-organisms.

1. Resistance to rot and bacteria (see Table I) in compost with 30 to 40 per cent. humidity at 20 to 25 deg. C. The yarns were wound on glass tubes of 6 cm. exterior diameter. After the tests, the yarns were washed and aired and the tensile strength was established. The cotton and jute yarn rotted away completely after two weeks but the acetylated yarn still showed the original tensile strength after 26½ weeks.

2. Comparative mildew resistance tests carried out by the Manchester Chamber of Commerce Testing House and Laboratory. Entry No. 342934 Prog. No. 380124 of 15.10.1956 (see Table II).

Hank No. 1 marked 3/10's Cotopa XL (acetylated cotton yarn) Howard Green (raw cotton, soap scoured and vat dyed, followed by acetylation).

Hank No. 2 marked 3/10's Howard Green raw cotton treated with Copper Naphthenate (raw cotton, soap scoured and vat dyed and impregnated with Copper Naphthenate in accordance with BSS 2087).

These samples were tested for resistance to mildew according to the method prescribed in the Standards Association of Australia Interim Specification S.A.A. Int. 88 Sect. 3.

Specimens from each sample were washed in a water spray for 7 days and other specimens were treated for 5 days at 70 deg. C. ± 2 deg. C. in an oven with a forced air circulation. Then, with some grey cotton yarn as control, they were sterilized and pressed on to nutrient agar medium in sterile, covered, glass vessels, inoculated with a spore suspension of *Memnoniella echinata*, and incubated for 14 days at a temperature of 30 deg. C. ± 2 deg. C. and 95 to 100 per cent. relative humidity.

They were then removed, washed, aired, and their tensile strengths determined with the following results:

Single thread strength on Goodbrand machine. Distance between jaws 12 inches. Speed of traverse of

TABLE I

Buried in compost days	Tensile strength (as per cent. of original) after interment					
	raw cotton yarn (Egyptian)		kier-boiled and bleached cotton yarn (Egyptian)		Jute	
	non-acetylated	acetylated 28% acetic acid	non-acetylated	acetylated 28% acetic acid	raw, non-acetylated	boiled acetylated 31% acetic acid
	100	100	100	100	100	100
3	25	129	27½	116	—	
7	9	128	23	124	41	159
14	0	113	0	121	13	112
28		105	—	124	3	112
56	—	117	—	123	0	137
117	—	104	—	101	—	112
185	—	108	—	88½	—	104

TABLE II. UNPROOFED GREY CONTROL

As Received		*After Incubating*	
7·9	8·0	0·1	0·1
8·7	8·2	0·5	0
8·9	7·7	0·2	0·4
7·9	8·4	nil	nil
8·0	8·1	nil	0·6
8·2	9·1	0·1	0·4
8·0	8·2	0·2	0·1
8·7	8·7	0·6	0·1
8·0	8·6	nil	0·4
8·9	8·3	nil	0·6
8·3 lbs.		0·2 lbs.	
Loss, per cent. ..		.. 97½	

Marked: "3/10 Cotopa XL Howard Green"

As Received lb.		*After Incubating* lb.		*After Washing and Incubating* lb.		*After Heating and Incubating* lb.	
5·7	4·6	5·1	5·3	5·3	4·6	4·9	4·4
4·9	5·2	5·3	5·1	4·7	4·7	5·1	5·2
5·5	4·7	5·4	4·9	4·9	5·7	4·5	5·3
5·4	5·1	5·0	4·7	5·2	5·6	4·9	4·7
5·9	5·1	5·1	4·1	5·3	5·3	4·7	4·4
4·8	4·5	4·9	5·2	5·2	5·8	5·1	5·3
5·8	5·1	5·7	4·2	5·3	5·2	5·2	5·6
5·7	5·1	5·3	5·1	4·7	5·2	5·1	5·5
4·7	4·9	5·1	5·2	5·4	4·9	5·7	5·2
4·6	4·9	5·5	5·5	5·1	5·0	4·3	5·6
5·1		5·1		5·2		5·0	
Loss, per cent.		nil		nil		2	

Marked: "3/10 Howard Green Raw Cotton treated with Copper Naphthenate"

As Received lb.		*After Incubating* lb.		*After Washing and Incubating* lb.		*After Heating and Incubating* lb.	
5·7	5·8	4·2	6·0	2·4	2·4	3·4	4·2
6·0	5·2	5·7	5·7	9	0·7	3·0	3·3
5·8	6·2	4·9	5·8	4	1·4	4·4	3·2
6·1	5·2	5·7	5·8	·1	2·4	3·6	4·2
4·9	5·7	5·9	5·4	1·4	0·9	3·2	2·9
..	..	..	..	..	1·6	3·4	4·7
5·6	5·6	5·6	5·1	0·9	1·7	3·2	3·5
5·2	5·1	5·5	5·6	2·4	0·6	3·7	3·7
5·8	5·7	5·6	5·7	0·7	2·6	4·2	3·2
5·3	5·6	5·1	5·6	0·8	2·3	2·9	3·4
5·6		5·5		1·5		3·6	
Loss, per cent.		2		73		36	

lower grip 18 inches per minute. Machine capacity 10 lb.

It will be seen that the "3/10 Cotopa XL Howard Green" sample was not affected by the incubation either before or after washing or heating. The "3/10 Howard Green Raw Cotton treated with Copper Naphthenate" sample, however, lost 73 per cent. of its strength after washing and incubating and 36 per cent. after heating and incubating.

These figures clearly show the superiority of partially acetylated cotton.

3. Resistance to Sea Water

(a) Comparative tests on fishing lines in tidal waters showed that cotton lines were very weak after two months, but the acetylated lines were still strong after seven months.

(b) Similar results were obtained in testing untreated and acetylated sisal twine in sea water. The tensile strength of the untreated twine dropped within a week to 50 per cent.; the acetylated sisal material lost 50 per cent. after nine weeks.

Application of partially acetylated cellulose fibres

The extraordinary resistance of partially acetylated fibres to long immersion in water makes them most suitable for fishing lines, ropes and seines. Fishing nets made of acetylated fibres are more flexible, remain cleaner and are easier to handle than normal nets which are impregnated and must undergo regular cutch treatment, which increases costs in time and money. Nets of acetylated fibres or mixtures of synthetic fibres and acetylated cellulose do not have to be treated again. Another advantage is that acetylated fibres facilitate knotting.

Tests in Scotland with herring nets made of partially acetylated cotton cord have shown excellent results to date, but more tests will be made before a conclusive report is issued in such mixtures.

Tests of fishing nets made of acetylated cotton twist are being made in Germany, supervised by the official German testing station (Bundesforschungsanstalt für Fischerei, Hamburg).

EVALUATION OF ROT-RETARDING NET PRESERVATIVES

by

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Abstract

The most important methods of examining the effectiveness of rot-resistant protectants are (1) the static method, (2) the aquarial method, and (3) the fishing method. The author describes these in detail and points out some of their defects. In the second part of the paper Dr. Klüst's tests on impregnated fish netting are discussed and certain amendments are suggested.

Evaluation des agents de presérvation retardant la pourriture des filets

Résumé

Les plus importantes méthodes d'examen de l'efficacité des agents protégeant la résistance à la pourriture sont: (1) la méthode statique par enfouissement dans le sol, (2) la méthode par immersion dans un bac et (3) la méthode réalisant les conditions de pêche. L'auteur décrit ces méthodes en détail et fait ressortir quelques-uns de leurs défauts. Dans la seconde partie de la communication, l'auteur examine les essais du Dr. Klüst sur les filets imprégnés et suggère certaines modifications.

Evaluación del efecto de los preservativos que retardan la pudrición de las redes

Extracto

El autor describe, en detalle, los métodos más importantes para determinar la eficacia de los preservativos que retardan la pudrición de las redes de pesca., a saber: (1) el entierro del material tratado, (2) la inmersión en agua, y (3) el uso en la pesca, y señala sus defectos. En la segunda parte del trabajo, se analizan los ensayos del Dr. Klüst con redes de pesca entintadas y se sugieren algunas modificaciones.

A PROPER and generally recognized method of examination of preservatives used for cellulose fabrics should be introduced. An ever-increasing number of preservatives of different rot-resistant strengths are appearing on the market and the indications of their resistant properties, as given by the manufacturers or by the research laboratories, are not comparable and can result in misuse.

Two important factors causing deterioration of textile fabrics must be considered when evaluating the preservative: (a) the decomposing effect on cellulose of cellulose-producing organisms, and (b) the rinsing properties of water, its mechanical destruction of the protective layer and its slow chemical effect on the cellulose of the fabric. The first of those factors is generally taken into consideration, whereas the second is often practically neglected. Even a mild preservative which is not very soluble in water is more effective in the first stage, than later on when it has been partly rinsed out and a local bacterial invasion has taken place, causing partial rot. If this bacterial invasion spreads, the fabric is regarded as useless, even though the chemical indicators of the preservative remain unchanged.

So far, no suitable laboratory methods have been established which can constitute a proper examination of preserved textile fabrics. There is no method which enables one to determine and to estimate the suitability of various preservatives for fishing purposes. On the one hand, such a method would have to ensure a proper estimation of the intensity of bacterial degradation and the effect of water on the sample and, on the other, it would have to enable the regulation and determination in each case—of the principal factors. It is no less important that other parameters, effecting the final results, should likewise be guaranteed.

The most important methods of examining the effectiveness of rot-resistant protectants are:

(1) the static method
(2) the "aquarial" method
(3) the "fishing" method

(1) The *static method* consists of burying the samples in soil. The soil is watered systematically at a temperature of 18 to 20 deg. C. thus causing the cellulose-destroying bacteria which live in the mouldy soil to increase abundantly, and bring about a rapid decomposition of cellulose fabric.

A disadvantage of this method is that there is scarcely any rinsing out of the preservative by the water. Another drawback is that the results of tests from different parts of the soil are always found to differ, which is particularly obvious in the first stage of decay, i.e., after the same period of time similar tests show different losses in initial strength. A number of factors, such as a lesser contact of the fabric with the soil, an unequal access of oxygen, etc., seem to be responsible.

There are certain modifications, such as inoculating the impregnated cellulose fabric with certain bacterial cultures or fungi causing decomposition of the cellulose, and then storing the samples in thermohygrostats.

These methods have no practical use in fishing gear research except in certain experiments connected with storage of fishing net.

(2) With the *"aquarial" method* the samples are immersed in an aqueous solution of mineral salts—the nutritive components essential for the bacteria. A necessary amount of cellulotytic bacteria suspension is added to the solution. If therophilic bacteria are used, it is possible to evaluate the rot-resistance of the sample within two days. If, however, mezophilic or psychrophilic bacteria are applied, no results are apparent under a fortnight. In laboratory practice, pure cultures of cellulolytic bacteria are not always applied, and frequently river or sea water is used for the experiment with mud-suspension—a rich source of cellulose-destroying organisms. This experiment is, however, difficult to repeat and the results of the examination are generally incomparable. Considering, however, the simplicity of the procedure, it is, in spite of its drawbacks, often applied to evaluate various kinds of netting protectants, although the rotting period of the examined fabrics, especially when sea water is used, is relatively very long.

One of the main defects of the "aquarial" method is that the impregnation is not rinsed out as much as in natural conditions. If the water in the aquarium tank is not changed at all, the surroundings undergo a gradual intoxication by the substances rinsed out from the samples, which invariably stops the normal activity of the organisms and causes manifold biological changes in the medium used. A frequent changing of water, on the other hand, causes a change of physical conditions effecting the intensity of the bacterial growth. The results obtained by means of this method can, therefore, only be treated as material for further research.

(3) The *"fishing" method* consists in laboratory examination of cellulosic cotton fabric in conditions approximating those normal to fishing gear when in use. This method, developed by Dr. Meseck, seems, therefore, to be generally recognised as the most suitable, especially for industrial practice.

The impregnated twine samples are fixed to frames and immersed in deep water. At certain intervals the samples are taken out of the frames and tested for mechanical resistance. To evaluate the surrounding medium, the temperature, oxygen content, pH value, geographical conditions and the presence of hydrogensulphide at the bottom of the water, etc., are repeatedly tested.

Russian scientists do not, as a rule, use twine in their experiments but samples of fish netting. These samples are either tested apart or are sewn into different parts of the fishing gear working on industrial scale. Sometimes both methods are applied simultaneously.

From the above survey of practical methods of examination we see that each affects the deteriorating factors in a different way. Whilst the static method does not lay much stress on the "rinsibility" of the preservative, the fishing method guarantees this condition sufficiently but does not give any possibility of interfering with the parameters influencing the intensity of cellulose decomposition. The results obtained by the two mentioned methods must necessarily be quite different and misleading in assessing the actual rot-resistance of the given fabric.

In 1952, the laboratories of the Polish textile industries started to promote a very practical and cheap method of impregnation of cotton twine by means of copper-treatment, the process consisting in emulsive coating of the fabric with a copper naphthenate. At the same time the laboratory of the Sea Fisheries Institute rejected this method for fish netting purposes. The two contrary conclusions were the result of two different methods applied to evaluate the same rot-resistant protectant.

Tests were then carried out with copper-treatment of fish netting by two methods—the "static" and the "fishing" method.

"Static" method

Samples of treated and untreated twine were buried in compost soil 10 cm. below the surface. The soil was sprayed regularly every day with distilled water in order to ensure its proper water content. The temperature was kept within the range 18 deg. to 20 deg. C. The average moisture of the medium was 70 per cent. The raw samples were removed approximately every 5 days and their mechanical resistance determined. Every 10 days fresh samples of raw twine were deposited and their loss in strength was determined for the purpose of ascertaining whether the intensity of the cellulose-decomposition differed in the course of the tests. The treated samples were removed and tested for mechanical resistance at longer intervals.

"Fishing" method

Samples of twine wound into strands with 32 to 34 strings each were fixed on frames by means of grips and immersed in water in a tank specially erected for testing fish nets. The depth of the immersion was about 0·6 m. below the water level. The distance from the bottom was about 1 m. The samples were removed from the water every 10 days and dried in the air, then tested for mechanical resistance by means of the Schopper dynamometer (distance between grips 500 mm, breaking-time 10 secs.).

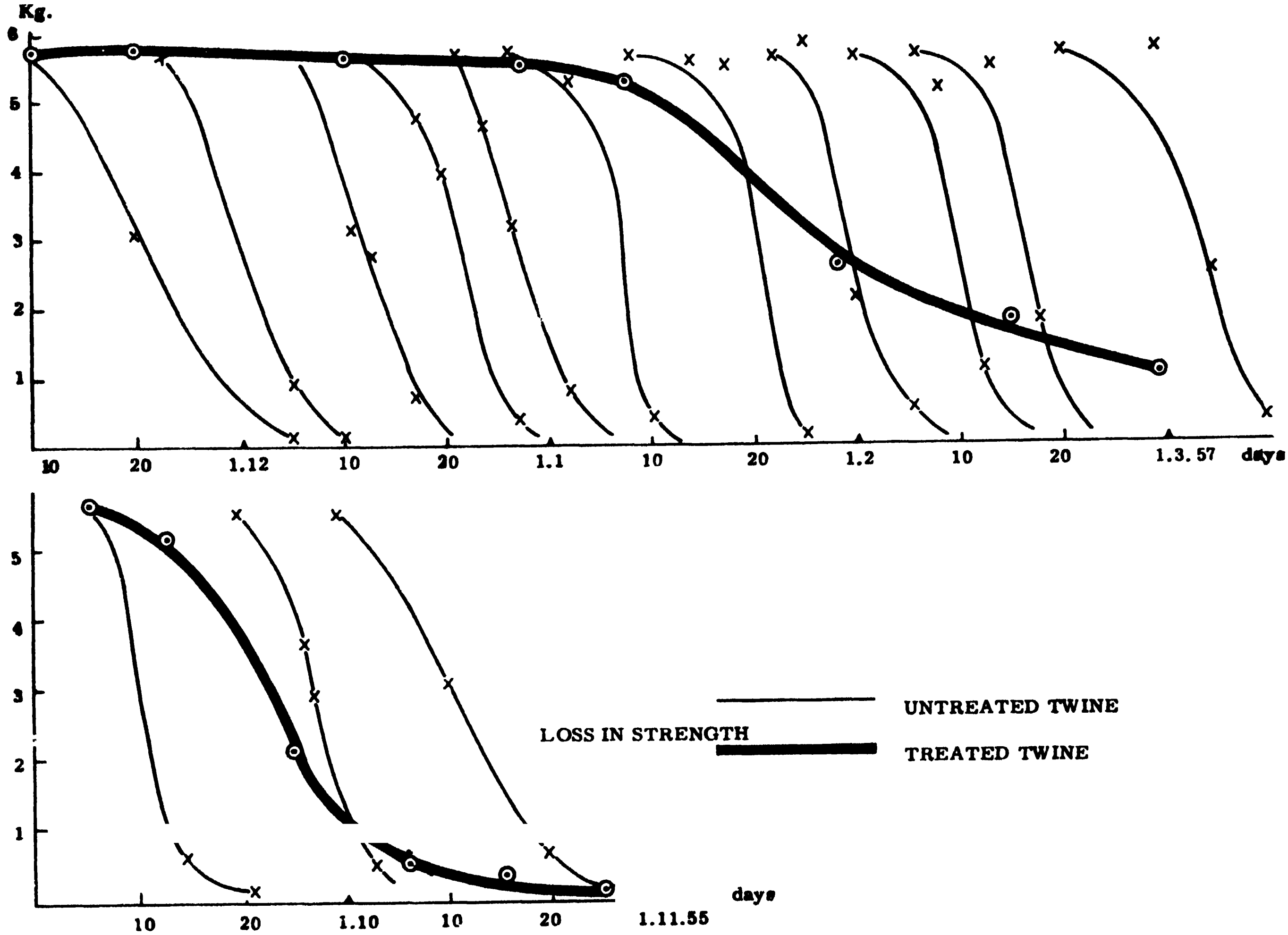
During a test that lasted from 6.9.55 to 26.10.55 the parameters of water medium were on an average as follows:

Measured parameters	*Value*
Temperature of water	September 16 deg. October 12 deg.
Salt content	7·2 to 7·6 per cent.
*p*H	8·2 to 8·4

For both tests, cotton twine with the following properties was used:

Metric number	40/3 · 3
Initial breaking strength	5·640 kg.
Length increase	11·4 per cent.

The impregnating solution was a water emulsion of copper-naphthenate, 10 g. of $CuSO_4 . 5H_2O$ diluted in 100 ml. of water warm. After cooling, a quantity of 25 ml. of 5 per cent. ammonia solution and water up to 500 ml. were added. A separate sample of 20 g. of naphthenic acids was neutralized with 10 per cent. ammonia solution and diluted with water up to 500 ml. The two solutions were mixed and a "ready-for-use" impregnated mixture was obtained in which the cotton-



Figs. 1 and 2.

twine was copper-treated. The samples were immersed for 15 minutes, the surplus drained off and the twines dried at 80 deg. C.; after drying, the samples had a light green colour. The copper content in samples calculated as dry values was 0·65 per cent. Other properties were:

Metric number	40/3×3
Initial breaking strength	5·690 kg.
Length increase	13·5 per cent.

Figs. 1 and 2 illustrate the results obtained during the experiment. Fig. 1 shows the loss in strength as evaluated by the "static" method, whilst fig. 2 indicates the results obtained by applying the "fishing" method. Both figures are drawn to an equal scale (of time and strength); they also show the loss in strength of untreated twine samples, in order to demonstrate the intensity of bacterial degradation of the examined medium. We see a distinct difference in the process of loss in strength of treated samples examined by "static" and "fishing" methods, although the degree of rotting, on the whole, is almost the same. The almost identical loss in strength of untreated cotton twine in both experiments can be seen from the parallel curves in figs. 1 and 2, whilst the results with treated cotton twine differ widely. Hence, the evaluation of fish netting twine of the same dimensions, treated in the same way, differs considerably according to the test method applied. The numbers which showed how many samples were decomposed up to 50 per cent. of their initial strength, during the time that the treated twine sample had lost 50 per cent. of its initial strength, served as comparable indicators for both method of protection, the condition being that each successive untreated twine sample was not immersed in the medium before the preceding one had lost 50 per cent. of its initial strength.

For the treated twine samples evaluated by means of the "static" method, this number amounted to "PT" (Protection Test) = 9, whilst for the twine samples evaluated by "fishing" method it was "PT" = 3. The mere comparison of the two numbers proves sufficiently how different the two methods are. The obvious conclusion is that for fishing purposes the so-called "fishing" method is the most suitable one, provided it is carried out under actual fishing conditions. Although, hitherto, it has yielded non-comparable results (which could be prevented by a greater number of experiments), yet it seems to be by far the most reliable and appropriate for industrial practice.

Evaluation Tests of Protection Methods

A great disadvantage of all the methods for testing the quality of impregnated fish nettings, either described in literature or known in laboratory practice, is that none of them are practically repeatable, and their results are therefore difficult to compare and to transfer to any other conditions or surroundings. Consequently, various research laboratories, unable to compare the results of their experiments, were forced to carry out the same investigations relating to an identical or practically identical protection method.

The first efforts to compare the value of different protection methods were undertaken by Dr. Klust and put into practice in 1952. His tests consisted of determining the so-called "rotting value" of the medium in which the experiments were carried out. Accordingly, the "rotting value" of the medium is equal to the total losses in strength, expressed as percentage values of the initial strength of the successively examined samples of untreated twine Nm 50/15, so that the test of Dr. Klust, as such, stands for the sum of "rotting values" of the medium during the time in which the examined sample of treated twine has lost 50 per cent. of its initial strength.

Dr. Klust has examined a number of twine preservatives and has given them his own symbols expressed in numbers, the higher the number the better the quality of the preservative.

From our own experiments, in completely different conditions, we have obtained quite different numbers for certain kinds of preservatives, probably resulting from the fact that the "rotting value" of our medium was 2 to 2·5 lower. Another cause was the very strong rinsing effect of the water currents and its mechanical destruction of the protecting coating of the twine threads. Other parameters involved in the experiments did not seem to have such a great effect.

In his tests Dr. Klust has given a very exact method for determining the main destroying factor of the cellulosic fabric, i.e., the activity of the micro-organisms, thus enabling a proper comparison of the deteriorative effect of microbial activity when examining the fish netting fabric. Dr. Klust has, however, disregarded the influence of the second important factor, viz.: the rinsing effect of water and the mechanical destruction of the membranous structure of the protection layer of each fibre. The importance of this factor is evident when applying certain excellent preservatives almost insoluble in water; the smallest local destruction of the protective layer then causes an immediate invasion of bacteria and a complete destruction of the thread. The case is different with preservatives more soluble in water. A mechanical destruction of the layer does not, at first, provoke a general attack of bacteria, as the exposed area is protected by the field of diffusion of toxic bactericidal components of the protectant. After some time, however, the process of diffusion slows down, its field diminishes and the bacterial activity becomes more effective. Therefore, when comparing different kinds of protectants, the influence of non-biological factors of water on the impregnation of fish netting fabric must be considered.

Another minor disadvantage of Dr. Klust's tests is that they have no physical value and are merely symbol numbers comparable with each other. The way of obtaining them seems also rather questionable. It is not quite clear to us why Dr. Klust has taken as a basis for the treated twine the 50 per cent. of its loss in strength and has not applied the same principle to the untreated twine. Presumably, in this case Dr. Klust wanted to avoid any extrapolation—in time—of his results. Though, when taking into consideration the typical loss in strength of the untreated twine which, in the first stage and for quite a long period practically retains its initial strength, then begins to lose it rapidly, it may be concluded that the loss in strength taken in regard to time is quite different in the range 0 to 30 per cent. and 50 to 80 per cent. Therefore a lesser mistake would be, in our opinion, to extrapolate—in time—the results of the loss in strength of the examined twines down to a certain point of their strength, than to apply the principle of summing up their actual losses in strength. The extrapolation would have to be possibly small in time, seeing that it affects the exactness of the calculation of the protection tests. In our opinion, both treated and untreated twine samples should be brought down to 50 per cent. of loss of their initial strength.

We would suggest a modification of the test as follows:

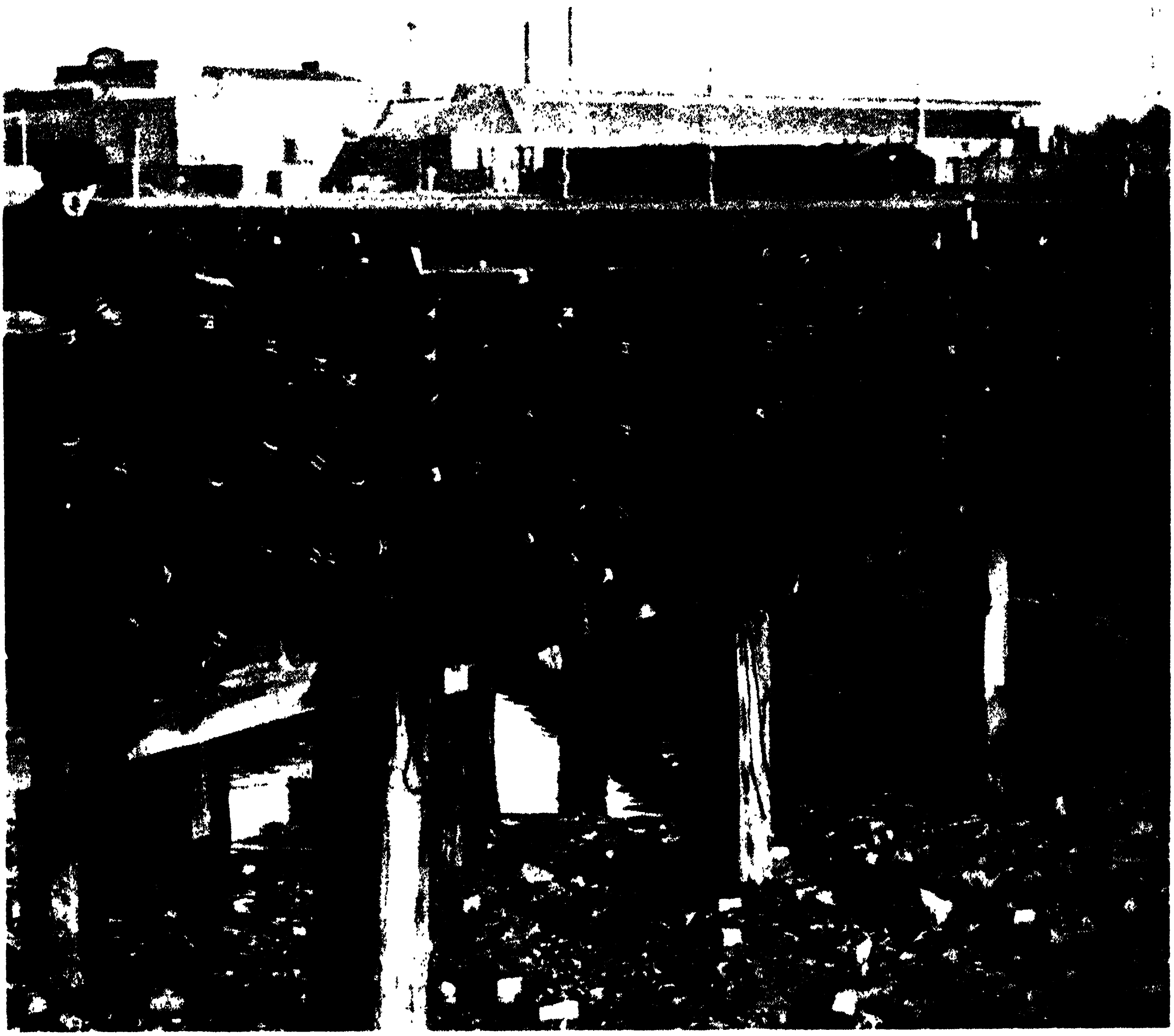
The protection test of the examined treated twine Nm 50/15 stands for a certain number of the same untreated twine samples which successively have lost 50 per cent. of their initial strength *in the time in which the sample has also lost* 50 *per cent. of its initial strength.* Due to such a definition the tests acquire a real physical sense and the reader can see at once how many times stronger is the treated twine than the untreated one.

Such a definition does not alter the principal idea of Dr. Klust but modifies it to a certain extent having eliminated the so-called "rotting value" of the medium. But, in spite of this definition, the test does not illustrate the effects of the second factor, viz.: the non-biological parameters, the intensity of water current in the research station, etc. Considering the changeability of all these non-biological factors, it is difficult to determine any of them or to choose one or more to introduce in some form into the test. To a certain extent, the time in which the experiment is carried out gives an approximate idea of the resultant activity of the above mentioned non-biological factors, and, although it does not help us with any indications it lets us have a general idea of their activity and gives us indications as to the nature of the medium in which the experiment has been carried out. The factor of time enables us to judge the degree of resistance of various protectants to the bacterial decomposition, particularly in highly infected mediums for, even an ineffective protectant will initially keep the twine from rot, until after a certain time when mechanical damage has taken place the micro-organisms will invariably cause complete decomposition. If such a treatment process were only to be evaluated according to Dr. Klust, a very high number—denoting efficiency—would be obtained in a highly infected medium. The same treatment process evaluated in a medium with smaller bacterial activity (a low rotting number of the medium) would yield a different result—a relatively low number. This example shows that the duration of the experiment has a great influence on the results.

Therefore, we would suggest that to the test of Dr. Klust be added a number to indicate the duration of time (months) in which the experiment had been carried out. Maybe such a test would be less comparable, but much more useful, for it would help to avoid greater mistakes which undoubtedly occur in the simple and attractive interpretation of Dr. Klust.

Hence, "PT" 20/5 would signify that in the course of 5 months the treated sample of cotton twine Nm 50/15, had lost 50 per cent. of its initial strength and that in the same period 20 successive untreated twine samples had also lost 50 per cent. of their initial strength.

In spite of this modification, the "PT" test will go on being a non-comparable number, as long as there is no better method to determine and to regulate the rotting processes and the "rinsibility" of the preservative. These demands, however, are in a technical way still difficult to answer. At present, there is no practical answer except to continue applying the classical method of Meseck for fishing purpose. Results obtained by any other method should be considered with great care. They can only be reliable if confirmed by the "fishing" method the results of which, in practice, have not been reported as contradicting each other.



Herring nets used in the East Anglian fishery being dried at Gt. Yarmouth, U.K.

METHOD OF TESTING RESISTANCE OF NET MATERIALS TO MICRO-ORGANISMS

by

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Abstract

This paper describes a method of assessing the efficiency of net preservatives independent of the rotting powers of the waters in which the nets are used.

A numerical value has been found for the test figure T, which is the amount of rotting activity necessary to reduce the initial breaking strength of a material by 50 per cent. and the following criterion is used to assess the value of preservatives:

T =	200 or less —	poor efficiency
=	200 — 500 —	low ,,
=	500 — 1000	medium ,,
=	1000 2000 —	good ,,
=	over 2000 —	very good ,,

In this way it is possible to make comparisons which are quite independent of the type of water and time of year

Technique d'essais de la résistance aux micro-organismes des matériaux employés pour la fabrication des filets

Résumé

Ce document décrit une méthode permettant d'évaluer l'efficacité des agents de préservation des filets, indépendamment du pouvoir de putréfaction de l'eau dans laquelle ceux-ci sont utilisés.

On a trouvé pour le test de la Figure T une valeur numérique qui représente le pouvoir de putréfaction nécessaire pour réduire de 50 pour cent. la résistance initiale à la rupture des matériaux et l'échelle suivante est utilisée pour évaluer l'intérêt des agents de préservation:

T =	200 ou moins —	mauvais
=	200 à 500 —	médiocre
=	500 à 1000 —	passable
=	1000 à 2000 —	bon
=	plus de 2000 —	très bon

Il est ainsi possible de faire des comparaisons tout à fait indépendantes du type de l'eau et de la saison de l'année.

Método para determinar la resistencia a los microorganismos de los materiales empleados en la fabricación de redes

Extracto

En este trabajo se describe un método para evaluar la eficacia de los agentes empleados en la preservación de redes, excluyendo el efecto putrefactivo de las aguas donde se calan los artes.

Al determinar los valores (T) obtenidos en las pruebas, se han encontrado cifras que representan la cantidad de acción putrefactiva necesaria para reducir en un 50 por cent. la resistencia a la ruptura que inicialmente tenía el material. En la evaluación del valor de los preservativos se usó el siguiente criterio:

T =	200 o menos	eficacia	muy baja
=	200 — 500 —	,,	baja
=	500 — 1000 —	,,	mediana
=	1000 — 2000 —	,,	buena
=	más de 2000 —	,,	muy buena

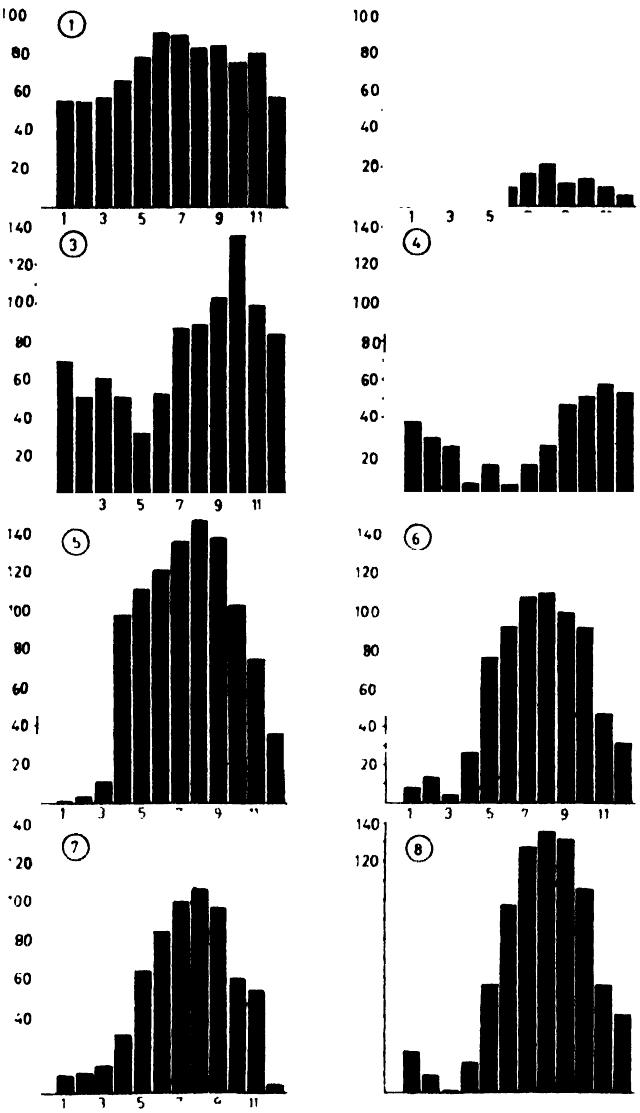
De esta manera es posible hacer comparaciones con independencia del tipo de agua y de la época del año.

NATURAL fibres tend to rot when they are exposed to humidity and unfavourable temperatures. The destruction is caused by micro-organisms, bacteria, and even by fungi, which attack the cellulose and protein. Numerous methods of preserving the nets have been developed, but their efficiency varies considerably. An adequate method in one kind of water may fail in another, not only because of the varying strains on fishing gear, but also because of the variable activity of these organisms. This activity varies in different fishing areas, and in a characteristic rhythm during the year (Diagram 1-8).

These varying factors make it difficult to compare the efficiency of preservative methods, and so an attempt has been made to find a method of testing net preservatives irrespective of place and season.

TESTING METHODS

The growth of fungi and the amount of destruction in textiles are usually tested by the accelerated fungal inoculation method, or the soil burial method. Standards have been established in several countries for carrying out these tests.



Figs. 1–8.

(1) Monthly rotting activity as compared with cotton twines in the course of a year in a eutrophic lake (Lowentien lake, East Prussia, average 1938/1942).

(2) Monthly rotting activity as compared with cotton twines in the course of a year in an oligotrophic lake (Wigry lake near Suwalki, average 1940/1942).

(3) Monthly rotting activity as compared with cotton twines in the course of a year in the North Sea (light vessel Elbe I, average 1948/1956).

(4) Monthly rotting activity as compared with cotton twines in the course of a year in the Baltic (light vessel Kiel, average 1952/1956).

(5) Rotting activity (fortnight-figure) as compared with cotton twines in a non-polluted running water (Schlitz river near Schlitz-Hessen, average 1951/ 1956).

(6) Rotting activity (fortnight-figure) as compared with cotton twines in c heavily polluted running water (Elbe estuary near Cuxhaven, average 1947/1956).

(7) Rotting activity (fortnight-figure) as compared with silk twines in a non-polluted running water (Schlitz river near Schlitz-Hessen, average 1955/1956).

(8) Rotting activity (fortnight-figure) as compared with silk twines in a heavily polluted running water (Elbe estuary near Cuxhaven, average 1953/1956).

These methods cannot simply be adopted for fishing gear because fishing gear is subject to continuous rinsing by water. Tests therefore should be carried out in water.

In testing under natural conditions, net twines, lines or ropes are freely immersed in water. Their breaking strengths are ascertained before and during the experiment. The smaller the loss in breaking strength after a certain period, the greater the resistance to rotting. The rotting action of the water is determined separately and related to the loss in breaking strength. Rotting activity and breaking strength indicate the preservation test figure.

DETERMINATION OF THE ROTTING ACTION OF THE WATER

The monthly rotting degree of the test water is determined by immersing test-twines, cotton twines Nm 50/15 (Ne 30/15), on the first day of each month. Before immersion, the twines are boiled in distilled water, and their initial breaking strength is determined in wet condition. With new cotton twines Nm 50/15 it amounts to about 6·0 to 6·5 kg. Four bunches of 10 twines, each twine 30 cm. long, are used in the experiment. After one, two or three weeks, and on the last day of the month, one bunch is taken from the water to determine the average loss in breaking strength of the twines.

The loss in breaking strength of the sample remaining in the water throughout the month indicates the rotting activity for that month. By dividing it by the number of days the rotting activity per day is determined.

CHANGE OF THE METHOD WITH HEAVY ROTTING ACTIVITY

In heavily rotting waters, i.e., in running waters, a 100 per cent. loss of breaking strength may occur before the end of the month, possibly already after a week, and in that case it is impossible to determine the rotting activity as described above, so the samples are replaced by new ones when they have lost approximately three-quarters of their initial breaking strength. The losses in breaking strength of all samples are added up to establish the monthly rotting activity. The loss of breaking strength shown in a graph has the form of an S-curve. The monthly figure may therefore only be computed from the figures, for instance, of a fortnight, if the sample has lost at least three-quarters of its strength (but not more that 90 per cent.) after 14 days. Frequently, that date cannot be foreseen, so it is suggested that four samples should be put in the water on the first day of the month, as described before, and subjected to a weekly control. This guarantees that the samples rotted up to three-quarters of their initial strengths are recorded and renewed.

Table I is an example of recording the monthly rotting activity in a year in per cent. loss of breaking strength.

In Table I the first four months show the loss in breaking strength of the cotton test twines after 1, 2 and 3 weeks and 1 month. In the fifth month the samples rotted within two weeks and had to be replaced. (The sign "*" in the table means that the samples had been

TABLE I

Test month	*Loss in strength after* 1		3	4 *weeks*		*Value per month*	*Value per day*
January	(0	0	20	54*)		54	1·7
February	(0	0	20	54*)		54	1·9
March	(0	5	40	78*)		78	2·5
April	(0	9	70	100*)		100	3·3
May	(40	93*)	(50	100*)		193	6·2
June		(88*)	(88*)	(73*)	period:	249	8·3
July		(88*)	(100*)	(84*)	10 days	272	8·8
August		(84*)	(81*)	(90*)	not 1	255	8·2
September		(80*)	(75*)	(74*)	week	229	7·6
October		(76*)	(75*)	(65*)		218	7·0
November	(10	40	76*)	(36*)		112	3·7
December	(10	40	76*)	(18*)		94	3·0
				Value p. year :		1908	

renewed.) In the following five months the samples lost about three-quarters of their breaking strengths after ten days, and had to be replaced twice. In the last two months the test-twines had to be replaced after three weeks.

PREPARATION OF SAMPLES AND NUMBER OF SAMPLES

For tests of preservatives a uniform twine Number as cotton Nm 50/15 (Ne 30/15) is recommended. The material should not be too strong, or the test will take too long, but it should not be too fine because the differences of the preservation should be distinctly demonstrated.

The samples are cut into pieces of twine 60 cm. long and treated with the preservative. The increase in weight by the treatment may be determined, the stiffness measured and the content of certain substances determined, etc. In any case, the wet strength after the treatment has to be determined.

The twines are then folded together and bound into bunches 30 cm. long. It is important not to use binding material which may rot and influence the preservative, or which may even be destroyed by it. The bunches would get loose and be lost.

The free end of each twine is knotted to prevent the bunch from becoming matted. The bunches are sufficient for 6 tests of 10 twines each or 12 tests of 5 twines each. Thicker bunches are not recommended as they might influence decay of breaking strength.

It is not necessary to rinse the bunches. As with fishing nets, rinsing occurs automatically during the first days. Differently treated samples should not be exposed together as they may have a reciprocal influence.

DESCRIPTION OF EXPERIMENT

The bunches are fastened to a cord of Perlon, nylon or similar material, the distance between them being about 10 cm. They are suspended so that they neither emerge nor touch the bottom or piles, etc. In tidal waters the samples must be suspended so deeply that they do not get dry. Tests are carried out to obtain comparative values.

It is suggested that the preservatives should be tested several times, in order to obtain a sure average value of the method chosen as a standard. For instance, the following are used as standard preservatives:

Cutch | Testalin.
The same with Carbolineum.
Cutch, Potassium-Bichromate (or copper vitriol with ammonium).
as above, with Carbolineum.

Others may, of course, be used for these experiments.

All samples are simultaneously put into the test water. Considering the climatic conditions in Europe, it is thought best to remove the first sample of 5 or 10 twines after one month, and if no decrease in the breaking strength is found, the next samples may be removed at intervals of two or even three months. A test should be made every two months in summer and every three months in winter if the initial decay does not indicate tighter control.

Removed twines must be cleaned of weeds, etc., and their breaking strengths tested immediately in the wet condition. If it is impossible to do this at once, the twines should be dried and kept for a later test of wet-strength. Further decay may be prevented by using disinfectants. The wet-strength test is made with conventional testing instruments used in textile research.

EVALUATION OF THE RESULTS

The initial breaking strength (A) of the material to be tested is expressed in kg. (wet). The retained strength (B_1, B_2, etc. B_x) is tested after certain periods and is computed as percentage figures of the initial strength:

(1) Retained strength per cent. $= \frac{100 \times Bx}{A}$

(2) Loss in strength per cent. $= 100 - \frac{100 \times Bx}{A}$

Net twines are considered to be unserviceable when the loss in breaking strength exceeds 50 per cent. of the initial strength. This loss therefore is considered the value-limit.

Similarly, the loss of 50 per cent. of the initial strength of treated material determines the evaluation of a preservative. This will be explained by an example:

In Table II the wet breaking strengths of 4 net twine samples preserved by methods A, B, C and D are given in kg. for certain days. The test No. 1 is the initial strength.

TABLE II

Test Number / *Date*	1 / 1.I.	2 / 15.IV.	3 / 20.VI.	4 / 21.VIII.	5 / 15.XI.
A .	6·0	4·6	4·1	3·4	1·6 kg
B .	5·9	4·4	3·2	1·7	0·3
C .	5·8	4·2	2·9	1·7	0·3
D .	6·4	4·9	1·8	0·1	—

Table III gives the several retained breaking strengths in per cent.

TABLE III

Test Number	1	2	3	4	5
Date	1.I.	15.IV.	20.VI.	21.VIII.	15.XI.
A .	100	77	68	57	27
B .	100	75	54	29	5
C .	100	72	50	30	5
D .	100	77	28	2	

Sample A lost 50 per cent. of its strength between the fourth and fifth tests, sample B between the third and fourth, sample C in the third and sample D between the second and third test. It is assumed that the rotting activities mentioned in Table I were existent throughout the experiment. The rotting activity required to reduce the initial strengths of the test-material by 50 per cent. test figure T, is computed according to the following formula:

$$(3)\quad T = \frac{(t_2 - t_1) \times (R_1 - 50)}{R_1 - R_2} + t_1$$

In this formula t_2 means the rotting activity which became effective when the test-material had lost more than 50 per cent. and t_1 means the rotting activity before that state was reached. The desired test-figure T must lie between these two figures. R_1 is the breaking strength before and R_2 the breaking strength after the said state.

The rotting activities, as explained in the above example, result according to Table I in the following:

Period 1.I. to 15.IV.:	January	54
	February	54
	March	78
until	April 15th	50 (15 × 3·3)
		236

Rotting activity is computed from the daily figures for months which have not been completely tested.

Period 1.I. to 20.VI.:	Jan. to May	479
	until June 20th	166
		645
Period 1.I. to 21.VIII.	Jan. to June	1000
	until August 21st	172
		1172
Period 1.I. to 15.XI.	Jan. to Oct.	1702
	until Nov. 15th	56
		1758

If the obtained values are inserted into the formula (3), the following values are obtained as test-figures for the preservatives A to D:

Medium A

$$T = \frac{(1758 - 1172) \times (57 - 50)}{(57 - 27)} + 1172$$

$$T = \frac{4102}{30} + 1172 = 1309 \sim \underline{1310}$$

Medium B

$$T = \frac{(1172 - 645) \times (54 - 50)}{54 - 29} + 645$$

$$T = \frac{2108}{25} + 645 = 729 \sim \underline{730}$$

Medium C : As the date was exactly the 20th June, T = $\underline{645}$

Medium D

$$T = \frac{(645 - 236) \times (77 - 50)}{(77 - 28)} + 236$$

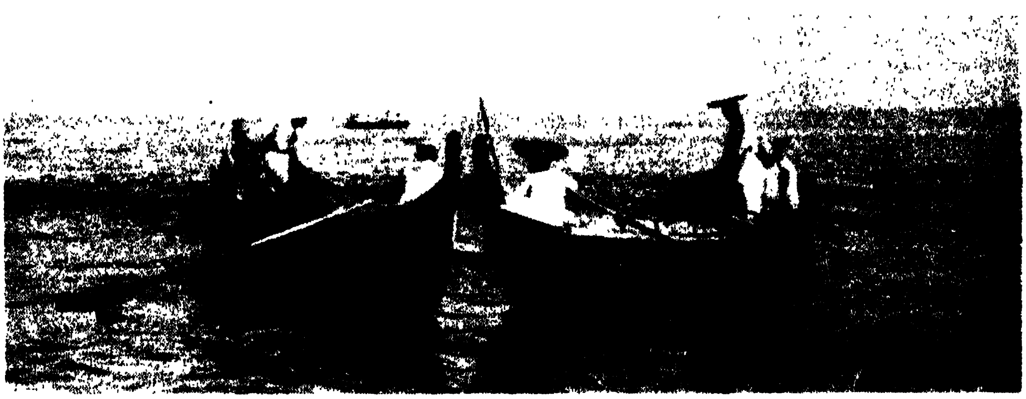
$$T = \frac{11043}{49} + 236 = 461 \sim \underline{460}$$

The greater the test-figure, the greater the performance of the preservative method.

EVALUATION OF THE TEST-FIGURE

The efficiency of the several methods of preservation can be summed up as follows:

Test figure up to 200:	poor effect.
200 to 500:	minor effect.
500 to 1000:	medium effect.
1000 to 2000:	good effect.
above 2000:	very good effect.



Two boat midwater trawling on the Malabar coast of India—an age old method !

DISCUSSION ON NET PRESERVATION

Dr. Reuter, Rapporteur. When using natural fibres the fisherman must periodically treat his nets with preservatives against rotting, as he knows from experience that if this is not done regularly and properly his nets will deteriorate very quickly. His knowledge of preservation is based mainly on practical experience. The available data from preservation experiments with textile yarns are not directly comparable as these are invariably conducted on materials in dry condition, whereas fishing nets are always used in wet condition. Such tests can therefore only be used as a guide. The fishermen in various countries and even in different areas of the same country use different preservation methods, each being convinced that his method is the best. Some only dry the nets, others use coaltar while a third may use cutch; others may use linseed oil, copper sulphate or a combination of two or three products. Very rarely can they give reasons for their choice and they are normally very reluctant to change the custom.

In his paper, Takayama considers the different types of preservatives and their action, showing that some kill the bacteria while others make it physically impossible for the bacteria to attack the fibre.

The decisive factors are the *Cu*-content in copper compounds and the *tannin* content in cutch or catechu. When buying such preservatives the fisherman is, therefore, only interested in the amount of these active agents, i.e. the percentage of Cu or tannin—but not in the bulk alone. Gear Research laboratories can render valuable service in analysing the various brands of preservatives, determine the percentage of active ingredients and advise on proper measures to prevent leaching out of the preservatives by fixing them chemically or by waterproofing.

When conducting preservation experiments, one of the difficulties is to obtain results that can be compared with those obtained at a different season or in a different area. Dr. von Brandt gives a solution to this problem in his paper; his method not only gives a measure of the "rotting value" of the medium in which the experiment is conducted, but also the value of the preservation agent used. The values obtained are expressed in numbers by which the rotting value of different waters and the preserving power of different preservation methods can be expressed.

The way in which this is done is as follows: While untreated cotton yarns are subjected to rot the loss of breaking strength is determined regularly and the percentage of loss added. This number gives the rotting power of that period. A treated yarn is tested in the same way, but the experiment is stopped as soon as the breaking strength has decreased by 50 per cent. The total percentage of white yarn decrease of breaking strength during this period is an indication of the "preservative power."

All natural fibres are open to attack by small organisms, so that all have to be protected against rot and loss of strength. In the face of growing competition of the non-rotting synthetic fibres, the producers of natural fibres are trying to find new ways of immunizing them against micro-organisms, and whereas all older methods are based on preventing the organisms from reaching the fibre by giving it a protective coating, new methods are being considered which chemically change the fibres so that they become indigestible to the micro organisms.

The papers by Sandoz and Ciba Ltd., both describe such methods which are claimed to give good and long lasting protection without causing major changes in the physical properties of the fibre. This last is very important as most protective preservation methods do change some of the physical properties.

Although preservatives are mainly used for natural fibres, there are circumstances where they are useful for the synthetic fibres too. Vinylon nets and lines are generally tarred in Japan. Other synthetics are sometimes coal-tarred to give them more weight or stiffness, to give protection against abrasion, knot slippage, etc. In some cases synthetic fibres are dyed or otherwise treated to prevent deterioration through exposure to sunlight.

Dr. W. Hagenbuch (Switzerland). I am representing the chemical firm Sandoz in Basle, Switzerland. Dr. Reuter has mentioned modified natural fibres which, of course, are something different from synthetic or man-made fibres. I would like to make a few additional remarks on acetylated fibres such as cotton, manila, sisal, etc.

Acetylated cotton has been produced on an industrial scale for about 25 years according to a process which has been worked out by us in Basle, and consists in a reaction of the hydroxile group of cellulose with acetic acid or acetic anhydride, forming a new chemical compound. The result actually is a new fibre and the process is not comparable with a coating or a preservative. It is not cotton any more. Until now, acetylated fibres have been used mainly in the textile field because of their special properties in regard to dyeing. Acetylated cotton does not take up a dye-stuff as normal cotton does. This field, of course, is of no interest here, and the remark was made only to show how and why this has developed. Since about 10 years it has been used in the laundry industry because of its exceptional heat resistance, which is about six to seven times higher than with normal cotton.

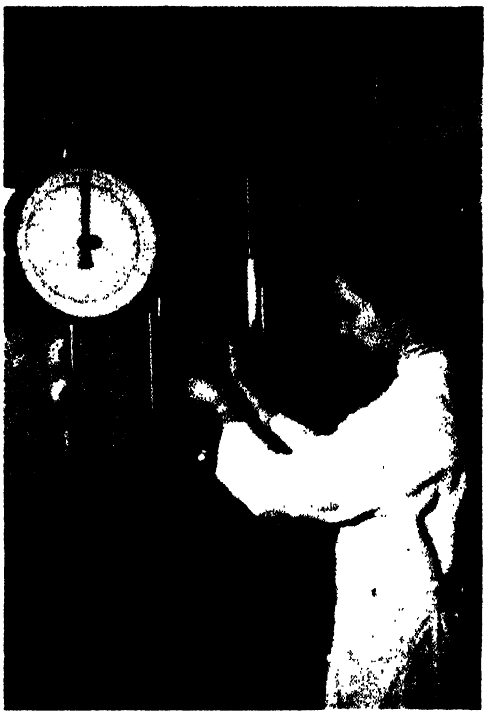
In recent times we have started studying the rot resistance of this acetylated material which proved to be very good in sea water. This rot resistance is permanent and the treatment does not smell or discolour the fibre and is not poisonous. Acetylated cotton looks exactly like normal cotton and can only be determined by chemical methods.

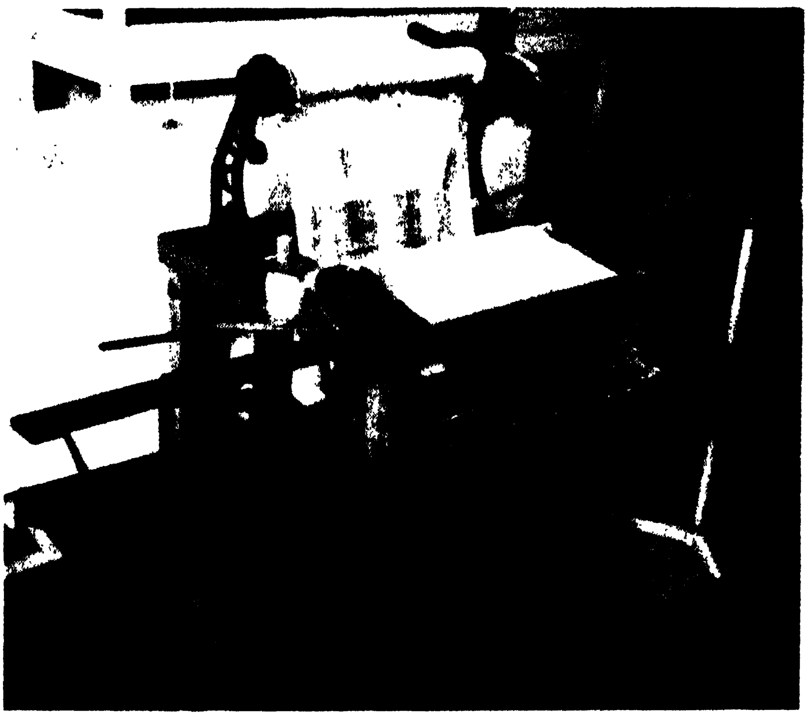
Under the name of Cotoba it has been produced in England since 1927. At the present experiments are going on in Scotland with herring nets and so far in 1½ seasons these nets have been behaving exceptionally well. The price is at the moment

10 to 30 per cent. less than for synthetic fibres, but it can be expected that with increased production a considerable decrease of price will take place, and then I think acetylated cotton will become a very interesting new fibre for the fishing industry.

Mr. A. Ruperti (Switzerland): I am representing the firm Ciba, Basle. We also have elaborated a procedure to prevent rotting by converting cellulose without chemically modifying the fibre itself. With this socalled "Arigal" procedure we also achieve permanent protection, and this is what really counts in fishery.

Mr. H. Levy (Morocco): For 12 years past I have been engaged in preserving fishing gear made of natural fibres, especially cotton. In Morocco we have three preservation methods, i.e. tarring and tanning with two different materials. Tarring is used only for twines that are constantly submitted to abrasion, i.e. certain parts of the big trap nets (madrague), the lower parts of trawl nets and especially the bags of sardine seines. Tanning with catechu gives satisfactory results, i.e. for the sardine net. The third method consists in tanning with ground pine bark which is very rich in tannin and, by the way, is abundant in North Africa. This gives really excellent results. But in recent years the Moroccan fishermen have found a combination of half catechu and half ground pine bark that gives results one would not even have dared to hope for. I would recommend strongly to all fishermen to give this new tanning method a test. The effect of tanning is improved by subsequent tarring to retard the tannin being washed out. Due to these preservation treatments in Morocco lines and ropes are worn out rather than deteriorated by putrefaction. But it must be said that this preservation effect is only obtained if the fishing gear is dried once every week, or at least twice a month.





Left: Operator is testing the breaking strength and extensibility of fishing twine. Right: With hand and foot operated net weaving looms such as the above, nets can be knitted three or four times faster than by hand braiding.

THE EFFICIENCY OF SYNTHETIC FIBRES IN FISHING, ESPECIALLY IN GERMANY

by

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Abstract

Gear is divided into three groups, according to strain on net material during operation. An attempt is then made to classify various fibres (polyvinyl chloride, polyvinyl alcohol, polyester, polyamide, polyethylene, polypropylene) by referring them to these groups.

Net twines of these synthetic fibres, and also net twines of vegetable fibres, are compared with regard to breaking strength (knotted and wet), extensibility and elasticity, and resistance to weather and abrasion. An estimate is then made of the suitability of the different fibres to various types of fishing gear.

For the fine gillnets, polyamide monofilament and twines of either polyamide high tenacity filament or of polyester filament are most suitable. For herring and salmon drift nets, twines of polyamide or polyester filament, and also twines of polyvinyl alcohol, are recommended. Polyamide staple should not be used.

For standing gear, such as trap nets (especially when much exposed to sunlight), twines of polyvinyl chloride fibres (PCU, Rhovyl, Teviron), may be used. Plaited twine made of polyamide filament (Perlon, nylon), which has very high tensile strength, abrasion resistance and elasticity, is considered the best net material for very heavily strained gear, such as bottom trawl nets.

L'efficacité des fibres synthétiques dans la pêche spécialement en Allemagne

Résumé

Les engins sont divisés en 3 groupes d'après l'effort exercé sur la matière du filet pendant la pêche. L'auteur a fait un essai de classification des diverses fibres (chlorure de polyvinyle, polyacrilonitrile, alcool de polyvinyle, polyester, polyamide) en les rapportant à ces groupes.

Les fils à filet de ces fibres synthétiques, et aussi les fils à filet de fibres végétales, sont comparés en ce qui concerne la résistance à la rupture (noués et mouillés), l'extensibilité et l'élasticité, et la résistance aux intempéries et à l'abrasion. L'auteur estime ensuite à quel degré les différentes fibres conviennent aux divers types d'engins de pêche.

Pour les filets maillants fins, le polyamide monofilament et les fils de polyamide à ténacité élevée ou de filaments de polyester conviennent le mieux. Pour les filets dérivants à harengs et à saumons on recommande les filés de filaments de polyamide ou de polyester, et aussi les fils d'alcool de polyvinyle. Il ne faut pas utiliser de polyamide tressé.

Pour les engins fixes comme les filets-trappes (spécialement quand ils sont beaucoup exposés à la lumière solaire), les fils de fibres de chlorure de polyvinyle (PCU, Rhovyl, Teviron), peuvent être utilisés. Le fil tressé de filaments de polyamide (Perlon, nylon), qui possède une très grande résistance à la traction, à l'abrasion et une grande élasticité est considéré comme étant le meilleur matériau pour fabriquer des engins supportant de grands efforts comme les chaluts de fond.

La eficacia de las fibras sintéticas en la pesca, especialmente en Alemania

Extracto

Como los artes de pesca pueden dividirse en tres grupos segun el esfuerzo a que se somete el material, se ha tratado de clasificar las diversas fibras (cloruro de polivinilo, policrilonitrilo, alcohol de polivinilo, poliéster, poliamida) en cada uno de ellos.

Para determinar la resistencia a la ruptura (anudados y húmedos), alargamiento, elasticidad y resistencia a los agentes climáticos y al roce, se procedió a evaluar las características de los hilos de estos materiales sintéticos con los de origen vegetal empleados en la fabricación de redes. Luego se valoraron las maneras como se prestan las características de las diversas fibras para tejer los artes.

En el caso de redes de enmalle finas son más adecuados los hilos de poliamida de una sola hebra o de varios filamentos con gran resistencia, ya sea de este material o de poliésteres, así como también los de alcohol de polivinilo. Para las redes de deriva que se utilizan en la pesca de arenque y salmón se recomiendan los hilos de poliamida o poliéster y también las de alcohol de polivinilo. En la fabricación de estos no conviene usar material preparado a base de poliamida.

Para los artes fijos, como las redes trampas (especialmente cuando quedan expuestas a la luz durante largo tiempo, deben usarse hilos formados por fibras de cloruro de polivinilo ("PCU", "rhovyl", "teviron") al tratarse de artes sujetas a grandes esfuerzos como las redes de arrastre de fondo, es más conveniente utilizar hilo de hebras de poliamida (perlón, nylón), trenzadas que poseen gran elasticidad, resistencia a la tensión y al roce.

I. PROOF AGAINST ROT—THE MOST IMPORTANT PROPERTY OF SYNTHETIC FIBRES IN FISHING

THE most important raw materials for nets in European fisheries have been vegetable fibres cotton, flax, hemp, sisal and manila. When immersed in water, they are exposed to cellulose-digesting micro-organisms, especially bacteria. The resistance of vegetable fibres increases in the following order: flax, hemp, ramie, jute, cotton, sisal, manila, coir (Klust 1961).

Factors affecting the durability of the net of vegetable fibres, and of more importance than this resistance are:

1. Duration of immersion in water: Fishing gear left in water for a long time are more liable to rotting than those used only temporarily. Rotting is stopped only when the nets are dried completely, also inside the knots.

2. Water temperature: The warmer the water, the quicker the rate of rotting[1].

3. Kind of water: Due to intensive rotting[4] nets will be destroyed considerably sooner in eutrophic than in oligotrophic or dystrophic waters[2, 3].

In middle European eutrophic water, with higher temperature, unpreserved cotton nets may become useless after 7 to 10 days. Only very intensive preservation methods can prolong their durability[5, 6]. Preservation is most effective for cotton nets whereas efficiency is poor with bast fibre or hard fibre nets.

The durability of fishing gear is primarily affected by rotting. The original cost is increased disproportionately owing to frequent renewals and preservation expenses. The smaller the business, the greater are the relative expenses for nets.

In a report on nylon as net material, Needham writes[7]: "Nylon brings to one of man's oldest occupations the miracle of science and, in doing so, provides easier living for the fisherman . . . " This statement can apply to all synthetic fibres, for this miracle is apparent in their proof against rot. The first synthetic fibre, known as PeCe (polyvinyl chloride), was developed by the former German I.G. Farbenindustrie, in 1931. Some years later, twines made of these fibres began to be used for smaller gears in German inland fisheries [8, 9], and its rot-proof quality became apparent. This meant much greater durability of gears (fyke nets made of PeCe, have been in continuous use for over 15 years), less work and lower preservation expenses, obviating the time consuming drying of nets and thus ensuring longer catching periods. Apart from this rot-proofness which is the most important characteristic of synthetic fibres, other important properties are: breaking strength, extensibility, elasticity, abrasion resistance, diameter, weight, stiffness, resistance to weathering, knot stability and behaviour in water, including change of length, sinking speed and visibility.

II. TYPES OF FISHING GEAR, WITH REGARD TO THE MATERIAL AND KINDS OF SYNTHETIC FIBRES USED

A great variety of gear is used in fishing, differing very much in size, structure, method and purpose of use. They have been classified by v. Brandt[10]. According to strain on the net-material German fishing gear can be divided into three groups[11]:

1. Low Strain

Fine gillnets belong to this first group. The traditional material is fine cotton twine of metric counts 270/6 to 70/9 (English counts 160/6 to 40/9) or similar thickness, with a diameter of less than 0·40 mm. and a breaking load (wet) not higher than about 3 kg.

2. Medium Strain

This group is formed by the various fishing gears of the German inland, coast and deep-sea fisheries which formerly were made of cotton twines, of metric counts 20 and 50 (English counts 12 and 30). Fine twines of flax or hemp were occasionally used. This includes:

most fishing lines
baskets, also trap nets and box nets
scoops
gape nets (without those mentioned above)
dragged gears also bottom trawls of smaller vessels
floating trawls of cutters
seines and purse seines
dip nets and lift nets
drift nets

3. Heavy Strain

Bottom trawls of large vessels (trawlers and cutters) and gape nets set in fast running rivers belong to this group. They were made of thick manila, sisal or hemp twines, with diameters up to 3·9 mm. and breaking loads up to nearly 200 kg.

Table I gives the characteristics relevant to fisheries purposes for the most important synthetic fibres, and shows for which of the three groups these fibres could be used. In the column "trade names", only the best-known are listed. Only nylon and Perlon are given for the

TABLE I

Fibre	*Trade Names*	*Characteristics*	*Suitable for use in*
Polyvinyl Chloride	F: Rhovyl G: PCU, Rhovyl J: Envilon, Teviron	medium breaking strength, medium abrasion resist., very good resistance to weathering	group 2
Polyvinyl Alcohol	J: Vinylon, Manryo, Kuralon, Trawlon, Cremona, Mewlon G: PVA	low price, medium breaking strength, medium abrasion resistance, good resistance to weathering	group 2
Polyester	GB: Terylene USA: Dacron G: Diolen, Trevira F: Tergal I: Terital J: Tetoron	very high breaking strength, low extensibility, medium abrasion riesistance, relatively good resistance to weathering	groups 1 and 2, group 3?
Polyethylene	GB: Courlene X3, Drylene N: Nymplex G: Polyäthylen-Hoechst	high breaking strength, very high abrasion resistance, wiry, swimming in water	group 2, group 3?
Polypropylene	I: Meraklon USA	low price, medium to high breaking strength, low resistance to weathering, swimming in water	group 2, gr.1a.3?
Polyamide mono-filament	Nylon-monofil., Perlon-monofil., Platil	transparency (little visibleness in water), very good resistance to weathering, wiry	group 1, group 2: fyke nets
Polyamide staple	Nylon—staple, Perlon- staple	high breaking strength, high abrasion resistance, good knot stability, very high extensibility, low resistance to weathering	group 2
Polyamide continuous filament	Nylon—filament Perlon—filament	very high breaking strength, very high abrasion resistance, high elasticity, low resistance to weathering	all 3 groups of gear

F=France, GB=Great Britain, G=Germany, I=Italy, J=Japan, N=Netherlands.

polyamides, although fibres of this group and of equal value to fishing gear are produced in different countries under various names, such as: Amilan, Anzalon, Dayan, Dederon, Ducilon, Enkalon, Fefesa, Forlion, Grilon, Kapron, Kenlon, Knoxlock, Nylock, Rilsan, Silon, Steelon and Tynex.

III. EVALUATION OF THE MOST IMPORTANT PROPERTIES OF SYNTHETIC FIBRES USED IN FISHING

Properties of primary importance in the evaluation of net twine are rot-proofness, breaking strength, extensibility and abrasion resistance. Resistance to weathering may be of primary importance for fishing gears, which are used just below the surface or partially out of water.

Based on experience in German fisheries and on investigations by the Institut für Netz-und Materialforschung, an attempt is made below to evaluate these special properties.

1. Breaking strength, in knotted, wet condition

Twines of cotton, hemp and manila are strongest in wet condition. With synthetic fibres there are groups which have the same or nearly the same strength wet or dry: Polyvinyl chloride (PeCe, PCU, Rhovyl), Polyester (Terylene, Dacron, Trevira, Diolen), polyethylene polypropylene and some copolymers (Saran, Vinyon, Dynel, Acrylan). Other groups show a loss of strength when wet, such as: polyamide (Nylon, Perlon), polyacrylonitrile (Orlon, PAN), polyvinyl alcohol (PVA, Manryo, Kuralon, Vinylon). Diminution of strength occurs as soon as the net twines come in contact with water. After a 24 hour immersion the following approximate losses of strength were observed: twines made from polyamide staple and cont. filament 13 to 17 per cent., polyamide monofilament nearly 20 per cent., twines made from polyvinyl alcohol staple about 25 per cent.

During prolonged immersion in water extending over several months, a further gradual decrease of strength takes place,[12] though by no means comparable to that of even well-preserved net twines of vegetable fibres.

It is of importance to know the decrease in strength caused by knotting. This is connected closely with the properties of the fibre substance. Continuous filaments of polyamide and polyester are of high tenacity (highly stretched) in order to obtain as high a strength as possible, and have a lower extensibility. Unfortunately, they show a diminution of knot strength too. Losses of strength of wet twines by knotting (in the average):

Twines made from	losses in per cent
manila, medium fine tw.	30
manila, thick twines	40
hemp	25
cotton	30
Perlon staple	35
Nylon contin. fil., fine tw.	33
Nylon contin. fil., medium fine tw.	43
Nylon contin. fil., thick tw.	50
Perlon contin., twisted (trawl twines)	50
Perlon contin., braided (trawl twines)	42
Perlon monofilament (trawl twines)	30
Polyester contin., (trawl twines)	50
Polyethylene	36

Net material, therefore, has to be evaluated according to its *strength in knotted and wet condition.* Table II gives such an evaluation for net twines from group 2. Based on tests of a great number of net twines of different thickness, the breaking length in km. and tensile strength have been calculated. For calculating the tensile strength (kg./mm.^{2}) the following specific gravities (which are mostly taken from the list of Grünsteidl and Preussler[16]) have been used:

TABLE II

Breaking strength of net twines, single knot and wet

Twines made from	*Breaking Length km.*	*Tensile Strength kg./mm.^{2}*
Polyvinyl chloride		
Rhovyl-Fibre (staple)	6·4	9·0
Rhovyl, continuous filament	7·6	10·6
PCU, staple	8·2	11·5
Polyvinyl alcohol, staple	10·2	13·3
Polyacrylonitrile, continuous filament	14·5	17·0
Polyester, continuous filament	26·3	36·3
Polyamide, staple	15·7	17·9
Polyamide, continuous filament	30·1	34·3
Cotton	12·2	18·5
Hemp	28·9	42·8

Polyvinyl chloride	·40 g./cm.
Polyacrylonitrile	·17 „
Polyvinyl alcohol	·30 „
Polyester	·38 „
Polyamide	·14 „
Cotton	·52 „
Hemp	1·48 „

Hence of the synthetic net twines considered here, those of continuous polyamide and polyester are by far the strongest. Their wet knot-strength is twice that of cotton twines.

2. Extensibility and Elasticity

The extensibility of net twines consists of several components: that of the fibre, the single yarn, and finally extensibility of the end product or twine. The inherent extensibility of synthetic fibres varies, being large for the polyamide group and comparatively small for the polyester group. Short staple fibres produce a higher extensibility than continuous filaments. Hard twisted yarn is more extensible than a soft twisted one. The manufacturing process of the final products is also of great importance. The more the twine is twisted or the tighter the braid is plaited, the greater the extensibility. To obtain a high extensibility, it is better to use fibres with a large original extensibility than to use hard twisting of yarn and twine to attain this high extensibility.

Total extensibility comprises a part of elastic extension and the permanent elongation. Apart from the nature of the fibre and the manufacturing process, their value is dependent on the applied load. Where the total extension results mainly from the manufacturing process, i.e., from twist of yarn and twine, elasticity will be small, and the permanent elongation, which remains after unloading, will be comparatively great.

Net twine has a greater efficiency, if total extension and elasticity are high. It will be able to absorb kinetic

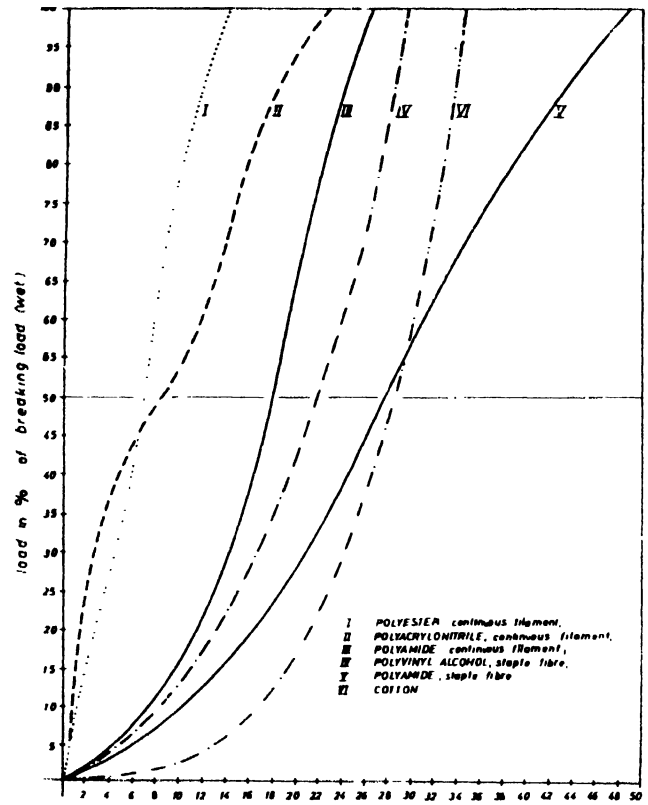

Fig. 1. Load–extension curves.

energy and will take up shock loads better than net twines of small extensibility. This problem was first examined thoroughly with nylon ropes[17]. It is of particular importance for gear under heavy strain where one has to reckon with sudden strong loads[18].

It is difficult to evaluate the breaking extension of nets, as it must be expected that, for high-class fibres, knot-strength reaches only about 50 to 60 per cent. of the breaking load. Knowledge of breaking extension, is, therefore, not very important. The degree of extension with ascending load which, at the most, may amount to 50 per cent. of the breaking load is more important. The relation between load and extension, up to this limit, has to be observed, and an example is represented by the load-extension curves of fig. 1 for net twines of material group 2. The curves have been drawn from average values which were calculated from the results of several tests of twines.

Two different types of extensibility are represented in fig. 1; that of polyester and polyacrylonitrile (both of continuous filament), and that of polyamide, polyvinyl alcohol and cotton.

The total extensibility of the first type is small, and such twines offer strong resistance, even at small loads. There is a steep ascent of the curves, as for those of manila twines.

The second type is affected at low tension or pressure, where the increase of extension already exceeds the increase of load. All curves apply to wet twines. Twines of staple fibres are much more extensible than those of

TABLE III

Extension in per cent. (dry)

Twine.	*Perlon filament*	*Polyester filament*	*Manila*	*Cotton*
Immediately after loading	8·3	3·8	2·2	14·2
1 hour loaded	9·0	4·2	2·4	15·0
Immediately after unloading	2·2	1·2	1·4	8·0
1 hour after unloading	1·7	0·8	1·2	6·0
1 day after unloading	1·0	0·4	1·2	5·0
Final condition	0·8	0·4	1·2	5·0
Total extension in per cent.	9·0	4·2	2·4	15·0
Elastic extension in per cent.	8·2	3·8	1·2	10·0
Permanent elongation in per cent.	0·8	0·4	1·2	5·0
Degree of elasticity in per cent.	91	95	50	67

continuous filaments, especially if the latter, as in the case in question, are of high tenacity. When cotton twines are wetted they show a shrinkage of nearly 10 per cent. With a small load, the extension of wet cotton twines is very great; with low tension pressure, shrinkage will be compensated by extension. Twines of fibres which have small shrinkage in water, such as twines of polyester or polyamide filament, will also show small differences between dry-extension and wet-extension.

Extension in connection with elasticity is of special interest. Elasticity regarding the stronger net twines, which are used for large bottom trawls, is shown in Table III. The twines have been loaded in dry condition for one hour by 30 per cent. of their breaking load.

The thick cotton twine shows the highest extension at load. After unloading, a rather high permanent elongation remains. For manila, the total extension is very small. Therefore, the absolute measurement of the permanent elongation is also small, though it comprises 50 per cent. of the total extension. Polyester twine is very elastic, its extensibility, however, is very small. Perlon filament twine has a proportionately high extensibility, together with high elasticity.

What significance does this difference in behaviour have for fishing gear?

A fixed extensibility cannot be set for net twines, as the requirements differ according to the type of gear.

In drift nets, for example, the fish will be caught in the meshes. The mesh sizes, which must be adapted to the size of the fish, should not alter, so the permanent elongation must be small. The twine should yield to the pressure of the fish caught in the mesh. Extension and elasticity, however, must not be too great, otherwise the fish would be squeezed in too tight, the quality of the fish would suffer, and it would be also very difficult to release it from the net. The very extensible twines of polyamide staple fibres are therefore less suitable for drift nets. Twines of polyester (Terylene, Dacron, Trevira, Diolen) (see fig. 1 and Table III) would, however, be especially qualified for these gears, since their permanent elongation is small, but their relative elasticity great.

The requirements of gear exposed to strong tension or pressure are very different. This applies to trawls, especially the codends, when they are rushed up from a great depth to the surface or while heaving a large catch on deck. These nets were made of strong manila or sisal twines, in order to stand sudden shock loads. In consequence of their very small extensibility, hard fibres are not able to absorb kinetic energy. Best suited for large bottom trawls are twisted or plaited twines of polyamide filament (e.g. Perlon, nylon). Their extensibility is great enough to stand strong shock loads, and the high degree of elasticity guarantees a good constancy of mesh size. In the German trawl fishery most of the lighter bottom trawls and floating trawls of cutters are now also made of Perlon (in this case from staple fibres) because its high elastic extension gives the necessary strength for handling, also big catches. Perlon staple fibres have also proved suitable for otterboard stow nets.

As regards extensibility, drift and trawl nets are examples of extreme types of gear. Between them there is a great range of other types of gear with different requirements of extensibility and elasticity. For synthetic fibres, polyester filament and polyamide staple fibre are the extremes as regards extensibility.

3. Abrasion resistance

In practice, it is scarcely possible to obtain exact knowledge of the relative abrasion resistance of nets made of different kinds of fibres. One is dependent on laboratory test methods, and only relative and never absolute values are obtained and these, moreover, are dependent on the test method employed.

For the following tests, the machine for testing abrasion resistance after Sander was used, in which the wet net twines are chafed across a bar of carborundum[10]. The counts or runnages of the various types of twines under comparison were taken as equal as possible. Thicker twines for large trawl nets were compared with one another, and also twines for gears of material group 2. If in the first case, abrasion resistance of thick cotton twine is equal to 100, the following approximate relation can be established:

Cotton	= 100
Manila	= 130
Hemp	= 280
Polyester cont. filament	= 230
Polyamide cont. filament	= 460

These figures refer to new, unused and wet twines, with a runnage of above 350 m./kg. The abrasion resistance of manila twines is very low. As some tests have shown, it is about the same as for sisal twines. As the breaking strength of nets of natural fibres is reduced by rotting, abrasion resistance will also be reduced. For twines of manila and hemp, the following relations have been established[10]:

Diminution of		
breaking strength in per cent.	*abrasion resistance manila, per cent.*	*hemp, per cent.*
10	2	5
20	3	9
30	5	14
40	6	19
50	15	23
60	26	27
70	37	34
80	48	50

Trawl nets are very much exposed to abrasion, which largely explains the short durability of manila nets. Polyamide fibres (Perlon, nylon) show the best abrasion resistance, and are by far superior to those of natural fibres. Trawl nets of Perlon filament used in the German trawl fishery, show about ten times the durability of manila nets, this is due not only to their rot-proofness, but also to the greater abrasion resistance of polyamides. Twines of polyester filament have only half the abrasion resistance of twines of polyamide filament, but their resistance is better than that of cotton and manila twines.

Abrasion resistance depends not only on the type of fibres and on the diameter, but also on the manufacturing process of the twine[18]. Hard twisted twines of polyamide filament have less abrasion resistance than soft twisted twines. Corresponding features apply to braids of polyamide filament.

The finer twines for gears of material group 2 have the following abrasion resistance (wet), when cotton is again equal to 100:

cotton	= 100
polyvinyl chloride	
Rhovyl-staple	= 50-55
PCU-staple	= 75
polyvinyl alcohol	
staple	50-60
filament	= 110
polyacrylonitrile	
cont. filament	70
polyamide	
staple	170-250
cont. filament	400-500

These relative figures correspond to twines of the same runnage or count. If the calculation is based on the same diameter, the values will be somewhat displaced. The third possibility would be a comparison of abrasion resistance of twines of the same breaking strength. In that case twines of high tenacity fibres, such as polyamide filament and polyester, do not show such a great superiority, since they are much finer than twines of weaker types of fibres.

4. Resistance to weathering

There are few experiments on the resistance to weathering of nets made of vegetable fibres. These fibres are injured by sunlight. But such damage is small compared with that caused by micro-organisms in the water. Resistance to light and weathering is about the same in all vegetable fibres.

Synthetic fibres show very great differences in their

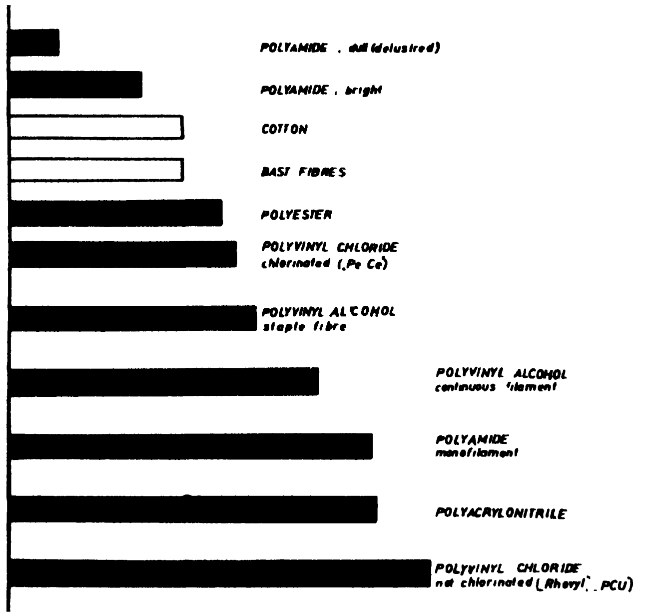

Fig. 2. Relative resistance to weathering.

degree of resistance to light and weathering. Fig. 2 demonstrates their relative resistance to weathering[20]. Of the fibres represented here, delustred polyamide offers least resistance, so that dull polyamide twines are not suitable for fish nets, since their resistance to light is too small.

It could be mentioned here that the USA are said to have succeeded in producing a dull nylon type with the same resistance to weathering as bright nylon.[21] The resistance of twines made of bright polyamide (staple and filament) is still below that of cotton and hemp twines. Polyamide monofilament and fibres of polyacrylonitrile and non-chlorinated polyvinyl chloride have a very great resistance to weathering.

However, the other excellent physical properties of twines made of polyamide filament and staple more than compensate for their smaller resistance to light, especially for fishing gear of special economic significance, such as trawl nets.

As an example: in the Portuguese purse seine fishery, nets of unprotected (uncoloured) Perlon-staple twines, have been used for 1,306 working days and are still serviceable, whereas preserved cotton nets usually last for no more than about 500 working days.

For trap nets and other baskets, which stand partly out of the water or close below the surface, colouring of the material as a protection against light will often help. In this case nets of polyvinyl chloride, polyacrylonitrile and polyamide monofilament would be rather suitable.

IV. CHOICE OF SYNTHETIC FIBRES FOR VARIOUS FISHING GEAR

The discussion in Section III may now serve to answer the question as to the suitability of certain synthetic fibres for certain gear used in Germany (ref. especially Table I).

Material Group 1. This comprises the different types of set gillnets, floating gillnets and trammel nets used in inland fisheries. Also fine herring nets of the Baltic fishery belong to this group. Gillnets are passive gears into which migrating fish swim by accident and become stuck in the meshes. Here, invisibility is of prime importance. The twines must therefore be of small diameter of just sufficient breaking strength, this depending on the species of fish to be captured.

Accordingly, it would be advantageous to use very fine twines from strong types of fibres. Two types of synthetic fibres have a particularly high strength: *polyester filament* and *polyamide filament* (Table II). Very fine twines made of the latter have stood the test very well in inland fisheries, and also for herring gillnets in the Baltic. They catch more fish than cotton gillnets, since they are finer and softer and less visible. The best material for fine gillnets is, undoubtedly *monofile polyamide-wire*. Its translucency makes it nearly invisible in water. The catch of gillnets of this material is many times that of cotton nets, as many fishing countries can testify.

Material Group 2. German fishing gear belonging to this group were all formerly made of cotton twines. For this, twines of breaking strength of 3 kg. up to about 50 kg. were used.

The largest gear of this group, the herring drift nets of the North Sea drifter, have been discussed in Section III, (2), showing why twines of polyester filament are regarded as particularly suitable. Extension and elasticity of twines of polyamide filament are also suitable, but not twines of polyamide staple.

For gear of such large dimensions, the initial costs must especially be taken into consideration. The complete string of herring drift nets (called "fleet") often consists of more than 1,500 kg. cotton twine. The much greater strength of the synthetic fibres just mentioned cannot be fully utilized. It is not possible to use twines as fine as the breaking strength would permit, because of the damage that could be caused to the fish. Therefore, the weight advantage as compared to cotton nets and, consequently, the lower costs, will not be as great as for other gears. Thus, drift nets of polyester or polyamide are much more expensive than cotton nets. Perhaps it would be better, in this case, to use polyvinyl alcohol which is the cheapest synthetic fibre. Drift nets made of that fibre are scarcely more expensive than cotton nets and may be completely suitable, if a good stiffening process is used. The production of knotless drift nets of polyvinyl alcohol fibres would be a great advantage. Satisfactory results have been obtained in a first test with such nets made of Japanese Manryo.

During 1956 the German Baltic Fishery recorded very good results with *salmon drift nets* made of polyamide filament, and this material will probably completely displace the traditional hemp nets during the next few years.

Passive gears, such as *baskets*, with the exception perhaps of the large trap nets (box nets, stake nets, fixed nets) of the coast fishery, do not generally require a very strong material. If fibres such as polyamide and polyester filament are used, then here too, may be a chance of catching more fish with a finer twine. Since all synthetic fibres are rot-proof, there is a very great choice of suitable materials. For trap nets, such as the Danish "Bundgarn", which stand partly out of the water, fibres of high resistance to light would be recommendable, e.g., polyvinyl chloride fibres PCU and Rhovyl and also the new Japanese Teviron or Envilon.

Translucency, a special property of polyamide monofilament, has proved to be of primary importance in catching more fish, also with baskets. Eel fyke nets, made of monofilament, caught about twice as much as those made of cotton; that also would be true of other baskets. But this would not seem profitable, if the long leaders and wings of trap nets, were also made of monofilament. They would not lead the fish into the trap net (net proper), but act as gillnets and the fish would be caught in the meshes[22].

Dip nets, lift nets and falling nets (lantern nets, cast nets) are of little importance in the German fishery, but what has been said about material for baskets will mostly be applicable.

The most important gears of German rivers are *gape nets*. According to the flowing speed of the water, they require material of great to very great strength, of relative high extension and elasticity and of great abrasion resistance. Polyamides have these requirements. For swing nets (stow nets) at anchor (also for otter-board stow nets), with the smaller mesh sizes or such nets which are in rivers with a flowing speed of less than 5 km./hr., twines of Perlon-staple have lasted very well for more than six years. For stiffening, they were treated with "Black Varnish". Gape nets with large mesh sizes from rivers with strong current (e.g. the Rhine), are made either wholly, or in their most forward part, of plaited or twisted twines of polyamide filament, belonging to group 3.

Two more gear types of material group 2 are seines and light cutter trawls.

For *seines*, and also for *purse seines*, there are many possibilities of choice of synthetic twines. During the first years of introduction of PeCe into the German inland fishery there were, for instance, boat seines made of these fibres, although breaking strength and abrasion resistance were less than those of cotton twines. Since the physical properties of the non-chlorinated polyvinyl chloride fibres are superior, these can also be used for seines. The same goes for polyvinyl alcohol twines which are also inexpensive. These fibres, however, do not have a very high absolute strength in wet and knotted condition. Therefore, one cannot count on the gear being lighter than a cotton net of the same size. For polyester and polyamide, however, these relations are more favourable. If the breaking strength, wet and knotted, is taken as a basis, then gear of polyamide filament is only half as heavy as that of cotton.

Material group 3. The requirements of the material of *trawls*, have already been partly indicated in Section III, 2. They are the same as for large gape nets; very high breaking strength and abrasion resistance and comparatively great extension and elasticity, and possibly the smallest weight. That goes both for lighter bottom trawls and floating trawls of cutters which still belong to material group 2, and for the large bottom trawls of deep sea trawlers belonging to *material group* 3. There are differences only in the degree of strain and not in principle. By far the best material for these purposes seems to be polyamides. For cutter trawls, besides twines of polyamide filament of titer 210 denier, weaker twines of polyamide staple may also be used. For heavy and large trawls, plaited and laid twines of polyamide filament have stood the test so excellently that the German trawl fishery works now mostly with Perlon nets for the catch of herring and of round fish.

Especially in the Japanese fishery, trawl nets of polyvinyl alcohol are frequently used. But their advantage seems to be in the low price only, as rot-proofness is peculiar to all synthetic fibres. They may be perfectly suitable for lighter trawl nets of smaller fishing boats, but for gears of large trawlers, twines of polyvinyl alcohol fibres do not seem to be very suitable. The test figures for one Japanese Manryo twine and for twines of manila and Perlon-filament, with nearly the same runnage, given in Table IV, may serve as an illustration.

TABLE IV

	Manryo 20'*S*/120 *twine*	*Manila* *Nm* 0. 7/3	*Perlon* *Nm*. 3/12
Runnage, m/kg.	239	~230	242
Breaking strength, wet, kg.	79·2	~ 95	156
Strength, wet, knotted, kg.	35·7	~ 60	99

The lighter a trawl net is, the easier its handling and the lower its trawling resistance. These aspects are particularly important for large gear. From Table IV it can be seen that trawl nets of Manryo become much heavier and must have thicker twines, if they are to be as strong as manila trawl nets. The great advantages of trawl nets of polyamide filament in this respect are apparent.

REFERENCES

[1] Klust, G. und H. Mann: Experimentelle Untersuchungen uber den Zelluloseabbau im Wasser. "Vom Wasser" Bd. 21, 100-109, 1954.

[2] v. Brandt, A.: Über den Zelluloseabbau in Seen Arch. f. Hydrobiol. Bd. XL. 778-821, 1944.

[3] v. Brandt, A.u. G. Klust: Zelluloseabbau im Wasser. -Arch. fur Hydrobiol. Bd. XLIII, 223-233, 1950.

[4] v. Brandt, A.: Cellulose-Abbau in Fliessgewässern. Ber. Limn. Station, Freudenthal, Bd. 4, 17-19, 1953.

[5] v. Brandt, A.: Untersuchungen zur Konservierung von Fischnetzen.--Prot. z. Fischereitechnik, H.7, Nr. 14, 1952; H.10, Nr. 19, 1953.

[6] Klust, G.: Die Beurteilung der konservierenden, Wirkung von Fischnetz-Konservierungsverfahren. Melliand Textilber., Bd. 33, 763-764, 1952.

Klust, G.: Testing methods of fishing net preservation. Cordage World, Vol. 33, Nr. 396, 1952.

[7] Needham, E. R.: Use of Nylon yarns in fish-netting. Canadian Textile Journ., 74-76, 1953.

[8] v. Brandt, A.: Bekommen wir unfaulbare Netzgarne? Fischerei-Ztg. Bd. 42, 301-302, 1939.

[9] v. Brandt, A.: Die bisherigen Erfahrungen mit PeCe-Garnen in der Fischerei. Zeitschft. f. Fischerei, Bd. 42 45-65, 1944.

[10] v. Brandt, A.: Fanggeräte-Systematik. Protok. z. Fischerei technik Bd. 2, Nr. 13, 1952.

[11] Klust, G.: Zweite Ubersicht uber die Verwendung von Perlon in der Fischerei. Prot. z. Fischereitechnik, Bd. 2, Nr. 20, 1953

[12] Klust, G.: Zur Wasserbeständigkeit von Netzgarnen aus einigen synthetischen Faserstoffen. (vorläufige Mitteilung) Prot. z. Fischereitechnik, Bd. 4, 168-174, 1957.
[13] Klust, G.: Untersuchungen an Fischnetzgarnen aus endlosen Polyamidfäden.—Arch. f. Fischereiwiss., Bd. 8, H. 1/2, 1957.
[14] Carrothers, P. C.: Tests on Kuralon twine. Western Fisheries, Vol. 50, No. 6, 1955.
[15] Klust, G.: Polyvinylalkohol-Zwirne. Melliand Textilberichte —Bd. 38, 134-136, 1957.
[16] Grünsteidl, E. und H. Preussler: Chemische Faserstoffe und ihre Eigenschaften. St. Johann i.T., 1953.
[17] British Ropes Ltd.: Ropes made from Nylon. Leigh/Edinburgh, 1948.
[18] Klust, G.: Perlonschnüre, ihre Herstellung und Eigenschaften unter Berücksichtigung ihrer Verwendung in der Fischerei. Ulm/Donau, 1957.
[19] Klust, G.: Untersuchungen über die Scheuerfestigkeit von Fischnetz-Schnüren. Prot. z. Fischereitechnik, Bd. 3, 64-68, 1954.
[20] Klust, G.: Zur Wetterfestigkeit, von Zwirnen aus einigen synthetischen Faserstoffen. Textil-Praxis, Bd. 12, 233-237, 1957 (Hier auch weitere Literaturangaben zu dieser Frage!)
[21] Ashton, H. and J. Boulton: A review of developments in the properties processing and utilisation of man-made fibres. Journ. Text. Inst. Vol. 47, No. 8, p. 532-566, 1956.
[22] Schlieker, E.: Mehr Perlongeräte für die Fischerei. Deutsche Fischerei-Zeitung. Bd. 3. 356-367, 1956.

Spinning a cotton fishing yarn in an Indian fishing village.

SYNTHETIC FIBRES IN THE FISHING INDUSTRY

by

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Abstract

This is a general account of the use of nylon and "Dacron" polyester fibre for all kinds of fishing gear. The lightness, elasticity and durability of these fibres makes them ideal for gillnets, seines, traps and pots, but the risk of total loss makes them a doubtful investment for bottom trawls. An important recent improvement has been the introduction of Type 330 nylon yarns which have better sunlight durability than cotton or previous types of nylon, an important attribute in hot and sunny climates. The use of "Taslan" textured nylon, a process which creates tiny loops in the individual filaments of the yarn, means better knot holding properties and easier blending of two or more continuous filament yarns.

Les fibres synthétiques dans l'industrie des pêches

Résumé

C'est un exposé général sur l'emploi du nylon et du Dacron, fibre de polyester, pour toutes sortes d'engins de pêche. La légèreté, l'élasticité et la durée de ces fibres les rend idéales pour les filets maillants, les sennes, les trappes, les casiers et les nasses, mais le risque de perte totale en fait un investissement douteux pour les chaluts de fond. Un important perfectionnement récent est l'introduction des fils de nylon type 330 qui a une meilleure durée sous l'action du soleil que le coton ou les types précédents de nylon, ce qui est une qualité sous les climats chauds et ensoleillés. L'emploi de nylon texturé "Taslan", un procédé qui crée de petites boucles dans les filaments individuels du fil, signifie une meilleure tenue des noeuds et une union plus facile de deux ou plusieurs fils du type filament continu.

Las fibras sintéticas en la industria pesquera

Extracto

Descripción general de los usos ed las fibras de poliésteres, nylón y dacrón, en todos los tipos de artes de pesca. El poco peso, elasticidad y duración de ellas hacen que sean ideales para la confección de redes de enmalle y cerco, nasas, etc. pero el riesgo de la pérdida total durante la pesca ponen en duda su empleo para fabricar redes de arrastre de fondo. Una mejora importante introducida recientemente es el hilo de nylón tipo 330, más resistente a la acción de la luz solar que el algodón o tipos de nylón usados anteriormente, lo cual es una propiedad importante en climas cálidos o con mucho sol. El uso de "taslan"- nylon sometido a un procedimiento que crea pequeños lazos en los filamentos individuales --permite obtener nudos no tan corredizos y un material que se retuerce en mejores condiciones al mezclarlo con dos o más filamentos continuos.

WHILE Du Pont 66 nylon was first tested experimentally in the fishing industry in the United States for gillnets in 1939, military demand for nylon during the war delayed further work in the fishing industry. Since 1948, however, the use of nylon in gillnetting has grown rapidly. Recent estimates show that well over 90 per cent. of all Great Lakes' gillnets are now made of nylon.

More recently, nylon has taken over most of the salmon gillnetting in the Pacific. This rapid acceptance has been due primarily to the great increase in numbers of fish caught by nylon gillnets compared to the nets they replaced, as well as their lower maintenance costs, longer life, and easier care. Gillnets made of nylon twines have reportedly caught from 3 to 12 times more fish per net than those used previously, although the reasons for this phenomenon are not thoroughly understood.

In the heavier types of netting which used cotton twines in the past, nylon has also gained the approval of American fishermen. The first menhaden seine made entirely of nylon was placed in service in June 1954, and proved to be far more durable than nets previously used. In addition nylon nets have proved more economical in the long run. Significant growth has also been noted for nylon in lobster and shrimp gear and in tuna seining. Nylon is also being used in longlining for tuna and halibut.

In addition to the wide, general use of nylon twines for nets, the use of ropes of nylon and "Dacron" polyester fibre for hanging and purse lines has become quite common. Present industry sales of nylon in the U.S.A. for fish netting and twines amount to over 1,000,000 lb. annually. It is expected that in about five years' time at least 75 per cent. of all nets used in this country will be made of nylon.

FIBRE PROPERTIES

Du Pont 66 nylon has gained acceptance in netting because it offers an outstanding comdination of properties and price. Of these properties, high strength, wet or dry; abrasion resistance, complete resistance to rotting caused by marine organisms and high impact strength are the most important. Some specialized applications that call for low stretch under load have resulted in the use of "Dacron" polyester fibre in both net and rope forms.

The following table gives some of the most important specification properties of nylon and "Dacron" used in netting:

Property	*Du Pont 66 nylon* *Type* 300	*Type* 700	*"Dacron"* *Type* 51
Denier	210	840	220
Filaments	34	140	50
Denier per filament	6·2	6·0	4·3
Tenacity Dry (grams/denier)	8·0	8·7	6·4
Tenacity Wet (grams/denier)	6·8	8·1	6·4
Tenacity Loop (grams/denier)	5·4	7·1	3·9
Total extension dry (%)	17	17	10
Total extension wet (%)	22	24	10

These properties combine to produce more economical or more efficient nets.

Continuous filament nylon is the predominant synthetic type of raw material used by netting and rope manufacturers in the U.S.A., because it offers the highest breaking strength and maximum abrasion resistance. Spun nylon and combination twines are also being used successfully. Early problems of knot slippage or knot loosening have been largely overcome in nets made from continuous filament twines by the use of special resin-treated twines, special knots, or heat treatment of the finished nets. Spun twines of 100 per cent. nylon or twines made of filament nylon combined with spun fibres are also used as a means of overcoming knot slippage without the need for any special twine treatments. Combination twines of filament nylon and spun fibres, in addition to good knot holding properties, offer the advantage of increased bulk at lower cost for certain types of netting where handling of fine twines might be a problem.

GILLNETS

The high strength of nylon allows the use of thinner continuous filament twines which gill fish more effectively. Thus, the higher initial cost of nylon is more than offset by the greater number of fish caught per net. In addition, some fishermen feel that the elasticity of the nylon allows fish to force the twines apart and become caught. This may account for the fact that larger sized fish have been caught with a given mesh size than previously. The abrasion resistance of nylon is less important in this type of netting, but its rot resistance allows continued use of nets without the need for drying and treating.

PURSE SEINES

Abrasion resistance and resistance to rotting due to micro-organisms in sea water are the most important requirements for this type of net. It is also important to use twines of sufficient size to make handling easy. One hundred per cent. filament nylon twines are being used in menhaden purse seines to give maximum abrasion resistance as are combination twines of filament nylon and spun acetate, which give the required bulk and still achieve satisfactory strength and abrasion resistance.

To illustrate the unusually high abrasion resistance of nylon, a cotton "bunt" or centre section of a menhaden seine used in one area lasts an average of 5,000,000 fish caught. A 100 per cent. nylon menhaden net placed in service during June 1954 has caught a total of 50,000,000 fish; the net was still in service at the last report with the original bunt section intact.

The largest nylon purse seine ever manufactured in the U.S.A. was produced in early 1956 for tuna seining. Because of the greater strength of nylon, slightly finer twines were used which resulted in a weight saving of of approximately 2,400 lb., as compared to an all-cotton tuna seine. The nylon tuna seine weighed a total of 10,000 lb. and was 410 fm. long and 34 fm. deep. When wet, this nylon net weighs only half as much as a wet cotton net of the same size.

The Pacific fishermen, after using this net for nearly two years, are highly enthusiastic about its light weight and easier handling characteristics. In addition, the net shows little wear and the fishermen estimate it will be in service for a number of seasons to come.

In order to achieve optimum handling characteristics fishermen in the U.S.A. ordinarily dip nylon purse seines in a stiffening agent, such as an asphalt base tar, to impart required stiffness. Also, it has been found that slightly heavier weights should be used on the leadlines to provide the desired sinking qualities to the net.

TRAP NETS

The use of nylon in trap nets is growing slowly, although acceptance in the sardine industry has been widespread. Since these nets are stationary, rot resistance and abrasion resistance (particularly in the bottom section of the net) are important properties. Because of nylon's natural rot resistance, fishermen have found they can leave their nylon nets in the water almost indefinitely without fear of damage. One hundred per cent. filament nylon or combination twines of nylon and spun acetate are being used in trap netting. In the sardine fisheries experience has been good with a net of filament nylon, produced on a high speed knitting machine. This type of webbing has no knots and the mesh formation is made by proper settings on the knitting machine.

TRAWLS

In shrimp trawls where the sea bottoms that are fished are moderately level, nylon nets perform well and are being accepted. In the larger nets for bottom fish where equipment is frequently snagged and either lost or badly torn, the extra cost of nylon may often not be justified.

FISH NET ROPES

With the increased use of synthetic fibres in fish netting, ropes and lines with the same strength, elasticity and rot resistant properties as the net material itself are preferable in most cases. For this reason, the use of ropes of nylon and "Dacron" polyester fibre has grown considerably as more fishermen have switched to synthetic netting. Nylon ropes require no preservative treatment and give outstanding wear life compared to ropes made of natural fibres. A tuna fisherman on the Pacific coast, for example, has reported that his nylon net lines have been in service for over five years, and are still in good condition.

A certain amount of difficulty was experienced at first in hanging nets on ropes of nylon or "Dacron". This was due primarily to the difference in elongation and shrinkage properties of ropes of these fibres as compared with natural fibre ropes. As a result of long experience with natural fibre ropes, the number of meshes of netting to hang per foot of rope had become well known and were correct for the stretch and shrinkage of such ropes. Fishermen have now learned that properly made ropes of nylon or "Dacron" stretch somewhat more than manila but do not shrink when wet. They have modified their hanging techniques to compensate for these differences.

Treated nylon is being used in longlining for ground fish such as halibut. Similar lines are being used for lobster pot warps, as well as for headers in the pots. In these cases, the shock absorbency resulting from the high elasticity of nylon is a definite advantage, particularly in rough weather.

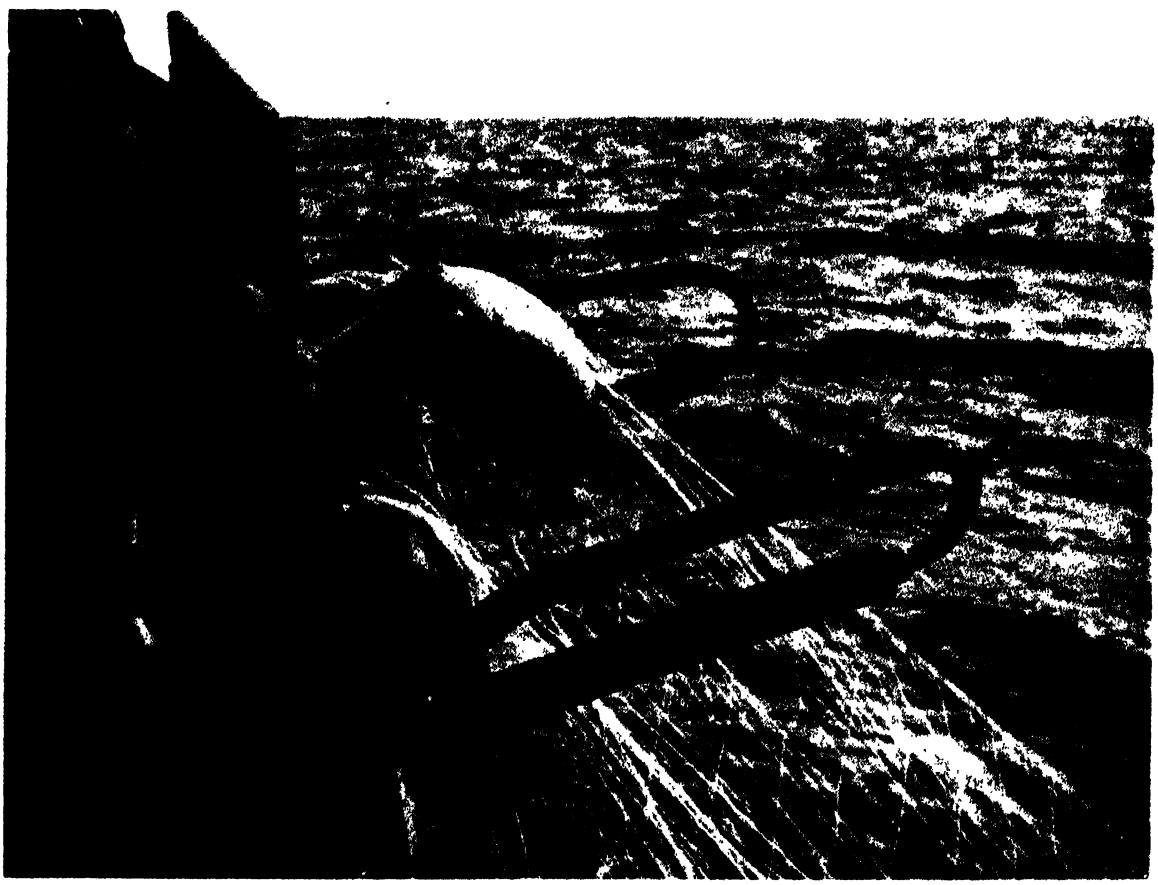
NEW DEVELOPMENTS

Improvement of the nylon yarn as produced by Du Pont, as well as improved preparation of the twine by the net manufacturer continues.

An example is the recent introduction by Du Pont of Type 330 nylon yarn. This yarn has better resistance to sunlight than either cotton or previously available types of nylon. This yarn is now available to fish net manufacturers and should insure longer life for nets when sunlight is a significant factor.

A new development in the manufacture of nets of continuous filament yarn has been the use of "Taslan" textured nylon for netting twines. The texturing process creates tiny loops in the individual filaments, imparting new surface characteristics. Thus, good knot firmness can be obtained by the use of twines made from "Taslan" yarns. In addition, the texturing process is useful for combining two or more continuous filament yarns intimately without the need for twisting.

Such developments – and many others – are typical of the avenues which will continue to be explored as means of improving gear for the fishing industry.



Bottom-set, cod gillnets of nylon being hauled mechanically off Iceland.

THE FEATURES AND USE OF "AMILAN" FISHING NETS

by

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Abstract

"Amilan" is the registered trade name for nylon, made under licence by the Toyo Rayon Co., and nets made with this material are at present being used extensively in Japan, and in addition, they are being exported to the U.S.A., Canada, Africa, etc. The use of "Amilan" nets of various kinds is discussed, and the rise in the catch of Pacific salmon and trout since the introduction of these nets is remarkable. It is true that the initial cost is high compared with cotton, but in spite of this, fishermen are changing over more and more to the use of these nets, because the physical properties of the material give it a longer life.

Les caractéristiques et l'emploi des filets de pêche d' "Amilan"

Résumé

"Amilan" est le nom commercial déposé du nylon fabrique sous licence par la Toyo Rayon Co. Les filets fabriqués avec ces matériaux sont à présent largement utilisés au Japon et sont, de plus, exportés aux E.-U., au Canada, en Afrique, etc. On examine l'emploi des filets d'Amilan de différents types; l'augmentation des captures de saumons et de truites du Pacifique depuis l'introduction de ces filets est remarquable. Il est vrai que le coût initial est élevé par rapport a celui du coton, malgré cela les pêcheurs se rallient de plus en plus à l'emploi de ces filets parce que les propriétés physiques du matériau leur assurent une plus longue duree d'existence.

Características y usos de las redes de "amilán"

Extracto

En este trabajo se estudian los usos de los diversos tipos de redes de "amilán" (marca comercial registrada del nylón manufacturado por la "Toyo Rayón Co.") que se han difundido ampliamente en el Japón y, además, se exportan a los E.U.A., Canadá, Africa, etc. La introducción de estas redes en las pesquerías de salmón del Pacifico y trucha ha permitido notables rendimientos, notándose que, a pesar de su alto precio inicial comparado con las de algodón, los pescadores las prefieren a causa de su mayor duración y propiedades fisicas del material.

SYNTHETIC fibre nets are now popularly used and their efficiency is highly appreciated by fishermen all over the world.

Amilan is the trade name of nylon produced by the Toyo Rayon Co. under licence and with the technical cooperation of E.I. du Pont de Nemours and Co., U.S.A. Amilan fishing nets are very well known today among fishermen in Japan, and are also exported to many fishing countries.

In the following sections the use of Amilan for nets in various types of fishing is described.

SALMON AND TROUT GILLNETS IN THE NORTHERN PACIFIC

The Northern Pacific fishing has become vitally important to Japan, as sea products are indispensable to feed Japan's ever-growing population. In pre-war days, the main practice in the Northern Pacific was large scale drift net fishing near to the coast of Kamchatka Peninsula, under agreement with the U.S.S.R. At present, however, the chief fishing is based on mother-ship operation, which method originated around 1929.

When the Pacific War ended, production of Amilan was started and by 1953, fishermen were using both conventional ramie and Amilan nets in the same quantity. A series of tests clearly indicated the superior catching ability of nylon nets which in addition are claimed to stand about three years of consecutive use as compared to half a season for ramie. At that time, the price of Amilan nets was twice as high as that of ramie nets, but taking into account the durability and larger catches, they proved, however, more economical.

The catch figures illustrate this point. In 1952, the first fishing fleets after the war caught 37,000 salmon and trout in the Northern Pacific. In 1953, the catch was twice as much, at least partly due to the increased catchability of Amilan nets. Since then, more and more boats have adopted the nets and they are now used by every fishing vessel

Year	*Number of fleets*	*Number of ships*	*Total catch (in 1000's)*	*Catch per ship*	*No. of Amilan nets used (yds.)*	*No. of Ramie nets used (yds.)*
1952	3	57	2,100	37	2,784	127,200
1953	3	115	7,700	73	174,000	124,800
1954	9	210	20,500	100	780,000	0
1955	14	405	64,040	163	2,040,000	0
1956	16	506	52,000	103	3,000,000	0

SANMAI NET (TRAMMEL NET)

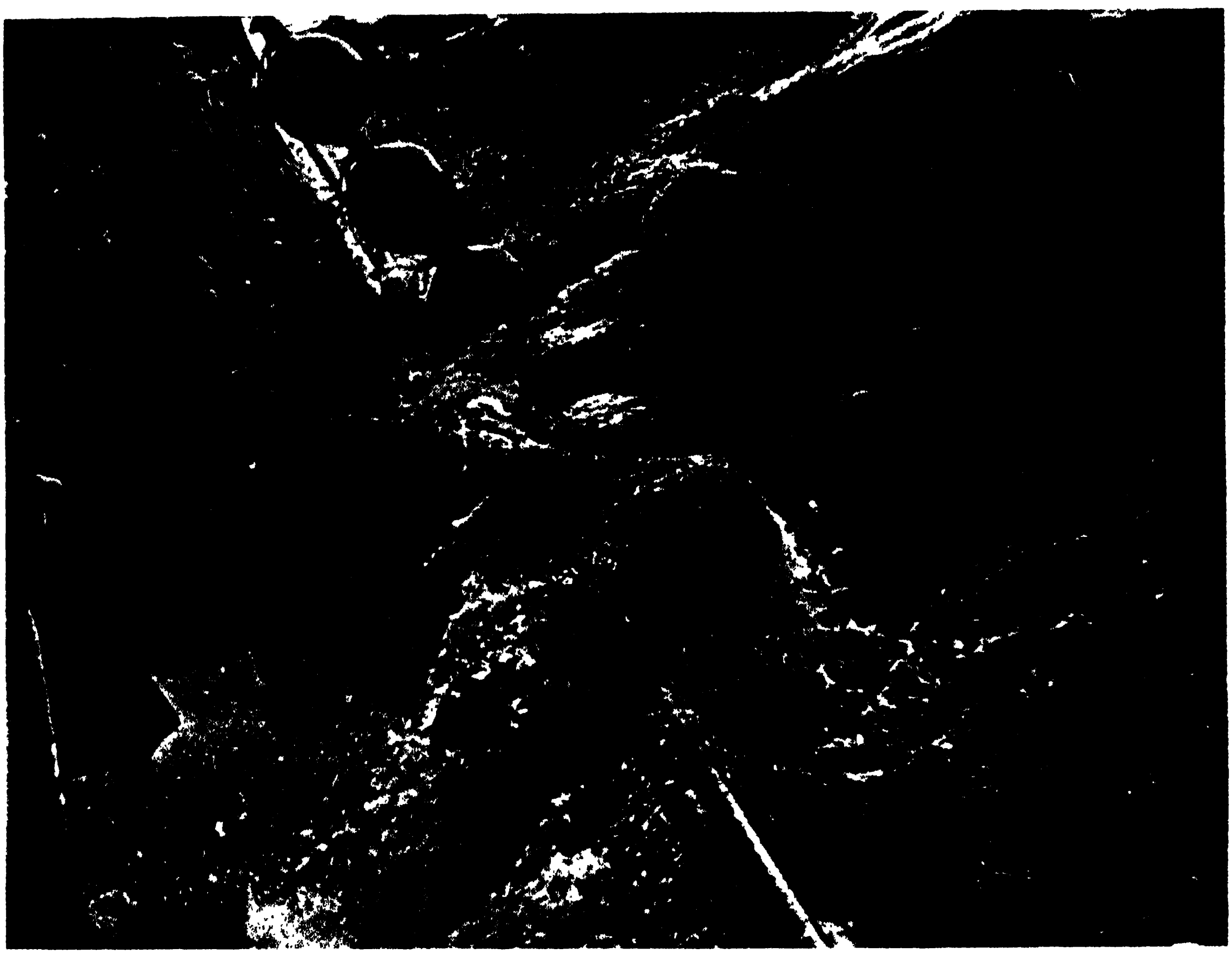
This net is known by different names in Japan, such as Jigoku-Net (Hell Net), Sanzyu-Net (Three-fold Net), etc., and is widely used for inshore fishing. Before nylon made its appearance, the nets were made of natural fibres such as cotton, ramie and silk. Today, the nets are made of Amilan and about 80 or 100 times more of such nets are being operated.

PURSE SEINE NET

The use of nylon for the construction of these nets has great advantages owing to its increased tensile strength per weight unit, as compared to cotton. When Amilan is used the boat and crew can work a much larger net, or less crew is necessary to operate a purse seine of the size a cotton net would require. Amilan is therefore now used widely in the tuna and bonito fisheries of Japan.

DRAG NET

The strength, lightness, small moisture absorption and durability of Amilan trawl nets allow for increased trawling speed. During 1952-55 tests by Fukuoka Fisheries Experiment Station showed that the nets produced higher catches. Some small fishermen, however, still hesitate to use them, because of the cost, but it is considered that their advantages outweigh this factor



On this Arctic trawler, the belly, codend and headline of her trawl are made from nylon which ably withstands the strain of heavy catches.

DEVELOPMENT OF SYNTHETIC NETTING AND ITS EFFECT ON THE FISHING INDUSTRY

by

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Abstract

No fibre is as yet available which would suit the requirements of all types of fishing gear, although some of the new synthetic fibres come closer to an ideal material than the natural fibres. Blending two synthetic fibres can produce twines particularly suitable for some specific gears.

Le dêveloppement de filets des fibres synthètiques et ses effcts sur l'industrie de la pêche

Résumé

Il n'existe pas encore de fibre satisfaisant toutes les exigences pour tous les types d'engins de pêche, bien que quelques-unes des nouvelles fibres synthétiques se rapprochent plus du matériau idéal que les fibres naturelles. Le mélange de deux fibres synthétiques peut produire des fils particulièrement appropriés à la construction d'engins déterminés.

Perfeccionamiento de las redes de hilos sintèticos y su influencia sobre la industria pesquera

Extracto

Todavía no se dispone de ninguna fibra sintética que satifaga los requisitos exigidos por todos los tipos de artes de pesca, si bien muchas de las obtenidas últimamente se acercan al producto ideal más que las fibras naturales. Es necesario agregar que la mezcla de dos fibras sintéticas permite fabricar hilos especialmente adecuados para ciertos tipos de artes de pesca.

THE Japanese fishing net manufacturing industry has made considerable progress in the last few years, due largely to the development of synthetic fibres, such as nylon, vinylon, vinylidene, vinyl chloride, and combination synthetics. The export of nets, twines and ropes of all types from Japan, including natural fibres, totalled 7,163,000 lbs. in 1956, a 22 per cent. increase over the previous year's figure, compared with an increase of 9½ per cent. in exports of natural fibre fishing nets, twines, and ropes.

The following are the highlights in a survey made by the Japanese Government's Fisheries Agency of export trends in fishing gears, classified according to natural and man-made fibres.

NATURAL FIBRES

The exports of cotton fishing gear continue to lead all other kinds of fishing nets, totalling 5,220,000 lbs. in 1956. This accounts for 73 per cent. of the total exports; 460,000 lbs. of manila hemp were exported in 1956; 336,500 lbs. of sisal and a total of 22,000 lbs. of other natural fibres (flax, coir, ramie and silk).

SYNTHETIC FIBRES

The exports of nylon nets, twines and ropes amounted to 683,000 lbs. and increased 158 per cent. in 1956 over 1955. More than 91 per cent. were nylon fishing nets, while 8 per cent. were twines; ropes constituted 1 per cent. of this total. The export of other synthetic fibres in 1956 was as follows; vinylon 221,000 lbs. (increased 2·8 times over the previous year); vinylidene 63,500 lbs.; vinyl chloride (which is a comparatively new synthetic fibre) 3,000 lbs.; combination synthetics 165,000 lbs. (increased 3·8 times in 1956 and are expected to exceed 420,000 lbs. in 1957).

DIFFERENT FIBRES FOR DIFFERENT FISHING PURPOSES

Synthetic fibre fishing gear has contributed materially toward the stabilization of the fishing industry, but because of the industry's complexity, no synthetic fibre developed to date is ideal for all types of fisheries. At present, gillnet fisheries find nylon a satisfactory replacement for linen netting. The purse seine fisheries have accepted Marlon (nylon/vinylon) as a replacement for cotton netting, while vinylon may prove an acceptable replacement for cotton and manila for fishing lines and ropes. For trawl fishing however, no particular synthetic stands out as acceptable to replace natural fibres. Approximately 75 per cent. of the nylon netting exported from Japan is used in the gillnet fisheries of various countries. A great variety of nylon types can be produced by changing its chemical construction, production method, yarn size, degree of twist, amount and method

Fig. 1. Manufacture of synthetic twines.

of relieving the stress in the twine, and the different processes for setting the knots.

It should be borne in mind that when selecting the appropriate nylon twine to replace linen for a gillnet, wet knot strength of nylon is less than that of first grade linen. So, where it is necessary to maintain the same strength a slightly heavier nylon twine must be chosen.

Nylon exposed continually to sunlight of normal intensity for two months can lose as much as 40 per cent. of its tensile strength. It must therefore be kept away from direct sunlight.

Nylon is not weakened by bacteria, but a nylon net should be kept clean, as acid caused by fish slime can be harmful.

DEEP WATER GILLNETS AND SEINES

To determine the twine diameter most suitable for deep water gillnets, consideration must be given to:

a. Strength of the twine
b. Fishability
c. Form of the net in the water when fishing
d. Durability and
e. Initial cost of the net.

Factors a and b are opposite in function, namely thicker twine means higher strength, but lower catching ability, therefore, a compromise has to be found.

The specific gravity of the material influences the form of the net when fishing and it was found that pure nylon nets were too light. Attempts were made to overcome this deficiency by hanging a strip of vinylidene net 360d/30 ply on a ratio of nylon 4 : vinylidene 1 under the nylon. This method was not entirely satisfactory.

The later method, which proved satisfactory, was to combine nylon and vinylidene fibre during manufacture of the yarn and twine. This product called Livlon has considerable merit for deep sea gillnetting operations.

It is especially important to determine accurately the most suitable twine size for deep water purse seine because the webbing is subject to much water resistance while sinking. The specific gravity of a fibre can be determined by the laws of physics, but accurate determination of the resistance is complicated by various factors.

For a comparative study, the unit of resistance K D/L can be used where D is the diameter of the twine and L the meshsize (stretched).

The unit of resistance of a standard sardine purse seine made of cotton twine 20/15 ply with a mesh size of 20 m/m would be 0·05.

If the influence of the surface condition of the twine on the resistance is called "R", the numerical values of "R" for different types of twine are as follows:

Cotton	1·00
Nylon	0·75
Vinyl Chloride ..	0·70
Vinylon	1·00

Fig. 2. Mechanical knitting of synthetic fibre nets.

Fig. 3. Inspection of machine-braided webbing.

Fig. 4 Fishing with two-boat purse seines of Marlon (in Japan).

These factors "K" and "R" influence the shape of the seine in operation, sinking speed, etc.

It may be assumed that a set is made with a cotton seine 20/15 ply, 20 m m stretched mesh, 300 fathoms long by 10 fathoms deep, on a sardine school of 100 tons, 20 fathoms in width, that the travelling speed of the school is 0·5 fathoms second, and that it takes 2 minutes for the sardines of the lower part of the school to arrive at the skirt of the net. In this case, the seine must be pursed within two minutes to catch the entire school, thus the net must sink at a rate of 1 fathom per second, which is quite difficult to accomplish with cotton netting. However, Livlon seine netting of smaller diameter twine, manufactured with a special twisting method equal in specific gravity to cotton, is able to meet the requirements.

Marlon netting was first put to commercial use in 1951, and many of the original nets are still giving good service. Its most notable characteristics are derived from the combination of the best features of nylon and vinylon fibres.

Some of the advantages of such a combination are: increased specific gravity of the twine, maintenance of strength by the predominance of nylon fibre in the twine and decreased knot slippage.

Marlon netting is available in a variety of colours, twine and mesh sizes, and completely made up purse seines of standard or controlled specifications are available.

Like most synthetics, it requires little maintenance, but reasonable precaution should be taken to prevent undue exposure to sunlight.

CONCLUSIONS

Synthetic fibres are rapidly replacing natural fibres in the construction of all kinds of fishing gear, but an ideal synthetic fibre suitable to all types of gears is not yet available to the fishing industry.

At present the synthetic fibres most commonly used in the main types of fishing gear can be listed as follows

Type of Gear	*Synthetic most used*
Gillnets, trammel nets, tangle nets	nylon
purse seines, beach seines, lamparas, trap nets	Marlon and other combination synthetics
beam trawl, otter trawl, balloon trawl	various but none entirely satisfactory
twines and ropes	vinylon, nylon and combinations

TESTS WITH NYLON FISHING TACKLE IN SWEDISH INLAND FISHERIES

by

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Abstract

It has become quite clear that nylon is, in several respects, superior to cotton, flax or hemp, and among its foremost advantages are its rot-resistance and its high fishing capacity. Fishing experiments have proved that continuous multifilament nylon has something like twice the fishing capacity of cotton, and that the monofilament nylon has a fishing capacity about seven times as good as cotton. During the last five years practically every professional fisherman has changed over to nylon nets, and while it is true that the initial cost of these is high, this is offset by higher catches of fish and longer life for the gear.

In the case of set nets, those parts which are constantly above the surface of the water are soon destroyed by the sun's rays and have to be replaced, so now these parts should better be made of such materials as Saran, Kuralon or Terylene which are less sensitive to ultra-violet rays. The monofilament nylon is especially good for fishing in clear water because of its invisibility, but in muddy waters this advantage is lost.

Essais effectués sur des engins de pêche en nylon dans les pêches intérieures suédoises

Résumé

Il est devenu évident que le nylon est supérieur, à plusieurs points de vue, au coton, au lin ou au chanvre; ses principaux avantages étant son imputrescibilité et sa grande capacité de pêche. Des essais ont montré que la capacité de pêche du nylon à fibres multiples continues était deux fois supérieure à celle du coton, et celle du nylon monofilament, sept fois. Au cours des cinq dernières années, la presque totalité des pêcheurs professionnels ont adopté les filets de nylon, et bien que leur prix d'achat soit élevé, il est compensé par leur plus longue durée et les pêches plus abondantes qu'ils permettent de réaliser.

En ce qui concerne les filets fixes, les parties qui se trouvent constamment au-dessus du niveau de l'eau sont rapidement détruites par les rayons du soleil et doivent être remplacées, en sorte qu'il serait préférable de les fabriquer en matériaux tels que le saran, le kuralon ou le térylène qui sont moins sensibles à l'action des rayons ultra-violets. Le nylon monofilament est particulièrement efficace en eau claire à cause de son invisibilité, mais il perd cet avantage en eau trouble.

Pruebas hilo de nylón para aparejos de pesca usados en las pesquerías interiores de Suecia

Extracto

Es evidente que el nylón resulta, desde varios puntos de vista, superior al algodón, lino o cáñamo, contándose entre sus ventajas más sobresalientes su resistencia a la pudrición y alta capacidad de pesca. Los experimentos hechos han demostrado que los hilos de nylón formados por gran número de filamentos continuos y los de una sola hebra, permiten obtener el doble y siete veces más rendimiento que los de algodón. Durante los últimos cinco años prácticamente todos los pescadores profesionales han comenzado a usar redes de nylón, cuyo alto costo inicial se compensa con la mayor cantidad de pesca y duración del arte.

En el caso de las redes fijas, las partes que están constantemente sobre la superficie del agua son destruidas con más rapidez por la acción de los rayos solares y deben ser reemplazadas. Para evitar este inconveniento se recomienda confeccionar dichas secciones con materiales como: sarán, kuralón o terrileno que son menos sensibles a los rayos ultraviolados. El nylón de una hebra se presta especialmente para la pesca en aguas claras a causa de su invisibilidad, pero en las cenagosas esta ventaja no ejerce ninguna influencia.

THIS paper gives a description of tests which were begun in 1947 by the Institute of Freshwater Research (Sötvattenslaboratoriet), on the design of nets made of nylon.

One of the greatest disadvantages, particularly of continuous filament or monofilament nylon, was the difficulty of making knots that would not slip. This was gradually eliminated by using various methods, such as the treatment e.g. chemical treatment of the material before or after knotting, as well as the use of double knots. In cases where the nets are exposed to great stress, the last-mentioned method is still the most generally used.

Certain difficulties are still encountered in the manufacture of monofilament nylon nets. Apart from the use of double knots, the chemical treatment has proved to be most effective.

One more disadvantage of nylon nets for fishing purposes is their relatively high sensitivity to ultra-violet rays. Tests carried out with both normal sunshine and quartz-lamps have proved multifilament nylon to be most sensitive to such radiation, whereas the monofilament nylon is more resistant. While it is true that special impregnation of multifilament nylon with catechu offers a certain protection it cannot prevent the gradual reduction in strength. From the practical point of view this sensitivity to light is not an important disadvantage to the fisherman. If he knows of the destructive influence of light on his fishing tackle, he can take care that his nets and tackle are not exposed to sunshine more than necessary. Practical experience gained by Swedish fresh-water fishermen has also proved that nets that must be discarded after 3 to 4 years have not become unserviceable due to the destructive action of sunshine, but to damage through tearing during intensive fishing.

Quite different are, on the other hand, the conditions prevailing in connection with the use of certain types of fixed fishing tackle such as bottom nets and fish baskets (bow nets), when part of the tackle often remains standing above the water level. In such cases the sensitivity of nylon to sunshine necessitates frequent replacement of the destroyed parts. It would be practical to use for these parts Terylene or Saran fibres, which are extremely resistant to U.V. radiation.

It must be mentioned here that monofilament nylon very easily becomes slimy through the adherence of microscopic particles whirling about in the water, particularly when the wind is strong. Since the comparatively high catching ability of this type of net is mainly dependent on its relative invisibility in water, the slimy coating of the net reduces its efficiency which, in certain cases, becomes less than that of spun nylon. This slimishness is particularly noticeable when the catch is checked without lifting the net from the water, and the net is thus left in a submerged position, sometimes for several days. The thorough rinsing of the nets is absolutely necessary to avoid a reduction of the catching ability. This disadvantage is responsible for the relatively limited use of monofilament nets in many flat-country lakes, where the water often has a high slime content.

THE RESULTS OF COMPARATIVE FISHING TESTS

In order to estimate the catching ability of continuous multifilament nylon compared with cotton, fishing tests were carried out, using nets of equal size. Separate tests have proved the catching ability of nylon nets to be twice that of cotton nets. Other tests showed that the excess catch made with nylon nets varied between 1·75 to 3 times.

Apart from the tests carried out by the Institute, supervised tests were made by professional fishermen and gave, on the whole, the same results. All tested nylon nets were manufactured from continuous-multifilament twine as staple nylon twine is unsuitable for gillnets. The reason for the high catching ability of nylon is its low water absorption, relatively high elasticity and high breaking strength. These qualities permit the use of thinner twine than is possible with the weaker cotton. This rule is valid for all kinds of net fishing: the catching ability of nets increases with a reduced twine diameter. The choice of the proper diameter is naturally merely a question of experience. The twine must not, however, be so fine as to cause very quick wear and consequent need for frequent repairs.

Since 1951 the Institute has carried out catching tests with nets made from monofilament nylon. This is an almost ideal material for certain fishing tackle as, due to its transparency, it is practically invisible in water. It was found that the monofilament gillnets caught not less than seven times as much fish as cotton nets, and approximately four times as much as nets of continuous-multifilament nylon.

The tests, which were carried out during both summer and autumn, also proved that the catching ability of nets made of monofilament nylon are to a certain extent dependent on light conditions. Thus, the excess catches were higher during the light season when the advantage of transparency is greater. It has also proved possible to achieve good results with these nets in daytime in lakes with clear water, when cotton or continuous-multifilament nylon nets were quite unsuccessful.

A test was carried out during the same season in two different lakes. The degree of visibility in these lakes was 13 yards and 1⅓ yards respectively. In the former lake, the ratio of the catches made with nets of cotton, continuous-multifilament and monofilament nylon was 1:2:14. The corresponding figures for the lake with reduced degree of visibility were 1:2·5:11. The fact that the catches made with monofilament nets in the latter lake were unexpectedly high indicates that apart from the positive influence of the invisibility in water on the fishing results, this material must possess additional advantages on account of its structure.

Continuous-multifilament nylon proved to be more efficient than cotton quite irrespective of the size of gillnets used—whether high or low (superiority varying between 1·75 and 3).

When higher (18 to 22 ft.) nets made of monofilament nylon came into use, it was discovered that the superiority of this material compared with continuous-multifilament nylon disappeared and that the catch, in some cases, was even less. Professional fishermen using such high nets had the same experience. The reason most probably lies in the increased stiffness of the monofilament nylon used for these nets. This may have an adverse influence on the flexibility of the net surface, which is of importance when fish jostle against the net. Nevertheless, singular positive results were achieved and one of these cases may be quoted.

In a fishing test a net of monofilament nylon caught 60 per cent. more white fish than a corresponding net of continuous-multifilament nylon. The net used for this species of fish is 20 ft. deep, provided with extremely light weights, and has its floats on the water level, connected to the net by lines by which the net position between bottom and surface can be varied.

THE SCOPE OF APPLICATION OF NYLON NETS

The change from cotton to nylon nets among professional fishermen, despite their conservative attitude to modernization, is practically 100 per cent. They soon realized the great advantages of nylon, thanks to its high catching ability and absolute resistance to rot as compared with cotton. It is also undeniable that the introduction of the new material for fishing tackle has brought about a considerable improvement in the economic situation of professional fishermen. Today, the tackle of professional fishermen is mostly made of continuous-multifilament or staple nylon. The shallow nets used by the non-professional and casual fishermen are made of monofilament nylon.

EXPERIENCE IN THE USE OF NYLON NETS

In order to secure the greatest possible catches when using nets made of monofilament nylon, it is necessary to follow certain rules. Perhaps the choice of the right diameter in relation both to the mesh size and to the species of fish for which the net is intended, is the most important. There are quite a number of different species of fish in the same lake and consequently the material must be strong enough for the strongest species of fish. The following standard diameters are used for certain mesh sizes in Swedish lakes: 0·12 to 0·15 mm. for 42 to 55 mm. stretched mesh; 0·15 to 0·20 mm. for 60 to 75 mm.; 0·20 to 0·25 mm. for 85 to 100 mm.; and 0·22 to 0·30 mm. for 110 to 150 mm. In many lakes in northern Sweden, where the catches often consist mainly of white fish, thinner material is used for the respective mesh sizes, as such fish does not tear the nets to the same extent as pike, pike-perche, trout or char.

Unfortunately, nets made of monofilament nylon earned a bad reputation, because the firms delivered nets where the material was too thick in relation to the mesh size, which resulted in inferior catching ability. Another reason was that with some of the nets the knots were slipping.

The nets made of continuous-multifilament nylon at present on the market are almost without exception of good quality with good resistance against slipping.

Fishermen using fixed fishing tackle have to a great extent changed over to the use of nets made of staple nylon twine, particularly in lakes where this kind of fishing is carried on practically the year round and where the rot-problem in connection with cotton becomes extremely serious. As already stated, the parts of the tackle remaining above water level must be renewed now and then, due to deterioration by sunshine.

The staple nylon twine used for this type of tackle is always treated with a stiffening agent which also makes it less elastic. As a rule coal-tar or bituminous varnish, dissolved in an equal quantity of benzol, is used.

The maintenance of fishing tackle made of nylon is extremely simple. The nets must not be exposed to sunshine for long periods of time. The repairs are, however, somewhat complicated. So far as continuous-multifilament twine or monofilament is concerned, special knots must be made since usual netting knots, such as those used with cotton twine, are not firm enough.

Photo of television screen showing monofilament (left) and ordinary cotton net under water. Photo: v. Brandt.

EXPERIENCE WITH SYNTHETIC MATERIALS IN THE NORWEGIAN FISHERIES

by

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Abstract

Tests carried out by the Directorate of Fisheries, Bergen, showed that the use of nylon and Perlon gillnets in the commercial fisheries produced from twice to seven times the number of fish per net per day caught by the traditional cotton and hemp nets, and as a result of these tests the import of synthetic materials has risen from 15 to 20 tons in 1954/55 to 400 tons in 1956/57. Cod traps made of Kuralon have been in continuous use for 3 to 6 months whereas traps made of cotton and hemp had to be renewed every seventh week. Experiments are continuing with other kinds of gear such as purse seines and herring nets.

L'expérience des pêches norvégiennes avec les matériaux synthétiques

Résumé

Les essais effectués par la Direction des Pêches, Bergen, ont montré que l'emploi des filets maillants de nylon et de Perlon dans les pêches industrielles produisait de deux à sept fois plus de poissons par filet et par jour de pêche que les filets traditionnels de coton et de chanvre. A la suite de ces essais l'importation de matériaux synthétiques est passée de 15 au 20 tonnes en 1954/55 à 400 tonnes en 1956/57. Les trappes à morues de Kuralon sont employées continuellement de 3 à 6 mois alors que celles de coton et de chanvre doivant être renouvelées toutes les sept semaines. Les expériences se poursuivant avec d'autres sortes d'engins tels que la senne tournante et les filets à harengs.

Experiencias con materiales sintéticos en las pesquerías noruegas

Extracto

Las pruebas hechas por la Dirección de Pesca, en Bergen, han demostrado que el uso de redes de enmalle de nylón y Perlón permite obtener diariamente entre dos y siete veces más pescados por arte que las tradicionales de algodón y cáñamo. Como resultado de estas pruebas ha aumentado la importación de materiales sintéticos desde 15 - 20 tons en 1954-5, a 400 tons en 1956-7. Las redes "trampas" de "kuralón" pudieron usarse continuamente durante 3 a 6 meses, pero las hechas de algodón y cáñamo debieron reemplazarse cada semana. En la actualidad se continúan los ensayos con otros tipos de artes de pesca, como redes de cerco ce jareta y para arenque.

SYNTHETIC materials are mainly used in Norway for catching cod and coalfish with gillnets, and have mostly replaced the conventional cotton and hemp fibres. Nylon 66, nylon 6 and Terylene are chiefly used, the twine being imported from Great Britain, Canada, U.S.A. and the continent, although a small amount is produced in Norway. Synthetic materials are also used for snoods, lines and ropes.

The use of synthetic materials by Norwegian fishermen has gradually increased since 1955, following experiments with gillnets of nylon and Perlon which were started by the Directorate of Fisheries in 1951 and continued in 1952, 1953, 1954 and 1955. On the condition that reports were made on catchability, etc., certain fishermen along the coast were given a quantity of nets of nylon and perlon to use alongside the conventional gillnets made from cotton and hemp. The number of fish caught by each type of net was counted in every haul and a report sent to the Directorate of Fisheries when fishing was finished. The following example is typical of the reports received (overleaf).

As will be noticed from the report, the catchability of the nylon nets was approximately twice that of the conventional nets. This figure is also typical as an average, although according to several reports, catches were sometimes seven times higher. The types of twine used in these experiments were comparable as to wet knot strength and, according to the reports, durability and strength were satisfactory.

When the results of these promising experiments were published, the interest in the synthetic material grew rapidly among the fishermen and production of nylon gillnets was taken up by the Norwegian manufacturers to meet the increasing demand. The nets produced in Norway are mainly the single knot type.

The following figures illustrate the growth of imports of synthetic material for the fisheries, including twine, filaments and nets (a large part of the nets are of the double knot type):

1954/55	approx.	15 to 20	tons
1955/56	,,	290	,,
1956/57	,,	400	,,

1954/55 was the first season when nylon came into use.

The strength of nylon is often overestimated when first used for fishing gear. The dry tensile strength of nylon shows a great superiority when compared to that of natural fibres, but it sustains a great reduction of strength when wetted, whereas the tensile strength of cotton increases in wet condition. The strength of nylon

1953 Date	*65 ordinary codnets (cotton and hemp)* Total catch per day	Average catch per net per day	*10 nylon nets* Total catch per day	Average catch per net per day
19/2	40	0·62	19	1·9
21/2	108	1·66	132	13·2
23/2	168	2·58	170	17·0
24/2	29	0·44	17	1·7
26/2	21	0·32	14	1·4
27/2	27	0·42	9	0·9
28/2	71	1·09	11	1·1
2/3	45	0·69	9	0·9
3/3	371	5·70	112	11·2
4/3	87	1·33	26	2·6
5/3	234	3·60	47	4·7
7/3	319	4·90	111	11·1
10/3	323	4·96	133	13·3
11/3	235	3·61	93	9·3
12/3	140	2·15	21	2·1
14/3	314	4·83	71	7·1
16/3	221	3·40	83	8·3
17/3	307	3·18	93	9·3
18/3	59	0·90	12	1·2
19/3	76	1·16	31	3·1
20/3	231	3·55	52	5·2
24/3	498	7·66	129	12·9
25/3	87	1·33	14	1·4
26/3	14	0·22	9	0·9
27/3	73	1·12	18	1·8
28/3	366	5·63	57	5·7
30/3	82	1·26	27	2·7
31/3	140	2·17	16	1·6
1/4	270	4·15	28	2·8
Total	1,885 nets	4,956 fish	290 nets	1,564 fish
	Average = 2·63 fish per net per day		Average = 5·38 fish per net per day.	

is further reduced by knotting. This has often led to the wrong selection in size of nylon twines in replacing cotton and hemp twines.

For example, nylon twine, chosen on the basis of dry tensile strength, produced a fine netting with good catchability but resulted in much damage to nets in hauling the catch in the cod fishing season 1954/55. An investigation showed that the twine was too fine and the wet mesh strength of the nets was lower than that of similar nets of hemp and cotton.

Tests, wet and dry, with and without knots, were carried out with nylon, hemp and cotton to find a rule for choosing nylon as a substitute for cotton and hemp for a particular net.

As a result of these tests it was found that a nylon twine with 50 per cent. more runnage than the cotton it would replace, or which was 50 per cent. longer per unit weight, had a satisfactory wet knot strength.

Knot slippage in single knot nylon netting has also created problems, but experiments and experience have led to methods being evolved to overcome this difficulty. The application of heat and/or bonding agents has made it possible to produce a single knot webbing which is satisfactory as regards knot slippage and stiffness of the netting.

The degree of knot slippage depends on the construction of the knot and double knots show less tendency to slip than single knots. On the other hand, mending double knot webbing requires more work.

Polyester fibre nets of Terylene are used for catching cod and coalfish. Their catchability and durability seem to be similar to those of nets made from the polyamide fibres.

In 1954/55 experiments with codtraps made from the Japanese polyvinyl alcohol fibre Kuralon were carried out by the Directorate of Fisheries. As this type of gear is almost continuously in the sea until it is renewed, traps made from hemp or cotton have a relatively short life, being destroyed by micro-organisms. A first report from fishermen said that Kuralon traps had been in the sea continuously for 20 weeks while, during this same period, traps from hemp and cotton had to be renewed every seventh week. Up to April 25th, 1957, seven reports said that Kuralon traps had been in the sea continuously from 3 to 6 months, averaging 4·5 months, and there were no signs of reduction in the strength of the twine.

Experiments are still being carried out with most types of fishing gear, such as purse seines, herring nets, etc. made of synthetic material. Despite the high cost of these materials, there seems to be a great future for their use in the various types of fishing gear.

ON THE FISHING POWER OF NYLON GILLNETS

by

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Abstract

A series of experiments was carried out in Norway to test the fishing capacity of nylon nets as compared with nets made of cotton. In the mackerel and coalfish fishery, nylon gillnets were used; in the cod fishery, nylon and Perlon were used. It was found that the observed fishing power of the nets made of artificial fibres was from 2·5 to 4·4 times that of cotton in the case of cod, 1·4 to 2·3 in the case of coalfish, and 1·2 to 1·3 in the case of mackerel. The reason for this variation between the different species may be related to the shoaling habits of the fish and this possibility is discussed in the report.

Sur la capacité de pêche des filets maillants de nylon

Résumé

En Norvege, on a effectué une série d'expériences pour essayer la capacité de pêche des filets de nylon comparés a filets de coton. On a utilisé des filets maillants de nylon pour la pêche du maquereau et du colin, et des filets de nylon et de perlon pour la pêche de la morue. La capacité de pêche qui a été observée pour les filets de fibre artificielle était de 2,5 à 4,4 fois celle du coton dans le cas de la morue, 1,4 à 2,3 fois dans le cas du colin et 1,2 a 1,3 fois dans le cas du maquereau. La raison de cette variation entre les différentes espèces peut être attribuée aux habitudes de vivre en bancs des poissons et cette possibilité est discutée en détail dans le rapport.

La capacidad de pesca de las redes de enmalle de nylón

Extracto

En Noruega se hicieron series de experimentos para determinar la capacidad de pesca de las redes de nylón en comparacion con las de algodón. En las pesquerías de caballa y colín se utilizaron artes del primero de estos materiales y de perlón, encontrándose que el rendimiento de los tejidos con fibras artificiales era de 2,5 a 4,4, 1,4 a 4,4 y 1,2 a 1,3 veces mayor que los d algodón en el caso del bacalao, colin y caballa, respectivamente. En el informe también se analizan detalladamente las causas de estas variaciones entre las diversas especies, que se hallan relacionadas con los habitos gregarios de los peces.

ON the provision of the Fisheries Director, Bergen, a few fishing experiments for cod with gillnets made of artificial fibres were carried out in northern Norway in 1952 and 1953. The results obtained were promising and for the season 1954 a large series of experiments was planned in order to ascertain the fishing power and the practical usefulness of such nets compared with conventional ones.

The experiments were planned and carried out under the leadership of Fisheries Consultant M. Halaas, Fisheries Directorate, Bergen. An agreement was made with a number of fishermen from different parts of the coast that they should include some nets of artificial fibres in their sets of conventional nets and report on the results. As a whole this arrangement proved to be successful. Most of the fishermen continued this work also in the season 1955.

SPECIFICATIONS OF THE NETS

The experiments include the species cod, coalfish and mackerel. In the Norwegian gillnet fisheries for cod and coalfish the mesh size and the dimensions of the nets vary in the various coastal districts. In order to obtain comparable results the nylon nets were in each case made to match these different specifications as far as possible.

The following types of artificial fibre nets were used:

Mackerel: nylon, 210/2 × 3, 600 m./kg., breaking strength 8 kg. 18 knots per ell (24 inch).

Cod: nylon, 210/5 × 3, 2,500 m./kg. breaking strength 20 kg. 6¼ and 7 knots per ell (24 inch).
Perlon No. 26, continuous multi-filament, 2,200 m./kg., breaking strength 19 kg., 6¼, 6½ and 7½ knots per ell (24 inch).

Coalfish: nylon, 210/6 × 3, 2,000 m./kg. breaking, strength 24 kg., 7½, 8 and 8½ knots per ell (24 inch).

The knots in the Perlon nets were single, in the nylon nets double.

The conventional nets used for comparison were of the following types:

Mackerel: cotton, 18 knots per ell (24 inch).

Cod: cotton, 12/12 and 12/15, 6¼ and 6½ knots per ell (24 inch).

Coalfish: hemp, 7/3, and 8/3, 8 and 8½ knots per ell (24 inch).

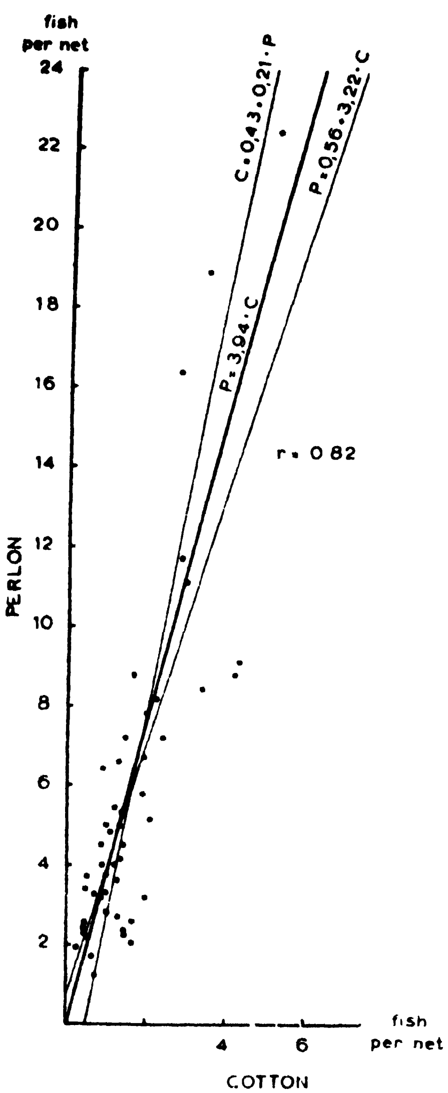

Fig. 1. C=cotton. P=Perlon.

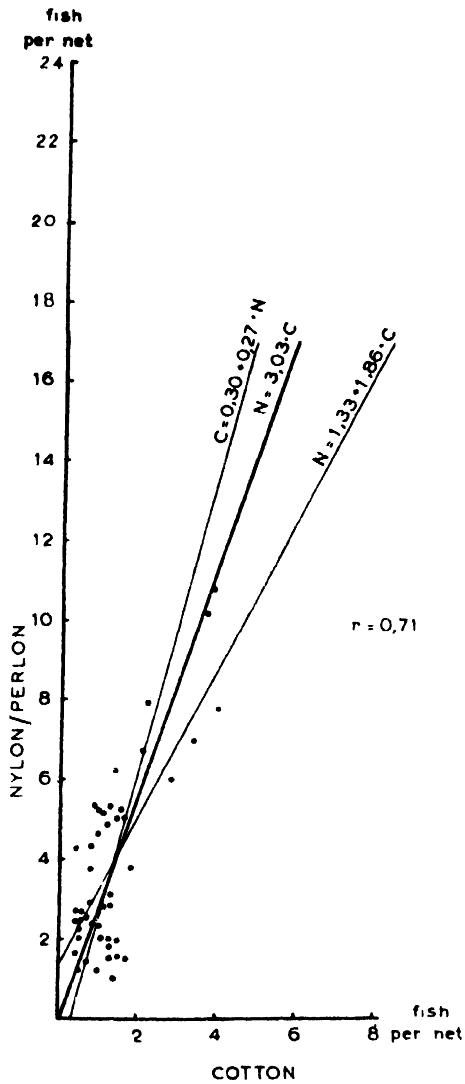

Fig. 2. C=cotton. N=nylon.

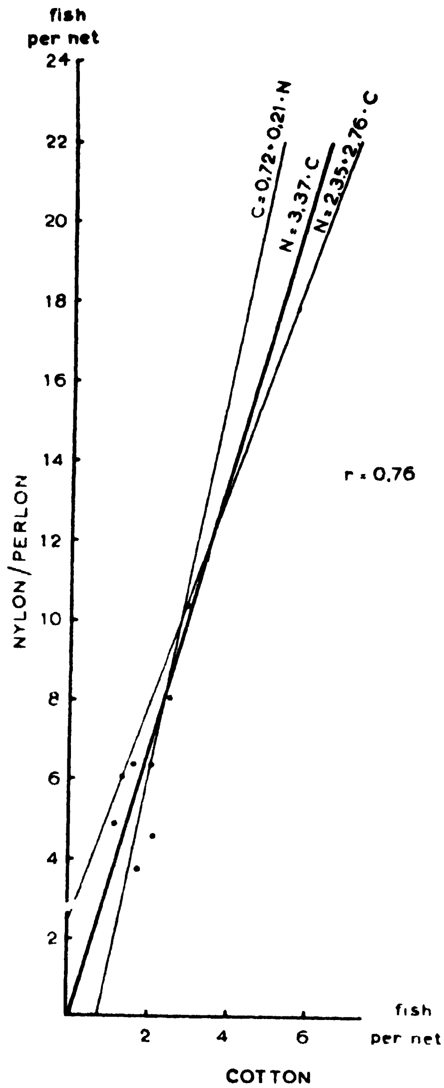

Fig. 3. C=cotton. N=nylon.

FISHING RESULTS

In the reports from the fishermen the following data were given for each lift: number of conventional nets used, number of synthetic fibre nets used, and total number of fish caught in each type of net. The distribution of the fish in the single nets is thus not available, but each lift can be described by a paired mean.

In most cases the numbers of nylon nets used were small compared with the numbers of other nets in the sets, causing a large spread in the distribution of the paired means. This is, however, partly compensated by the large number of lifts in most of the series.

Fig. 1 shows the distribution of the paired means from one of the experimental series. In this case the number of both types of nets were almost equal. The regression lines have been fitted by the method of least squares. (The fact that there was a small variation in the number of nets used in some of the lifts has not been accounted for in this calculation.)

In our analysis there is no logical reason to prefer one of these regression lines to the other. They run almost symmetrically relative to the origin, and it seems fair to assume that the true relation is a simple proportionality The best description of this relationship is therefore a straight line through the origin and the paired mean of all the observations shown as the line P=3·94 C in fig. 1.

Fig. 2 and fig. 3 show the results of two more series of cod catches with regression lines calculated in the same way as in fig. 1. The spread is larger, but the regression lines are still fairly symmetrical around the origin.

Similar cluster diagrams were made for all the series or smaller groups of experimental series, and they all show a more or less pronounced trend in the distribution of the paired means. In Table I the results have been listed as the probable proportional relationship between the fishing powers of the two types of nets used, represented by the straight line through the origin and the paired mean of all the observations.

TABLE I

Series No.	Species	Locality—year	Sum nets × lift	Sum catch convent. nets	Sum catch artific. fibre nets	Probable relation of fishing power
1.	Cod	Senjabank, 1955	Cotton 500, Perlon 452	744 fish	2,651 fish	P : 3·94.C
2.	,,	Kvaenangen, 1954-55	Cotton 1496, nylon/Perlon 374	1,835	1,396	N/P : 3·03.C
3.	,,	Båtsfjord, 1954	Cotton 982, nylon/Perlon 44	2,868	430	N/P : 3·37.C
4.	,,	Vesterålen, 1953	Cotton 477, nylon/Perlon 95	1,703	1,036	N/P : 3·03.C
5.	,,	Sørøy, 1954-55	Cotton 1926, nylon 172	4,830	1,361	N : 3·15.C
	,,	,, ,,	,, ,, Perlon 127	,,	802	P : 2·51.C
6.	,,	Magerøy, 1954-55	Cotton 1124, nylon 175	3,211	2,189	N : 4·37.C
	,,	,, ,,	,, ,, Perlon 69	,,	735	P : 3·72.C
7.	Coalfish	Karmøy, 1954-55	Hemp 2986, nylon 436	14,037	4,744	N : 2·30.H
8.	,,	Herdla, 1954-55	Hemp 900, nylon 150	2,644	888	N : 2·01.H
9.	,,	Herdla, 1954-55	Hemp 2128, nylon 225	15,253	2,281	N : 1·41.H
10.	,,	Bremanger, 1954-55	Hemp 645, nylon 100	2,738	923	N : 2·17.H
11.	,,	Stad, 1954-55	Hemp 748, nylon 114	5,515	1,211	N : 1·44.H
12.	Mackerel	Langesund, 1954-55	Cotton 2749, nylon 210	30,841 kg.	2,721 kg.	N : 1·16.C
13.	,,	Flekkerøy, 1954	Cotton 2850, nylon 150	27,357	1,826	N : 1·27.C

N=nylon; P=Perlon; C=cotton; H=hemp.

In the series numbered 2 to 6 in this table both nylon and Perlon nets were used in the same sets together with the conventional cotton nets. Records of the catch by each of these types of artificial fibres are available only from the series 5 and 6. They show slightly lower values for Perlon than for nylon, but the number of observations is too small to allow conclusions.

CONCLUSIONS

In the case of the cod it is seen that the observed fishing power of the nets made of artificial fibres varies from 2·5 to 4·4 times that of the cotton nets. The corresponding range for the coalfish is from 1·4 to 2·3 and for the mackerel 1·2 and 1·3.

The variation "within the species" may partly be chance variation, partly due to different experimental conditions such as the rigging of the nets, the arrangement of the two types of nets in the sets, etc. The variation "between the species" is, however, probably a true one, and must in some way be related to the nature of the higher efficiency of the artificial fibre nets.

The observer of experiment No. 6 remarked in his report that the nylon nets seemed to catch a wider range of fish sizes than usual. A sampling was planned for the season 1955/56 to ascertain whether such a difference in the selectivity really existed, but sufficient data was unfortunately not obtained. Such a difference could be caused by the higher elasticity of the nylon twine. Another practical experience which may touch on this point is that the quality of the cod caught on the nylon nets seems to be inferior to that of the fish caught on cotton nets, presumably because the fish die more quickly in the nylon nets.

If the higher fishing power of the nylon nets is connected with the ability of the nets to catch a wider range of fish sizes, then this would offer us an explanation of the different efficiency of the nylon nets towards the different species found in these experiments. As a result of the pronounced schooling behaviour of the coalfish, the range of fish sizes present in a concentration of coalfish is usually considerably smaller than in a concentration of cod. This phenomenon is even more striking in the mackerel. In agreement with this hypothesis is v. Brandt's (1955)[1] report of only up to 35 per cent. increase of catches with Perlon nets in herring drifting.

REFERENCE

[1]Brandt, A. v., 1955. Perlon-Netze in der Loggerfischerei. Fischwirtschaft, 1955, 99-101.

DISCUSSION ON RELATIVE EFFICIENCIES OF NETS MADE OF DIFFERENT MATERIALS

Mr. B. B. Parrish (U.K.) Rapporteur. When judging the relative efficiencies of gear made of different materials, selectivity must be considered. By selectivity we mean how much will a certain gear catch, what species and sizes of fish?

All fishery workers are concerned with this question in one form or another. The fisherman usually wants from each of his operations the greatest possible catch, but not necessarily the greatest amount of any or all kinds of fish. He tries to catch fish of a species and size for which there is a market in his particular area. The technologist sees in the catch an indication of the efficiency of the gear used, as compared to another.

The fishery economist looks at the catch as an income resulting from a certain expenditure.

The fishery biologist looks at the catch from the point of view of its significance with regard to the fish stock from which it has been taken, as that stock determines what can, and in part what will, be taken in the future. For him the catch is a proportion of the stock and the removal of this proportion signifies certain effects on the stock-changes in its size and other properties.

Let us first of all define what selectivity really is. We can say that every individual in a fish population of a certain area has an equal chance of being caught, then the catch will reflect the composition of the whole population. When the proportions in the catch show a different composition, then the gear may be said to be selective. This can be due to the biological characteristics of the fish, to the type of the fishing operation, to the behaviour of the fish in relation to the operation or to the rig and design of the gear so that selection is not attributable to the characteristics of the gear alone.

Another type of selection will operate when the fishing boats of a certain area fish in regions where certain high quality fish are to be found, to satisfy the market demands for a particular species.

Perhaps the most important factor, determining the extent to which this type of selection process will operate, is the knowledge of the distribution of the species wanted. The collection of such knowledge should benefit from a close cooperation between fishery biologists and the fisherman. So we can say that selection begins as soon as the fishing fleet puts to sea and concentrates in places where the most desirable catch is to be found. This selection process becomes more complex where several types of gear operate at the same time to supply different market demands. A second stage of selection, which we can call gear selection, starts when the gear is put into operation.

Gear selection can be divided into two components: that due to the avoidance of the gear by certain species and that due to the ability or tendencies to escape from the gear when the fish come into contact with it. If the magnitude of these components can be identified and measured, then the gear designer, the gear manufacturer and fishermen can take account of them in the construction and operation of the gear, or the fishery administrator in his fish conservation practices.

In gillnet fishing, for instance, the catch depends on fish swimming into and being meshed or entangled by a wall of net. The influence which biological factors may have in this action is illustrated very clearly by Nomura who discusses the factors affecting the selectivity and fishing ability of gillnets in Japanese waters. This paper demonstrates that the behaviour of the fish in relation to the visibility of the nets, plays a very important part. Saetersdal and Mugaas also mention data which point to the inter-action of the fish behaviour to, and the gear selectivity of, different types of material used for gillnets, as being important in determining the size of catch and its composition. In line fishing, too, there are data which demonstrate the importance of these factors; fish of some sizes or ages, for example, may avoid baits of a particular shape or size, while others will take them A further stage at which selection takes place is the escapement of fish from the gear once they have contacted it, such as through the meshes of the net.

This mesh escapement, of course, is a process which is well known to technologists, fishermen and fishery administrators as well as fishery biologists. It is, in fact, the selection process which is utilized in effecting fishery conservation practices in some important regional fisheries.

For example, we have learned a great deal in recent years about the behaviour of fish in trawl codends and seine codends by the adoption of television techniques, under-water observations by frogmen, by measuring devices attached to nets, by controlled experiments with gears and observations on the catches in different parts of the net. This has shown that mesh escapement is effected by features of the gear as well as by the behaviour of the fish. One of the most important of the gear factors which affects escapement is the material from which the net is made. The results of experiments have shown conclusively that the escape of fish differs between nets having the same mesh size but made of different materials. Some quality of the material which is being identified by many workers with the property of flexibility and stretchability of the twines is responsible for this. Mesh escapement is also affected by the size of the catch as fish in the codend will tend to block meshes and prevent further escapement.

I do not propose to go into the methods by which the selection processes can be studied and examined yet I must draw attention to the method known as comparative fishing. Comparative fishing has been used almost exclusively hitherto to study selectivity and other features of fish operations, such as determining the fishing power of nets of different structures, different materials and so on, and in four of the present papers there are examples of the use of the comparative fishing technique. That the method must be worked under strictly controlled conditions is apparent from the experiments referred to in the papers on the efficiency of gillnets made of natural and synthetic fibres. Whereas these papers conclude that the synthetic fibres are catching much more efficiently than the natural fibres, the results of similar experiments conducted elsewhere show very little superiority of synthetic fibres. The higher catches of synthetic fibre nets may be due to the decreased visibility when they are fished in clear water. On the other hand, one would not expect to find a marked difference in very turbid water.

Mr. S. Holt (FAO). In measuring how effective one gear is by comparison with another slightly different gear, we use the "comparative fishing method". Although it essentially means fishing the two gears side by side and comparing the results, the difficulty has been that results are very variable and therefore rather complex statistical methods have to be used if we are to make the correct interpretation of the results of such trials. The trouble is that, although we can measure the differences between gears, we do not know if that difference will be true when we make the same experiment on another day, or in a different place, a different season, or at a different time of day.

Comparative fishing experiments can give us measurements, they cannot tell us the reasons why. The problem of interpretation of the results is a matter for both biological and technical study. There are very complex problems involved, as Mr. Parrish has said, but somehow they have got to be solved if we are to try to devise gears rationally. If we are going to accelerate the rate at which we can improve fishing gears, we must do more than just make trials working in the dark the whole time. To do this at all we will need to understand a lot more about the reactions of fish, particularly to different characteristics of fishing gear such as its visibility, the speed at which it moves, and so on.

At a meeting of biologists in Lisbon this year, it was suggested that this Congress was the appropriate place to tell technologists and fishermen what kind of information biologists expect from them.

Fishery biologists are in general responsible for measuring the properties of the fish which determine its liability to capture. They believe it is the responsibility of gear technologists to analyse and measure the corresponding properties of the gear. They believe that this work would be greatly assisted if a world catalogue and description of fishing gears could be compiled and if a classification of gears based on toxonomic principles could be devised. They believe that a simple classification of gear would serve the following purposes. Firstly, it would stabilize the nomenclature of gears with special reference to synonymous terms used in various countries. Secondly, it would assist the population dynamic worker by indicating the essential properties of gears with which they are working, and thirdly it would facilitate the correct comparison of results obtained with various gears in different circumstances.

The biologist cannot advise on the correct gear to use, unless he knows what is the composition of the fish stock on the ground. If that changes, then the choice of gear must also change, i.e. another gear may be more economical. The trouble is, we cannot wholly measure the composition of the fish on the ground without also knowing a great deal about the selectivity of the gears which are actually being used by the fishermen. The only solution is by very close co-operation between the fishermen, the gear technologist and the biologist.

Mr. S. Springer (U.S.A.). In the Gulf of Mexico we use shrimp trawls which run from 12 ft. across the mouth to 125 ft. and all of these are used to a very great extent some on the same boats. The smaller nets are used for try nets to test the ground and the larger nets are used for production. The smaller nets are usually a lot faster than the larger nets. I presume that all of these nets work well enough but one thing that we have found in analysing the catches of the nets of different sizes is that the smaller nets catch smaller fish than the larger nets. Yet it appears that, owing to the greater speed of the smaller net, this should not be so. One explanation of why this may happen could be seen in the television film showing haddock inside the codend. In general, these haddock seemed to move and swim forward to a certain extent before they actually go into the tail of the codend. It would seem to me that we might infer from this that the net has to have a certain length in order to retain the large fish that is, a short net with a short codend would catch more small fish because the larger fish, being faster swimmers, can escape. I would be interested to know if there is any experience like this in other fisheries and whether there is any relation between the length of the throat and the codend and the size composition of the catch.

Dr. Went (Ireland). From a point raised this morning it would appear that the fisherman in general is not convinced of the practical value of selectivity and comparative fishing for the industry. I think we must stress the very great importance of this subject to the practical fisherman who, of course is interested in getting fish. However, if he is to continue obtaining good catches, fish conservation regulations must be made to preserve the stock. I think the experiments on selectivity of fishing gear and comparative fishing will give us the basis on which to draw up such international regulations.

Mr. M. Ben-Yami (Israel). I would like to emphasize the importance of comparative fishing in assessing the relative value of fishing gear. We met this problem in Israel in connection with the high opening trawl we had developed. We were aware of the difficulties in determining the actual value of differences in catching efficiency between two types of gear accurately. But, for the commercial fishermen only very obvious differences count. I, therefore, think that accurate statistical evaluation, as applied in selection experiments, is not needed for such practical purposes. We actually used two techniques of comparative fishing: one and the same trawler fishing with the new gear and the conventional gear alternatively, and two boats, one with the new gear and one with conventional gear, towing side by side. These experiments were conducted for several months in commercial operation in various areas. After eliminating all not strictly comparable hauls, some 60 comparative tows remained, the evaluation of which indicated that the new gear gave about 20 per cent. better catches. For such commercial comparative fishing it is advisable to put a very experienced and very conservative, but good, fisherman in charge of the conventional gear and make the designer of the new gear compete against him. If a new design passes such a test successfully, I think one can be sure and the fishermen can be convinced, that something worth while has been achieved.

THE USE OF MODEL NETS AS A METHOD OF DEVELOPING TRAWLING GEAR

by

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Abstract

This paper deals with the theory and practice of using models in connection with the design of fishing gear and the study of fish behaviour in relation to the gear. A certain amount of success has been achieved by underwater photography by frogmen but there are hazards and difficulties when the gear is towed quickly in areas of low visibility. The use of models in shallower water can overcome some of these difficulties, and the author lays down rules governing the making and operation of small-scale nets.

Models were observed in action in a West Scottish sea loch by frogmen working in pairs and hanging on to a tow-rope instead of to the net itself, and several photographic records have been procured by this means.

The need for correlating observations and measurements of models with observations on the full-sized gear is stressed and it has been found that the agreement between the performance of models and full-sized gear has generally been sufficiently close to conclude that much can be learned from models, provided that comparisons are viewed critically. Models can show fairly accurately the effect of alternate methods of rigging a gear and can at the same time reveal faults, but they are not intended as a substitute for instrumentation or comparative fishing, the latter being regarded as the final stage of gear-testing. The paper is fully illustrated.

Utilisation des modèles de filets dans la mise au point des chaluts

Résumé

Cet article traite de la théorie et de la pratique des essais de modèles en vue de la construction des engins de pêche et de l'étude du comportement du poisson en fonction des engins. Des photographes sous-marines prises par des hommes-grenouilles ont permis d'obtenir quelques succès, mais l'operation est difficile et dangereuse lorsque l'engin est remorqué rapidement dans des zones où la visibilité est faible. L'utilisation de modèles dans des eaux peu profondes permet de surmonter certaines de ces difficultés et l'auteur pose des règles applicables à la fabrication et à l'utilisation de filets de petites dimensions.

Des hommes-grenouilles travaillent deux par deux et se tenant à un câble de remorquage au lieu de se tenir au filet lui-même ont observé des modèles en action dans un loch, sur la côte ouest de l'Ecosse et plusieurs enregistrements photographiques ont été obtenus de cette manière.

L'auteur souligne la nécessité d'établir un rapport entre les observations et les mesures des modèles et les observations faites sur les filets et sur les engins de grandeur naturelle et il a été constaté que le comportement des modèles et des engins de grandeur naturelle a été suffisamment analogue pour permettre de conclure que les modèles peuvent constituer une excellente source d'enseignement, sous réserve de soumettre les comparaisons à un examen critique. La construction de modèles peut montrer d'une façon assez sûre l'effet des diverses méthodes possibles pour garnir un engin et en même temps en montrer les défauts, mais elle n'est pas destinée á remplacer les instruments ou la pêche comparée, cette dernière étant toujours considérée comme l'étape finale de l'essai des engins.

Uso de modelos de redes de pesca como metodo para perfeccionar artes de arrastre

Extracto

En este trabajo, que cuenta con numerosas ilustraciones, se estudia la teoría y práctica del uso de modelos a escala reducida en relación con el proyecto de los artes de pesca y el estudio de la manera como reaccionan los peces ante las redes. Se ha logrado cierto éxito mediante fotografías submarinas tomadas por "hombres ranas", pero este método es peligrose y ofrece dificultades cuando la red es arrastrada rápidamente en zonas de poca visibilidad. Como el empleo de modelos en aguas menos profundas puede evitar algunas de estas dificultades, el autor da algunas reglas que gobiernan su construcción y uso.

En una ensenada de la costa occidental de Escocia parejas de buzos que colgaban del cable de remolque en vez de la red, observaron el comportamiento del modelo y tomaron varias fotografías.

La necesidad de correlacionar las observaciones y medidas de los modelos con observaciones de los artes de tamaño correinte han permitido encontrar que existe una concordancia entre el rendimiento de los modelos a escala reducida y las redes normales, lo suficientemente estrecha como para llegar a la conclusión de que pueden sacarse grandes experiencias con el uso de modelos siempre y cuando las comparaciones se analicen con sentido crítico. Los modelos pueden demostrar con bastante certeza el efecto que ofrece el empleo de métodos alternativos empleados en la confección de las redes y, al mismo tiempo, revelar sus inconvenientes pero no se trata de utilizarlos para reemplazar el uso de instrumentos o la pesca comparativa, ya que esta última es considerada como la etapa final de las pruebas a que es necesario someter un arte.

WORK was begun on the observation of models underwater in 1954 by the Marine Laboratory in Aberdeen. Data obtained in the meantime, from measurements by instruments on the performance of full-sized trawling and Danish seine net gear, together with the underwater films and measurements already made, served as a comparison against which the performance of models could be judged. The comparison between models and fullsized gear was sufficiently encouraging to warrant repeating and extending the trials in 1955 and 1956.

There are three reasons for observing fishing gear or models of it in operation:

1. To form an impression of the performance of the gear, to seek defects in its design and to try the effect of alterations in design and rigging.
2. To make measurements to obtain a fuller appreciation of the gear's hydrodynamical performance.

3. To obtain information on the reactions of fish to the gear.

Certain rules should be observed as closely as possible when modelling, and if the conditions of water-flow are to be similar for model and full-sized net, there should not be too great a change of Reynold's Number. When the scale becomes too small the rules cannot be followed. The purpose will also dictate how far the rules should be obeyed. Lastly, the choice of model size is dependent on the towing power of the available boat.

When the purpose is to look for bad features in the design of a net, the model should correspond mesh for mesh with the original and the twine diameter should be proportionally reduced. Practical considerations, however, often force a compromise. Expense and the availability of suitable materials have to be taken into account and, if the setting of the net is to be altered during the experiment, labour costs must be considered. A quarter scale model with a half scale mesh, or an eighth scale model with a quarter scale mesh, are reasonable compromises. If a true scale model is required, a scale of one quarter is about the smallest that can reasonably be used.

Small nets of some 20 ft. headline length towed by the 15 h.p. coble shown in fig. 1, are big enough to be effective fishing instruments, and there is little likelihood of significant fish behaviour passing unnoticed. For this purpose the nets should be made with meshes of the size used commercially.

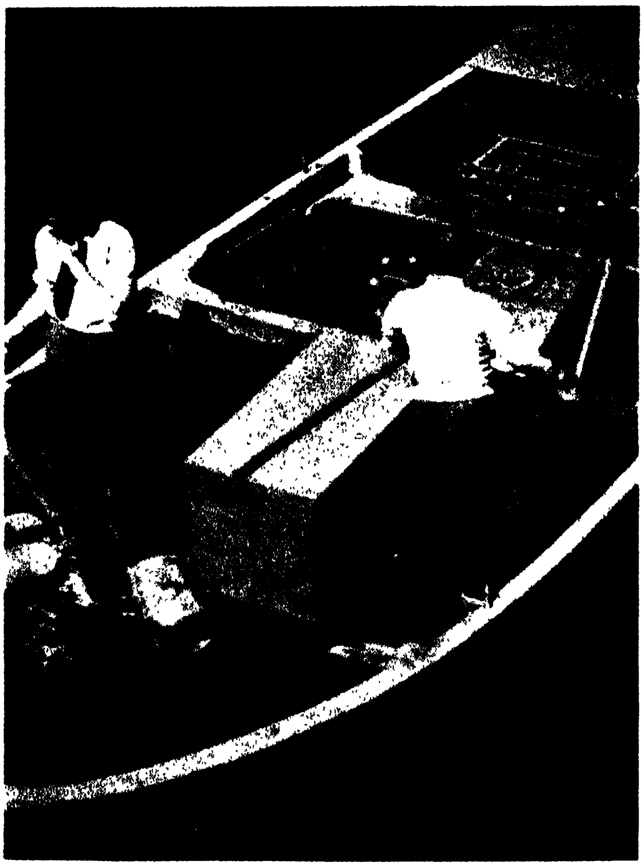


Fig. 1. Coble with cameras and breather set on the foredeck and winch in the stern.

COMPARISON BETWEEN AN EIGHTH SCALE MODEL AND THE FULL-SIZED GEAR

Measurements on models can be taken by direct readings on measuring sticks, strings and spring balances, but to take corresponding readings on a full-sized trawl requires some degree of instrumentation. In most cases only a few spot-checks are possible. The net chosen for the present comparison is the small "Aberdeen" trawl used by most trawlers from that port. Its headline length is 62½ ft. The model is to one-eighth scale with the mesh-size and twine diameter reduced to approximately one-quarter. The following data were obtained for the model and full-sized net in a series of trials. (Scaled up values of the model data are given in brackets.) The original and the model were rigged in the same way with 10 fm. sweep lines, bobbin danlenos and 20 ft. spreading wires.

	Full Size Net	*8th scale Model*
Warp Length	100 fm.	10 fm. (80 fm.)
Spread of otter boards	105 ft. (by wire angle at surface)	11 ft. 8 in. (93 ft. but equivalent to 97 ft. with 100 fm. aft).
Headline Height	6 ft. (by differential depth recorder)	9 in. (6 ft.)
Drag of Gear	3·25 tons (by warp tension recorder, 1·63 in each warp)	16 lb. (3·7 tons lowest estimate) 40 lb. (9·2 tons highest estimate)
Towing speed	3 knots	1 knot

The comparison is close enough to emphasize the value of models and yet divergent enough to give the hint that significant differences can arise.

A photograph of the differential depth recorder used to measure the headline height is shown in fig. 2. It is an ordinary depth recorder, except that the pressure inside is maintained at headline depth through the collapsible rubber tyre attached to the headline, the recorder itself being attached to the ground rope. The instrument used for recording warp tension is shown in

Fig. 2. Differential depth recorder.

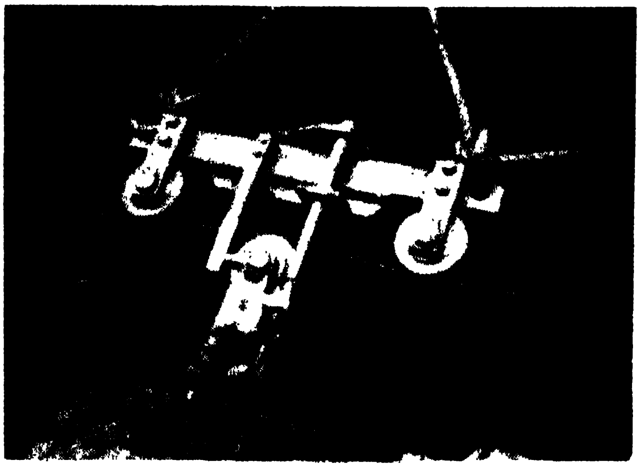


Fig. 3. Warp tension recorder.

Fig. 4. Starboard wing and part of the square of the small Aberdeen trawl. Shot from the film "Trawls in action" made by "Basic Films" for M.A.F.F. Fisheries Laboratory, Lowestoft, in conjunction with Siebe Gormans Ltd.

Fig. 5. Model of small Aberdeen trawl. Note loose lastrich line

fig. 3. It works on the principle of one wheel deflecting the warp a small lateral distance between the two outside wheels at a fixed distance apart. The deflecting wheel is mounted on the piston of an oil-filled cylinder and the oil pressure recorded. The instrument can work whether the rope is moving or stationary.

As the small "Aberdeen" trawl was photographed in the M.A.F.F. film "Trawls in Action", we may compare it with a photograph of the model. Fig. 4 shows a view of the net and fig. 5 one of the model.

MODELLING RULES

As a model is scaled down, all weights and floats dependent on volume decrease by the cube of the scale, while all lifts and drags due to water-flow and dependent on surface areas decrease by the square of the scale.

F and W are proportional to l^3	where F and W are floatations and weights in the original and where l is a unit of length.
D and L are proportional to $l^2 v^2$	where L and D are lifts and drags due to water flow in the original and where v is the towing speed.
F_s and W_s are proportional to $(s\ l^3)$	where F_s and W_s are floatations and weights in the model, where l is as before and s is the scale.
L_s and D_s are proportional to $(s\ l)^2\ (s^{\frac{1}{2}}\ v)^2$	where L_s and D_s are lifts and drags due to water flow in the model.

It may be seen that for $\frac{L}{L_s} = \frac{D}{D_s} = \frac{F}{F_s} = \frac{W}{W_s}$ there are several requirements.

1. *All* dimensions of length must be reduced to scale.
2. Floats and sinkers must be of the same density in the model as the original, otherwise the change in flotation or weight will not be proportional to the cube of the scale. Netting twine should also be of the same material otherwise there is a change in density, and here arises a difficulty. Most big nets are made of manila twine, which cannot be obtained thin enough for model making, hence the usual material for model making is cotton twine. Although there is no very definite agreement about specific gravities of twine the following figures may be used:

Manila (green proofed with cuprinol)	SG 1·29
Cotton (green proofed with cuprinol)	SG 1·34
Nylon	SG 1·12

3. The speed of towing must be reduced by the square root of the model scale. In operations such as seining where time is also a factor, the timing must also be scaled down by the square root of the scale.
   If the normal towing speed of trawls is taken as 3 knots:

   $\frac{1}{2}$ scale towing speed is $3/\sqrt{2}$ or about 2 knots
   $\frac{1}{4}$ scale towing speed is $3/\sqrt{4}$ or $1\frac{1}{2}$ knots
   $\frac{1}{8}$ scale towing speed is $3/\sqrt{8}$ or about 1 knot

4. It is assumed that the lift or drag due to water-flow changes proportionally with the square of the velocity, but this will only be so over a limited range of change in scale and change in speed. This will be discussed more fully later.

In practice these rules are not always honoured accurately. It is, therefore, necessary to understand in each case whether and how they are being broken and the direction of the resulting bias, so that it may be allowed for or measures taken to overcome it. Consider only one of the probable compromises here, that on which the models described were made where mesh and twine size were reduced less than by the scale.

Let l be the length of twine in the original (m.)

R be the runnage of the twine in the original (m./kg.)

P be the density of the twine in the original (g./cm.³)

W be the weight of the twine in the original (kg.)

d be the diameter of the twine in the original (mm.)

A be the projected area of the twine in the original (mm.²)

Similar letters with the suffix s refer to the model

S be the scale of the model

S_m be the mesh scale, and

S_d be the twine diameter scale

Then $W = \frac{l}{R}$ (1)

$A = ld$ (2)

$W_s = \frac{l_s}{R_s} = \frac{1}{R_s}\frac{S^2 l}{S_m}$ (3)

$A_s = l_s d_s = \frac{S^2 l}{S_m} S_d d$ (4)

and $\frac{1}{R} = P\frac{\pi}{4}d^2$ approx., $\frac{1}{R_s} = P_s\frac{\pi}{4}d_s^2$ approx. (5)

Hence $S_d = \sqrt{\frac{PR}{P_s R_s}}$ (6)

When the model scale is a true one

$W = \frac{l}{R}$; $S = S_m = S_d$; $R_s = \frac{R}{S^2}$; $P = P_s$

$A = ld$

$W_s = S^3 \frac{l}{R}$

$A_s = S^2 ld$

But take the simple case:

$S = \frac{1}{8}$; $S_m = S_d = \frac{1}{4}$; $P = P_s$; $R_s = \frac{R}{S_d^2}$

$W_s = \frac{S_d}{R} S^2 l$

$A_s = S^2 ld$

The area of twine projected to the water-flow is correctly scaled but the model is twice as heavy as it should be, and this has to be balanced by increased flotation. Where the model cannot be made of the same material as the original, similar effects occur. These physical difficulties in constructing an accurate model are not the only ones to be considered.

Reynold's Number is a dimensionless number given by $R = \frac{vl}{n}$ where v is the velocity,

l is an arbitary length unit such as say the diameter of the floats or the twine diameter:

n is the Kinematic viscosity and $n = \frac{\mu}{P_m}$ where

μ is the viscosity of the medium

P_m is the density of the medium

So long as R remains constant it can be taken that the conditions of the water-flow round the immersed body remain the same. In model tests in the sea n cannot be altered, and, therefore, for constant R, the velocity of the model should be inversely proportional to the scale but for constant flotation to drag ratio, the velocity of the model should be directly proportional to the square root of the scale. Both conditions cannot be met at the same time and some change of Reynold's Number must be accepted. The question is, what change of drag coefficients does such a change in Reynold's Number bring?

Fig. 6 shows that for the spherical headline floats there might be little change of drag coefficient between the full size and one-eighth scale at scale towing speed[1].

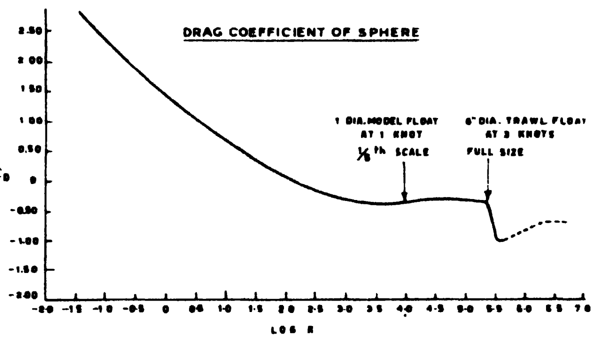


Fig. 6. Relation of coefficient of drag for spherical floats to the value of Reynold's Number.

Possibly in the full sized net the proximity of the headline to the balls and their method of attachment would encourage the onset of turbulence, so that the drag coefficient might decrease to values given in the sharp dip in the graph.

The drag coefficient of a sphere over a wide range of Reynold's Number has been thoroughly investigated but far less in known about how sheets of netting behave over a wide range of scale and speed. The indications are that at one-eighth scale the curve of the drag coefficient rises appreciably and would rise more steeply at smaller scales. This, and the physical difficulty of making accurate small scale nets, puts a lower limit on scale size.

Information on the lift and drag of otter boards is scanty. Gawn gives some data on flat boards of low aspect ratio at a Reynold's Number of about 4×10^5.[2]. These boards (corresponding to about 1/12th scale) were towed at speeds up to 5 knots without apparently much change in the lift and drag coefficients. These data cover the model range up to one-quarter scale quite well.

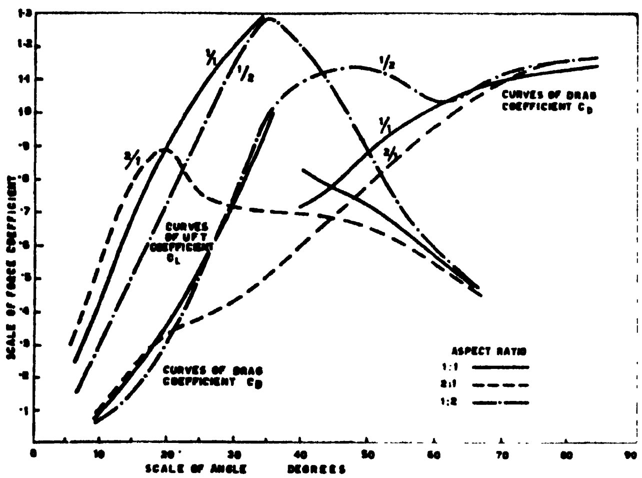


Fig. 7. Forces on rectangular and square plates. From Gawn[2].

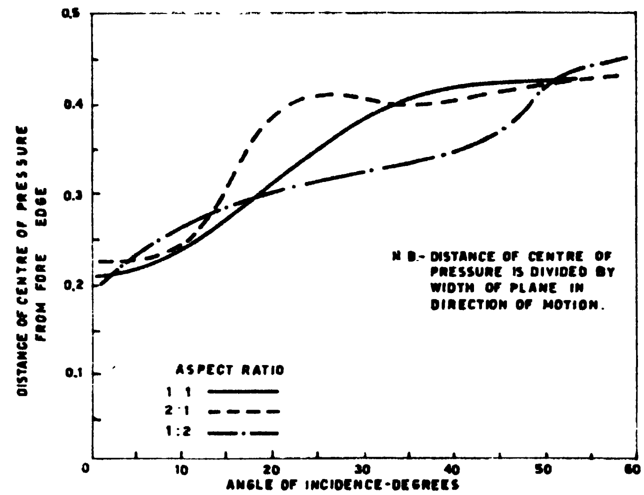


Fig. 8. Curves of centre of pressure of planes. From Gawn[2].

Some of Gawn's graphs are reproduced in figs. 7 and 8. Trawl boards are, however, in contact with the bottom, which affects their drag and alters their lift. Since an otter board bears down on its heel, the friction acts through a point aft of the centre line, bringing the effective centre of pressure further aft than indicated in fig. 8.

Even where frogmen can observe large trawl nets in action, convenience and safety of underwater observers demands reduced towing speed. The flotation to drag ratio is then upset, giving rise to inaccuracies and problems analogous to those met in the use of models.

MAKING SPECIFICATION DRAWINGS

There is no tendency towards standardization of the drawings and specifications of nets. Designers draw nets as they think best. Some drawings are made in specula-

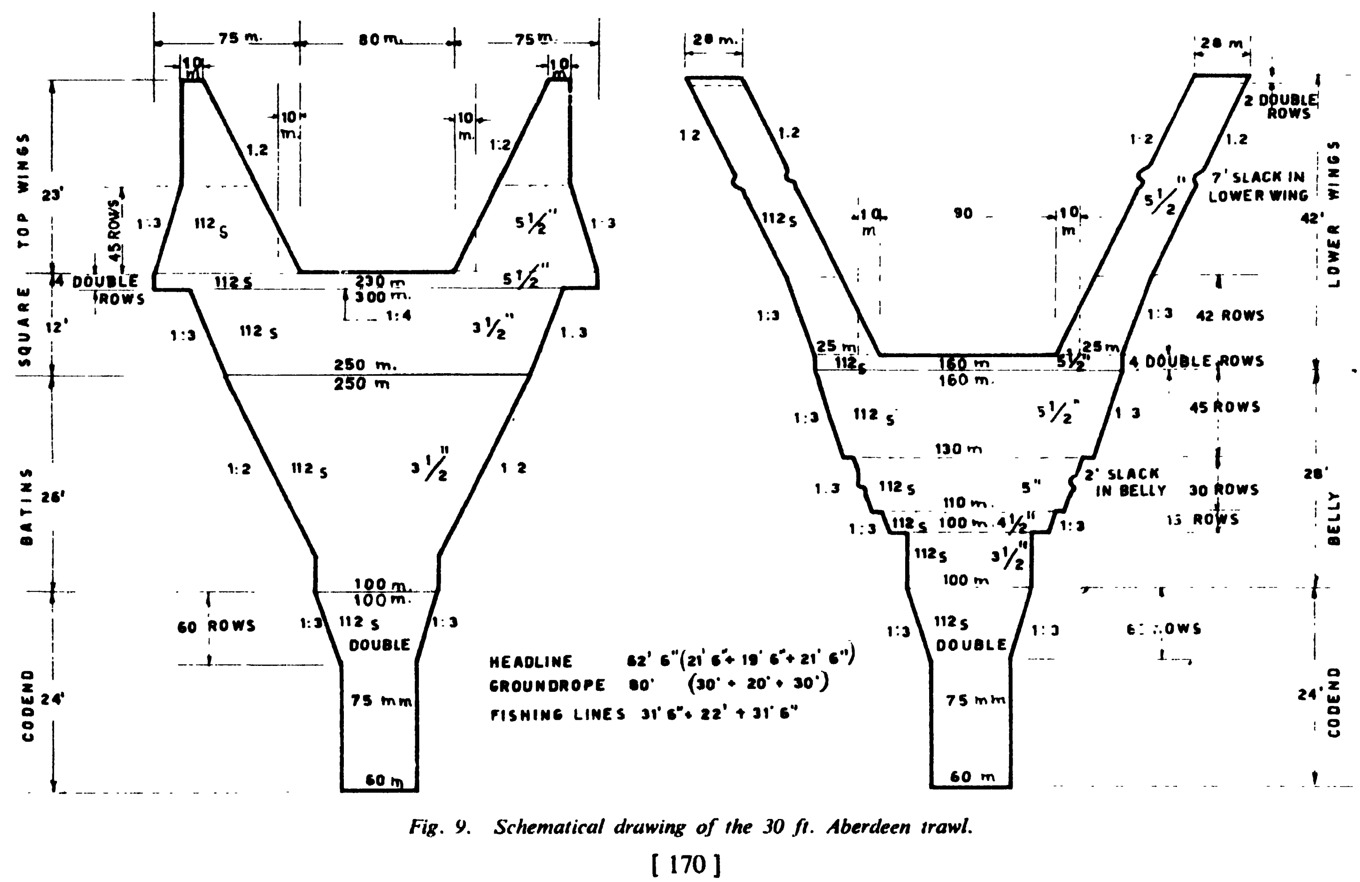


Fig. 9. Schematical drawing of the 30 ft. Aberdeen trawl.

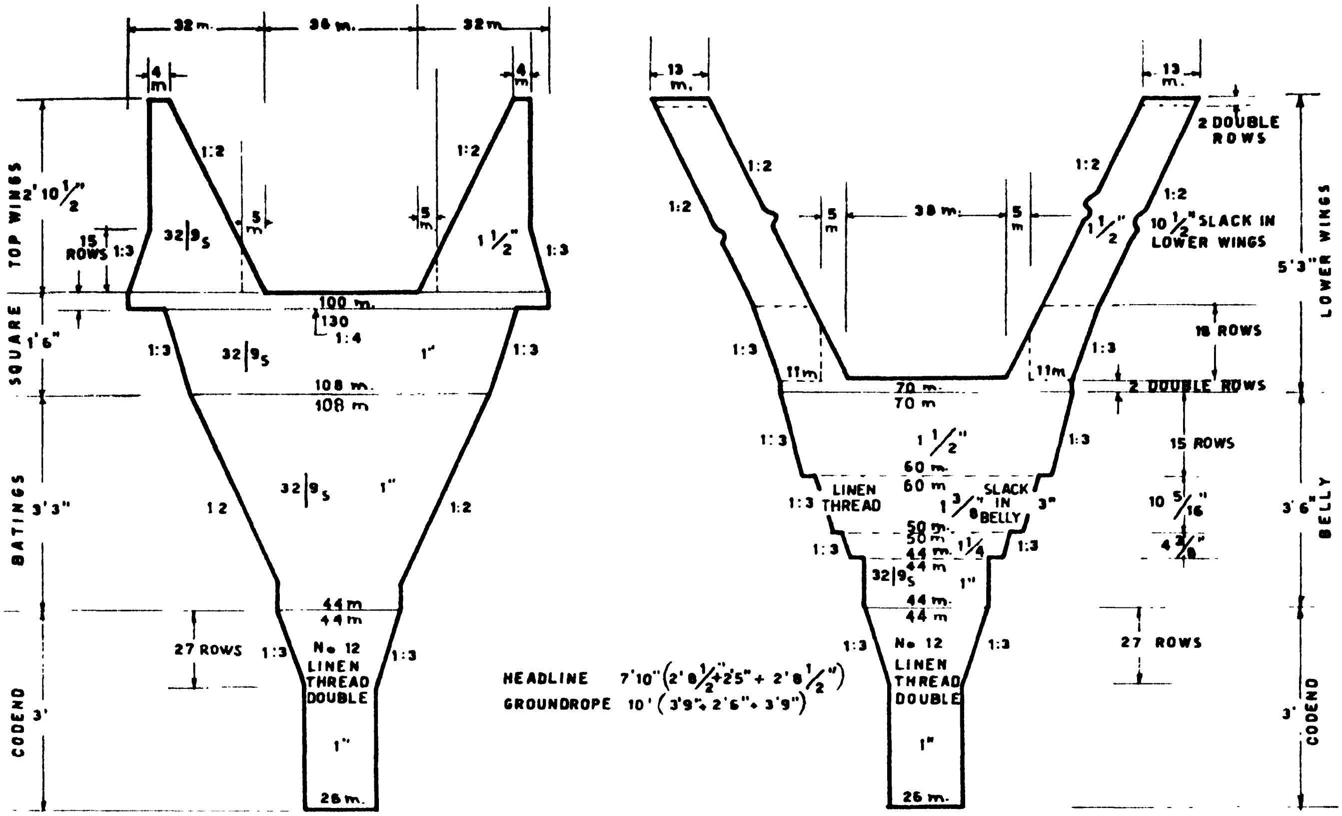


Fig. 10. Schematical drawing of the ⅛th scale model of the 30 ft. Aberdeen trawl.

tive fashion, in an attempt to show the net in the fishing position with a few dimensions added for good measure. It is rare for any of these drawings and specifications to be complete and it is not easy to tell from them the salient features of the nets or how they compare in shape with other nets, but it should be possible to make such drawings.

With a model net a glance at the drawings should show, when compared with those of the original, whether or not it is a fair replica. The scales can be so chosen that drawings of both model and original are the same size and can be checked by the use of tracing paper.

The following rules have been found useful in practice:

1. All lengths are true lengths with the netting stretched but any lengthways slack is noted on the drawing and indicated by an irregular line in the edge of the panel concerned.
2. All widths are taken by setting the meshes in by the half, e.g. 120 meshes of 1½ in. size set into

$$\frac{120}{2} \times 1\tfrac{1}{2} = 90 \text{ in.}$$

Such rules give the drawings a "stepped" appearance which the net does not, of course, have in practice, but they show directly the lateral slack and tautness. The drawings do not cover the setting of the nets to their ropes, details which may be added in note form. Figs. 9 and 10 show the drawings of the small "Aberdeen" trawl and model, according to these rules.

Provided that the same rules are always observed the patterns which turn out to be good and bad can be remembered and take on their own significance.

SOME UNDERWATER OBSERVATIONS

Models of a suitable size for this work are too big to be used in most testing tanks, consequently, a method was devised for inspecting the models towed in a West Highland sea loch.

The general requirements of a location are, a half mile stretch of clean smooth sandy bottom in depths between 3 and 6 fathoms, not too much tide, a shore reasonably free from surf, good sunlight and an underwater visibility range of not less than 30 ft. These conditions are difficult to satisfy in Scottish waters and the work described was done in conditions which fell short of the ideal. A frogman may hang on to a full-sized net without distorting its shape but not a model, nor could he swim at towing speed for long. He therefore hangs on to a towing rope. The frogmen work in pairs, one making measurement and one taking photographs. The remainder of the team of 5 comprise the divers' attendant, who follows the frogmen's air bubbles in a rowing boat, and two men in the motor coble towing models and frogmen.

An otter board is shown in fig. 11. The brackets and the "normans" to which the back strops are attached are set to give the board an angle of attack of about 35 degrees, giving the maximum lift with a large concomitant drag. It is not worked at or near the angle of maximum

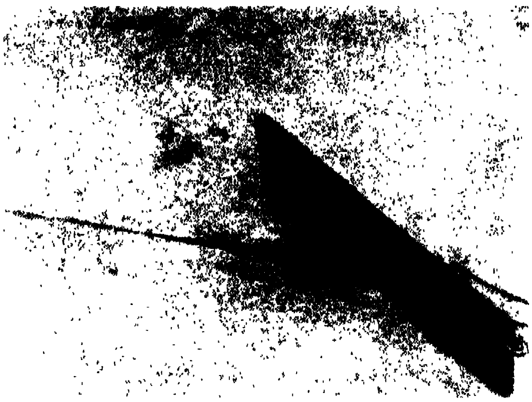


Fig. 11. Model otter board in action.

lift to drag ratio. Behind the otter boards come the sweepwires, the danleno bobbins, the legs or spreading wires, and then the net.

One of the main principles in net design, and in avoiding net distortion, is to shape the net as nearly as possible to the shape assumed in its fishing position. Meshes in the region of the "quarter" mesh, where the inside edge of the top wings join the square, are often subject to high

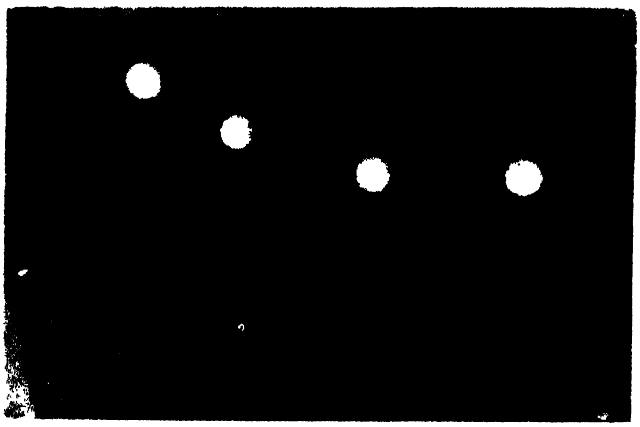


Fig. 12. Tension behind quarter-meshes on model of small Aberdeen trawl.

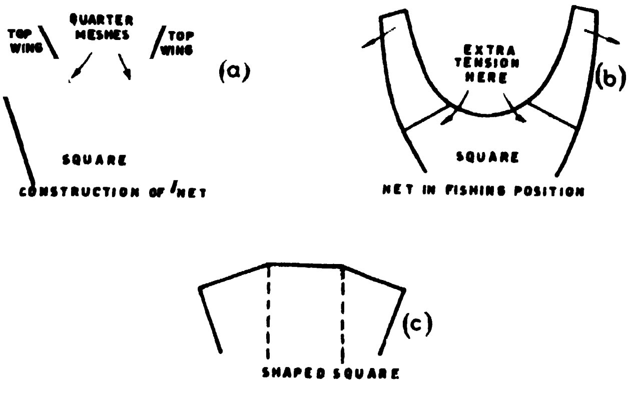


Fig. 13. Proposal for a better construction of the square.

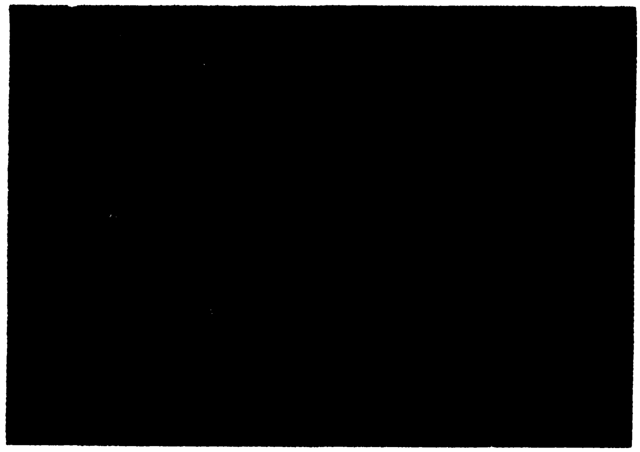


Fig. 14. Wing tip of model Vinge Trawl in action.

tension (see fig. 12). The reason for this is also seen in the backward bend of the leading edge of the square where it joins the wings. It is as if the net were hinged about the quarter meshes as shown in fig. 13 (b). There appears to be some argument for shaping the square as shown in fig. 13 (c) by "bating" or tapering meshes in the middle of the net rather than in the selvedge. This improves the appearance and tends to give all parts an equal strain.

It is not really surprising that a bulge in the selvedge at the join of top wings and square appears (figs. 9 and

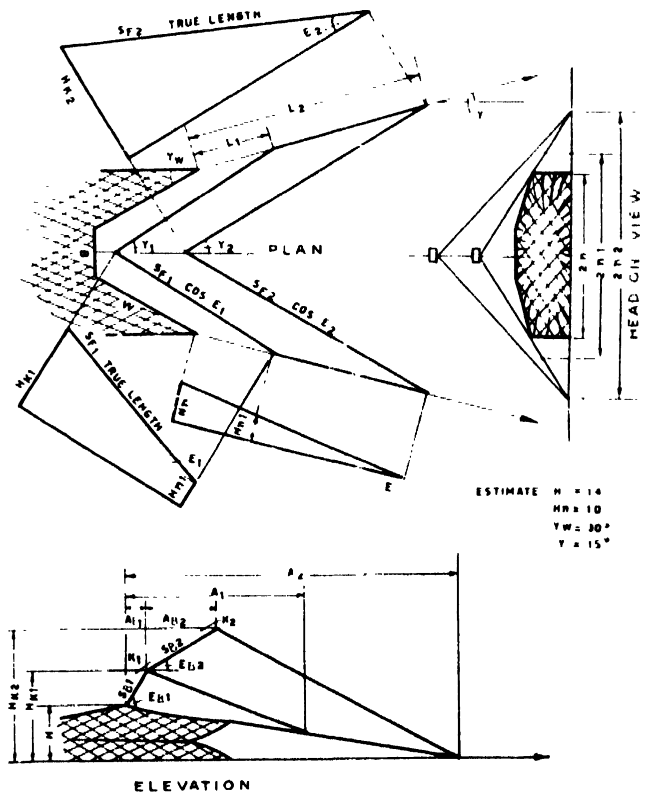


Fig. 15. Method to determine the proper length of false headlines

10) when the model is in fishing position (fig. 5). Conversely, this method of drawing leads, with a little practice, to a fair idea of what shape will be assumed underwater by a given design of net. It seems as if some alteration to the design of this small "Aberdeen" net could be advantageous, and such trials will be made.

To increase the headline height (particularly for herring trawling) has long been the objective of net designers. Various trials have been made to this end with Vinge trawls, where the wing ends are split down the selvedge. A model of this type was used with some success as a pilot in the development of a Vinge trawl for the 75 ft. research vessel *Clupea*. One wing end of the model is shown in fig. 14 where it is apparent that the net is set too loosely on the ropes, both headline and footrope being too short. Models are particularly useful for the correction of such faults.

The use of kites is common with herring trawls. It is difficult to tell how the lengths of the false headlines were arrived at in the first place, probably on an empirical basis. The shape of a net in the towed position cannot yet be theoretically determined, but it was felt that there was sufficient knowledge to estimate certain critical dimensions and then calculate the desired lengths of false headlines to bring the kites to determined positions. Fig. 15 shows the method. Values must be assigned to the headline height at its maximum and at its wing tips, to the spread of the net at its wing tips and to the angle of attack of the sweep wires. The agreement between the values predicted on the drawing and those obtained in practice on the model is reasonable.

	Predicted	*Observed*	
Spread of headline	41 ft.	54 in	(36 ft.)
Headline height H	14 ft.	21 in.	(14 ft.)
Height of 1st Kite HK1	22·7 ft.	36 in.	(24 ft.)
Height of 2nd Kite HK2	32·7 ft.	45 in.	(30 ft.)

The appearance of the kites above the net is to be seen in fig. 16.

REACTIONS OF FISH TO SMALL NETS

The ciné film is more useful than the "still" film for recording the reactions of fish to the gear.

The reaction most commonly observed is that fish tend to swim away perpendicularly in front of a moving wire or rope when both are on or near the bottom. This is shown diagrammatically in fig. 17 (i).

If the maximum swimming speed of the fish be V_f and the speed and angle of attack of the wire be V_t and E_T respectively, then the angle of arc (E_p) from which it

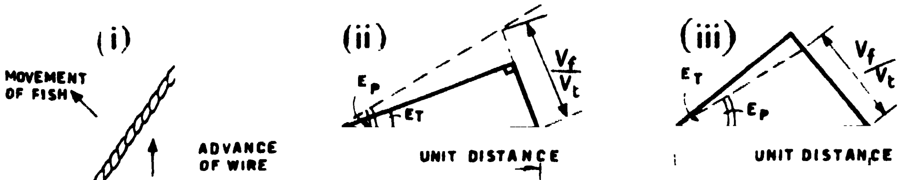
Fig. 16. Model herring trawl kites in action.

would be possible to shepherd fish can be calculated It is probably better to have E_T smaller than E_p, as in case (ii) because the chances are that the wire will increase the probability of capture within its limited arc In case (iii) it is possible the fish are already outside the arc of possibility of capture when near enough to be influenced by the wire. Not all fish in the path of sweeps and wires finish up in the path of the net nor, for that matter does every fish in the path of the net finish up in the codend!

A common line of escape from the path of a net is below the ground rope, so the balancing of sinkers and floats is critical, if good headline height is not to be sacrificed. There are other more interesting ways of escape. An observed escape between the legs or spreading wires is shown in fig. 18, where the usual movement perpendicular to the approaching wires turns into escape between them. Whether this is due to vision or discrimination between two approaching pressure waves or some other factor is not known.

Flat fish are often pinned against the netting by the flow of water through it, even in areas of the net where the taper does not appear to be unduly rapid, as in fig. 19 An outward turn of the flow lines inside the net might be inferred. The after end of the lower wings below the square is a particularly critical region and if the meshes there are large enough escape is possible.

Shoaling fish appear to behave somewhat differently. There is the shoal reaction as well as the individual reaction. Unfortunately, the only shoaling fish so far



$$E_p = E_T + \tan^{-1}\left\{\frac{\frac{V_f}{V_t} - \sin E_T}{\cos E_T}\right\}$$

Fig. 17. Diagram of the common reaction of fish to a rope.

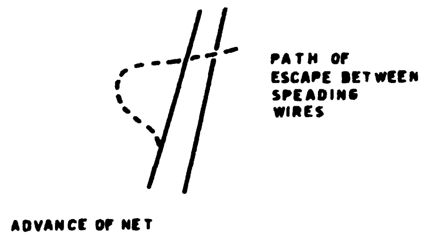


Fig. 18 Diagram of an observed reaction of fish to two ropes

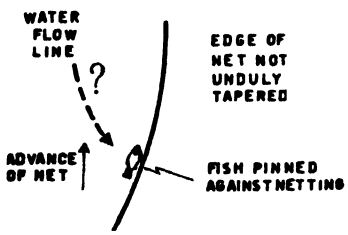


Fig. 19. Diagram of the way how a fish can become pinned to the webbing.

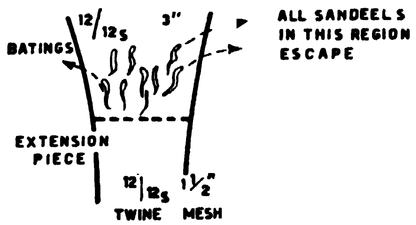


Fig. 20. Diagram of the escape of a school of sandeel through the funnel.

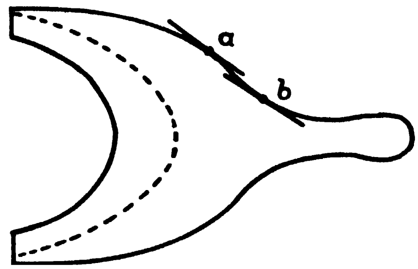


Fig. 21. Points of inflection in the shape of a trawl net in action.

observed in their reactions to a net have been sandeels. Although the mesh size presented no barrier to their escape, they kept their formation, becoming concentrated deep in the funnel, and only sought escape there (though a few outriders of the shoal escaped earlier). The escapes took the pattern shown in fig. 20 and there is presumably a pressure build up ahead of the small mesh netting, with a consequent increase in flow through the last piece of the larger mesh netting. Shoaling fish are both easier and harder to catch than other fish: easier, because any favourable reaction induced in the outriders can be transferred to the shoal, and harder because any escape by outriders may be followed by the shoal, therefore any defect in design is doubly serious.

The object of design must be to delay the escape reaction. All trawls so far observed have two points of inflexion at (a) and (b) as shown in fig. 21. For obvious reasons, as much of the net as possible should be in large mesh, but a critical region for escape lies near the first of these two points. If these inflexions are pronounced, the large mesh should be reduced short of the first one, while with a longer, more tapered net, in which the inflexions are more gradual, the large mesh may be carried farther aft. (In this sense a large mesh is merely designated as one through which the fish can pass.) The long net is the common type in herring trawls, often having a fairly rapid change from big mesh to small, escape-proof mesh, so that there is not a large area in which the herring become meshed as this is a nuisance when hauling the net. These considerations can also be applied to white fish trawls, but important compromises are required in their design because the groundrope is in close contact with the bottom, which is often rough. Firstly, the belly of the net should be kept as small as possible to avoid splits, and, secondly, most of the belly should be made in large mesh to allow as much bottom rubbish as possible to fall through, instead of passing into the codend, causing it to chafe. The planning of the inflexions and mesh reductions must be made within these limits.

This is a preliminary report but the results to date suggest that observations of fish reactions to small nets with full sized meshes provide ideas for shaping full sized nets. These ideas can next be applied on the drawing board when designing a full sized net.

CONCLUSIONS

Observations and measurements on models are of little use unless correlated with measurements and, where possible, observations on a full-sized gear. These cross-checks are necessary to establish confidence in the value of modelling as an auxiliary to the rational design of fishing gear. Much can be learned from the observation of models but the agreement between performance of models and full-sized gear is not, however, close enough to be accepted uncritically. Models at one-eighth scale, for example, tend to give a view of gear performance which is on the pessimistic side.

With care, models provide results which are difficult to achieve in other ways, such as the effect of alternative methods of rigging a gear and whether or not the advantages are real, and how errors in rigging and setting may be corrected.

Two other methods of gear testing which can be used to compare existing rigs or help in their design and development, are instrumentation and comparative fishing. What is claimed for modelling is not that it can be used as a substitute for the other two methods, but that it is complementary to them lending more confidence to the results obtained and giving a full picture of gear performance. Comparative fishing can be regarded as the final stage of gear testing—the proof of the pudding—but its results will be better and more confidently assessed if a fuller picture of gear performance is provided through the use of models.

REFERENCES

[1] Goldstein, S. Modern Developments in Fluid Dynamics. Vol. 1, Sect. 5, p. 16.
[2] Gawn, R. W. L. Steering Experiments. Trans. Inst. Naval Archt., 1943, pp. 35-73.

DEVELOPMENT OF MECHANICAL STUDIES OF FISHING GEAR

by

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Abstract

The efficiency of fishing gear is closely connected with the shape it assumes in the water under ordinary working conditions, and while underwater photography and television have helped to solve some of the problems, there still remain many to be studied. The author suggests experiments with models, provided that the law of similarity, by which the mechanical relation between the model and the full-scale gear, is observed; but the model law should be deduced from the mechanical theory of the operation of the gear.

In this paper the author gives a series of summaries of the research work done on the hydrodynamics of fishing gear—trawls, seines, purse-nets, etc. and their accessories, and gives the mathematical formulae governing their optimum performance, in relation to depth and current strength.

It is stressed, however, that after trials have been made with models to which the theory has been applied, the final test should always be on the full-scale gear in actual fishing operation.

Développement de l'étude des Engins de Pêche au point de vue mecanique

Résumé

Il existe un rapport étroit entre l'efficacité d'un engin de pêche et la forme qu'il prend dans l'eau dans les conditions d'utilisation ordinaires; la photographie et la télévision sous-marines ont bien aidé à résoudre certains problèmes, mais il reste encore de nombreux points à étudier. L'auteur propose de faire des expériences avec des modèles, à condition de respecter la loi de similitude à laquelle doivent obéir les rapports mécaniques entre le modèle et l'engin grandeur naturelle; mais la loi modèle devrait être déduite de la théorie mécanique du fonctionnement de l'engin.

Dans cet article, l'auteur résume une série de recherches sur l'hydrodynamique des engins de pêche (chaluts, sennes, sennes tournantes, etc., et leurs accessoires) et indique les formules mathématiques correspondant à leur meilleur rendement en fonction de la profondeur et de la force des courants.

Il souligne néanmoins qu'après les essais de modèles conformes à la théorie, l'essai final devra toujours porter sur l'engin grandeur naturelle au cours d'opèrations de pêche réelle.

Desarrollo de los estudios mecánicos sobre artes de pesca

Extracto

La eficacia de un arte pesca se halla estrechamente relacionada con la forma que toma en el agua durante el trabajo en condiciones normales. Si bien la fotografía y televisión submarinas han ayudado a resolver algunos de estos problemas, todavía existen muchos que deben ser estudiados. Por este motivo, el autor sugiere hacer pruebas con modelos siempre que rija la ley de la similitud, o sea, una relación mecánica entre el arte a escala reducida y el construdío a escala normal; no obstante la ley para el modelo debe deducirse de la teoría mecánica del funcionamiento del arte.

En este trabajo el autor da una serie de resúmenes de investigaciones sobre las características hidrodinámicas de los artes de pesca—redes de arrastre, de cerco, etc. y sus accessorios—además de fórmulas matemáticas que regulan su rendimiento óptimo en relación con la profundidad y la fuerza de la correinte.

Sin embargo, es necesario hacer notar que después de las pruebas hechas con modelos a los cuales se ha aplicado la teoría, debe efectuarse una prueba final con el arte a escala normal empléandolo lances de pesca reales.

THE efficiency of a fishing gear is closely related to the shape it assumes in operation. Until recently, the mechanical behaviour of the gear in action could only be assessed approximately by judging the tension and tilt angle of tow ropes or manipulating lines, or by the actual fishing results obtained with the gear. However, to design a gear efficiently or operate it effectively, an accurate knowledge is required of the mechanical properties of each part.

In recent years, underwater television, filming, and other submarine devices, have been used to observe the working pattern. These are very effective for determining shape and behaviour, but in order to improve a fishing gear, extensive testing is necessary. It is, however, very expensive to make up a new full-size net for each trial, therefore tests with models may be practical. In this case the law of similarity, by which the mechanical relation between the model and the full-scale gear is governed, must be observed.

Mechanical investigation of fishing nets in Japan started in 1915, when Dr. T. Terada and his associates made a series of experiments on the resistance of a plane net towed through the water. This paper gives a short review of research since then from the theoretical point of view, but space allows only a summary of the more important investigations, whilst most of the papers concerned are merely cited (see Literature).

THE HYDRODYNAMIC FORCE ACTING ON A TWINE

Fishing gears are composed mainly of twines or ropes of various sizes (exceptions are weirs, rakes, spears, etc.). Consequently it is of fundamental importance to have an accurate knowledge regarding the hydrodynamic force of relative velocity of current acting upon an element of a twine.

Tauti[49] assumed in his theory on the resistance of a fishing net to the flow of water:

(1) That the magnitude of resisting force, R_θ, per unit length of a twine varies proportionally with the sine of the angle θ between the twine and the current, and is directed normal to the twine in the plane, including directions of the twines and the current, i.e.

$$R_\theta = R\sin\theta, \qquad (1)$$

where R is the drag or resisting force of the twine per unit length when it is supported perpendicularly to the current.

Another method is given below. Resolve the velocity vector, U, of the current into its normal component U_n and tangential component U_t with respect to the direction of the twine, then if we assume that both the velocity components act independently with each other and Newton's law for hydro-dynamic drag is tenable to the normal component, we come to the conclusion:

(2) That R is proportional to $U^2 \sin^2\theta$, i.e.,

$$R_\theta = R\sin^2\theta. \qquad (2)$$

This assumption is supported by experimental evidence[52, 53].

The tangential component, F is rather obscure. Experiments show that the tangential force is much smaller than the normal force, and is substantially independent of the angle until the twine becomes almost perpendicular to the current and then drops quickly to zero. Since the tangential force is very small, it is difficult to measure accurately and, hence, the precise nature of its variation with the angle cannot be given with any assurance. It may be permissible, for the sake of simplicity of calculation, to assume:

(3) That the tangential force is constant, F, over the whole range of θ.

THE EQUILIBRIUM CONFIGURATION AND TENSION OF A FLEXIBLE TWINE IN A UNIFORM FLOW

Thews and Landweber[52] have made a general analysis of the equilibrium configuration of a flexible twine suspended in a uniform current, under the assumptions (2) and (3). Pode[39] has carried out a series of comprehensive numerical computations for the case in which neither the weight of the twine nor the tangential force of the hydrodynamic action can be neglected.

Suppose the form of a twine in a uniform steady flow of velocity U (see fig. 1). Choose rectangular coordinates (x, y), whose origin is located at a point on the twine where the twine is normal to or parallel to the current. Let x-axis be directed parallel to the current measured positive up-stream and y-axis be directed vertically upwards. Let s be the arc length along the twine from the origin O to any pont P (x, y) on the twine, T and T_o be the tensions in the twine at the points P and O respectively. The angle of inclination of the twine against the stream is measured clockwise from the direction of the current to the direction of increasing s. Furthermore, let W be the weight of the twine of unit length in water, and put $w = W/R$. These forces may be resolved to and along the twine as shown in fig. 2, then the equilibrium of the twine element ds requires:

$$\frac{dT}{ds} = F + W\sin\theta \qquad (3)$$

$$T\frac{d\theta}{ds} = R\sin^2\theta + W\cos\theta \qquad (4)$$

The solution of these differential equations can be written in a parametric form:

$$\frac{T}{T_o} = \tau(\theta); \quad \frac{Rs}{T_o} = \sigma(\theta); \quad \frac{Rx}{T_o} = \xi(\theta); \quad \frac{Ry}{T_o} = \eta(\theta) \qquad (5)$$

where τ, σ, ξ and η are transcendental functions of angle θ, and also of the ratios $f = F/R$ and $w = W/R$. Pode's numerical solutions are partly reproduced in Table I (reference point at $\theta = \pi/2$) and Table II (reference point at $\theta = O$). In these tables another expression of w is introduced. Suppose the cord is simply trailed by itself, without any towed body at the lower end, then its

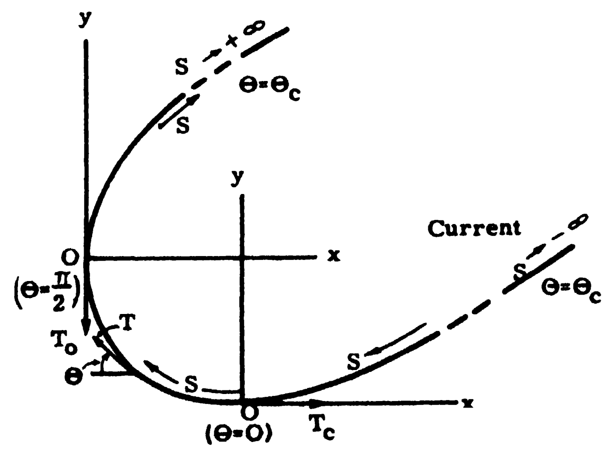

Fig. 1. Configuration of a twine in a flow of water.

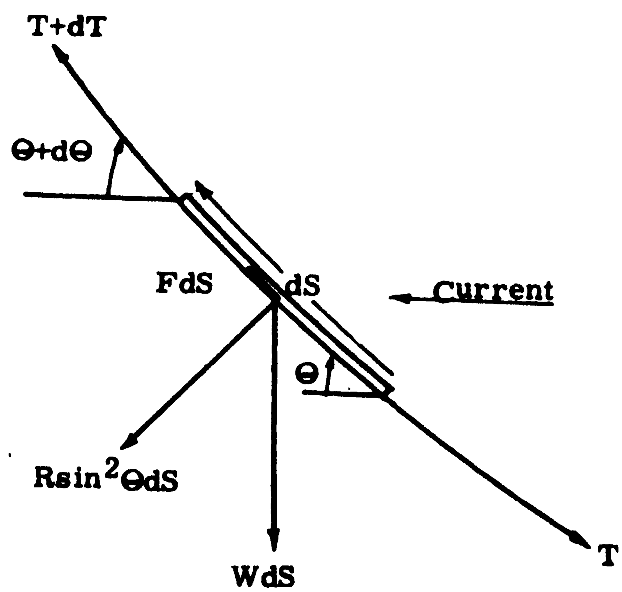

Fig. 2. Forces acting on a twine subjected to flow of water.

configuration may be a straight line inclined to the current at such an angle:

$$\theta_c = \text{arc cos}\frac{-w + \sqrt{w^2-1}}{2} \qquad (6)$$

This angle θ_c is called the critical angle, and will be used in place of w.

ESTIMATION OF THE FISHING DEPTH OF A TOWED GEAR

To illustrate an application of these solutions to cable problems, let us consider estimating the depth of a deep trolling gear [12]. All parameters related to the point where the line is attached to the depressor and where it intersects the water surface, are distinguished by subscriptions 1 and 2 respectively. It is required to find the depth $h(=y_2 - y_1)$ of the depressor when the submerged length $l\ (=S_2-S_1)$ of the tow line is given. From the equations given in the preceding section, we have

$$\left.\begin{aligned} \frac{R}{T_2}h &= \frac{\zeta(\theta_2)-\zeta(\theta_1)}{\tau(\theta_2)}, \\ \frac{R}{T_2}l &= \frac{\sigma(\theta_2)-\sigma(\theta_1)}{\tau(\theta_2)}, \\ \frac{h}{l} &= \frac{\zeta(\theta_2)-\zeta(\theta_1)}{\sigma(\theta_2)-\sigma(\theta_1)}, \end{aligned}\right\} \qquad (7)$$

where R is expressed as:

$$R = \tfrac{1}{2}C_D\rho U^2 D$$

C_D being the drag coefficient of the trolling line and its numerical value being approximately equal to 1·5 for ordinary stranded twine, ρ the density of fluid, U the velocity of motion and D the diameter of the twine. The relations between h/l, θ_1, θ_2 and Rl/T_2 can be graphically represented in a chart, which greatly facilitates the estimation of the working depth of a depressor. If the value of R is given, the ratio h/l can be read directly from this chart by using any two values out of three values.

The tension of the warp at the vessel in trawling is transmitted to the gear and the various modes of fishing performance of the gear must be contingent upon the magnitude and the direction of the force acting on the gear. The cable problems also have a bearing in this connection, i.e. in regard to mid-water trawling. The working depth of these nets can be regulated to some extent by adjusting the length of the towing warps. In these cases, if the weight of the warp in water is not negligible as compared with its resistance, similar charts for various values of critical angles must be prepared.

Another example of the application of these formulae [17, 4], is a simple current-measuring device, the *Siomi-ito*, which is in traditional use on coastal fishing grounds in Japan. It consists of dropping overboard several sinkers attached to strings of different lengths. Each sinker is subjected to the current at a depth corresponding to the length of the string. The tilt of the string at the surface will be determined by both the profile of the current velocity and the length of the string. If the configuration of the string in a given current profile is known, we have a possibility of determining the current profile from the tilt angles of several strings of different lengths at the surface. Kawakami and Iitaka[17] have made some investigations of this problem. They designed a new type of *Siomi-ito*, and proposed a proper way to manipulate it.

THE RESISTANCE OF PLANE NETTING IN A CURRENT

The resistance, R, acting on a plane net subjected to a uniform current of velocity U, was first studied experimentally by Terada, Sekine and Nozaki[52], then by Tauti, Miura and Sugii[47] and by Miyake[3c]. The experimental method adapted by these workers was the same in principle. Two rectangular frames, on which a sample webbing was spread out, were connected with each other along one side and spread at an angle of 2φ. This pair of frames was put in motion through the water under the action of constant force of known magnitude.

Their results are coincident in that the resistance varies proportionally with the area, S, of webbing and also approximately with the square of the velocity U, i.e.,

$$R = kSU^2 \qquad (8)$$

where k is a coefficient of resistance depending upon the construction of the webbing and the angle of attack α. The construction of the webbing may be characterised by the length, L, of the bar of the mesh, diameter, D, of the netting twine and the angle, 2φ, between two adjacent bars of the mesh.

Terada and his collaborators have proposed a supposition that the value of k might be proportional to the area of webbing projected on the plane perpendicular to the direction of motion. Tauti and his associates showed that k varies linearly with the angle α. Miyake deduced a theory based on the supposition proposed by Terada and his collaborators, and verified that the theory coincided approximately with his observed value.

The most detailed theoretical analysis on the force acting on the webbing has been conducted by Tauti[40] under the assumption (1). Suppose a mesh of webbing be suspended in a current of velocity U (see fig. 3), in which $\vec{OA}$ and $\vec{OB}$ are two adjacent bars and $\vec{OC}$ the velocity

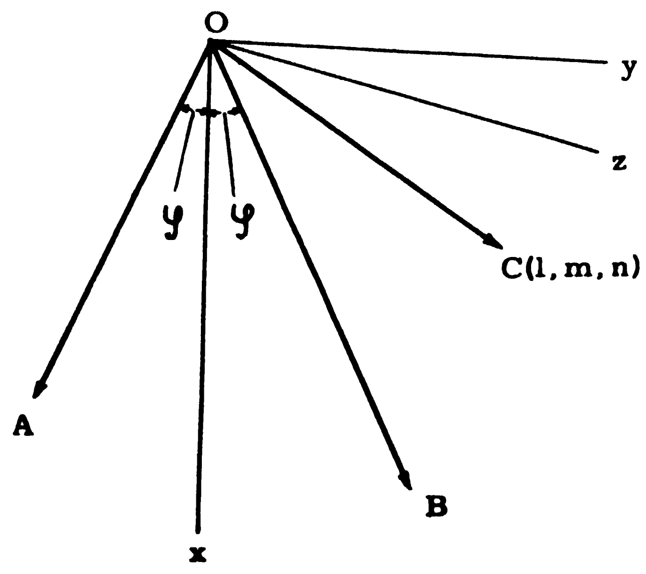

Fig. 3. A left-hand system of rectangular coordinates chosen in the mesh of webbing.

vector of the current. Denote the angle between two bars OA and OB by 2φ. In a left-hand system of rectangular coordinates (x, y, z), let x-axis be the bisector of the angle between two adjacent bars, y-axis be perpendicular to x-axis in the plane of webbing and z-axis be normal to the plane. Denote by (l, m, n) the direction cosines of the velocity vector $\overrightarrow{OC}$.

Mechanical analysis, after some mathematical procedures, gives a result that the x-, y- and z- components of k can be represented respectively by

$$k_x = a\left(\frac{D}{L}\right) l \tan\varphi + \left(\frac{D}{L}\right)^2 f$$
$$\left(\frac{D}{L}\right) m \cot\varphi + \left(\frac{D}{L}\right) f_y, \qquad (9)$$
$$\left(\frac{}{L}\right) \sin\varphi \cos\varphi \left(\frac{}{L}\right) z,$$

where a is a constant depending on the drag co-efficient of the netting twine and is given by

$$a = C_D \rho/2$$

in ordinary hydrodynamical expressions, and second terms are correction due to knots. The factors f_x, f_y, and f_z vary with the direction of current relative to the coordinates system. These correction terms would be negligible in comparison with the first term in the case of large meshes of fine twine.

When the direction of current lies in the xz plane, i.e., $l = \cos\alpha$, $n = \sin\alpha$, where α is the angle of attack of the webbing, drag coefficient of the webbing may be represented from the expressions (9) by

$$k = a\left(\frac{D}{L}\right) \cot\varphi \,(\sin^2\alpha + 1) \qquad (10)$$

in which the correction terms are neglected. This means that the value of k varies linearly with $\sin^2\alpha$.

In these analyses, it is assumed that the knots and twines of meshes are mutually independent. Since, however, the actual net is a complicated system of netting twine, the hydrodynamical interference between neighbouring twines and knots should be taken into account, when the net is kept in a certain range of attack-angle. Fujita and his collaborator[5, 6] have investigated this phenomenon.

Miyamoto and his associates[31, 36] have made a series of experiments to secure accurate data for different types of webbing. They measured the drag of a piece of webbing when $\theta = 90$ degrees and $\varphi = 45$ degrees, then the value of k_z were determined. The results are given by

$$k_z = a\left(\frac{D}{2L}\cdot 10^2\right) + b\left(\frac{D}{2L}\times 10^2\right)^2, \text{ (kg.wt. sec}^2\text{./m}^4\text{)}$$

where numerical values of a and b are tabulated below:

Kind of webbing	a	b
Knotless	1·72	0·370
Flat-knot	1·70	0·433
Trawler-knot	1·68	0·475

The value of k_z becomes greater with decreasing or increasing of φ from $\varphi = 45$ degrees. As regards the material of the netting cord, the value of k is somewhat larger in staple fibres than in continuous fibres. In general, it may be concluded that the fibre ends sticking out of a twine made of short fibres have a tendency to catch dirt and create more resistance.

EQUILIBRIUM CONFIGURATION OF WEBBING IN A CURRENT

A stretched piece of webbing may be considered as a continuous membrane, in the case where differences in physical states between neighbouring meshes are negligible. This membrane will be subjected to two kinds of external force, i.e., the hydrodynamic force due to the current, and the apparent weight in water. The hydrodynamic force is given by kU^2. Let W be its apparent weight of unit area in water, (l_g, m_g, n_g) be its direction cosines referred to coordinate axes O-x, O-y, and O-z, which are chosen in such a way that the principal curvatures at the elemental portion of webbing membrane lie on the xz- and yz- planes. Let r_x and r_y respectively be the radii of curvature on these planes, and T_y and T_x be the tensions of the webbing per unit length along the x- and y- directions respectively. Tauti[50] proposed the following differential equations required to maintain a mechanical equilibrium of the webbing membrane:

$$\left.\begin{aligned} \frac{dT_x}{dx} + k_x V^2 + l_g W &= 0, \\ \frac{dT_y}{dy} + k_y V^2 + m_g W &= 0, \\ \frac{T_x}{r_x} + \frac{T_y}{r_y} &= k_z V^2 + n_g W. \end{aligned}\right\} \qquad (11)$$

In the analytical treatment of mechanical problems of fishing nets, it is of fundamental importance to know exactly the configuration of a strip of net and the distribution of tension when subjected to a current. Miyamoto[68], Fujita[6], and Kawakami[15] have made a theoretical analysis on this problem, based on Tauti's law.

Suppose that a long narrow strip of webbing of a constant width is supported vertically by both ends, A

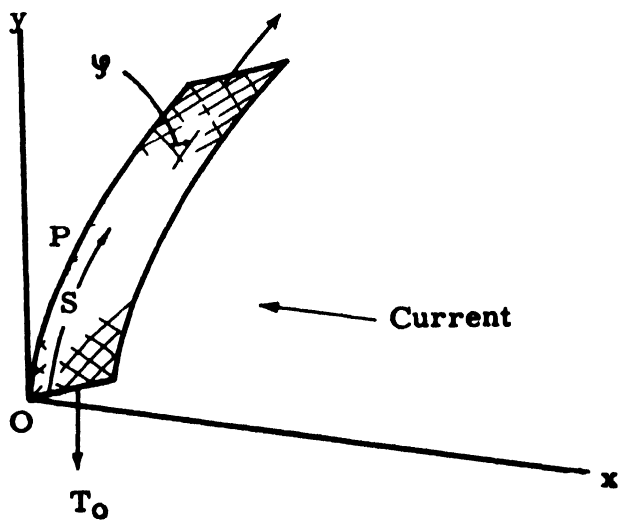

Fig. 4. Configuration of a rectangular strip of webbing subjected to flow of water.

and B, in a uniform current and is in equilibrium condition. A system of coordinate axes, O-x and O-y, is chosen as shown in fig. 4, i.e., the origin is located at the point on the webbing where the webbing is perpendicular to the current, and the x- and y-axes are directed upstream and upward respectively. Then let s be the arc length of the net from the origin, O, to any point P (x, y) and T and to be the tensions of the webbing per unit length at the points P and O respectively. Denote the angle of the netting membrane against the current at the point P by θ. If the net is of homogeneous mesh of 2L in stretched measure, woven with a netting twine of diameter D, and hung to the framing lines with such a degree of slack as to make an angle 2φ between two adjacent bars, then the equilibrium equations (11) take the form:

$$\frac{dT}{ds} = K \sin^2 \varphi \cos \theta + W \sin \theta \qquad (12)$$

$$T \frac{d\theta}{ds} = K \sin \theta + W \cos \theta \qquad (13)$$

where K is the normal component of the resisting force per unit area of the webbing when the webbing is perpendicular to the current and W is the weight of unit area of the webbing in water.

Let a be the area enclosed by the x-axis, the arc of the webbing, and the straight line parallel to the y-axis, x=x, then the solution of these equations may be written in a parametric form:

$$\left.\begin{aligned} \frac{T}{T_o} &= \tau_n(\theta), \\ \frac{Ks}{T_o} &= \sigma_n(\theta), \\ \frac{Kx}{T_o} &= \xi_n(\theta), \\ \frac{Ky}{T_o} &= \eta_n(\theta), \\ \left(\frac{K}{T_o}\right)^2 a &= \alpha_n(\theta), \end{aligned}\right\} \qquad (14)$$

where τ_n, σ_n, ξ_n, η_n, and α_n are transcendental functions of angles θ and φ, and the ratio $r = K/W$. A part of these relations has been calculated numerically by Miyamoto[68].

If the weight of the webbing be negligible compared to its resistance, the solutions will be simplified to:

$$\begin{aligned} \tau_n &= (\sin \theta)^{-\sin^2\varphi}, \\ \sigma_n &= \int_{\pi/2}^{\theta} (\sin \theta)^{-(1+\sin^2\varphi)} \, d\theta \\ \xi_n &= \frac{1}{\sin^2 \theta}(\tau - 1), \\ \eta_n &= \int_{\pi/2}^{\theta} \tau \, d\theta \\ \alpha_n &= \int_{\pi/2}^{\theta} \eta \, d\xi \end{aligned} \qquad (15)$$

The numerical solutions have been calculated by Kawakami[15].

MECHANICS OF AUXILIARY GEAR (Floats, sinkers, shearing devices, mooring equipment.)

The buoyancy or specific gravity of floats and sinkers is given by elementary mechanics. The reserve buoyancy of gillnets has been discussed by Miyamoto[31].

These accessories, however, are subjected to currents of various speeds, which cause the unfavourable deformation of the gear. It is essential, therefore, that the shape of these accessories be streamlined to reduce the drag to a minimum.

Apart from floats and sinkers which work on the static principle, other such accessories based on dynamic principles are used, such as: otter boards, kites and depressors.

The action of the otter board has, by some authors, been treated as that of a flat plate in a current. When a flat plate of a length c is subjected to a current at an angle of attack α, to the direction of flow, its resistance force, P, is approximately normal to the plane and the magnitude is given by Duchemin's equation:

$$\frac{P}{P_o} = \frac{2 \sin \alpha}{1 + \sin^2 \alpha}, \qquad (16)$$

where P_o is the value of P when the plate is normal to the flow. The distance δ from the centre of the plate to the point through which the total resisting force acts is given by

$$\frac{\delta}{c} = \frac{3}{4} \cdot \frac{\cos \alpha}{4 + \pi \sin \alpha} \qquad (17)$$

If the board is a hydrofoil, its hydrodynamic characteristics must be investigated in advance by a model experiment. Polar diagrams of various types of hydrofoil depressors for trolling gear have been drawn by Okuno[36].

To fix a trap net at a point in the sea, sand bags or anchors are commonly used. The holding power, H, of a sand bag falls off as the angle, β, of the mooring rope with the horizontal at the bag end is increased. The variation of the holding power with this angle has been investigated by Tauti[17]. He assumed the ordinary frictional resistance, the coefficient of which is represented by μ, between the under surface of the bag and the sea-bed, and obtained the following result:

$$\frac{H}{W} = \frac{\mu}{1 + \mu \tan \beta}, \qquad (18)$$

where W is the weight of the bag in water.

With regard to the anchor, the circumstances differ. The holding power of an anchor is due to the action of its fluke which digs into the sea-bed. Assuming that the resistance is proportional to the total quantity of bottom material scooped by the fluke when the anchor is pulled, Tauti has derived the following relation:

$$H = p \tan(\alpha - \beta) \sin(\alpha - \beta) \qquad (19)$$

where α is the angle between the shank and the fluke and p is the proportionality constant depending upon the type and size of the anchor, and also upon the physical properties of the bottom material.

ANALYTICAL STUDIES ON TOWED GEAR

For analytical studies of the mechanical characters of trawl nets Kawakami[16] designed a mechanically simple model. It had two wings of narrow rectangular webbing and a kind of codend simple enough to make mechanical analysis possible. He solved a set of equilibrium equations for each portion of the net and obtained the theoretical relation between the tension of the warp, the angle of its inclination to the flow, and the horizontal spread of the wings. This relation is of fundamental importance in designing a precise assembly of the net rigging such as headline and otter boards.

As regards the codend, Taniguchi[43-46] has made a series of studies on various types of bagnets. He pointed out that the main factors affecting its resistance are total area of webbing used, the working gape of the bag, and the ratio D/L as defined in the previous section, and that the shape or mode of assembly has little bearing upon the total resistance. His further experiments showed that the length of the bag has also relatively little effect on its resistance.

It is doubtful whether the shearing action of otter boards is purely hydrodynamical or whether the ploughing action on the sea bottom contributed in some measure. Kawakami[14], using Duchemin's equation, made an analytical treatment of otter boards attached to the end of a rectangular strip of webbing. Fig. 5 shows the variation of spreading action of the otter boards according to the adjustment of the brackets. The optimum spread can be obtained theoretically.

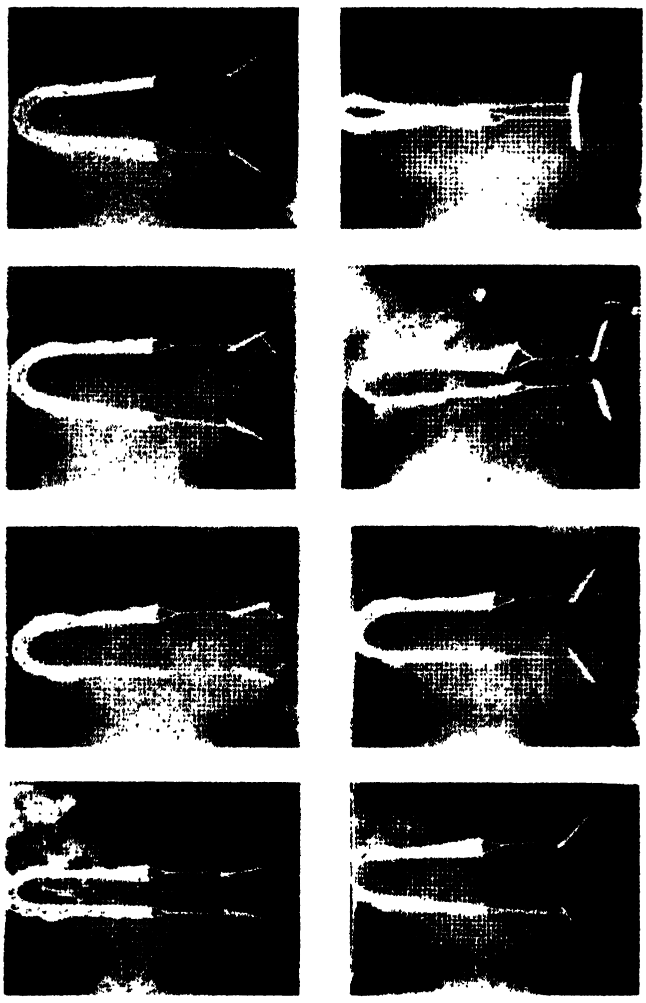

Fig. 5. Showing the variation of shearing action of the otter board according to the adjustment of the brackets.

A series of experimental studies as well as a theoretical discussion on the midwater trawl has been made by Kobayashi and his associates[19-23]. Their net was fitted with specially designed depressors and otter boards. They obtained fairly good working stability. The mechanical calculation of the working depth and of the towing resistance were found to coincide fairly well with the results of full-scale tests.

PRACTICAL PROCEDURES OF MODEL EXPERIMENTS (GENERAL RULES)

The applicability of analytical methods is, of course, limited, in which case model experiments are often useful. In making a model test, it is essential to know what conditions have to be fulfilled to ensure similar mechanical and geometrical relations between the full-scale net and the model. This law of similarity was first deduced by Tauti[50], based on the assumptions:

1. That the elongation of the net twine is negligible when in operation;
2. That the net twines are perfectly flexible;
3. That the change in the form of the net occurs so slowly that the external forces acting on each element of the net can be considered to be in quasi-equilibrium, and
4. That Newton's law of hydrodynamic force is valid for every portion of the net, irrespective of its Reynolds' Number.

Model experiments are generally conducted in an experimental tank, using either one of two different methods. With the first the water is at rest and the gear is towed as in the testing of ship resistance. The net is attached to a carriage moving on rails and towed through the water by means of the towline. This method is convenient for the trawl net. The still water tank is also suitable for such gear as encircling or lift nets.

The second method, where the net is stationary and the water flows, is comparable to a wind tunnel in an aeronautics laboratory. This method has sometimes an advantage, especially for the fixed net, because changes in shape of the net can be photographed easily. Fig. 6

Fig. 6. Model tank of circulation type.

shows an experimental water tank of circulation type.

Practical procedures of model experiments are as follows:

(′) following a value denotes a full-scale test.

(″) denotes a model test.

1. In the first place, define the reduction ratio, Λ, of the model as large as the circumstances permit, i.e.

$$\frac{\lambda''}{\lambda'} = \Lambda \tag{20}$$

where λ is the linear dimension of each section of the net.

2. Next, determine the diameter, D, of the net twine and the density, ρ, of its material such that the ratio:

$$\frac{D''}{D'} \cdot \frac{\rho'' - \rho_w''}{\rho' - \rho_w'} = E \tag{21}$$

has the same value for all sets of corresponding portions of model and full-scale, where ρ_w is the density of water.

3. Then, the length, L, of the bar of a mesh should be determined so that the ratio:

$$\frac{D''}{D'} \cdot \frac{L''}{L'} = M \tag{22}$$

has the same value throughout all parts of the webbing. Thus the reduction ratio of mesh is not necessarily the same as that of the net itself.

4. Assemble the webbing of the model net with the the same ratio of take-up or slack for all corresponding parts of both nets. This means:

$$\varphi'' = \varphi'. \tag{23}$$

5. For the model thus made up, the ratio of velocity, V, between model and full-scale is given by:

$$\frac{V''}{V'} = \sqrt{\Lambda E} \tag{24}$$

The ratio of tension, T, in the webbing and the ratio of tension, T_r, in the manipulating rope are given respectively by:

$$\frac{T''}{T'} = \Lambda E, \qquad \frac{T''_r}{T'_r} = \Lambda^2 E. \tag{25}$$

6. As regards the ropes in the net, the density ρ_r of its material and the diameter, D_r, should be chosen so as to hold the next relations simultaneously:

$$\frac{\rho''_r - \rho''_w}{\rho'_r - \rho'_w} = \frac{E}{\Lambda}, \qquad \frac{D''_r}{D'_r} = \Lambda \tag{26}$$

7. The size, D_a, and the density, ρ_a, of the material of the accessories such as floats and sinkers should be chosen so as to satisfy simultaneously the relations:

$$\frac{\rho''_a - \rho''_w}{\rho'_a - \rho'_w} = \sqrt{\frac{n}{n'}} \cdot \frac{E}{\sqrt{\Lambda}}, \qquad \frac{D''_a}{D'_a} = \sqrt{\frac{n''}{n}} \cdot \sqrt{\Lambda}. \tag{27}$$

where n is the number of the accessories attached for unit length.

8. If the net is fixed to the sea bottom by means of sand bags, as in the case of fixed or trap net, the weight, W, of the bag in water, should be chosen so as to hold the relation:

$$\frac{W''}{W'} \cdot \frac{k''}{k'} = \Lambda^2 E. \tag{28}$$

where k is the holding coefficient of the bag.

9. In the case where the accessory is made of canvas, its apparent weight in water being negligible, the dimension, λ_a, is given by

$$\frac{\lambda''_a}{\lambda'_a} = \Lambda \tag{29}$$

10. When the accessory effects hydrodynamic forces as in the case of otter boards in a trawl gear, its size, λ_b, and density, ρ_b, of the material should satisfy simultaneously the relations:

$$\frac{\lambda''_b}{\lambda'_b} = \Lambda, \qquad \frac{\rho''_b - \rho''_w}{\rho'_b - \rho'_w} = \frac{E}{\Lambda} \tag{30}$$

11. Where the shape of a net changes with the fishing operation, as in the case of a purse seine or Danish seine, additional conditions must be satisfied to maintain the mechanical similarity. Let V_p and t be the corresponding velocity, and required time to attain a corresponding stage of operation, then the next relations should be satisfied:

$$\frac{V''_p}{V'_p} = \sqrt{\Lambda}, \qquad \frac{t''}{t'} = \frac{\Lambda}{\sqrt{\Lambda}} \tag{31}$$

12. If a net is worked in relatively weak currents, as in the case of a fixed net in a cove, the resistance of the rope due to the current being negligible in comparison with its apparent weight in water, the values of D_r and ρ_r can be chosen so as to satisfy only the next relation:

$$\frac{D''^2_r}{D'^2_r} \cdot \frac{\rho''_r - \rho''_w}{\rho'_r - \rho'_w} = \Lambda E. \tag{32}$$

13. If a net is worked in relatively strong current, as in the case of high speed trawling, the weight of the rope being negligible compared to its resistance, then the next relation holds approximately:

$$\frac{D''_r}{D'_r} = \Lambda \tag{33}$$

14. With regard to the sinkers or floats, if the resistance

is negligible, compared to the apparent weight or buoyancy, the relations (27) are simplified to

$$\frac{D''_a{}^3}{D'_a{}^3} \cdot \frac{\rho''_a - \rho''_w}{\rho'_a - \rho'_w} \cdot \frac{n''}{n'} = E\Lambda. \qquad (34)$$

SOME MODEL TESTS OF FISHING GEAR

A number of model experiments have been made for various fishing nets since Tauti presented the law of similarity in 1934. A short description of these studies is given below and an overall picture of the investigations is given by the bibliography.

Fixed nets

The fixed net is one of the most important and popular of gear in the coastal and inshore waters of Japan. In setting out the nets, fishermen first place the frame-work of ropes with the sand bags and buoys in position and attach the bag net or impounding net afterwards. These nets are subjected to tidal currents. Excessive alteration in shape, caused by a strong current, may hinder the fish from entering the net; a very strong current induces an enormous tension in the net, and tends to drag the sand bags or anchors which serve to moor it. It is very laborious and often impossible to haul the net under such conditions. Sometimes the entire net is swept away.

Figure 7 shows a model test of a very popular trap net for fishing yellow-tail. The bagnet is seen at the right hand side, the sloping funnel for entrapping the fish is in the middle and the impounding portion is at the left. In this case the current, the full-scale speed of which is 1 knot (50 cm./sec.) runs from left to right. It is clearly seen that the bottom of the net is deformed by the strong current. This is an extreme case which rarely occurs in actual practice. Under such conditions, almost all floats are pulled under. Owing to the decrease of the angle β in the equation (18), this increases the holding power of the sand bags and at the same time reduces the pull they have to withstand. A minimum number of floats should therefore be used.

Towed nets

Almost all types of towed nets are used in Japan. Their efficiency depends on their mechanical behaviour in action, especially the working gape, fishing depth, or degree of contact of the footrope with the sea-bed. Model experiments carried out on these problems are not yet satisfactory.

Figure 8 shows an example of a model test of a shrimp beam trawl commonly used in the Seto Inland Sea.

Encircling nets

Although the purse seine is one of the most important gear in the commercial pelagic fisheries, few model experiments have been conducted. These nets undergo a marked change in shape during setting and pursing. The speed of this transformation and the maximum depth to which the bottom margin could reach are important factors in the fishing capacity of the net.

When the purse seine is operated in a region of strong underwater current, the lower part of the net sometimes becomes entangled. The solution has yet to be found to this urgent problem.

Other nets

The *Genziki-ami* (105) is a bottom drift net of a rather peculiar type. It consists of a single wall of webbing, the lower margin of which is curved to form a pouch. The net is drifted over the sea-bed by means of the tidal current. It is used to catch shrimps in waters where the bottom current is strong.

FULL SCALE TESTS USING UNDERWATER MEASURING INSTRUMENTS

Model experiments obviously have their limitations, mainly due to the difficulties in complying accurately with the rules of similarity between the actual gear and its model. Therefore, final tests at sea, using the full-size gear, are indispensable. For this purpose underwater measuring instruments of various types have been devised, such as:

- Depth-meter to measure the fishing depth of the gear.
- Dynamometer to measure the tension in the warps and ropes.
- Clinometer to measure the tilt of a rope or other accessory.

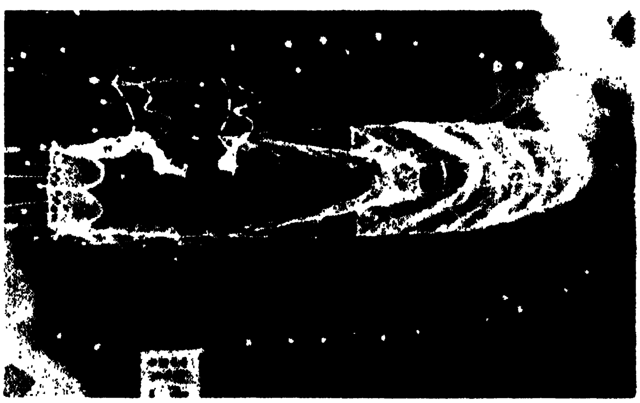

Photo by Honda.

Fig. 7. Example of a model test of a set-net. The direction of flow is from left to right.

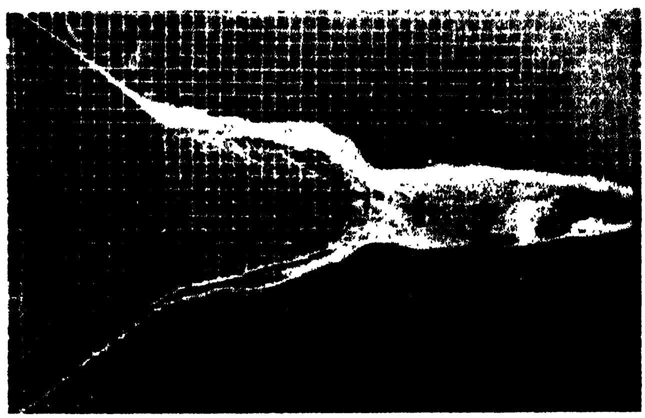

Photo by Taniguchi

Fig. 8. Example of a model test of a trawl.

Differential manometer to measure the vertical distance between two points.

Attack-angle meter to measure the angle of attack of an otter board.

Spread meter to measure the horizontal distance between two points in the net.

These instruments are all provided with a self-recording appliance, and are constructed to withstand rough handling and high pressure in deep seas.

Literature

Parenthesized papers are written in Japanese. Asterisks before the titles denote that an English synopsis beside the Japanese text is given. The following is the key to the abbreviations of the name of scientific periodicals cited.

B.F.C.	Bulletin of the Fisheries Research Board of Canada.
B.F.H.	Bulletin of the Faculty of Fisheries, Hokkaido University.
B.F.N.	Bulletin of the Faculty of Fisheries, Nagasaki University.
B.S.F.	Bulletin of the Japanese Society of Scientific Fisheries.
B.T.L.	Bulletin of Tokai Regional Fisheries Research Laboratory.
D.H.Z.	Deutsche Hydrographische Zeitschrift.
F.F.B.	FAO Fisheries Bulletin.
F.I.S.	Fishery Investigation (Supplementary Report), The Imperial Fisheries Experimental Station.
J.A.P.	Journal of Applied Physics, Japan.
J.F.I.	Journal of the Imperial Fisheries Institute.
J.K.C.	Journal of the Kagoshima Fisheries College.
J.O.S.	Journal of the Oceanographic Society of Japan.
J.T.F.	Journal of the Tokyo University of Fisheries.
M.A.K.	Memoirs of the College of Agriculture, Kyoto University.
M.F.K.	Memoirs of the Faculty of Fisheries, Kagoshima University.
P.P.C.	Progress Report of the Pacific Coast Station.
R.E.M.	Report of the U.S. Experimental Model Basin.
R.T.M.	Report of the David W. Taylor Model Basin.
R.U.M.	Report of the Faculty of Fisheries, Prefectural University of Mie.
T.G.K.	Teiti-Gyogyô-Kai (The World of the Fixed Net Fisheries).
T.R.F.	Technical Report of Fishing Boat.

[1] Carruthers, J. N., A. J. Wood and A. J. Lee. On the instrumental measurement of line shape under water. D.H.Z. *7*(1/2), 1954.

[2] Carruthers, J. N. Some simple oceanographical instruments to aid in certain forms of commercial fishing and in various problems of fisheries research. F.F.B. *3*(3), 1955, 130.

[3] de Boer, P.A. Trawl gear measurements obtained by underwater instruments. Interim copy.

[4] Fukutomi, T. *A method of approximate estimation for lee way or ocean current from the inclination of the lead line. J.O.C. *2*(3), 1943, 19.

[5] Fujita, H. and T. Yokota. The drag action on a net in a uniform current. I. J.A.P. *20*(2), 1951, 59.

[6] Fujita, H. The drag action on a net in a uniform current. II. M.A.K. *66*, 1953, 11.

[7] Hamuro, C. *A study of Danish seine by means of recording the height of entrance and direction of ground rope. B.S.F. *20*(5), 1954, 353.

[8] Hamuro, C. and K. Ishii. *Study on the automatic net depth meter, automatic net length meter for salmon gillnet and the results of measurement at sea. T.R.F. *8*, 1956, 29.

[9] Hamuro, C. *Study of the automatic net depth meter, net height meter for crab tangle net and its practical application. T.R.F. *8*, 1956, 183.

[10] Hayashi, H. *An investigation of a spreading device for trawling net. J.F.E. *3*, 1933, 37.

[11] Hosino, S. and N. Sato. (An experiment on the forms of the fishing net piece in the air currents.) F.I.S. *8*, 1941, 1.

[12] Isouti, N. and T. Kawakami. Mechanical studies on the trolling gear. I. Estimation of the fishing depth. M.A.K. *76*, 1957, 1.

[13] Kawakami, T. and H. Tubota. On the configuration and distribution of tension of a rope in a uniform stream. M.A.K. *66*, 1953, 1.

[14] Kawakami, T. Mechanical action of the otter board of the trawl net. B.S.F. *19*(4), 1953, 228.

[15] Kawakami, T. Equilibrium configuration of a rectangular strip of net subjected to a uniform current. M.A.K. *72*, 1955, 1.

[16] Kawakami, T. Mechanical characters of the drag net. M.A.K. *72*, 1955, 5.

[17] Kawakami, T. and Y. Iitaka. On a simple instrument, *Siomi-ito*, for detecting underwater current. B.S.F. *20*(11), 1955, 962.

[18] Ketchen, K. S. Preliminary experiments to determine the working gape of trawling gear. P.P.C. *88*, 1951, 62.

[19] Kobayashi, K. and H. Takahashi. *A study on fishing trawl perated in any depth of sea-water. B.F.H. *1*(3, 4), 1951, 139.

[20] Kobayashi, K. and H. Takahashi. *A study on fishing trawl operated in any depth of sea-water (Continued). On the relations between the length of warp and the frontage of otter board. B.F.H. *2*(1), 1951, 86.

[21] Kobayashi, K. and T. Deguchi. *An experiment of a beam-type trawl net for fish larvae at the various depths of sea-water. B.F.G. *3*(1), 1952, 104.

[22] Kobayashi, K., H. Takahashi and M. Ueno. *Fundamental studies on spherical glass floats for fishing nets. II. On the water resistance of glass floats. B.F.H. *4*(4), 1954, 348.

[23] Kobayashi, K. *An experiment on a mid-water trawl. IV On its mechanism and a trial practice. B.F.H. *7*(1), 1956, 21.

[24] Koga, S. *On the extension of the wing of trawl net. B.F.N. *3* 1955, 15.

[25] Kumakori, T., C. Hamuro and K. Ishii, O. Furuya. (Catch gauge for two boat trawl.) T.R.F. *3*, 1952, 139.

[26] Kumakori, T. and K. Ishii. (Experiments on manufacturing of remote control towing thermometer for mid-water.) T.R.F. *3* 1952, 159.

[27] Kumakori, T., C. Hamuro, K. Ishii and O. Furuya. (Catch gauge for two boat trawler.) T.R.F. *4*, 1953, 112.

[28] Kumakori, T. and K. Ishii. *Automatic net-height meter and automatic ground rope indicator for two-boat trawler and results of experiment for these apparatuses. T.R.F. *5*, 1954, 73.

[29] Kumakori, T., C. Hamuro, and K. Ishii. *Automatic net-height meter and automatic ground rope indicator for trawler and results of experiments for these apparatuses. T.R.F. *6*, 1955, 41.

[30] Miyake, Y. On the plane net. I. Resistance of plane nets in water. J.F.I. *23*(2), 1927, 21.

[31] Miyamoto, H. *The excess buoyancy of gillnet and the tension of them. B.S.F.*3*(3), 1934, 147.

[32] Miyamoto, H., M. Nomura and Y. Shimozaki. *Resistance of plane net against the flow of water. I. Effect of knot type on the resistance of net. B.S.F. *17*(8, 9), 1952, 249.

[33] Miyamoto, H. and M. Nomura. *Resistance of plane net against the flow of water. II. Effect of different shapes of the mesh upon the resistance. B.S.F. *18*(7), 1953, 327.

[34] Nomura, M. and Y. Nozawa. *Resistance of plane net against the flow of water. IV. On the inclination of threads in a current. B.S.F. *20*(9), 1955, 762.

[35] Nomura, M. and K. Mori. *Resistance of plane net against flow of water. III. Effect of kind of fibres on the resistance of net. B.S.F. *21*(11), 1956, 1110.

[36] Nomura, M. and K. Mori. *Resistance of plane net against flow of water V. On the inclination of net in a current. B.S.F. *21*(11), 1956, 1114.

[37] Okuno, H. *Model experiment on plates to sink an end of a trawl rope below the water surface or hydrofoil sinker. B.S.F. *5*(3), 1936, 155.

[38] Pode, L. An experimental investigation of the hydrodynamic forces on stranded cables. R.T.M. *713*, 1950.

[39] Pode, L. Tables for computing the equilibrium configuration of a flexible cable in a uniform stream. R.T.M. *687*, 1951.

[40] Pode, L. Configuration and tension of a light flexible cable in a uniform stream. (Appendix to the R.T.M. *717*), 1956.

[41] Sato, N. and I. Takayama. *Experiments on hydrofoil sinker for a troll line. J.F.I. *3*, 1933, 73.

[42] Sato, N. and S. Kurita. (An experiment on the resistance and lift for a float of a seine net.) F.I.S. *9*, 1943, 1.

[43] Taniguchi, T. *On the resistance of various codends fixed in a stream. I. B.S.F. *21*(5), 1955, 291.

[44] Taniguchi, T. *On the resistance of various codends fixed in a stream. II. B.S.F. *21*(9). 1956. 969.

[45] Taniguchi, T. *On the resistance of various codends fixed in a stream. III. *21*(11), 1956, 1107.

[46] Taniguchi, T. *On the resistance of various codends fixed in a stream. IV. B.S.F. *22*(12), 1957, 727.

[47] Tauti, M., T. Miura and K. Sugii. Resistance of plane net in water. J.F.I. *21*(2), 1925, 11.

[48] Tauti, M. (Holding power of anchors). T.G.K. *11*, 1930, 16.

[49] Tauti, M. The force acting on the plane net in motion through the water. B.S.F. *3*(1), 1934, 1.

[50] Tauti, M. A relation between experiments on model and on full scale of fishing net. B.S.F. *3*(4), 1934, 1.

[51] Terada, T., I. Sekine, and T. Nozaki. (Study on the resistance of fishing net against the flow of water.) J.F.I. *10*. 1915, 1.

[52] Thews, J. G. and L. Landweber. On the resistance of a heavy flexible cable for towing a surface float behind a ship. R.E.M. *418*, 1936. Appendix I.

[53] Thews, J. G. and L. Landweber. The tension in a loop of cable towed through a fluid. R.E.M. 422, 1936. Appendix. Model Experiment. (Fixed net).

[54] Honda, K. and Y. Matumoto. *Model experiment on the sea fixed net for fishing amber-fish. B.S.F. *12*(3), 1934, 91.

[55] Honda, K. and collaborators. Model experiments on fixed nets for amber-fish, *Seriora*, used in the coast of Mie Prefecture. J.T.F. *41*(2), 1955, 195.

[56] Kanamori, M. *A tentative experiment on the improvement of yellow-tail setting net (Preliminary report). J.K.C. *1*, 1950, 4.

[57] Kanamori, M. and S. Enami. *Studies on the improvement of yellow-tail setting net on the model experiment of mid-layer trap-net. I. M.F.K. *2*(1), 1952, 2.

[58] Miyamoto, H. *The form of amber-fish keddle net on the basis of model experiments. B.S.F. *4* (3), 1935, 153.

[59] Miyamoto, H. *Model experiments on sea fixed nets for fishing amber-fish, *Seriola*. I. Ettyu keddle net and ordinary keddle nets. B.S.F. *5*(3), 1936, 158.

[60] Miyamoto, H. *Model experiments on sea fixed net for fishing amber-fish, *Seriola*. II. Trap nets set on the fishing grounds under strong tidal currents. B.S.F. *5*(4), 1936, 227.

[61] Miyamoto, H. *Model experiments on sea fixed net for fishing amber-fish, *Seriola*. III. Trap nets. B.S.F. *5*(6), 1937, 361.

[62] Miyamoto, H. *Model experiments on sea fixed net for fishing amber-fish, *Seriola*. IV. Keddle nets and trap net. B.S.F. *6*(6), 1937, 311.

[63] Miyamoto, H. *Model experiments on sea fixed net for fishing amber-fish, *Seriola*. V. The relation between the weight of sinkers and the deformation of amber-fish nets subjected to various currents. B.S.F. *7*(6), 1939, 319.

[64] Miyamoto, H. *Model experiments on sea fixed net for fishing amber-fish, *Seriola*. VI. Fishing gear in relation to the current prevailing on the fishing ground. B.S.F. *9*(5), 1941, 181.

[65] Miyamoto, H. *Model and full scale experiment on set net. Preliminary report. I. Double trap net for cod. B.S.F. *13*(2), 1947, 51.

[66] Miyamoto, H. *Model and full scale experiment on set net. Preliminary report. II. Double trap net for cod. B.S.F. *13*(6), 1948, 263.

[67] Miyamoto, H. *Model and full scale experiments on set net. Preliminary report. III. Trap net for sardine. B.S.F. *14*(1), 1948, 31.

[68] Miyamoto, H. *Study on the set-net. B.T.I.. *2*,1951, 1.

[69] Miyazaki, T. *Model experiments on fixed nets for fishing salmon in Kamchatka. B.S.F. *8*(3) 1939, 129.

[70] Miyazaki, T. (Model experiment on the leading net). B.S.F. *11*(6), 1942, 287.

[71] Miyazaki, T. (Model experiment on a leading net. II.) B.S.F. *10*(2), 1942, 63.

[72] Miyazaki, T. (Model experiment on a fixed net). B.S.F. *11*(3), 1942, 101.

[73] Mori, Y. *Model experiment on the sea fixed net for fishing amber-fish. B.S.F. *10*(6), 1942, 278.

[74] Okabe, G. *Model experiments of a fishing net, *Anko-ami*. B.S.F. *6*(6), 1938, 305.

[75] Pack, Y. *A model experiment of sardine trap net "*Hisago-ami*". B.S.F. *22*(11), 1957, 657.

[76] Saito, T. *Model experiments on the two kinds of sea bottom fixed nets for fishing "*Tara*". B.S.F. *2*(5), 1941, 185.

[77] Sato, N. *On a tank experiment with seine nets. J.F.E. *3*. 1933, 49.

[78] Sato, N. (An experiment with models of a surface seine net). F.I.S. *9*, 1943, 35.

[79] Simizu, H. *Model experiments on the sea bottom fixed nets for fishing "*Tara*". B.S.F. *9*(5), 1941, 191.

[80] Sugano, S. *The model experiments on fixed nets for fishing salmon in Kamchatka. B.S.F. *4*(6), 1936, 397.

(Towed net).

[81] Barraclough, W. E. and W. W. Johnson. A new mid-water trawl for herring. B.F.C. *104*, 1956.

[82] Imamura, Y. (Model experiment of the British herring trawl) B.S.F. *10*(5), 1942, 221.

[83] Imamura, Y. (Model experiments on a trawl net). B.S.F. *11*(2), 1942, 61.

[84] Koike, A. *Model experiments on a *Teisô-hikiami* (trawl net). B.S.F. *19*(1), 1953, 8.

[85] Miyamoto, H. *The model experiments on drifter drag net for fishing "*Sirauwo*" in Lake Kasumigaura. B.S.F. *4*(5), 1936, 310.

[86] Miyamoto, H. *The model experiments on sailing trawl net used in Mikawa Bay. B.S.F. *4*(6), 1936, 391.

[87] Miyamoto, H. *Model experiments on trawl nets. B.S.F. *5*(1), 1936, 19.

[88] Miyazaki, T. Preliminary report on experiments with small trawl nets. I. R.U.M. *1*(2), 1952, 215.

[89] Miyazaki, T. Preliminary report on experiments with small trawl nets. I. Change in the height of square part at the mouth of the net with changes in the tension of the rope of the net. R.U.M. *1*(2), 1952, 223.

[90] Miyazaki, T. *The relation between the mouth height of the square part of small trawl net and its pulling velocity. B.S.F. *19*(4), 1953, 223.

[91] Nomura, M. *Model experiments on two boat type trawl net. B.S.F. *16*(8), 1951, 347.

[92] Nomura, M. and T. Yasui. *Model experiments on trawl nets of various types. B.S F *18*(12), 1953, 727.

[93] Ogura, M. *Model experiment on a *Tyûsô-hikiami* (trawl net). B.S.F. *20*(4), 1954, 259.

[94] Saito, T. and H. Simizu. Model experiments on "*Teguri-ami*", a drag-net, for fishing "*Tara*". B.S.F. *10*(1), 1941, 11.

[95] Sato, N. (An experiment on the use of a surface trawl net.) F.I.S. *1*, 1934, 1.

[96] Sato, N. (An experiment with models of a surface seine net). F.I.S. *9*, 1943, 35.

[97] Sugano, S. *Experiments with models of a surface trawl net for fishing salmon. B.S.F. *5*(1), 1936, 12.

(Encircling net)

[98] Iitaka, Y. Model experiments on the sardine purse seine operating in Hiuganada – I. B.S.F. *20*(7), 1954, 571.

[99] Iitaka, Y. Model experiments on the sardine purse seine operating in Hiuganada II. B.S.F. *21*(1), 1955, 6.

[100] Iitaka, Y. Model experiments on the sardine purse seine operating in Hiuganada - III. B.S.F. *21*(7), 1955, 459.

[101] Iitaka, Y. Model experiments on the sardine purse seine operating in Hiuganada - IV. B.S.F. *22*(7), 1956, 389.

[102] Inoue, M. Model experiments on a sardine ringnet. B.S.F *19*(9), 1954, 942.

[103] Uno, M. The form and the tension on pursing line of a mackerel ring-net used at Kosaitô, Tyôsen, as known by a model experiment. B.S.F. *4*(3), 1935, 147.

(Other nets)

[104] Pack, Y. Model experiments on a saury blanket net (*Bôuke-ami*). I. B.S.F. *21*(9), 1956, 978.

[105] Wang, Y. Model experiments of *Genziki-ami*, a kind of net for fishing shrimp. B.S.F. *5*(6), 1937, 369.

INCREASING THE OPENING HEIGHT OF A TRAWL NET BY MEANS OF A KITE

by

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Abstract

In order to catch fish that swim close to the bottom but not actually on it, it is necessary to have the opening of the trawl as high as possible, without unduly distorting the shape of the net. To do this, a new type of trawl kite has been designed and tested. This paper describes the rigging of a model trawl and kite, which can move freely along a false headline, and shows how the experiences with the model were translated to a full-size trawl. In the tests, three differently rigged trawls were used, (a) without the kite, (b) with the kite but with no gussets between the after end of the wing and the square, and (c) with both kite and gussets. In net (c), the net mouth was raised to twice the height of the control net, and in net (b) it was raised 1·5 m. more than the control.

L'augmentation de la Hauteur d'ouverture d'un chalut au moyen d'un panneau élévateur

Résumé

Pour pouvoir capturer le poisson qui nage tout près du fond sans le toucher, il est nécessaire que l'ouverture du chalut soit aussi haute que possible sans déformer exagérément le filet. Un nouveau type de plateau élévateur a été mis au point et essayé à cet effet. Les auteurs décrivent le montage de la maquette du chalut et du plateau élévateur qui peut se déplacer librement le long d'une fausse ralingue supérieure, et notamment comment les résultats des essais effectués sur la maquette ont été convertis en données applicables à un chalut de dimensions normales. Les essais ont porté sur des chaluts gréés de trois façons différentes: (a) sans le plateau élévateur; (b) avec le plateau élévateur mais sans goussets entre l'extrémité postérieure de l'aile et le grand dos, et (c) avec le plateau et les goussets. Avec le chalut (c), la hauteur de gueule atteignait le double de celle du filet témoin, et avec le chalut (b), 1 m.50 de plus que celle du témoin.

Aumento de la altura de la boca de las redes de arrastre mediante "puertas de elevación."

Extracto

A fin de capturar los peces que nadan cerca del fondo del mar pero no immediatamente sobre él, es necesario abrir la boca de la red al máximo sin defomar excesivamente su forma. Para lograr este objeto, se ha proyecetado y ensayado un nuevo tipo de "puerta de elevación."

En este trabajo se describe la construcción de un modelo de red de arrastre con su "puerta elevadora" que puede moverse a lo largo de una falsa relinga superior y se demuestra la manera como las experiencias con el modelos pueden aplicarse a una red de arrastre de tamaño normal. En las pruebas se usaron tres tipos de red arrastre, a saber: (a) sin "puerta de elevación", (b) con "puerta de elevación" pero sin refuerzos triangulares entre el extremo posterior de la banda o pernada y la visera, y (c) con "puerta de elevación" y refuerzos. En las redes (c) y (b) la altura de la voca ere 2 veces y 1.5 m. mayor, respectivamente, que en el arte usado como testigo.

ONE of the major factors influencing the catch of a trawler is the area of ground fished by the net. But, in the case of demersal fish such as cod, sea bream, hairtail, and prawn, which may not always be quite close to the bottom, the opening height is equally important. One example of the various devices being used for this purpose in Japan is a mouth stretcher for the bull-trawl, invented by Hayashi[1]. In practice the shape of a net should be maintained with the mouth as high as possible. But actually no trawl net can keep a constant shape all the time because of the interfering influences of currents, undulation of the sea-bottom and distortion of the wings due to movement of the boat.

In order to overcome these difficulties, a new type of trawl kite has been developed. This kite adjusts its position automatically according to the movement of the net. After preliminary model tests in a tank with circulating flow, a series of field experiments was conducted by the R.V. *Tenyo-Maru* and the *Taka Maru* of the Tokai Regional Fisheries Research Laboratory in Tokyo Bay in September 1956, and more recently by *Taiyo-Maru* No. 32 of the Taiyo Fishing Company in the central part of the Yellow Sea from February to April 1957. This paper gives the results obtained from these experiments.

MODEL EXPERIMENTS

Method

Model nets with and without the new device were tested comparatively in a glass-walled tank with an effective area of 65 cm. × 1 m. The nets were subjected to various velocities of flow. The shape of the net was controlled and the elevations of the net mouth and the kite were measured.

Construction and Specifications of the Nets

Several arrangements were made for constructing model rets; B and C, with kite (Table I and figs. 1, 2, 3).

TABLE I

Specifications of Model Net-

Name of part	*Material*	*Length or number*	*Remarks*
False head line	—	133 cm. (total)	
Floated part	Cotton	106 „	
"Riding wire" for kite	Copper	27 „	
Head line	—	164 „ (total)	
Bo·om	Cotton	37 „	
Wings	„	127 „	
Connecting Legs	„	8.7 cm.	See fig. 3-L
Gussets*	Silk	2 pieces	See fig. 3-S
Floats	Cork	16 „	Total buoyancy 1.2 gr.

* Mesh 1.3 cm., 11 x 11 meshes, diagonally cut into two, one of each inserted into the square at the quarter points.

(1) The false headline is not fixed to the kite, but passes freely through rings attached to the bridles of the kite, which consequently can slide smoothly on the wire rope used for the middle part of the false headline. This arrangement helps to prevent deformation of the net.

(2) Each end of the false headline is tied to either end of the upper wing so as to make handling of the net as easy, and lift the wing as high, as possible.

(3) A number of floats are attached to the false headline to keep it clear of the net.

(4) In type "C" net, a triangular gusset webbing is inserted into the square at both quarter points to extend the length of the headline in the bosom. This is meant to prevent strain in the webbing when the upper net is pulled up by the kite.

The sizes of the kite, false headline, gussets, and so forth, of course, have to be in correct proportion to the rest of the trawl gear. For that purpose their measurements have been determined on the basis of Tauti's law of comparison[6], by an experiment using a model of a 146 ft.-trawl. Specifications of the model net were obtained as follows:

(1) The measurements of the model, λ', are reduced to one thirtieth of the full scale, λ".

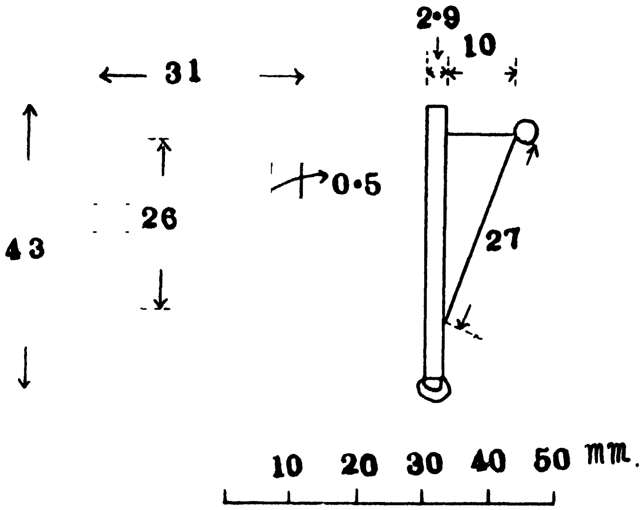

Fig. 2. Diagram of the model kite.

Material	:	*Wooden board, cedar*
Weight	:	*2·4 g.*
Buoyancy	:	*1·5 g.*
Volume	:	*3·9 cm³*
Specific gravity	:	*0·62*

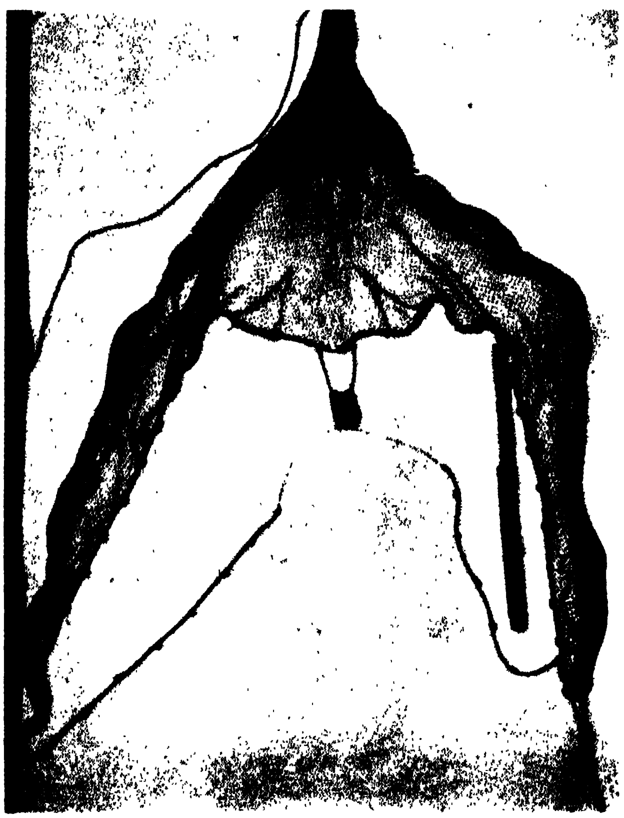

Fig. 1. General view of model net "C" with kite.

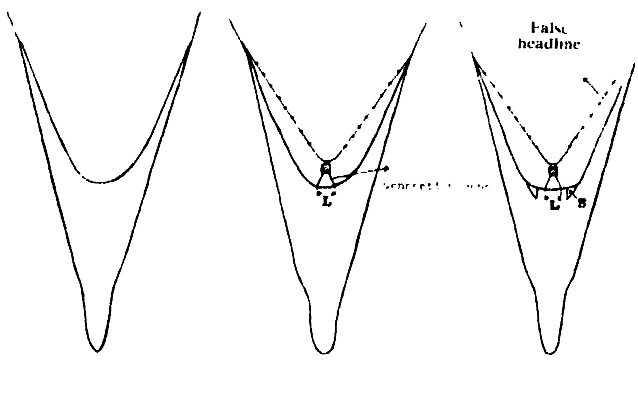

Fig. 3. Schematic diagrams of model nets "A", "B" and "C".
"A" Without kite.
"B" Furnished with kite but without gussets.
"C" Furnished with kite and gussets.

(2) For the net twine of the model, silk is used on the basis of the ratio

$$\frac{D'}{D''} = \frac{L'}{L''} = 0{\cdot}094$$

where D' diameter of twine of the model net
D'' „ „ „ the full scale net
L' mesh size of the model net
L'' „ „ the full scale net

(3) Using 0·094 as the mesh size ratio between both nets, 1·25 as the specific gravity of silk, ρ', for the model net's twine and 1·43 as the specific gravity of abaca, ρ'', for the full scale nets, one may obtain

$$\frac{V'}{V''} = \sqrt{\frac{L'(\rho'-1)}{L''(\rho''-1)}} = \sqrt{\frac{0{\cdot}094 \times (1{\cdot}25-1)}{1{\cdot}43-1}} = 0{\cdot}234$$

where V' and V'' denote the current velocities at which both model and full scale net have the same shape.

(4) We can ignore the hydraulic resistance of the ropes of a fishing net. When D'_1 represents the diameter of cotton twine used for the ropes of the model net; D''_1, the diameter of the combination rope for the real trawl; ρ'_1, the specific gravity of cotton (1·5), and ρ''_1, the specific gravity of the combination rope (4·6), then the ratio between D'_1 and D''_1 in both nets conforming with each other is:

$$\frac{D'_1}{D''_1} = \sqrt{\frac{\lambda'}{\lambda''} \cdot \left(\frac{V'}{V''}\right)^2 \cdot \frac{(\rho''_1-1)}{(\rho'_1-1)}} = \sqrt{\frac{1}{30} \times 0{\cdot}0547 \times \frac{4{\cdot}6-1}{1{\cdot}5-1}} = 0{\cdot}115$$

For the net twines made of the same material in both nets, the ratio of their diameters is:

$$\frac{D'_1}{D''_1} = \sqrt{\frac{1}{30} \times 0{\cdot}0547 \times 1} = 0{\cdot}0425$$

(5) Disregarding the hydraulic resistance of the float, the ratio between the buoyancy of the model float, F', and the full scale one, F'', is represented by

$$\frac{F'}{F''} = \left(\frac{\lambda'}{\lambda''}\right)^2 \cdot \left(\frac{V'}{V''}\right)^2 = 6 \times 10^{-5}$$

This ratio may also be applied in regard to underwater gravity of the foot ropes of those nets.

After the model net and the kite had been constructed according to the above proportions, the optimal proportion to obtain maximum height of the net mouth and the best shape to the net, was determined by repeated tests. The results are given in Table I and fig. 2. Additional experiments with kites of different shape, i.e. rectangular, with the height greater than the width, rectangular with the width greater than the height, and streamlined, revealed that the first was more practical than the others, though somewhat less efficient, because of its simple construction and superior underwater stability. Best results were obtained with an angle of attack of about 30 degrees.

Comparison of Height of Net Mouth

The three types of model trawls tested are shown in fig. 3. They are: A (without kite), B (kite but no gussets), C (kite and gussets). In type "B" the length of the false headline was 124 cm. or 85 per cent. of the length of the headline. The specifications of "C" are given in Table I and figs. 1 and 2.

The experiments show that with a distance of 26 cm. between the wings the opening height of the type "C" net is about three times that of type "A", and with 53 cm. about twice. Although in no actual case would the distance between the wing tips be as narrow as 7·8 m., i.e. 26 cm. × 30, this was tested for preliminary information. With type "C" net, the opening height depends obviously not only on the distance between the wings, but also partly on the size of the gussets. This means that for determining the proper size of the gussets the distance between the wings must be considered. Type "B" net was found to come between "C" and "A". Fig. 4 shows

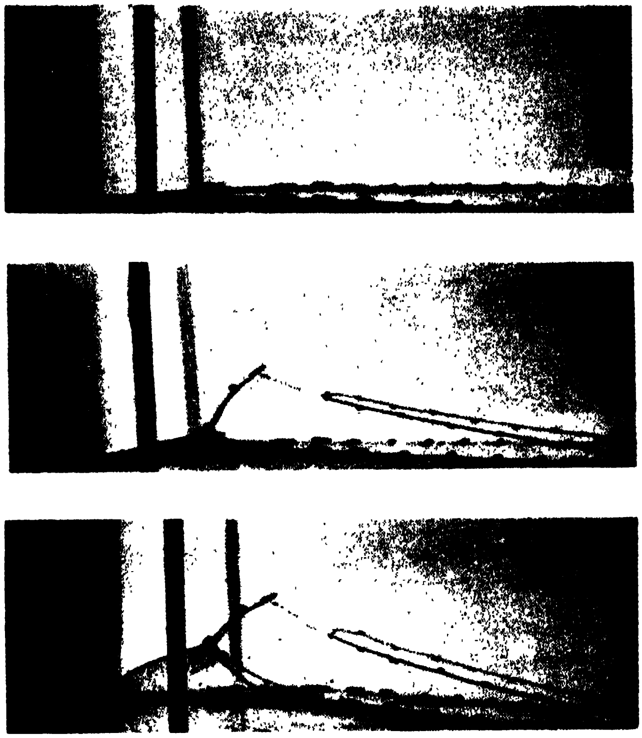

Fig. 4. Model tests with trawl gear type "A" (top), "B" (middle) and "C" (below) at a speed of flow of 0·29 m./sec., corresponding to 2·5 knots with full scale gear.

TABLE II

Comparison of the Height of the Net mouth of Various Model Trawls*

Type of trawl	*Speed of flow (m./sec.)*	*Distance between wing tips 53 cm.* Height of kite (cm.)	*Distance between wing tips 53 cm.* Height of net mouth (cm.)	*Distance between wing tips 26 cm.* Height of kite (cm.)	*Distance between wing tips 26 cm.* Height of net mouth (cm.)
A	0·29	–	5·7	–	6·3
	0·35	—	5·3	–	6·0
	0·41	—	5·0	–	5·7
B	0·29	16·0	9·3	17·3	12·7
	0·35	16·0	9·3	16·0	11·0
	0·41	13·0	8·3	15·0	10·0
C	0·29	18·3	11·7	23·3	17·0
	0·35	18·3	11·7	22·6	16·0
	0·41	17·0	11·0	21·7	15·3

* Height measured from the bottom of the tank.

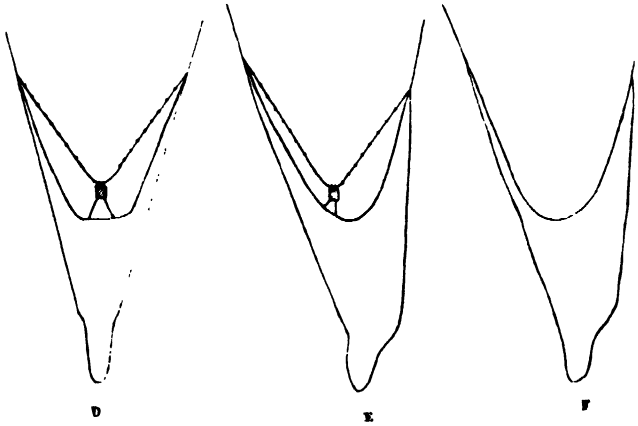

Fig. 5. Schematic views of figuration of model trawls.
D : Normal figuration of net "C" (with kite).
E : Kite adjusting distortion of net "C".
F : Distortion of net "A" (without kite).

the various types of model nets with a flow speed of 0·29 m./sec., corresponding to 2·5 knots in full scale.

Comparison of Net Shapes

During the tank tests observations were also made in regard to the deformation caused by one wing being fixed forward of the other. The distance between the wings tips was 53 cm. and the speed of flow was 0·3 m./sec., 0·35 m./sec. and 0·4 m./sec. respectively.

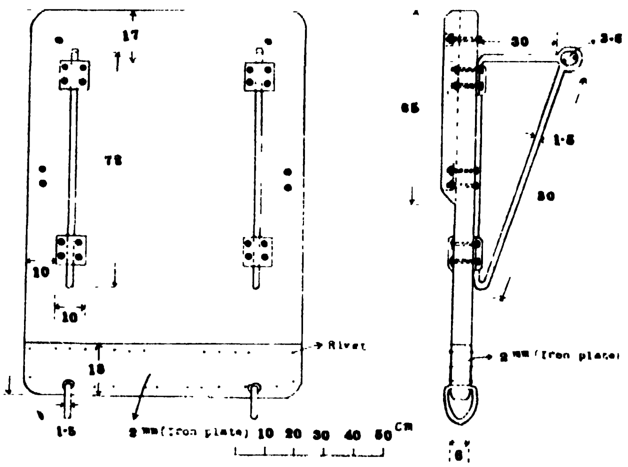

Fig. 6. Diagram of the full scale kite constructed according to the model.

Material	:	*Wooden board, cedar.*
Weight	:	*80 kg.*
Buoyancy	:	*23 kg.*
Volume	:	*103,000 cm³*
Specific gravity	:	*0·78*

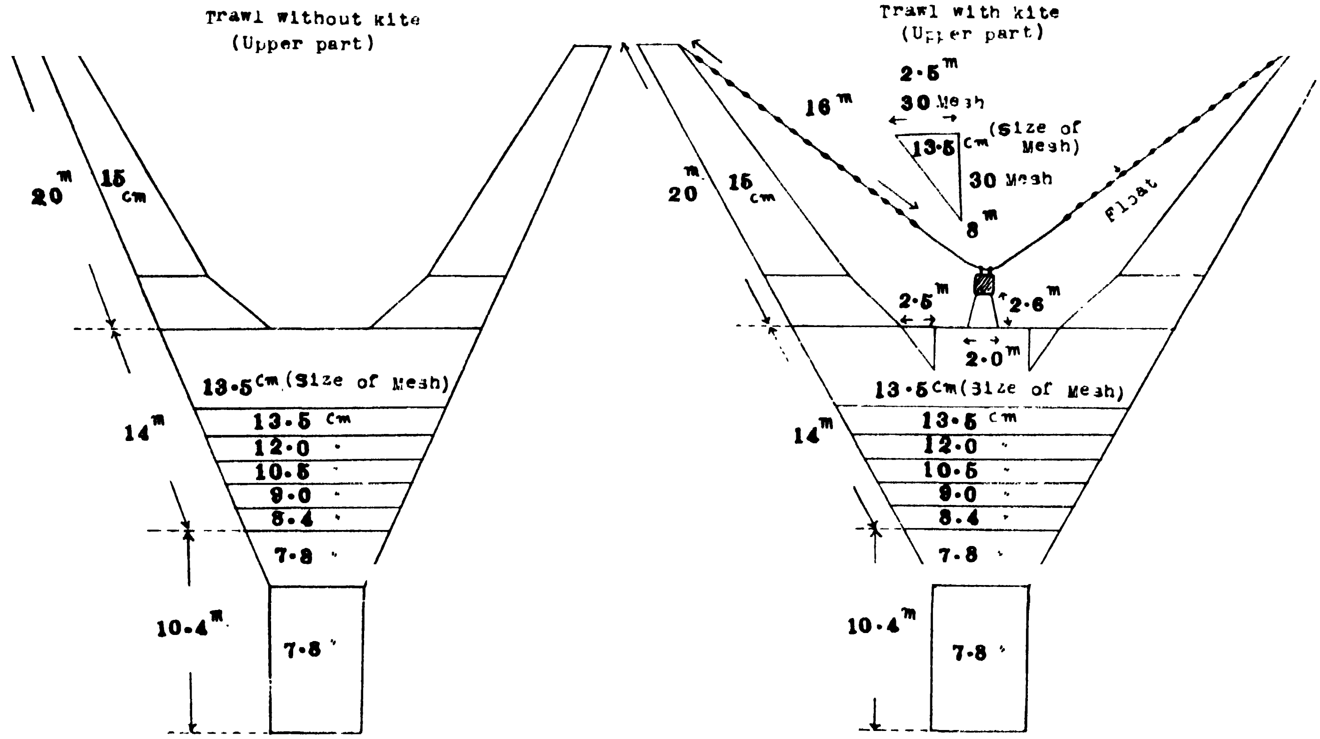

Fig. 7. Detailed diagrams of the full scale trawls with and without kite.

Headline for the trawl without kite.
Total length : 44·2 m., wings : 19·1 m., bosom : 6·0 m

Ropes and accessories for the trawl with kite.
Headline, total length: 49·2 m., wings: 19·1 m., bosom: 11·0 m
False headline, total length : 40·0 m.
for floated part, combination rope, 2 cm. diam., two lines, each: 16·0 m
"riding wire" for kite, wire rope, 12 mm. diam. : 8·0 m.
Connecting leg, two lines, tied at the centre of the bosom, each : 2·6 m
Floats, cylindrical, plastic sponge, buoyancy 0·2 kg. per piece: 100 pieces

It was found that the kite adjusted itself automatically according to expectation (see "E" in fig. 5). Furthermore, nets "D" and "E" had the same opening heights.

Conversion of the Kite from Model to Full Scale

The full scale kite is constructed from the model according to Tauti's ratio:

$$\frac{V'}{V''} = \sqrt{\frac{\lambda'(\rho'_2 - 1)}{\lambda''(\rho''_2 - 1)}}$$

where $\frac{V'}{V''}$ = speed ratio 0·234

$\frac{\lambda'}{\lambda''}$ = reduction scale 1/30

ρ'_2 = specific gravity of model kite, 0·62

ρ''_2 = specific gravity of full scale kite (calculated 0·78) see fig. 6.

Here, some degree of error is to be expected, partly because of a difference in Reynolds number for a small-sized model and partly because the kites are not absolutely similar geometrically.

The false headline and connecting leg for the full scale gear were also dimensioned on the basis of the conversion factors mentioned above (fig. 7). For the scale 1/30 the ratio of the number of meshes for the gussets between model and full scale was computed to be 0·36 and the ratio of mesh size 0·094 (fig. 7). On the basis of the model test result (Table II) the heights of the kite and net mouth in full scale were estimated for speeds of flow as shown in figs. 8 and 9.

Estimation of Hydraulic Resistance in various parts of the Kite gear

The extent to which the kite could affect the distance between the otter boards, and thus the distance between the wing tips, could not be determined by the model experiments. Although no reliable value for the total hydraulic resistance of the trawl can be given, a very rough estimate may be of interest. To simplify matters the problem will be considered as two dimensional, by calculating first, the resistance of each part of the kite gear, then the ratio of the resistance of these parts to the total resistance. Buoyancy and underwater gravity are neglected. The elevation of the kite and the resulting angle of the ropes will be computed on the basis of the data obtained in the model experiments.

The Kite

Let P_1 (kg.) be the resistance of the kite when the direction of flow is normal to its plane, then

$$P_1 = \frac{1}{2} C_x \frac{\rho}{g} \cdot V^2 \cdot S$$

where
- ρ : density of water in Kg./m.³
- g : acceleration of underwater gravity in m./sec²
- V : velocity of the current in m./sec.
- S : plane area of the board in m²
- C_x : coefficient dependent on function of Reynolds number.

If the kite has an angle of attack θ, the resistance is P_θ, according to Duchemin's equation:

$$P_\theta = P_1 \cdot \frac{2 \sin \theta}{1 + \sin^2 \theta}$$

Assuming that the kite is 1·3 × 0·93 m. in size: C_x = 1·13; θ = 32° and $\frac{\rho}{g}$ = 104 kg. sec²/m.⁴, the resistance at different speed of flow is given below (Table III).

TABLE III

Speed of flow knots	Resistance kg.
2	59
3	134
4	236

False Headline

As the false headline consists of wire rope for the riding wire of the kite, and the combination rope partly equipped with floats, the resistance has to be calculated for each part. The angle of attack of the false headline is assumed to be 16 degrees, as was the case with the model

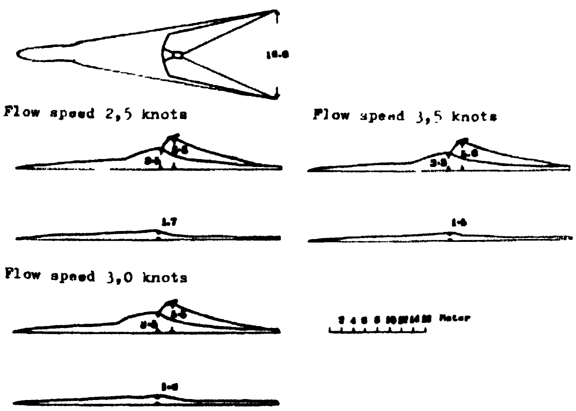

Fig. 8. Height of kite and net mouth with different speeds of flow computed from the model test results (Table II, Distance between wing tips 53 cm.)

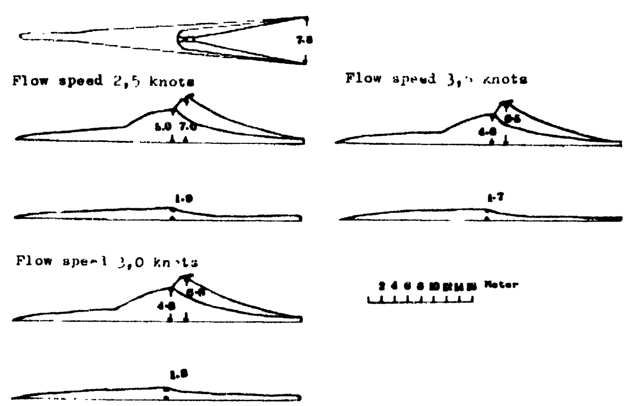

Fig. 9. Height of kite and net mouth with different speeds of flow computed from the model test results (Table II, Distance between wing tips 26 cm.).

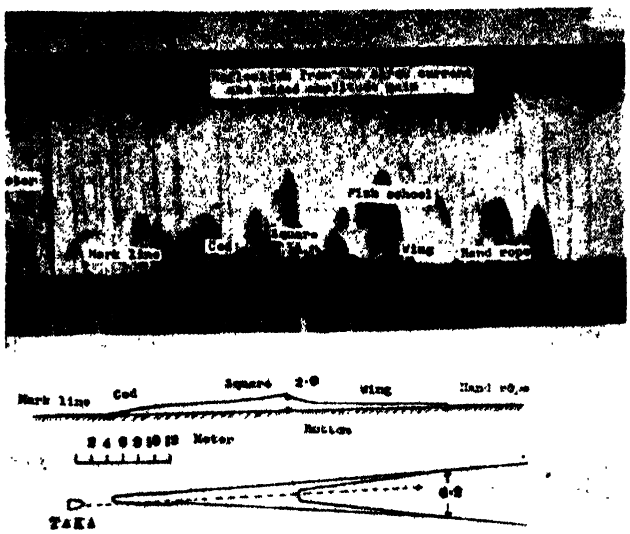

Fig. 10. Echoes from the trawl type "C" towed at 2·5 knots.
Date : Sept. 8, 1956, 0735 hours.
TENYO-MARU
Direction : S 45° W (head wind).
Angle between warps : 17°
TAKA-MARU
Speed : 3·8 knots.
Direction : S 44° W.

experiments. The resistance of a unit length of a rope at an angle of attack θ is

$$P\theta = \frac{1}{2} Cx \frac{\rho}{g} \cdot D \cdot V^2 \cdot \sin\theta$$

where D is the diameter of the rope in metres.

When Cx is 1·2, and $\frac{\rho}{g}$ is the same as in the last equation, the values of $P\theta$ for each length of the present type at false headline are tabulated below: (Table IV).

TABLE IV

Speed of Flow (knots)	*Resistance (Kg.) of* Combination rope D:0·021 *m*, *L*:16 *m*	*Floated part* D:0·055 *m*, *L*:16 *m*	*Wire rope* D:0·012 m, *L*:8m
2	5·9	15·4	1·7
3	13·2	13·2	3·8
4	23·5	61·6	6·7

The Connecting Legs

If, for the calculation, the same angle of attack is used as was found in the model experiments (44 degrees), the diameter of the rope is 0·021 m. and its length 5·2 m., $C_x = 1·2$ and $\frac{\rho}{g}$ the same as for the combination rope, the results obtained are given in Table V.

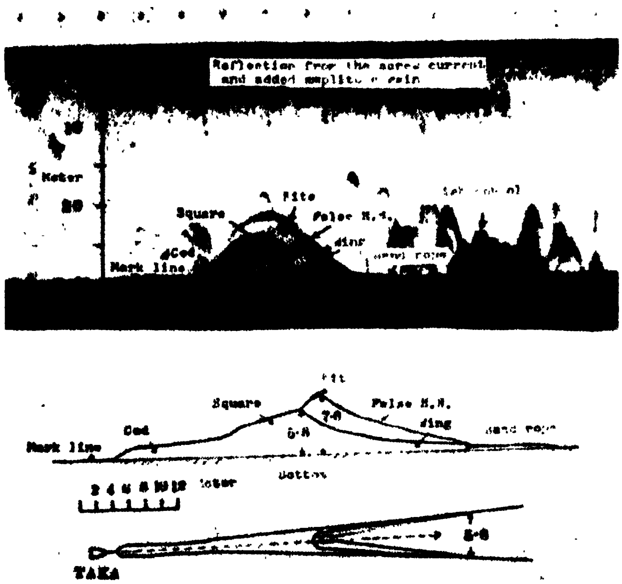

Fig. 11. Echoes from the trawl type "A" towed at 2·5 knots.
Date : Sept. 8, 1956 1010 hours.
TENYO-MARU
Direction : N 40° E (fair wind).
Angle between warps : 19°
TAKA-MARU
Speed : 3·0 knots
Direction : N 39° E.

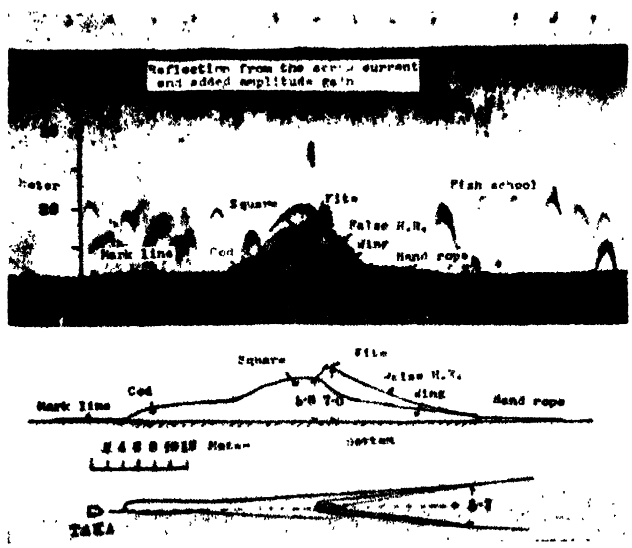

Fig. 12. Echoes from the trawl type "C" towed at 3·0 knots.
Date : Sept. 8, 1956, 0710 hours.
TENYO-MARU
Direction : S 45° W (head wind).
Angle between warps : 17°
TAKA-MARU
Speed : 4·2 knots.
Direction : S 44° W.

TABLE V

Flowing velocity (knots)	*Resistance (Kg.)*
2	4·7
3	10·6
4	18·8

By summing up the resistance of the different parts the total resistance of the complete kite gear is found to be 87, 196 and 347 kg. at the speed of flow of 2, 3 and 4 knots respectively.

For trawl type "C" an additional increase in the resistance has to be expected from the modification of the net, i.e., the inserting of the two gussets. At present there are no means of calculating this increase.

The resistance of a common 146 ft. trawl, though more or less variable according to the bottom conditions, has been found to be about 5 tons, at a towing speed of 3 knots under normal conditions[8]. Consequently the resistance of the kite gear of 196 kg. can be considered to be of minor importance. If, in a liberal estimation, it is assumed that the increase of resistance caused by the modification of the net is of similar magnitude, the total increase would not greatly exceed about 400 kg. As much increase often occurs because of changes in bottom conditions, warp length or amount of catch in the codend, it may reasonably be considered that the kite gear and the modification of the net would not critically affect the angle of attack of the otter boards.

FIELD EXPERIMENTS IN TOKYO BAY

Method and Equipment

In the Tokyo Bay experiments on September 7 and 8, 1956 two 146 ft.-trawls, one of type "C" (with kite and gussets), the other of type "A", were towed at various speeds, and their characteristics were observed by means of an echo sounder installed in a boat following the trawler. Furthermore, in certain intervals the position and tension of the otter boards were controlled. As there was no intention of catching fish, the codends were left open. The experimental conditions are given below:

Place:	Central area of Tokyo Bay, depth 26 to 29 m., bottom flat and sandy.
Trawler:	*Tenyo-Maru*, 230 tons, 430 h.p.
Sounding Boat:	*Taka-Maru*, 15 tons.
Trawling Speed:	2·5; 3·0; and 3·5 knots relative to the current.
Trawl Gear:	*Chosei* type, similar to V.D. type, in adjustment according to type 'A' and 'C' described above. Warp length 60 m. bridle length 100 m. Total length of net approximately 44 m., including 20 m. wing, 14 m. square and belly, and 10·4 m. codend (see fig. 7). Kite 1·2 m.^{2} (see fig. 6).

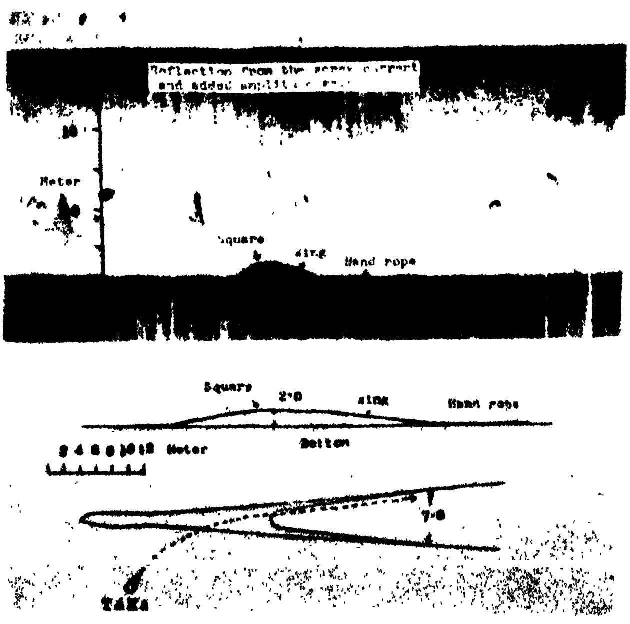

Fig. 13. Echoes from the trawl type "A" towed at 3·0 knots.
Date : Sept. 8, 1956, 0935 hours.
TENYO-MARU
Direction : S 45° W (head wind).
Angle between warps : 22°
TAKA-MARU
Speed : 4·5 knots.
Direction : No specific course was set.
Exact measurements of the figuration could not be taken because the boat did not pass properly over the net.

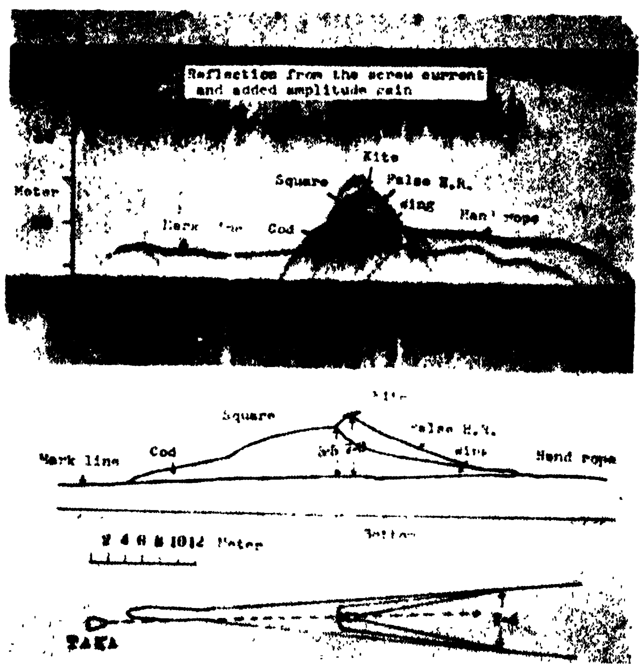

Fig. 14. Echoes from the trawl type "C" towed at 3·5 knots.
Date : Sept. 8, 1956, 0640 hours.
TENYO-MARU
Direction : S 45 W° (head wind).
Angle between warps : 23°.
TAKA-MARU
Speed : 5·5 knots.
Direction : S 43° W.
Note the net clearing off the bottom.

Echo-sounder: 50 kc., 50 m. range, half beam angle 30 degree.
Log: Current meter Model CM-3, electric, one for each boat.
Angle Meter: To determine the angle between the warps for calculating the approximate distance between the otter boards.
Dynamometer: Due to a fault in the instrument the measurements of the pull on the warps are not reliable.

Results

The results of these experiments are given in Table VI. The heights of the kite and the net mouth were computed from the recordings of the echo-sounder by the following method: When the trawler *Tenyo-Maru* tows a 44 m.-long net at a speed V' (cm./sec.) and the *Taka-Maru* steams with the echo-sounder at V (cm./sec.), both keeping the same direction, the length of time required by *Tako-Maru* to pass right over the net will be

$$\frac{4400}{V - V'} \text{ (sec.). Then } \frac{0 \cdot 6 \times 4400}{V - V'} \text{ (mm.)}$$

is the length of the net as recorded on the echo-sounder paper running at 0·6 mm./sec.

Since V and V' were known, and if *Taka-Maru*, in following the track of her partner, passed exactly over the nets, the calculated value should agree with the observed one. If this was not the case, it would mean that the boat with the sounder was not following right above the net. By selecting some of those data which coincided with the calculated values, we have plotted the heights of the kite and the net mouth on the recording papers (Table VI, figs. 10-14).

To find the distance between the wing tips, the distance between the otter boards was first of all calculated on the basis of the length-angle relationship of the warps presuming that they extend straight to the otter board. Then, from the isosceles triangle bounded by the distance between the otter boards as the base, and the length of the bridles (100 m.) plus the length of the net (44 m.), both supposedly forming a straight line, the distance between the wings can be computed. Such a calculation of course contains errors, but we have used it because there is nothing better and also because the errors would be the same for both trawls.

The data deduced from the echo-sounder records and the schematic views interpreted from them are presented figs. 10-14, with the position of the net indicated by the legend "mark line", which was a buoy rope tied to the codend to simplify the detection of the nets.

Discussion

The distance between the trawl wings ranged from 5·6 to 7·4 m. (Table VI and figs. 10-14). Such a narrow distance would be most unlikely to occur in commercial trawl operation. However, since this corresponds roughly to

TABLE VI

Data Relevant to Comparative Experiments of a 146 ft. Trawl with and without Kite in Tokyo Bay, September 8, 1956

	R.V. Tenyo-Maru							R.V. Taka-Maru *that followed the net by an echo-sounder*						
		CRUISING		*Angle*	*Revolution*	WIND			CRUISING		HEIGHT FROM BOTTOM		*Distance*	
	Time	*Speed* (knot)*	*Direction*	*of warp*	*of engine*	*Direction*	*Force*	*Time*	*Speed* (knot)*	*Direction*	*Kite (m)*	*Net mouth (m)*	*between wings (m)*	*Remarks*
Trawl with the pi it kite	0800	2·35	S45°W	17°	180	SW	2	0748	4·0	S43°W	7·0	5·9	5·6	
	0755	2·30	,,											
	0750	2·35												
	0735	2·5						0738	3·8	S44°W	7·0	5·8	5·6	Shown in fig. 10.
	0730	2·8	,,											
	0725	2·7	,,					0724	3·6	S45°W	7·0	5·8	5·6	
	0715	3·25	,,	18°	200									
	0710	3·0	,,	,,	,,			0713	4·2	S44°W	7·0	5·8	5·7	Shown in fig. 12.
	0705	3·2	,,	16°	,,	.	..	0703	4·5	S45°W	7·0	5·8	5·3	
	0650	3·6	,,	23°	248	,,	1	0648	5·5	S45°W	7·0	5·6	7·4	The net rose 4 m. above the bottom.
	0645	3·5	,,	,,	,,	,,	,,							
	0640	3·5	,,	,,	,,	,,	,,	0640	5·5	S43°W	7·0	5·5	7·4	The net rose 4 m. above the bottom (fig. 14)
	0635	3·5	,,	,,	,,	,,	,,							
	0630	3·4	,,	,,	,,	,,	,,	0629	5·6	S43°W	7·0	5·5	7·4	The net rose 3 m. above the bottom.
Trawl without the kite	1020	2·6	N40°E	20°	180	SW	2							
	1010	2·5	,,	19°	,,	,,	,,	1013	3·0	N39°E	—	2·0	6·2	Shown in fig. 13
	1000	2·6	,,	,,	,,	,,	,,	1008	3·5	N40°E		2·0	6·2	
	0945	3·0	S35°W	23°	200	,,	,,	0943	5·5	S35°W	.	2·1	7·4	
	0940	3·1	,,	22°	,,	,,	,,							
	0935	3·0	S45°W	,,	,,	,,	,,	0936	4·5	—	—	2·1	7·0	Shown in fig. 13.
	0930	2·8	,,	,,	,,	,,	,,							
	1035	3·5	N40°E	23°	240	,,	,,	1033	5·5	N40°E	—	2·2	7·4	The net r se too high
	1030	3·5	,,	22°	,,	,,	,,							
	1024	3·4	,,	23°	,,	,,	,,	1027	5·5	N39°E	—	2·6	7·4	The net rose too high

Neither applicable nor specified. * Relative speed of the boat.

7·8 m., obtained by the factor 30 from 26 cm. which was the distance between the model's wings, the observed heights of the net mouths seem to be comparable with the value calculated from the model tests (fig. 9). It will be recalled that for the models the net mouth of type "C" was nearly three times as high as that of net "A" (Table II), which factor closely approximates 2·5 to 2·9 obtained in the full scale tests. Furthermore, it can be assumed that the full scale nets had at 2·5 to 3 knots shapes rather similar to those of the models. At 3·5 knots, the full scale trawl type "C" was lifted off the bottom (fig. 14), and also the type "A" gear was liable to leave the bottom (Table VI). This is probably due to the fact that the footrope, which was a little too light and had been dried before use, hardly had time to increase its weight by absorbing enough water during the experiments. On the other hand, the model nets could not leave the bottom because their wings were fastened to the bottom of the tank.

The height of the full scale trawl with 7·8 m. distance between the wing tips and at 2 to 3 knots was approximately in accordance with the values calculated from the model experiments. It, therefore, may be assumed that with 16 m. distance between the wing tips the full scale type "C" trawl would maintain an opening height nearly twice as great as type "A" without kite.

The net can, of course, easily be prevented from rising off the bottom by adding some weight (chain) to the footrope. The data shown in Table VI may relieve our worries about some other technical difficulties connected with the operation of the kite. For one thing, the angle between the warps does not change to such an extent that a considerable decrease of the distance between the wing tips has to be apprehended.

The engine revolutions at 2 to 3 knots gave no indication of a considerable difference in the resistance of both types of trawl.

The present measurements of the load on the warps, unfortunately, are not reliable. The lack of differences in the loads, therefore, is not conclusive. For observing directly the kite adjusting itself to the distortion of the net modern diving techniques and underwater photography should be used. Unfortunately, circumstances did not permit the authors to use such aids. However, if the similarity between the results of the model and field experiments is considered, it may safely be assumed that with a towing speed limited to 2 to 3 knots, the kite would behave very similar as it was observed in the tank experiments.

During the present experiments the kite and the false headline never became entangled with the net, and the work of hauling the net was no greater than with an ordinary trawl, because these accessories can be left afloat on the water while only the codend is hauled aboard. Of course, during a long period of continuous operation, the kite would become water-logged and lose its buoyancy, which would most likely result in certain difficulties. Figs. 15 and 16 show the devices used in the experiments.

FIELD EXPERIMENTS IN THE YELLOW SEA

Method and Equipment

The second series of experiments were conducted by the trawler *Taiyo-Maru No.* 32 (369 gross tons, with 700 h.p. diesel engine) on a fishing ground for prawn (*Penaeus orientalis* Kishinouye) located in the central area of the Yellow Sea. In rigging a trawl (TT8-B1 type by the Taito Fishing Co., headline 128 ft. long) with the present device, the kite was used as in the preceding experiments, while the gussets and the "riding wire" of the false headline were somewhat modified in length (fig. 17). A length of chain was added to the ground rope to keep it on the bottom. A detailed specification of the gear is given in the footnote of fig. 17.

The height of the net mouth was measured by a height meter[2] attached to the centre of the head rope. All three types of trawl gear have been tested: "A" (without kite); "B" with kite but without gussets, the false headline being 85 per cent. of the headline length; "C" with kite and gussets. The distance between the wing tips was estimated from the angle between the warps and the trawling speed was determined by the "rail log" method.

Results and Discussion

With a relative towing speed of 3·3 to 3·6 knots, the height of the net mouth was about 2·5 m. for the gear type "A",

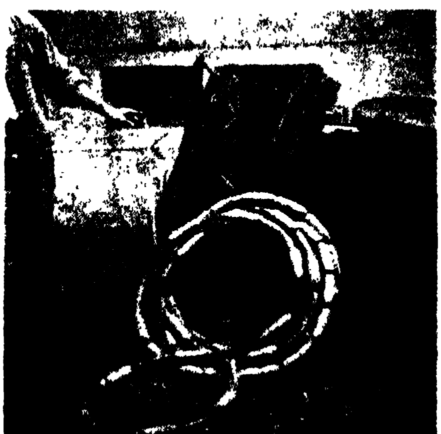

Fig. 15. Kite and false headline used in the experiments.

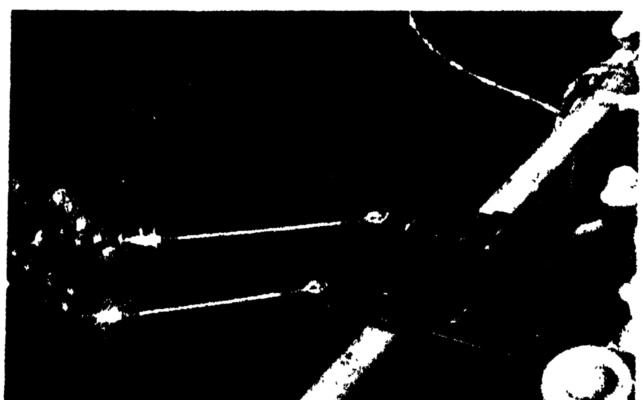

Fig. 16. Kite about to be put in use.

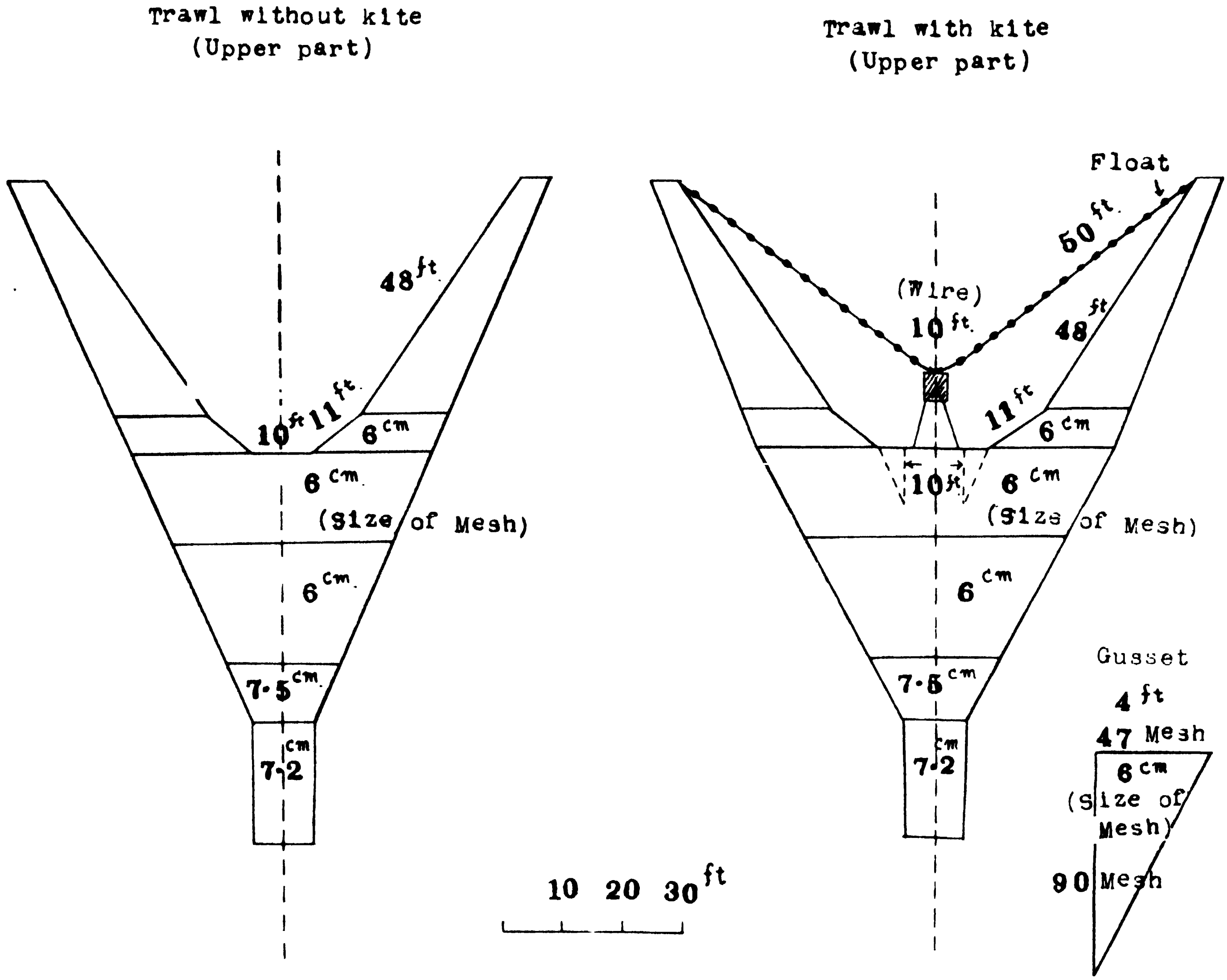

Fig. 17. Detailed diagram of the 128-feet-trawl with kite used by the Taiyo-Maru No. 32.

Ropes and accessories for the net with kite : False headline, total length	*110 feet*
for floated part, combination rope, 2 cm. diam., two lines, each	*50 ,,*
"riding wire" for kite, wire rope, 12 mm. diam.	*10 ,,*
Headline, extended by 8 feet for two gussets inserted into the square	*136 ,,*
Connecting legs, combination wire, 2 cm. diam., one end of each tied 3-1/2 feet apart from the centre of the square, the other end to the after edge of the kite, each	*9 ,,*
Chains, 12 mm. diam., for additional weight of footrope	*40 meters*
Floats for false headline, cylindrical plastic sponge, buoyancy 200 gr. per piece, 60 pieces per side	*120 pieces*
for bosom, glass ball, 24·2 cm. diam.	*10 ,,*
for wings, glass ball, 18 cm. diam. 3 feet distance, total number approx.	*40 ,,*

about 4 m. for type "B", and about 5·4 m. for type "C" (see fig. 18). The angle between the warps decreased by 2 to 3 degrees. The corresponding decrease of the distance between the wing tips for the trawls type "B" and "C" was approximately 3 to 4 m. The position of the kite would be some 2 m. above the headline. The frightening effect of the kite gear may possibly increase the effective mouth opening up to the level of the kite.

The distance between the wing tips was found to be about 16 to 17 m. The actual opening height determined in these experiments was considerably higher than in the model experiments (fig. 8). This may be ascribed partly to the net being smaller than it ought to be in proportion to the kite, and partly to the different type of net which for the purpose of catching prawns, is constructed for a higher opening than the one used on the model tests. The presence of a number of bottom-living flat-fish in the catch and of mud of the footrope was good evidence that the footrope had been kept on the bottom. The number of engine revolutions varied but little among the different types of trawls. In regard to handling of the kite gear very little difficulty was experienced during the first 5 days. But later the kite became water-logged and could not be kept floating by the floats on the false headline, thus causing considerable trouble to the crew.

Problems to be solved

(1) In order to prevent water-logging, the kite should be made either of plastic or of light metal alloy. At the same time, an optional weight of the footrope has to be determined experimentally with regard to the new type of kite, trawling speeds, and bottom characteristics.

(2) The gusset as used in the present net may not necessarily be the best means of securing an effective formation of the net mouth. It is suggested that the net mouth should not only be raised in height but also be as round as possible. One suggestion would be to insert a rhombical piece of webbing of the proper size between the upper and lower net along each side.

(3) A hydrofoil kite may provide the same lifting power with a smaller area. In that case, however, the underwater stability and the lower resistance against rough treatment must be considered.

Acknowledgements

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REFERENCES

[1] Hayashi, H. A study of a trawl mouth stretcher (in Japanese), Jour. Fish. Exp. St., 3, 1933.

[2] Imamura, Y. Model experiment of the British herring trawl (in Japanese). Bull. Jap. Soc. Sci. Fish. 10 (5), 1942.

[3] Nomura, M. and Yasui, T. Model experiment on various types of trawl net (in Japanese), Bull, Jap. Soc. Sci. Fish. 18 (12), 1953.

[4] Kanda, K. The notes on midwater trawl. Fish. Tech. 1 (7), 1954.

[5] Kumagori, T., Hamuro, S. and Ishii, K. Automatic net-height meter and ground rope indicator for trawler with the results of experiments (in Japanese), Tech. Rep. Fishing Boat. 6, 1955.

[6] Tauti, M. A relation between experiments on model and on full scale of fishing net, Bull, Jap. Soc. Sci. Fish. 3. (4), 1934.

[7] Tauti, M. "Physics in fishing technology" Asakura, Tokyo, Japan, 1949.

[8] Hayashi, H. The calculated tension in towing two-boat-type trawl (in Japanese), Fish. Invest. 20 (1), 1925.

[9] Hayashi, H. Ibid. 19 (7), 1924.

[10] Sato, E. and Kurita, S. An experiment on the resistance and buoyancy of floats for the seine (in Japanese), Fish. Invest. Fish. Ex. 9, 1943.

[11] Miyamoto, H. "Study on fishing gear and method," Kanehara, Tokyo, Japan, 1957.

[12] Saito, I. "Trawl fishery", Maruzen, Tokyo, Japan, 1954.

[13] Whiteleather, R. T. Commercial Fisheries Review 10 (6) 1948. PP. 1-6.

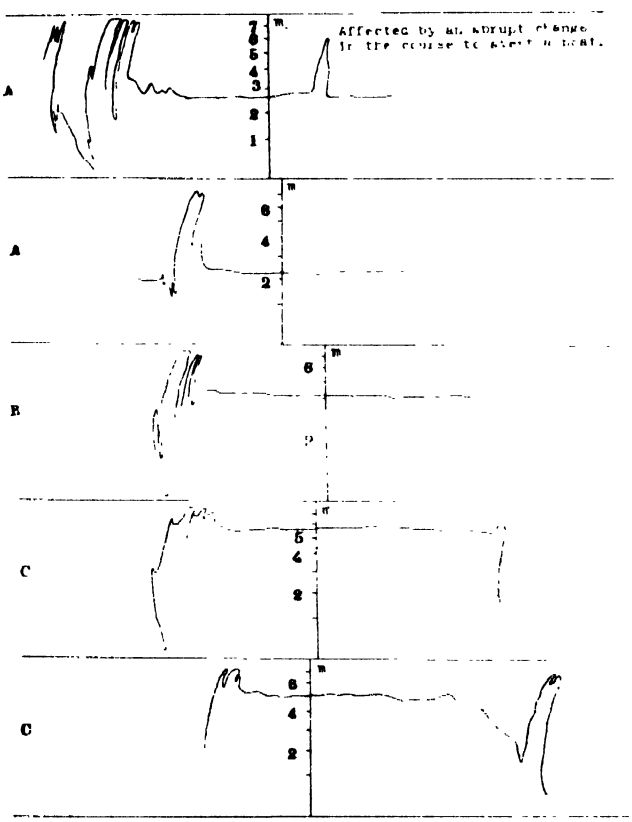

Fig. 18. Diagrams of the net-height recorder, giving the opening height of the different types of trawl gear tested by Taiyo-Maru No. 32.

Type of net	*A*	*A'*	*B*	*C*	*C''*
With or without kite	*Without*	*Without*	*With*	*With*	*With*
With or without gussets	*Without*	*Without*	*Without*	*With*	*With*
Headline length, total	*128 ft.*	*128 ft.*	*128 ft.*	*136 ft.*	*136 ft.*
Force of wind	*1, fair wind*	*1, head wind*	*2, fair wind*	*3, fair wind*	*2, head wind*
Depth	*70 m.*	*70 m.*	*75 m.*	*75 m.*	*80 m.*
Relative towing speed	*3·3 knots*	*3·5 knots*	*3·6 knots*	*3·5 knots*	*3·5 knots*
Engine revolution	*222/min.*	*226/min.*	*230/min.*	*220/min.*	*220/min.*
Warp length	*220 m.*	*220 m.*	*230 m.*	*230 m.*	*250 m.*
Angle between the warps	*16°*	*15·5°*	*13·5*	*13°*	*13°*
Chains added to foot rope	*Without*	*Without*	*12 mm. diam. 40 m.*	*12 mm. diam. 40 m.*	*12 mm. diam. 40 m.*
Major kind of catch	*Croaker, prawn and flatfish*	*Prawn and croaker*	*Prawn and croaker*	*Prawn, flatfish and croaker*	*Prawn and flatfish*

THE HEADLINE, THE FOOTROPE AND THEIR INFLUENCE ON THE VERTICAL OPENING OF THE MOUTH OF THE TRAWL

by

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Abstract

Although trawls have been changed frequently to increase their efficiency, designers are still without a complete picture of how a trawl works. Design, so far, has been largely determined by net materials available and the power and size of trawlers. There should be a thorough examination of the fundamentals in construction of a trawl to determine precise rules for designing it. This paper is confined to giving a few examples of construction problems and suggestions for overcoming them. It deals specifically with the influence of the headline and footrope on the vertical opening of the mouth of the net, and proposes formulae for determining the most effective proportions and arrangements.

La corde de dos, le bourrelet et leur influence sur l'ouverture verticale de la gueule du filet

Résumé

Bien que l'on ait modifié fréquemment les chaluts pour augmenter leur efficacité, les spécialistes qui les dessinent n'ont pas encore une représentation complète de comment fonctionne le chalut. Jusqu' ici, le modèle a surtout été déterminé par les matières premières existantes pour le filet, et la puissance et les dimensions des chalutiers.

On doit examiner soigneusement les principes de base dans la construction d'un chalut pour déterminer des règles précises d'établissement du projet. Cette communication donne quelques exemples de problèmes de construction et des suggestions pour les résoudre. Elle traite spécifiquement de l'influence de la corde de dos et du bourrelet sur l'ouverture verticale de la gueule du filet et propose des formules pour déterminer les proportions et les dispositions les plus efficaces.

Las relingas superior e inferior y su influencia sobre la altura de la boca de las redes de arrastre

Extracto

Aunque a menudo se ha modificado la boca de las redes de arrastre para aumentar su eficacia, los fabricantes no tienen todavía una idea perfecta de como funciona el arte. Hasta ahora, la forma ha sido determinada generalmente por los materiales disponibles, la potencia y tamaño de los arrastreros. Sin embargo, para determinar de manera precisa las normas de construcción debe hacerse un cuidadoso examen de los principios fundamentales que entran en la construcción de una red arrastre.

Este trabajo, que sólo tiene por objeto dar unos cuantos ejemplos de los problemas de construcción y sugestiones para evitarlos trata, especialmente, de la influencia que tienen las relingas superior e inferior sobre la altura de la boca y propone fórmulas para determinar las proporciones y armadura más adecuados.

DETAILS of the construction of trawl nets show substantial differences from place to place. This situation appears to result from the lack of a complete picture of the trawl in operation.

Although underwater films throw some light upon the subject, they do not tell us all we need to know; nor do the empirical investigations made by fishermen. What we need to determine are the precise rules on which the designs of the trawls should be based and, as designing a trawl is a complicated business involving a diversity of factors, it is necessary to start with an examination of the foundations of the construction of the trawl.

The opening height of the net must suit the particular fishing conditions. There are, therefore, constructional differences between trawl nets used for catching fish living on or very near the bottom and nets for catching fish normally found some distance off the bottom.

So far, this problem is being solved by using lifting devices and different qualities of net materials, and by the power and size of the ship. In the cutter trawls, made of cotton or synthetic fibres which are extensible, the vertical opening of the mouth depends mainly on the length of headline and footrope. In the bigger trawls made of less extensible materials (sisal, manila, hemp), the length of the bosom part of headline and footrope is probably most important.

A cutter trawl 18/23 and a trawl 22/24 (72 ft.) for big deep sea trawlers are used as examples in this study as they are common in the Polish commercial fishery. The indicated fractions denote the size of the trawl nets, the numerator indicates the length of the headline (in metres) occupied by the webbing, and the denominator half of the circumference of the front edge of the belly measured with stretched meshes.

THE POLISH HERRING TRAWL NET 18/23 FOR CUTTERS

This trawl is rigged with headline, footrope and belly lines seized to the side seams linking the upper with the lower net (fig. 1).

One of the most essential points in the construction of such trawls with sidelines is the proper length relation between the three elements: headline, footrope and

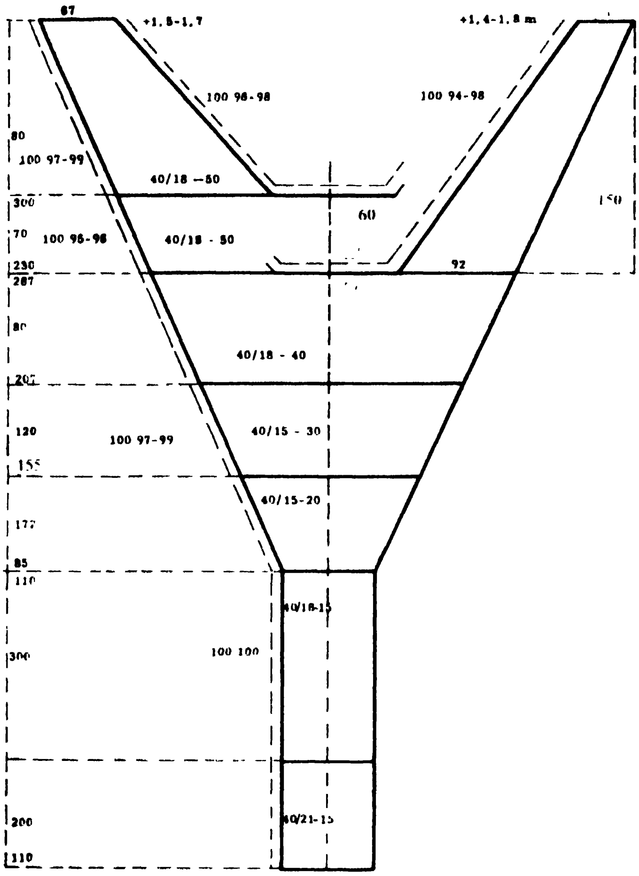


Fig. 1. The Polish Herring trawl net 18/23, for cutters.

sidelines. This can be affected either by adding triangular wedges to the wing ends, or by increasing the length of the headline and the footrope beyond the webbing.

The length of the triangular wedges is variable but, in practice, it never exceeds half of the number of meshes of the wing end multiplied by the stretched mesh size.

In fig. 2 the top wing of the trawl is outlined (A B C D), to which a triangular wedge of webbing (A B E) has been added. The wing there has the shape A E D C. From point A and E the wing legs, sideline leg and headline leg lead to the danleno. As both are of identical length, the configuration of the front part of the headline is changed. Point F will take the place of point B, which in turn will be shifted to point F, and consequently point D to point G. The position of points A and C on the side seam (BE BF = DG) remain unaltered. In the case shown in fig. 2 the lengthening of the headline is effected by inserting a certain amount of webbing. Of course, the same result can be obtained by simply lengthening the headline by the amount BE. The footrope can be treated similarly. In consequence of lengthening the inner edges of upper and lower wing, there is a shifting of the front part of the webbing in relation to the body of the net, the effect of which is more difficult to explain. The shape the headline takes in action is shown in fig. 3 for three coefficients of the opening width, viz., 0·5, 0·6 and 0·7 of the headline length. The curves are calculated according to the method of Baranov (parabolic equations).

The left-hand part of the drawing (a) shows the effect of an elongation of the headline by 1·6 m. on each side, while the right-hand part (b) shows the configuration with the original headline length of 18 m. In all three versions the length of the side seams remains unchanged.

In part "a" the figure A B O C shows the top wing with coefficient 0·5, i.e. the distance between the wing tips equals half of the headline length. Considering the effect of adding the triangular wedges, it appears as if a "surplus" has arisen, which may increase the vertical opening of the mouth.

In order to determine this "surplus" in the drawing, a line is drawn from point C parallel with the line A E, which represents the wing tips.

Point O denotes the spot where the foundation (C O) of the wing ends, and the bosom of the headline starts. The respective points for the other versions are O1 and O2. The figure C O R gives the "surplus" overlapping the square section of the twine.

With increasing horizontal opening, i.e. equal 0·6 or 0·7 of the headline length, the surplus decreases.

If the horizontal opening equals 0·5 of the length of the headline, the surplus of twine is considerable (C O R). At the opening of 0·6 it diminishes ($C_1 O_1 R_1$) and at 0·7 nothing is left.

This confirms that the increase of the headline length ensures correct working only within the limits of the horizontal opening between 0·5 up to 0·6 of the headline length. The amount of surplus obtained allows for a higher opening at 0·5 than at the 0·6 which is confirmed in the survey of de Boer. For sufficient surplus with 0·7 opening, the headline should be further lengthened by about 0·6 m.; otherwise the opening height would be unsatisfactory and trawling forces could cause a break up of the webbing in the joints of the wings.

The otter boards, consequently, have to be adjusted according to the constructional possibilities of the net. This, in practice, has led to great caution in determining the lengthening of the headline or footrope, and it has been fixed within tolerant limits to cover individual deviations of the trawl.

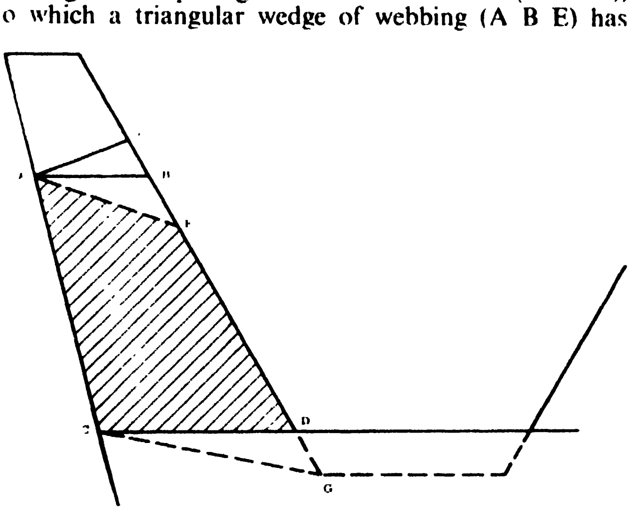


Fig. 2. The effect of lengthening on the shape of the headline.

Part (b) of fig. 3 indicates certain shortcomings in the

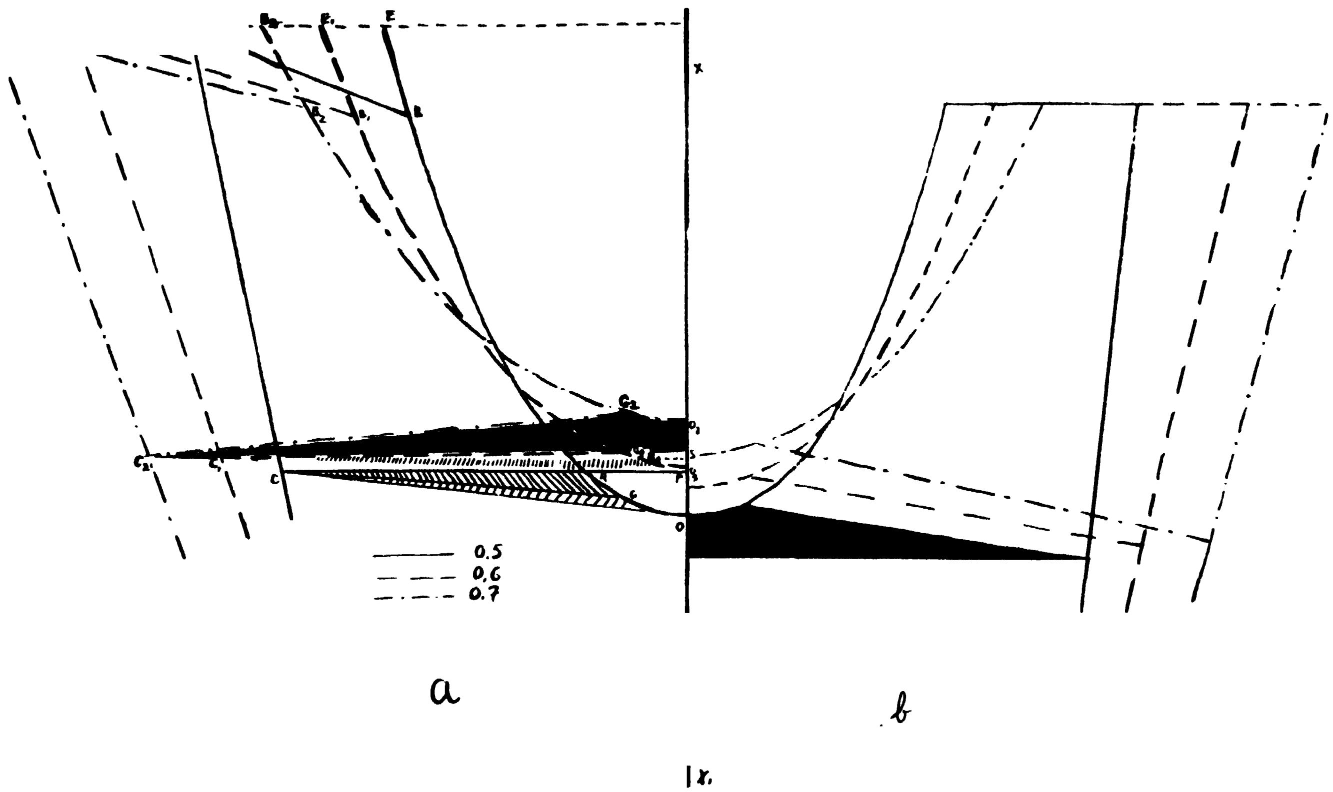


Fig. 3. The effect of lengthening the headline on the footrope on the webbing, with three different ratios of opening width to headline length.

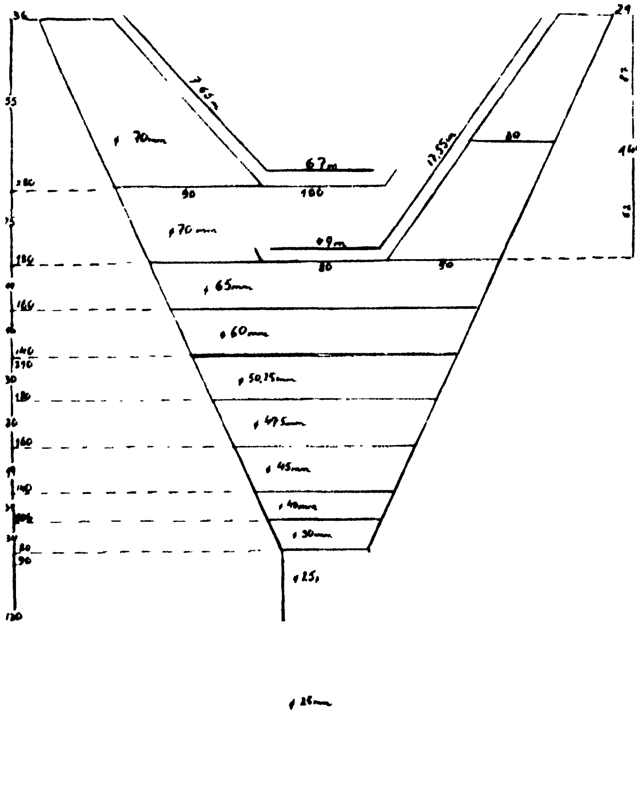


Fig. 4. The Polish Herring trawl net 22/24–72 ft. for large deep sea trawler.

webbing for the same coefficients discussed above. A trawl of such a construction will be inefficient, causing excessive strain in the webbing, or will have a very small vertical opening.

THE POLISH HERRING TRAWL NET 22/24/72 FT. FOR BIG DEEP SEA TRAWLERS

(Fig. 4). The headline length of this net is 22 m., i.e. 6·7 m. for the bosom and 7·65 m. for each wing. The headline is only slightly longer than that of the cutter trawl (with triangles).

Special attention, however, is to be paid to the character and significance of the headline bosom which, in our opinion, is one of the decisive elements influencing the vertical opening of the mouth. Fig. 5 shows the headline with the same three ratios of opening width to headline length (0·5, 0·6, 0·7). The headline is divided into the bosom part, to which the square is attached, and the wing sections. As the trawl has no sidelines, the analysis is somewhat different.

To examine the significance of the bosom for the three coefficients, the quarter points are connected by the straight lines GH, G_1H_1, G_2H_2, thus getting figures GHO, $G_1H_1O_1$, $G_2H_2O_2$, which are characteristic for the opening coefficients 0·5, 0·6 and 0·7 respectively. They differ in height as well as in area. The headline enters into the square to the depth indicated by the curvature of the bosom, thus constituting the actual surplus of webbing in the square, which permits an increase in the vertical opening of the trawl. This value diminishes as the distance between the ends of the wings increases, but it always constitutes a positive, not a

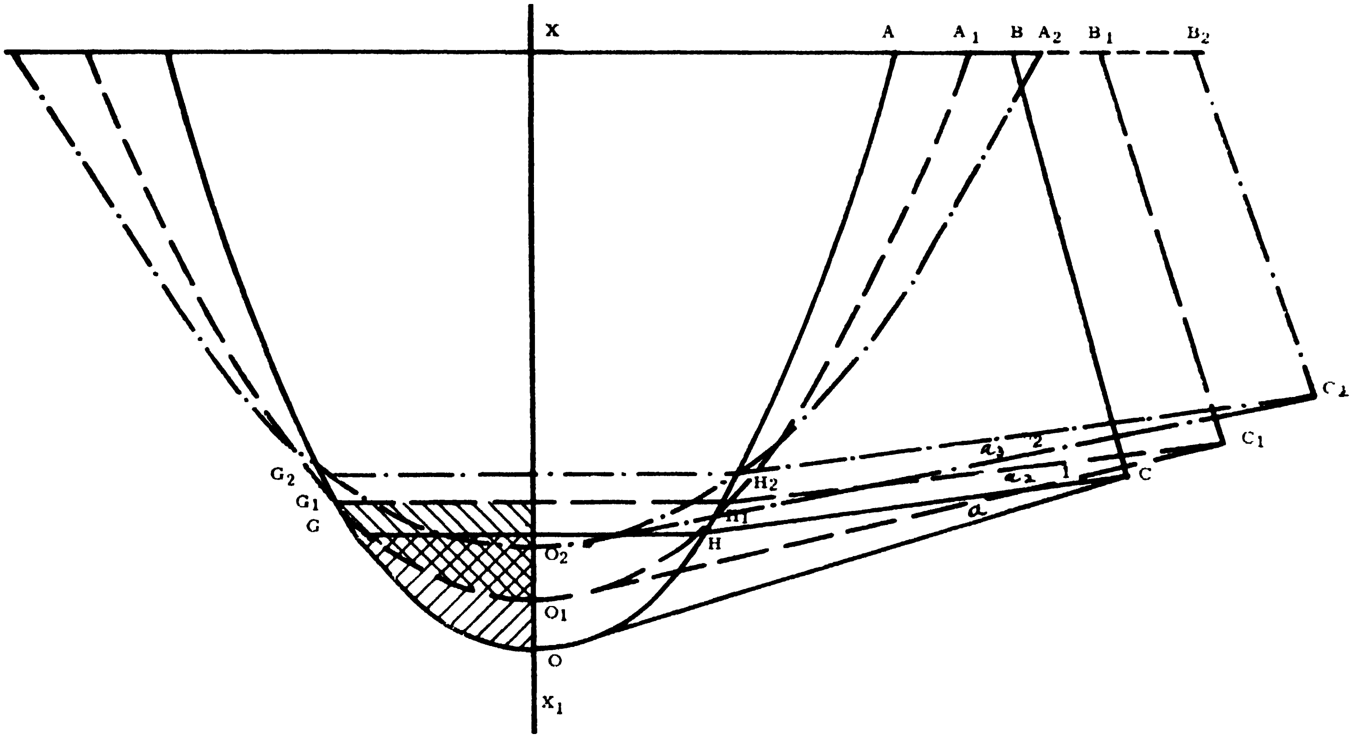


Fig. 5. The importance of the bosom length for the vertical opening at different ratios of opening width to headline length

negative factor. Contrary to the cutter trawls, an adequate vertical opening can be obtained by increasing the length of the bosom part of the headline. The same conclusion will, of course, be reached when reviewing the right-hand part of fig. 5, where the upper wing is introduced.

The dimensions have been defined from the coefficient of the horizontal opening of the headline. Consequently, the coefficient of the horizontal opening of the mesh fixes its length e.g. the coefficient 0·5 corresponds to 0·86, 0·6 to 0·7 and 0·7 to 0·7 (a square).

The straight lines HC, H_1C_1, H_2C_2 correspond to the foundation of the wings, whereas the lines CB, C_1B_1, C_2B_2 indicate the seam edge of the wing. Then we join the centre of the headline (O, O_1 O_2) with the outer end of the foundation of the wing (C C_1 C_2). The angles α, α_1, and α_2 between the foundations of the wing and the latter lines, express the possibilities of extra lift of the headline, which results from the depth of the curvature of the headline and the length of the bosom.

In our opinion the value of these angles is important in the choice of the proper length of the bosom. At various opening widths this value depends on the relation between the width of the whole square (including the bases of the wings) and the length of the bosom part Although we presume that the value of these angles will enable us to a certain extent to calculate theoretically the vertical opening of the mouth, this is a question for the future.

The footrope and the lower section of the webbing of the belly may be treated in a similar way, mainly to keep the footrope to the ground, which also may help indirectly to increase the vertical opening. This can be obtained by proper arrangement of the bosom part of the footrope and by increasing the length of the lower wings in comparison with the top wings. The fact that with herring nets the bosom part of the lower net is shorter than in the square—which is opposite to the arrangement in the trawls for demersal fish—constitutes sufficient proof that the first argument is right. A close contact to the ground is not needed in the herring trawls.

THE MOUTH OF THE TRAWL

by

JACK PHILLIPS

Managing Director of Phillips Trawl Products Ltd. of Grimsby, England

Abstract

Since it is the amount of fish in the codend that matters to a fisherman, nothing can be more important than to discover how best to fill the codend in the shortest possible time. There are many factors concerned in this, but one of the important ones must be the size of the mouth of the trawl, and this paper shows the necessity for raising the headline without its being restricted by the lateral pull of the doors etc. The development and application of the Trawl-plane for lifting the headline is described, and, by carrying out hydrodynamic tests in a 600 ft. tank, means of overcoming instability at towing speeds greater than 3½ knots were discovered.

La guele du Chalut

Résumé

Etant donne que c'est en definitive la quantité de poisson capturee dans le cul-de-chalut que intéresse le pêcheur, le point le plus important consiste à trouver le moyen de remplir ce cul-de-chalut dans le minimum de temps. Ce problème comporte un grand nombre de facteurs mais la dimension de la gueule du chalut en est un des principaux, et l'auteur démontre dans cet article la nécessité de hausser la ralingue supérieure sans que ce mouvement soit contrarié par la traction latérale des plateaux, etc. Il fait un exposé de la mise au point et de l'application du Trawl plane destiné à soulever la ralingue supérieure, et montre comment des essais hydrodynamiques entrepris dans un bassin de 180 mètres de long ont permis de trouver le moyen d'éliminer les phénomènes d'instabilité qui se manifestaient aux allures de chalutage supérieures à 3.5 noeuds.

La boca de una red de arrastre

Extracto

Como el interés de los pescadores es la cantidad de pescado en el copo, nada tiene mayor importancia que descubrir la manera de llenarlo en el menor tiempo posible. Aunque hay muchos factores relacionados con este asunto, uno de los más importantes debe ser el tamaño de la boca de una red de arrastre. Por este motivo, se demuestra la necesidad de elevar la relinga de boyas sin que lo impida el tirón lateral de las puertas, etc. En el trabajo, ilustrado con bastantes fotografías, también se describe el perfeccionamiento y uso de planos de elevación para hacer subir la relinga superior y los descubrimientos hechos mediante ensayos hidrodinámicos en un estanque de 600 piés (183 m.) a fin de evitar su inestabilidad con velocidades de arrastre superiores a 3 1/2 nudos

IN trawling, there is an old and often-quoted saying: "It all comes out of the codend". What, therefore, can be of greater importance than to discover how best to fill the codend with fish in the shortest possible time?

RAISING THE HEADLINE

The catch assembled in the codend has to enter first at the mouth of the trawl so that the larger the area of the mouth of the net, the more chance there is of catching fish. The example, given in figs. 1 and 2, illustrates this problem. Fig. 1 shows a packet of 20 cigarettes open at one end, exposing its contents; fig. 2 shows the same packet, but because the top edge has been raised, its capacity has been almost doubled. Note that it has been possible to insert no less than 17 additional cigarettes, without any structural alteration to the packet itself. This must indicate the importance of the fact that the vertical plane is more essential than the horizontal for high swimming fish and the height of the headline has a more direct bearing on the potential catching power than the spread caused by the trawl doors or otter boards

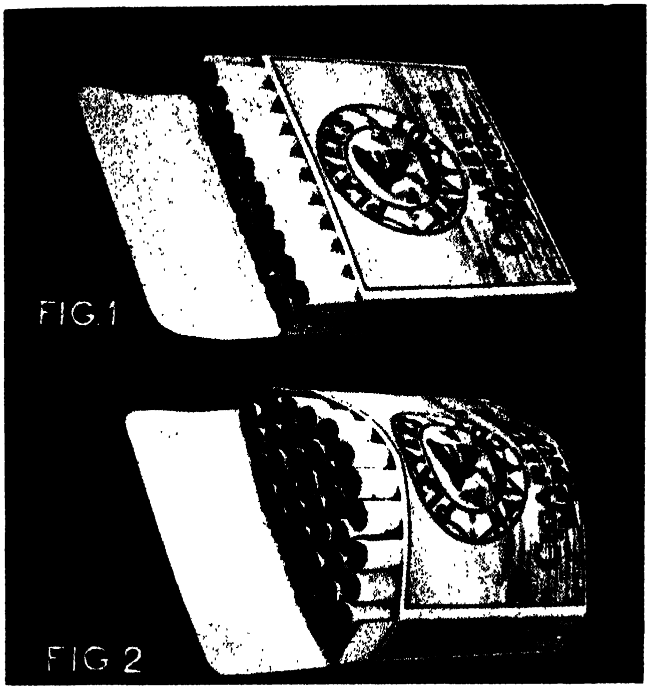
At low towing speeds the lateral spread does not appear to restrain the lift of the headline, but there is a tendency today for the more powerful trawlers to tow their gear at higher speeds. This gives more spread of the otter boards, making it necessary, in the case of the Granton trawl, to shorten the side line in order to overcome this tendency. (The shorter side line should be made of combination wire rope to withstand the additional strain.)

Having once ensured that the headline is free to rise to its maximum extent at all towing speeds, it is then a question of selecting the most suitable method of achieving this. There are two major factors concerned with this problem of raising the headline:

(i) the forces involved
(ii) the towing speeds.

THE FORCES INVOLVED

Fig. 3 illustrates these factors in the case of a float. Lift represents the total vertical component—being a force consisting of buoyancy and hydrodynamic upthrust, the



Figs. 1 and 2. Illustration of the effect of headline lifting.

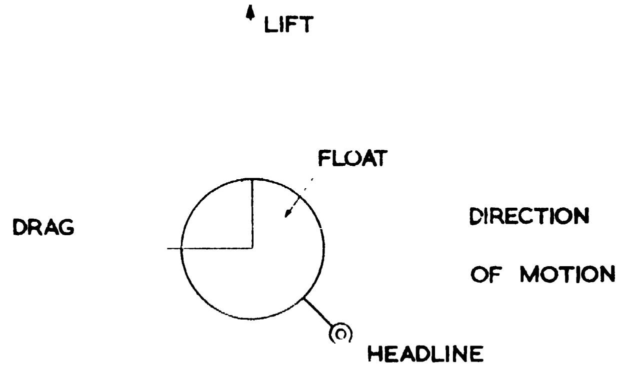


Fig. 3. Forces involved.

latter being generated by the passage of the submerged floats through the water. Drag is the horizontal component of the force generated by the passage of these floats. The lower the drag can be made for a given lift, the less the headline will be distorted backward and the greater the lifting result will be. Both these factors are influenced by the speed of tow. Hydrodynamically, all submerged objects in motion have critical speeds and when the drag force thus created overcomes that of lift, stalling

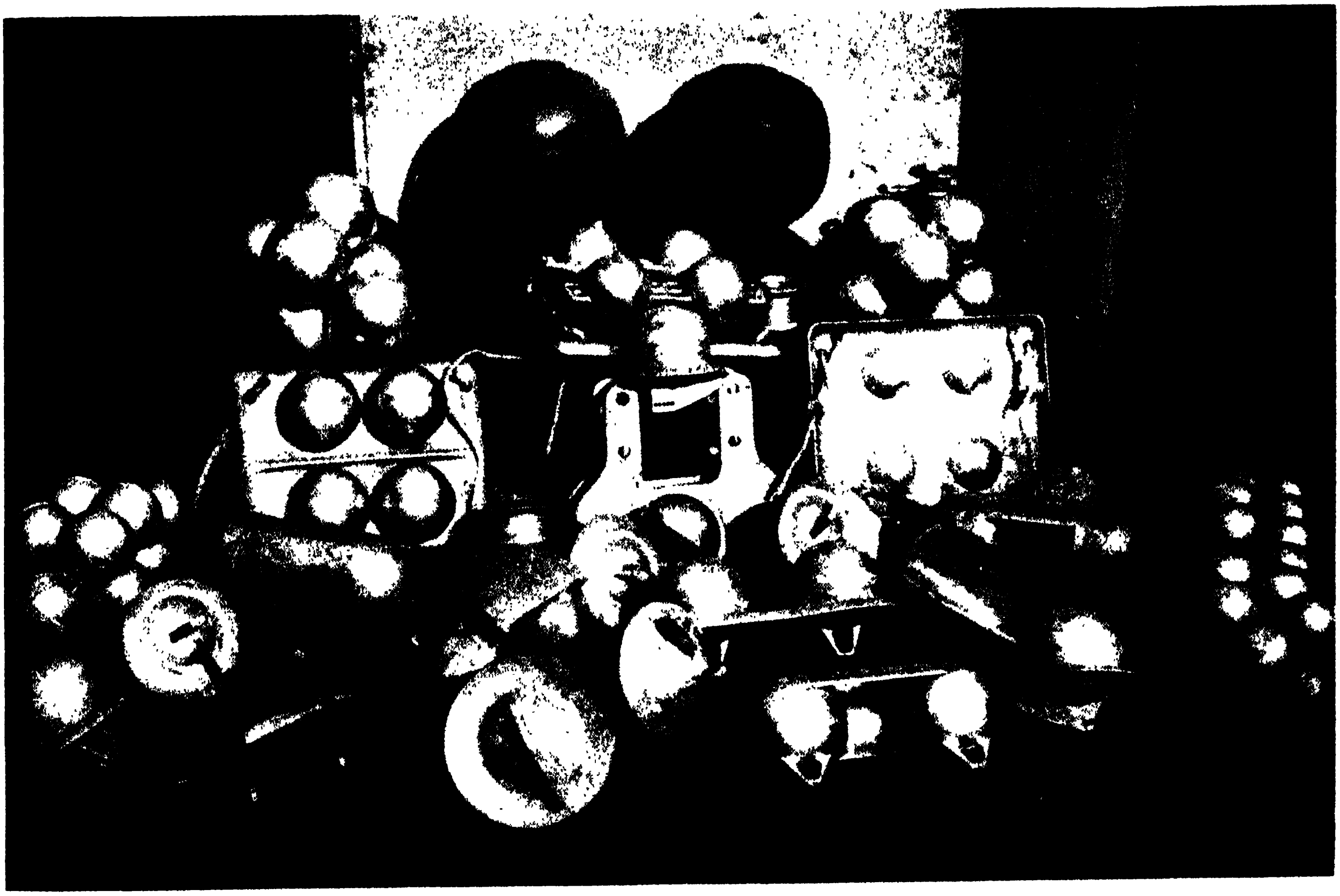


Fig. 4. Floats and kites used in hydrodynamic tests.

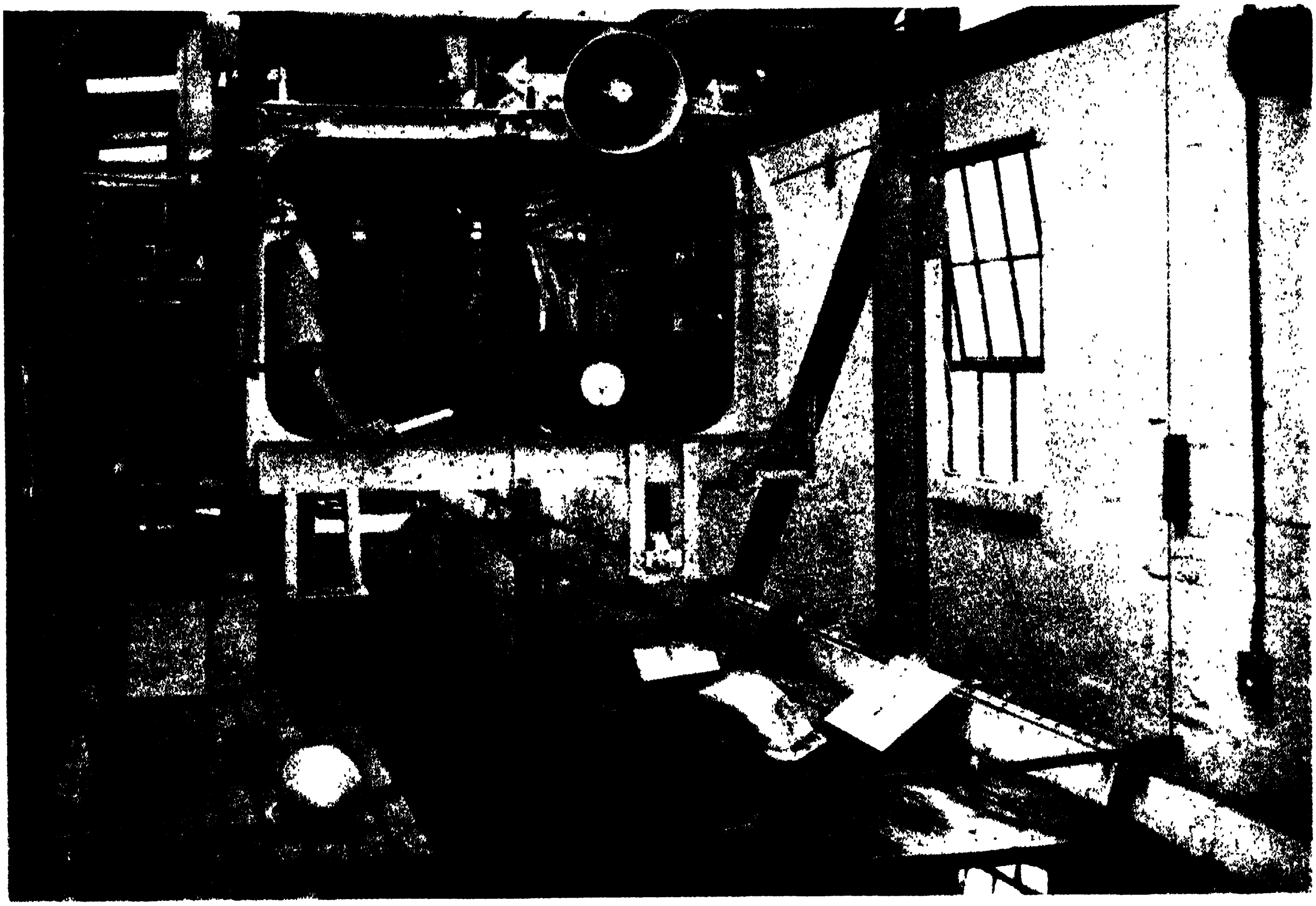


Fig. 5. Observation Cabin and Testing Tank.

is inevitable. This causes instability and violent oscillation, so that the float or elevating component becomes useless.

Fig. 4 illustrates a variety of experimental buoyant kites or elevators upon which hydrodynamic tests have been made, and their performances carefully recorded. Such considerations as simplicity of manufacture, external hydraulic pressure exerted on floats when submerged to great depths, easy handling and freedom from fouling the net, must all be borne in mind. Obviously a spherical float is better able to withstand external hydraulic pressure than floats of other shapes. Its static buoyancy depends on its own weight subtracted from the weight of the water it displaces.

By arrangement of suitable and carefully placed annular foils, partially or completely surrounding a spherical float, a substantial upthrust is obtained, giving a high lift/drag ratio which ensures the headline being elevated vertically, with the minimum distortion in the backward plane.

SPEEDS OF TOW—UNDERWATER OBSERVATION

Photographs and observations of frogmen watching gear being towed have answered many questions about the shape and behaviour of the net. These reports have, however, proved misleading when concerned with performances of floats towed at normal commercial speeds as, for obvious reasons, it was essential for the gear to be towed slowly during photographic operations. There is, for example, the experience of the Trawl Plane Float. Action photographs showed the Trawl Plane to be stable and efficient at that particular speed of tow and, thus encouraged, the Trawl Plane Float was assumed to be capable of functioning efficiently under all conditions. However, when the floats were put to use in commercial fishing, very varied opinions were expressed by the fishermen—some skippers criticising, others praising, while some, who had initially been satisfied, became critical when they changed to newer ships.

FURTHER RESEARCH TANK TESTS

The Hydrodynamic Section of Messrs. Saunders Roe, the aircraft manufacturers of Cowes, Isle of Wight, who have facilities for carrying out hydrodynamic tests, assisted in finding the solution to this problem. Their electronically controlled recording and observation cabin, and the rig used for testing the floats in the 600 ft. tank, are shown in figs. 5 and 6.

A programme for testing many varying types was de-

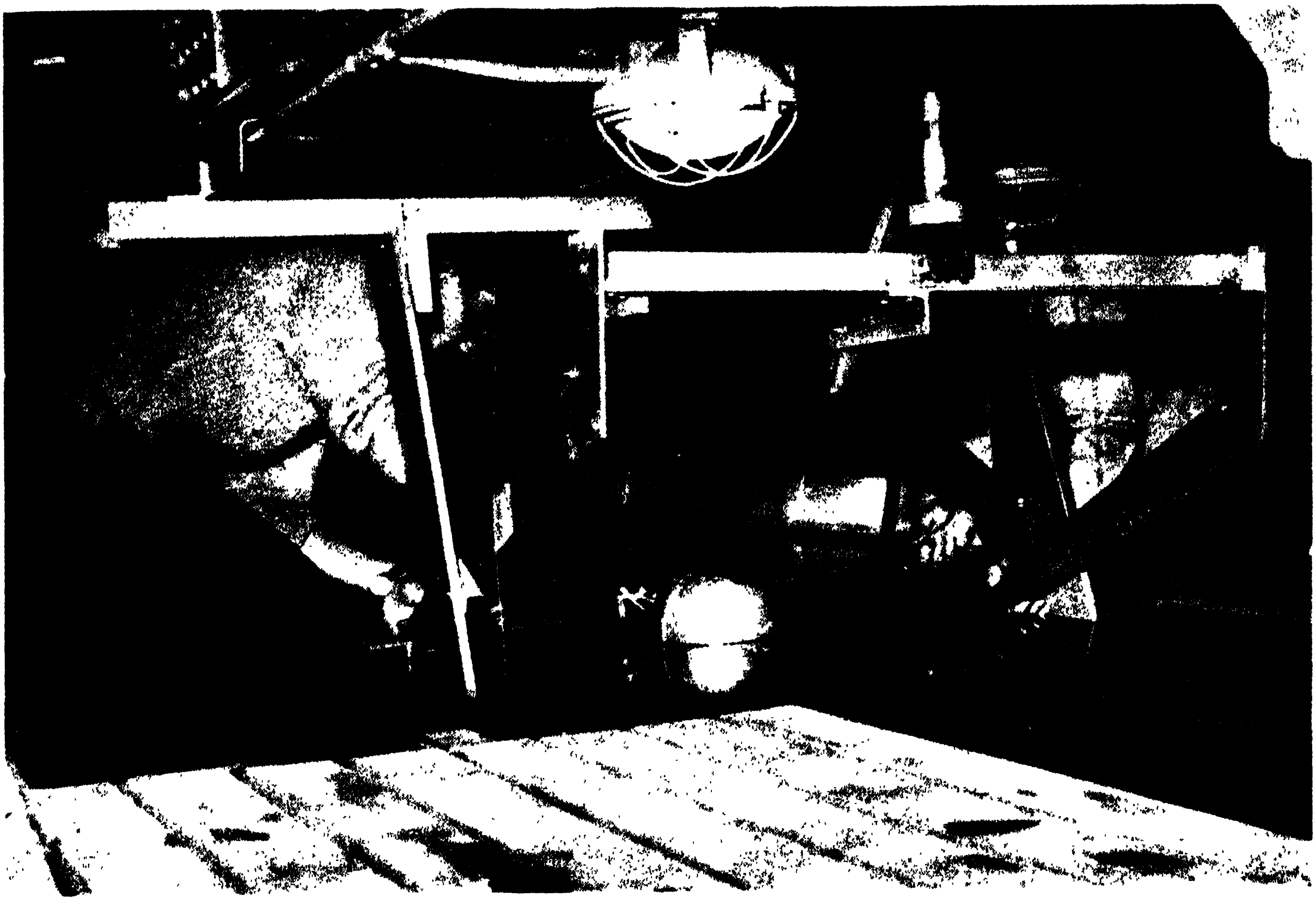


Fig. 6. Testing Rig.

Fig. 7. The new Upthruster float for high towing speeds.

cided upon, and the first task was to clear up the mystery of the inconsistent reports received on the performance of the floats. The tank tests began at 3 knots, at which speed the Trawl Plane Float behaved with complete efficiency. When the speed of tow was increased to 3·1/2 knots, both stability and efficiency were maintained during acceleration but, on reaching the speed, an indication of instability was noticeable. A trial at 4 knots revealed that the behaviour of the Trawl Plane altered completely; it became so unstable that the test run had to be abandoned to prevent the rig being damaged. These antics and oscillations were caused by the drag force overcoming the lift force.

LATEST DEVELOPMENTS

It is evident that optimum performance can only be achieved from floats or kites when a high lift/drag ratio is obtained. (The tests on the original Trawl Plane tended to show that this ratio was less than unity.)

The necessary adjustments were then made to enable the Trawl Plane to operate efficiently at speeds of tow beyond 6 knots. So recent, however, are these experiments that at the time of the Gear Congress, the modified float was not available for general commercial use, as the tooling up and die-making involved had yet to be completed.

Fig. 7 shows the fast towing hydrofoil float called the "Upthruster". When towed at 5·1/2 knots this float has a lift equal to ten ordinary spherical floats and the drag factor is only equivalent to three such floats and has now been tank tested up to 10 knots with perfect stability. The performance of this new float has been much improved by extending the stabilizer until it merges with the trailing edge of the flap to which it is attached, ensuring turbulent flow to eliminate a vortex forming in the float's wake as it passes through the water, and is largely responsible for the satisfactory drag factor.

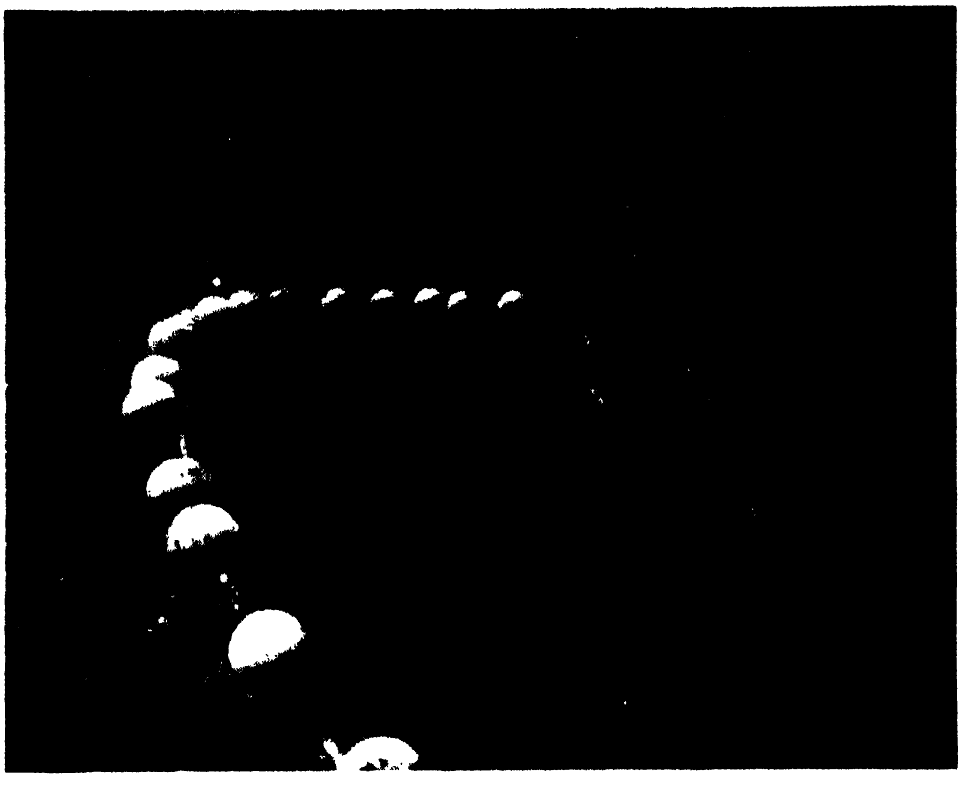
A further feature which contributes largely to its efficiency is the slotted flap on the trailing part of the foil; this controls the angle of incidence preventing the float from stalling at the high speeds sometimes experienced when shooting the gear.

The handle attachment is designed in such a way that a simple form of attachment is to thread a line or combination rope in and out of the handle forming a string of such floats which in turn can be readily lashed to the headline between each float, see fig. 8.

Fig. 8. Upthruster floats attached by simply threading a rope in and out of the handles.

To ensure that the float's stabilizer does its work properly and the float is free to function, it is desirable to leave freedom for each float to move unhampered when lashing the string of floats to the headline. An easy way of accomplishing this is after threading the line through the handle, pass the loop completely over the float forming a knot under the handle, making it impossible for the float to slide sideways along the line and giving it ample freedom to work. Alternatively, when lashing the string of "Upthrusters" to the headline it is important to leave ample play between the floats to enable them to move freely and take up unhampered their working position when in use.

Whilst this is as far as we have gone at present, two additional modifications to the design are being carefully investigated and which show promise of even greater efficiency being accomplished.



Underwater picture of the headline of a trawl with floats attached, from the film, "The Trawl in Action".

A LARGE-SIZED EXPERIMENTAL TANK OF TWIN SYMMETRIC ELLIPTICAL CIRCUITS

by

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Abstract

In this paper, the authors describe the general construction and performance of the large-sized experiment-tank set in the Faculty of Fisheries, Kagoshima University, which is much cheaper and gives better performance than the traditional towing tank for measuring resistance of fishing nets and fishing ships etc. in fluids.

Especially they explain the homogeneous speed field in the waterway of the tank which can be controlled more easily than with the old circulating tank, by moving the current blades horizontally, the vertically set wire netting, and the adjustable lip of the suppressor of wave motion.

Un grand bassin expérimental composé de circuits elliptiques symétriques jumelés

Résumé

Dans cette communication, les auteurs décrivent la construction générale et la fonctionnement du grand bassin d'expériences installe a la Faculté des Pêches de l'Université de Kagoshima, qui est bien meilleur marché et donne de meilleurs résultats que le bassin actuel à remorquage pour mesurer la résistance des filets de pêche, bateaux de pêche, etc., dans les fluides.

Ils expliquent en particulier comment le champ de vitesse homogène dans le canal d'essai du bassin peut être contrôlé plus facilement qu'avec l'ancien bassin à circulation en déplaçant horizontalement la lame de l'impulseur et au moyen des écrans verticaux de treillage métallique et de la lèvre réglable de l'effaceur de vagues. Ces derniers dispositifs ont été introduits par les auteurs après deux ans d'essais effectués dans le bassin.

Estanque experimental de gran tamaño provisto de los circuitos gemolos simétricos y de forma eliptica

Extracto

En este trabajo los autores describen la construcción general y rendimiento del juego de estanques experimentales de gran tamaño pertenecientes a la Facultad de Pesca de la Universidad de Kagoshima, el cual es mucho más barato y permite obtener major resultado que los estanques de experimentación utilizados en la actualidad para medir la resistencia de las redes y barcos de pesca, etc., en los líquidos.

Los autores explican especialmente la manera de alcanzar un campo de velocidad uniforme en la sección de ensayos del estanque, más fácil de regular que en el antiguo estanque moviendo la hoja que ataca horizontalmente corriente, la rejilla de alambre dispuesta en sentido vertical y la paleta regulable del supresor de olas, que fueron introducidos por los autores después de dos años de ensayos en dicho estanque.

THE accuracy of model tests on fishing nets depends especially on the similarity of twine characteristics of real and model net.

The tank itself must be large enough to allow the use of models having a construction similar to the full size prototype. In the present case, a large-sized tank having a two-metre wide waterway, was constructed for the experiments.

CONSTRUCTION OF THE CIRCULATING TANK

The tank consists of twin symmetric elliptical circuits 14·0 m. long, 7·1 m. wide and 1·0 m. deep, constructed of ferro-concrete (fig. 1).

The central waterway is 2·0 m. wide and the right and left waterways are 1·0 m. wide. The water flows symmetrically into the central section, forming a straight waterway for making tests, then branches off at the lower end to circulate further.

Paddle wheels of 2·5 m. diameter and 1·0 m. width, with 24 radial blades are set on each side of the waterway. They are driven by a varislip A.C. motor of 10 h.p. which is automatically regulated and remote controlled The resultant flow of water is symmetrical and easily adjustable.

The maximum speed of flow is 0·8 m./sec. which can be increased by decreasing the depth of water.

Observation windows, 2·0 m. long and 1·0 m. wide, are set in the right and left side walls of the central waterway and measurements and photographs can be taken through them.

The flow of water round the curves of a circulating tank is slower on the inside and faster on the outside of the curve. The flow near the walls and the bottom of the tank is decreased by drag due to the viscosity of water. To equalise the flow, current plates were fixed at the front of the paddle wheels and at the curves of the waterway. The plates divide the flow into several narrow paths (figs. 2 and 3).

There are also movable current blades at the curves of the tank, and these can control the horizontal speed of flow according to Bernoulli's theorem. Fixed current

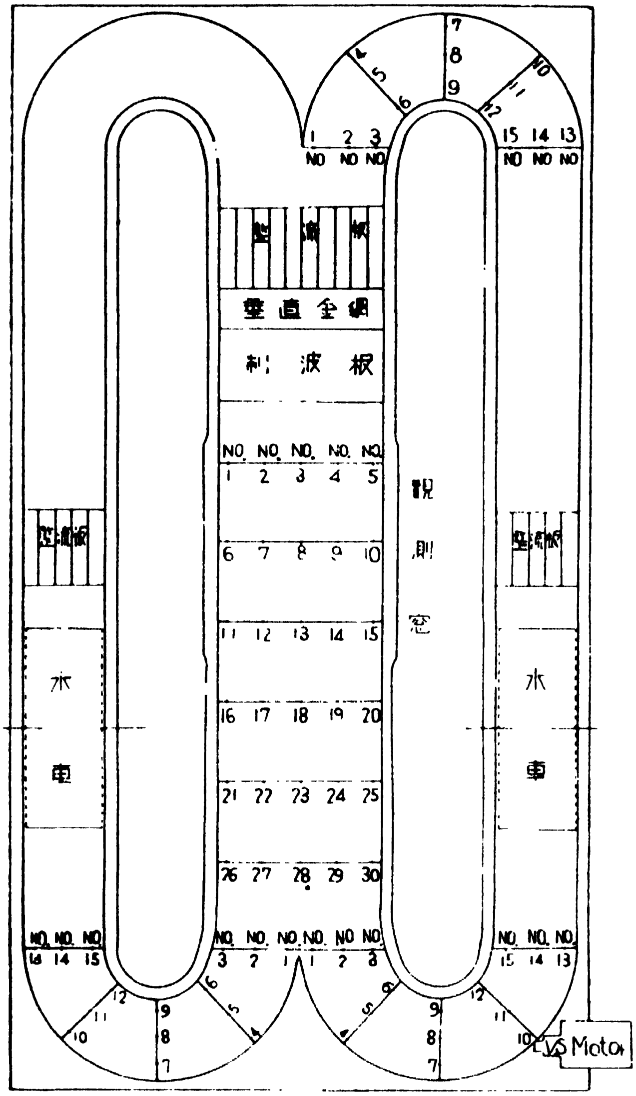


Fig. 1. Top view of the tank with reference points for waterflow measurements.

plates and vertical wire netting in frames of 25 cm. × 200 cm. are set in the lower stream. The mesh size of the wire netting can be adjusted to each speed of flow, while

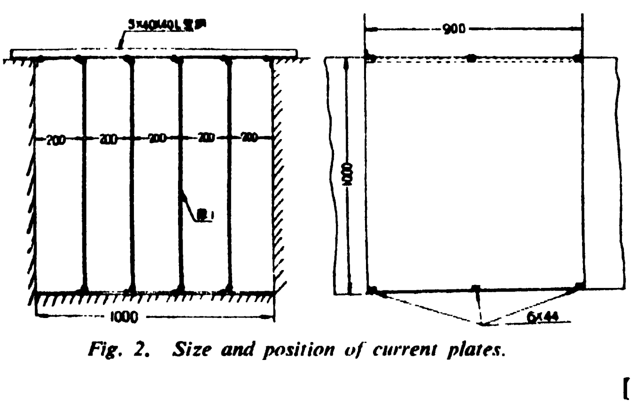


Fig. 2. Size and position of current plates.

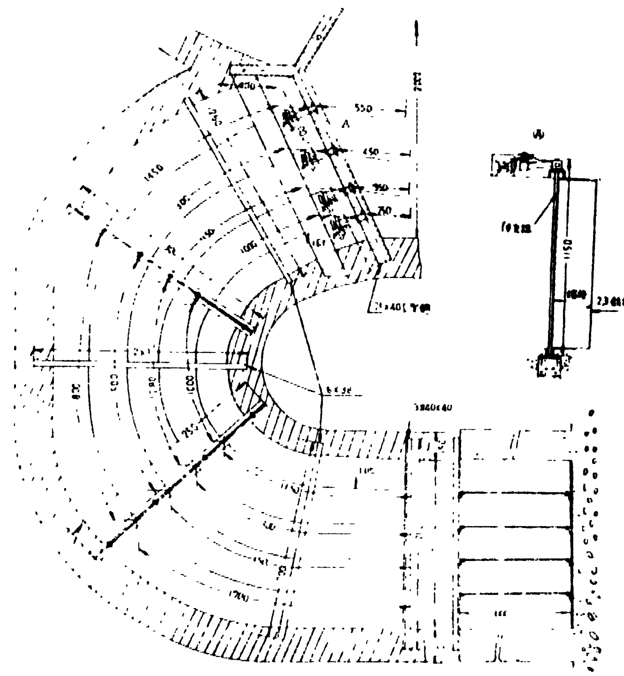


Fig. 3. Position of fixed and movable current plates in the tank.

an adjustable lip is set in the upper waterway as a suppressor of surface waves (fig. 4), thus controlling surface motion.

The carriage, consisting of three parts, moves easily along rails on the top of the sides of the central straight waterway. One part can be moved right and left, or up and down, and has a balance at the centre. Thus the point of resistance measurement is given three dimensional freedom of movement with an accuracy of 1 mm. The frames of the carriage are all made of steel and the dynamometer (the balance) is made of duralumin, according to Froude's system. Resistance is measured by the curve recorded on a revolving drum.

THE GENERAL PERFORMANCE OF THE CIRCULATING TANK

Fig. 1 shows the plan of the tank. The positions for measurement of speed are marked on the parts of the straight waterway. The speed of flow can be examined in

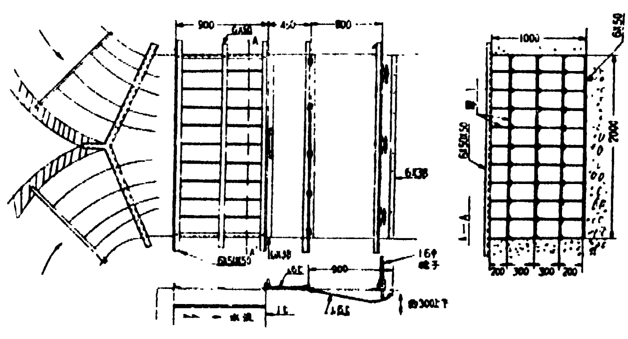
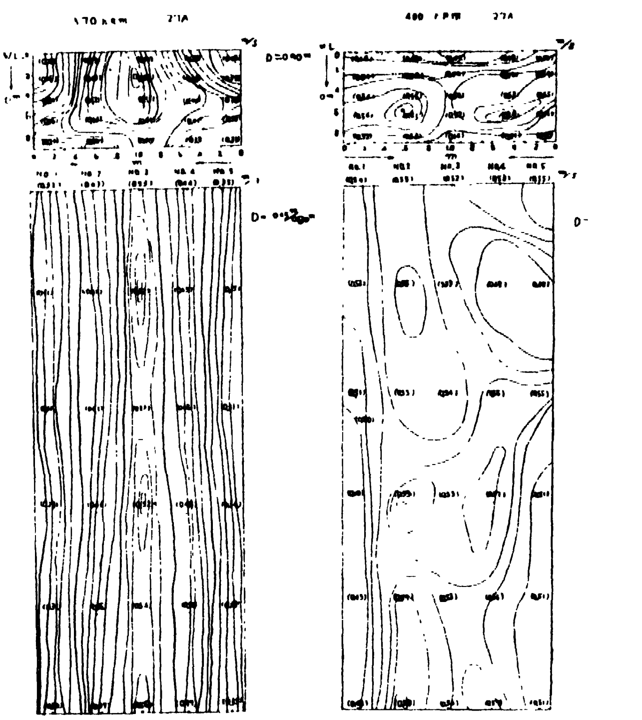


Fig. 4. Position of wire netting frames and wave suppressors in the tank.



Figs. 5 and 6. Distribution of flow speed in vertical (top) and horizontal (below) cross section. Fig. 5 without, fig. 6 with, current plates and wave suppressors

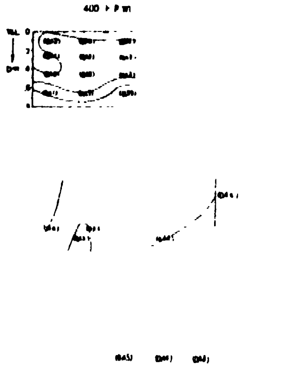


Fig. 7. Distribution of flow speed in vertical (top) and horizontal (below) cross section when wire net frames are used in addition to current plates and wave suppressors.

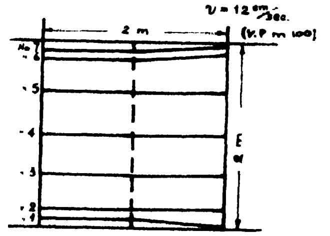


Fig. 8. Distribution of surface flow lines at low speed of the paddle wheel.

three dimensions, through 6 steps in the direction of length, 5 steps in the direction of breadth (7 steps later, including two supplementary steps right and left) and 5 steps in the direction of depth.

The current was measured with the "Hiroi" current meter. With no current blade and no suppressor of wave motion, the speed is maximum at about 0·7 of the water depth. The speed drops suddenly near the side wall and bottom (fig. 5). It can be seen that the homogeneous speed fields in the central vertical plane of the waterway are symmetric. Because of the symmetry of the waterway, a good natural effect is obtained as the water flows through the central section.

When the current blades and wave motion suppressor are mounted, the standard deviation from a homogeneous speed field is 0·04 (mean speed 0·55 m./sec.) (fig. 6). The experiment shows further that at a flow of less than 0·6 m./sec. the water surface is so calm that the wave motion suppressor is not necessary.

Fig. 7 shows that the speed field is more uniform and that the deviation from a homogeneous field is only 0·02 (mean speed 0·43 m./sec.) when the vertical wire screens are also used. The screens are of 3 cm. and 2 cm. mesh size, made of 1·1 mm. wire, and are set vertically in two steps under the surface, from 25 cm. to 50 cm. and from 50 cm. to 75 cm. Wire screens were used because control of the speed of flow is made easy in a comparatively shallow tank by the fluid resistance of the webbing.

The speed of flow becomes difficult to control when it increases beyond a certain limit, because the resistance of the net is proportional to the square of the mesh size. Therefore, the mesh of the net had to be enlarged when the mean speed in the tank was greater than 0·4 m./sec. At lower speeds, it is very easy to control the speed of flow accurately. As a rule the homogeneous speed field in the waterway can be set by controlling the r.p.m. of motor.

When the depth of water is constant, the r.p.m. of the motor is proportional to the rate of flow and the distribu-

TABLE I

(i) Relation of motor revolutions to deviation of equi-velocity distribution when current plates and wave suppressors are fixed

r.p.m.	*400*		*300*		*250*		*500 (without wire net)*	
Average velocity deviation	*Vm/s*	*S*	*Vm/s*	*S*	*Vm/s*	*S*	*Vm/s*	*S*
depth								
0·05 m.	0·43	0·017	0·32	0·017	0·26	0·020	0·63	0·033
0·225	0·44	0·010	0·33	0·010	0·27	0·013	0·66	0·033
0·40	0·43	0·011	0·32	0·011	0·26	0·010	0·60	0·044
0·575	0·42	0·010	0·31	0·010	0·25	0·010	0·52	0·034
0·75	—	—	—	—	0·22	0·027	0·52	0·041

(ii) Vertical section of velocity deviation

r.p.m.	*400*		*300*		*250*		*250**	
Average velocity deviation	*Vm/s*	*S*	*Vm/s*	*S*	*Vm/s*	*S*	*Vm/s*	*S*
Vertical section								
1	—	—	—	—	—	—	—	—
2	0·43	0·015	0·32	0·011	0·26	0·020	0·27	0·016
3	0·43	0·008	0·31	0·006	0·26	0·022	0·27	0·013
4	0·43	0·021	0·33	0·022	0·25	0·041	0·27	0·018
5	0·44	0·014	0·32	0·012	0·26	0·013	0·27	0·011
6	0·43	0·023	0·31	0·018	0·25	0·018	0·26	0·012
7	—	—	—	—	—	—	—	—

(iii) Horizontal section of velocity deviation.

r.p.m.	*400*		*300*		*250*		*250**	
Average velocity deviation	*Vm/s*	*S*	*Vm/s*	*S*	*Vm/s*	*S*	*Vm/s*	*S*
Horizontal section								
1	0·43	0·014	0·32	0·016	0·25	0·025	0·26	0·016
2	0·43	0·018	0·32	0·014	0·25	0·026	0·26	0·015
3	0·43	0·019	0·32	0·013	0·26	0·022	0·27	0·013

*In this calculation the velocity of flow at D=0·75 m. is omitted.

tion of water speed in the tank is uniform at all points.

When the motor revolves very slowly, the flow line of the surface water layer deviates about 1 per cent. inwards, being influenced by the hollows at the windows in the side walls. The flow lines are perfectly parallel to each other, so there is no disturbance to the model under experiment (fig. 8).

Table I shows the relation between the r.p.m. of the motor and the deviation when the current blade, wave suppressor and wire netting are used.

Table II shows the time necessary (17 mins.) for the speed of flow to become constant and uniform after starting the motor. After that, no change of speed is apparent. If an experiment is made within 7 mins. of starting the motor, an error of 3 per cent. should be allowed on resultant measurements.

TABLE II

Time required before speed is constant and uniform after the motor is started.

Point of measurement	*No. 4*		*No. 11*		*No. 18*	
Velocity	*Sec.*	*V m/s*	*Sec.*	*V m/s*	*Sec.*	*V m/s*
Time required						
7 min.	18·0	0·34	17·8	0·34	17·8	0·34
12	17·6	0·34	17·6	0·34	17·4	0·35
17	17·2	0·35	17·2	0·35	17·2	0·35
22	17·0	0·36	17·2	0·35	17·4	0·35
27	17·0	0·36	17·4	0·35	17·0	0·35

Trawl boards and wingdoor designed by K. H. Larsson (Sweden) based on model tests

MIDWATER TRAWL DESIGN BY UNDERWATER OBSERVATIONS

by

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Abstract

Underwater observations and evaluations of the Larsson *Phantom Trawl* and others are described. Direct observations of the fishing gear in operation were obtained by the use of underwater television and divers with cameras. By means of modification and refinement a practical midwater trawl was developed for use by American fishing vessels. The resulting net has been used by research vessels and also commercial fishing boats of 200 to 750 h.p. and, at speeds between 2 and 5 knots, catches ranging from 5,000 to 20,000 pounds have been taken.

Utilisation des observations sous-marines dans le dessin du chalut flottant

Résumé

L'auteur se fonde sur les observations effectuées sous l'eau pour évaluer le comportement du chalut Larsson, type *Phantom*, ainsi que d'autres types de chaluts. Des observations directes des engins en fonctionnement ont été obtenues par des appareils de télévision sous-marine et des plongeurs munis d'appareils cinématographiques. A la suite de modifications et de perfectionnements, on a mis au point un chalut flottant efficace à l'intention des navires de pêche américains. Ce chalut a été utilisé par des navires de recherche et des bateaux de peche d'une puissance de 200 à 750 c.v. et, à des vitesses de 2 à 5 noeuds les quantités pêchées ont atteint de 5,000 à 20,000 livres.

Uso de observaciones submarinas en el proyecto de redes del arrastre polágicas

Extracto

Se describen las observaciones y evaluaciones submarinas de la red de arrastre Larsson y de otros tipos de artes de pesca. Las observaciones directas de estas redes durante el lance efecutaron e con aparatos de televisión submarina y buzos provistos de cámaras fotográficas. Mediante diversas modificaciones y perfeccionamientos se logró construir una red de arrastre para profundidades intermedias, destinada a los barcos de pesca de Norteamémerica. El equipo resultante a sido usado por embaracciones de investigación y comerciales de 200 a 750 c.v. a velocidades que fluctúan entre 2 y 5 nudos, obteniéndose redades de 5,000 a 20,000 lbs. (2,227 a 9,072 Kg.) de pescado

THE recognition of the need for new and improved methods in fishing gear research has resulted in some promising new tools and techniques. In connection with some midwater trawling gear research studies, the United States Fish and Wildlife Service has demonstrated the systematic application of underwater television and divers using self-contained breathing apparatus and cameras as practical fishing gear research instruments

UNDERWATER TELEVISION

Since 1950, the U.S. Fish and Wildlife Service has conducted experimental trials with one- and two-boat midwater trawls. Results from earlier Service work had shown economical and operational advantages in the single boat type, and its continued development was favoured for possible use by American fishing vessels. In May 1954 a Service research vessel carried out some preliminary trials with the Larsson Phantom Trawl in North Pacific offshore waters. Results of fishing performance were inconclusive. The gear was then shipped to the Services Gear Research and Development Unit at Miami, Florida, for further test and evaluation, using underwater television and other experimental methods.

Here Service engineers had successfully adapted industrial type closed-circuit television for direct observations of fishing gear in action[4]. By means of progressive experiment and refinement of equipment a remotely controlled submersible vehicle was developed for the television camera[5].

In November 1954, a joint cruise of the Service research vessels *Oregon* and *Pompano* made the first practical use of underwater television in fishing gear research, with the Phantom Trawl as the subject to be viewed. While under tow in clear Gulf Stream waters, the trawl warps, doors and net opening were observed by a television camera streamed between the *Oregon's* towing warps. A second television camera was streamed from the *Pompano* to make simultaneous lateral observations of the gear. Still picture and kinescope recordings were made of the entire operation.

The first tests were made with the gear rigged as originally received from Sweden: cotton trawl, hydrofoil floats and depressors, aluminium floats, hydrofoil doors and 30 fathom manila towing legs with danlenos. Previous trials had established that this gear did open to an estimated 30 feet or more, but that it was unsatisfactory to tow the trawl at 3·0 knots and even below this speed. The heavy drag caused continued tearing at sudden speed variations or full vessel power[3]. With 50 fathoms of cable from vessel to net, the trawl was now seen well below the propellor wash at speeds below 3 knots. At a speed of 2·0 knots, the monitor screen revealed the trawl doors, warps, and net mouth to be quite stable in the water with the trawl in an approximately 20 feet square opening, and the headline rising in a gentle arc. A close-up camera lens revealed the terrific stress on the twine in a rigidly appearing trawl mouth. Most of the patent trawl floats had been cleared only with difficulty and those still fouled were seen to produce uneven stress on the twine. While the patent hydrofoil floats on short pennants performed well, a slight tendency to oscillate suggested turbulence particularly at wing tips. This was remedied by tying off the floats close-up. Round aluminium float performance seemed most satisfactory in comparison. Increases in speed up to the 3·0 knot limitation resulted in the estimated 30 feet horizontal spread with, however, a *closing* of vertical opening. This had been suspected in previous sounding tests, but not confirmed until registered on the television monitor.

In another trial the 30 fathom manila towing legs and danlenos were replaced by ⅜ in. wire cable and dandy-line gear to facilitate handling. Observers noted no appreciable change in net performance except that the trawl fished slightly deeper in the water and tended to close at the lower wings. This was remedied by adding one fathom of cable at each lower towing leg. No marked losses of horizontal or vertical spread could be attributed to the removal of the danlenos. There followed various substitutions and arrangements of floats, leads and depressors, in an effort to attain the desired vertical trawl opening at 2·0 to 3·0 knot speeds. With the use of adequate weights and depressors, the desired vertical opening was obtained, but at the sacrifice of horizontal spread in each case. Although the hydrofoil trawl doors had handled and performed well, they were replaced with standard type trawl doors of equal and of larger sizes in an attempt to improve performance. Apparently there was no appreciable change in the trawl opening.

Most noticeable to all observers during these trials was the evidence of continued heavy drag and extreme "sweep back" of head, breast and leadlines at all test speeds. Completely absent during all television observations was any appearance of the net acting as an inflated body containing a volume of water exerting a pressure on the twine.

It was indicated to observers that, due to the excessive drag, the trawl could not be opened to its maximum designed displacement without some structural modification.

DIVING SLED AND CAMERA OBSERVATIONS

Through 1955, experimental trials with the modified Phantom Trawl continued in clear Florida Gulf Stream waters, subject to observations by underwater television, surface water glasses and divers using a towed diving sled and camera gear. A diving sled was made by converting a tubular steel ambulance litter for use when underwater television observations were not feasible[6]. This device was equipped with elevator controls to permit manoeuvrability. It provided a large degree of comfort and protection for the pilot-observer and cameraman diving team while under tow from the research vessel. The diving sled permitted first-hand observations and photography of all aspects of the trawl performance from various angles, to detailed inspections in actual contact with the fishing gear.

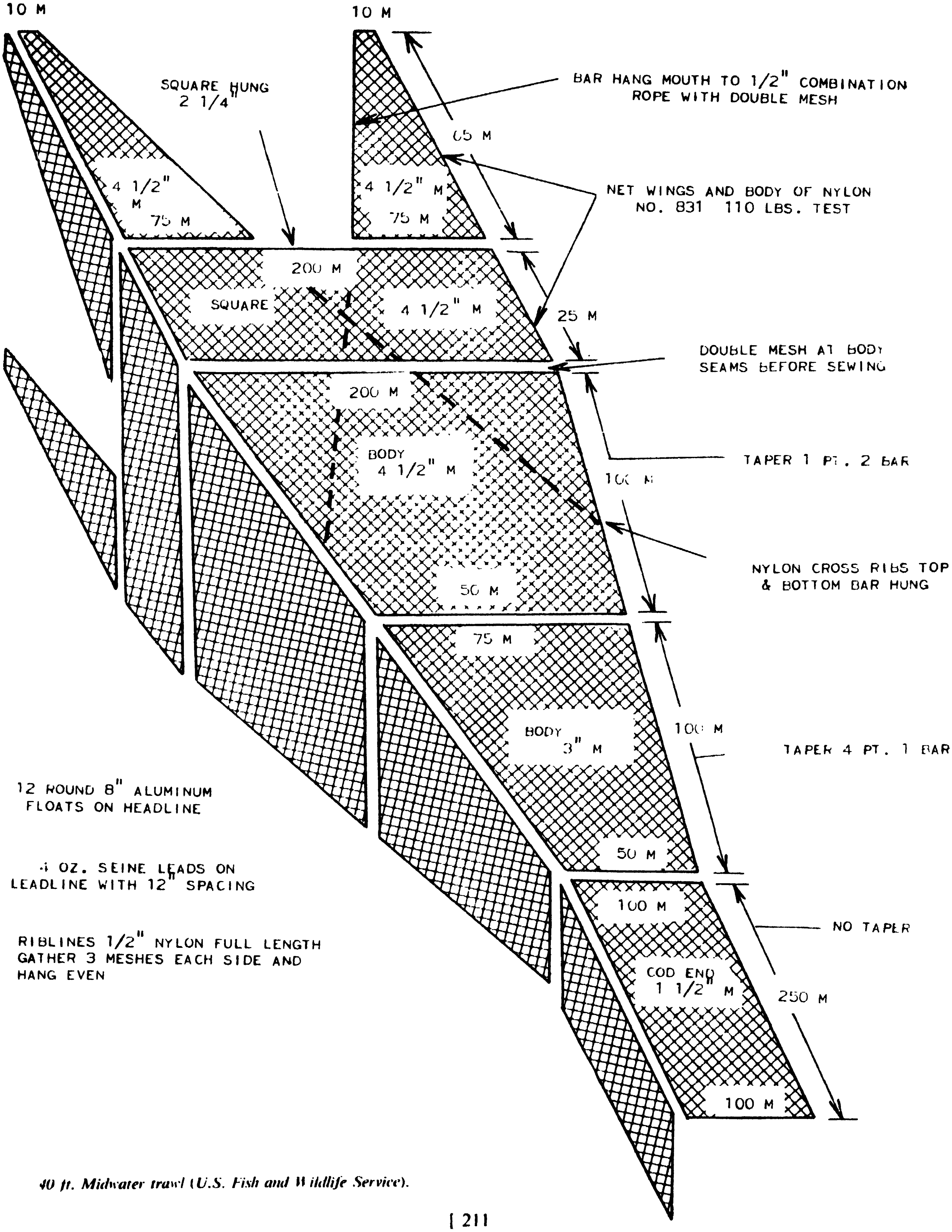
During some 20 towing observations at speed and depth ranges proximating the previous television trials, various trawl modifications and accessory rigs were considered separately and in combination. Since in the previous trials the trawl performance had not been seriously affected by open or closed codend, emphasis was placed on reducing resistance at the trawl mouth. Progressively the net wings were shortened, body length was reduced and trawl hanging and headline increased to enlarge the proportion of the net square dimension to the length. These were effected with no real improvement apparent to observers. The first indication that the gear was opening in a better manner was not obtained until head, breast- and leadlines were reduced by about one-third in diameter and the number of floats and weights reduced by one-half.

When quarter doors or kites of equal area were affixed at the four wings in the same angle of attack as the trawl doors, greater trawl opening was achieved but drag and turbulence on wings greatly increased. In a similar manner, triangular pieces of heavy canvas attached to the wing extremities failed to assist trawl opening due to low attack angle made necessary to reduce drag.

Trials were continued with the net modified to about two-thirds the original size and with trawl doors approximately twice the area of the patented hydrofoil doors. For the first time this net was seen to open to an estimated 90 per cent. of the possible mouth aperture at a 2·0 knot towing speed. At this speed, a bulge or lump in the top square was still seen to cause some uneven distribution of tension on the body twine. This was remedied by removal of two centre aluminium floats and replacement at wing tips. The midwater trawl now was completely inflated as if exerting a pressure from the centre outwards to all points on the twine. Meshes were revealed as taking the desired diamond shape under tension from every angle. That there was an apparent pressure effect within the trawl was determined by physical contact by the diving team who found the net rigid yet malleable—and capable of partially supporting a 50 pound lead weight placed upon the twine. With reduced towing speed below 2·0 knots, there was evidence that the net opened, more as a result of resistance to the water than as the result of lift by the floats. This was accompanied by some apparent transfer of towing strain to rib lines. Strong evidence had now been presented showing the need to restrict future midwater trawl construction to materials of higher strength and lower drag characteristics. Also, this demonstrated the need for float or lead and depressor rigs permitting better trawl opening. Recognised as of vital importance was the extreme need for symmetry in design, exactness in measurement, and careful sewing detail to ensure perfect twine balance.

DISCUSSION OF RESULTS

Within the frame of reference provided by the underwater determinations, an all-nylon 40 foot square opening trawl was constructed (see figure). Particular attention was given to choice of materials, twine sizes and dimensions, geometric configuration and proportions to permit



40 ft. Midwater trawl (U.S. Fish and Wildlife Service).

performance of the net as a turgid elastic body. Final adjustments to trawl and accessory gear were again subject to underwater inspection. The resulting trawl design has performed well in operation from Service research vessels in North Pacific and North Atlantic offshore waters, in open swells and moderate seas with 25-30 m.p.h. winds. In fishing trials from vessels of 200 to 750 h.p. at speeds of between 2 and approximately 5 knots, individual trawls have withstood over 100 tows without serious damage attributed to excessive drag from towing strain in taking catches varying from 5,000 to an estimated 20,000 pounds.

There remain a number of variables to be examined and the trawls currently in use are, of course, subject to continued refinement. It is noted also that the general design features compare closely with those of recently introduced Canadian and European midwater gears[1].

For more than four years, the experiments—using conventional gear research methods—were unsuccessful, until the application of underwater television and other experimental methods permitted direct observations of fishing gear in operation. Continued application of these valuable techniques should assist materially in removing a great barrier to research in fishing methods and equipment.

REFERENCES

[1] Barraclough, W. E. and W. W. Johnson. A New Midwater Trawl for Herring, Fisheries Research Board Canada Bulletin No. 104, 1956, 25 pp.

[2] Margets, A. R. Some Conclusions from Underwater Observations of Trawl Behaviour, World Fishing, August 1952, pp. 61-65.

[3] Richardson, I. D. Some Problems in Midwater Trawling, World Fishing, February 1957, pp. 26-31.

[4] Sand, R. F. Use of Underwater Television in Fishing Gear Research (Preliminary Report) U.S.F.W.S., CFR., Vol. 17, No. 4, 1955, pp. 1-5.

[5] Sand, R. F. Underwater Television Vehicle for Use in Fisheries Research, U.S.F.W.S., SSR. No. 193, December 1956, 15 pp.

[6] Sand, R. F. New Diving Sled, U.S.F.W.S., CFR., Vol. 18 No. 10, 1956, pp. 6-7.

Skindiver team of Coral Gables preparing for trawl observations.

STUDY OF THE MEDITERRANEAN TRAWL NET

by

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Abstract

This paper deals with an attempt to improve the performance of the Italian type of trawl as used in the Mediterranean Sea. Very little progress has been made with this gear because the fishermen considered that it represented the climax of achievement. The author has studied the working of the gear by means of underwater photography and direct observation by divers, and has been able to suggest ways and means of constructing a cheap, strong, and efficient trawl suitable not only for the Mediterranean Sea but also for other areas where the need for higher headlines is of greater importance.

Discussion sur le chalut méditerranéen

Résumé

L'auteur traite d'un essai d'amélioration du rendement de chalut de type italien tel qu'il est utilisé dans la mer Méditerranée. Cet engin a fait très peu de progrès parce que les pêcheurs considéraient qu'il représentait l'apogée de la réalisation, mais l'auteur a étudié le fonctionnement de l'engin au moyen de photographies sous-marines et d'observations directes effectuées par des plongeurs, et il est á même de suggérer des façons et des moyens pour construire un chalut bon marché, robuste et efficace convenant non seulement pour la mer Méditerranée mais aussi pour d'autres régions où il est très important d'avoir la corde de dos plus élevée.

Examen de la red de arrastre del Mediterráneo

Extracto

Este trabajo trata de las tentativas que se han hecho para mejorar el rendimiento de las redes de arrastre de tipo italiano, como las usadas en le mar Mediterráneo. Se ha logrado mejorar muy poco a este arte por considerar los pescadores que ha alcanzado el máximo de perfeccionamiento. No obstante, el autor al estudiar la manera de trabajo mediante fotografia submarina y observación directa valiéndose de buzos, ha sugerido formas y mdeios para construir una red de arrastre barata, resistente y eficaz, apropiada para el Mediterráneo y otras zonas donde tiene gran importancia el empleo de una relinga superior a bastante altura de la inferior.

SINCE the introduction of the otter trawl into the Mediterranean Sea, some thirty years ago, there has been no report whatsoever on the performance of the gear.

Attempts by the fishermen to improve the net have come to a standstill for, according to them, the present trawl gear represents the climax of achievement and any change in its technical pattern is unnecessary.

To provide at least a part of the required information, underwater photographs were taken of the Italian type trawl net in action, typical of those used in Israel and southern Italy[13]. Studies were also made of the "Tzofia" type hybrid net, and the "B" type hybrid net [1, 5, 6 and 7]. The observations were concentrated upon the trawl net itself, observations on other parts of the gear being left to the future when financial means would permit the work to continue.

Underwater measuring instruments, as used by De Boer[9] and Schärfe[20], were not available for this survey, so that assumptions and conclusions cannot be based on exact measurements. The numerous photographs, however, and the direct observations of the divers give, at least, a general picture of the shape and behaviour of the nets in action.

THE TRAWLER

The underwater observations were carried out in Haifa Bay at a depth of 6 to 7 fathoms. The skin divers attached themselves to the various parts of the net or floated just above it on a diving sled [12, 13].

The observed gear was towed by the F.R.V. *Hatzvi*, a Danish built wooden boat of Scandinavian type with 120 h.p. engine and converted to stern trawling.

THE GEAR (OTHER THAN NET)

The differences between the examined and the commercial trawl gear were as follows :

The warp was of 10 mm. ø steel wire, 100 m. long, and appeared to be proportional to the depth (under normal conditions 250 m. at 20 fathoms and 200 at 15 fathoms are used in this area). The otter boards were 160 × 90 cm. and typical for vessels of the *Hatzvi* size in the local trawl fishery. The sweeplines of 22 mm. ø combination rope were shortened from 210 to 100 m. The mudropes, which are several pieces of thick rope whipped together, 5 to 7 m. long and placed in the gear between the sweeplines and the wings

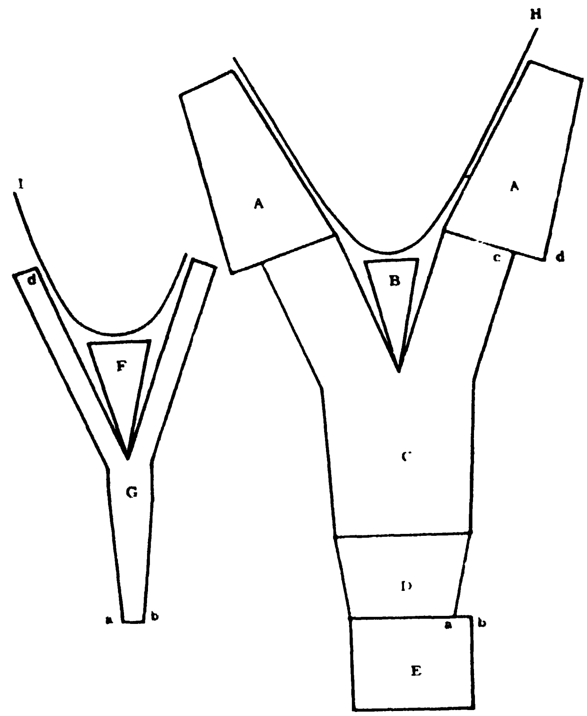

Fig. 1. Italian trawl net for 120 h.p. vessels.

A — *wing, 10-11 m. long, 140 meshes reduced to 90, 100 mm. stretched.*
B — *upper wedge, 5 m. long, 80 meshes reduced to 20, 80 mm. stretched.*
C — *belly, 15 m. long, 220 meshes in each part, at the connection to the wing, 400 meshes at the throat connection, 54 to 50 mm. stretched.*
D — *throat, 400 meshes reduced to 360 meshes, 40 mm. stretched, 4 m. long.*
E — *codend, 5 m. long, 400 meshes, 40 to 50 mm. stretched.*
F — *lower wedge, 5 m. long, 80 meshes reduced to 20, 100 mm. stretched.*
G — *lower body, 21 to 22 m. long, 60 meshes in each part, at the connection to the wing, 40 to 60 meshes at the codend, 50 to 60 mm. stretched.*
H — *headline, 14 to 16 mm. ø hemp rope, 28 m.*
I — *footrope, 40 mm. ø hemp rope, 34 m. The small letters: a, b, c, d, show how the lower body is connected to the rest of the net.*

of the net, form an integral part of the Mediterranean trawl gear. They were only used during one of the tows. The divers found that they raise a cloud of mud which interferes with visibility to such a degree that no records could be taken. As the divers did not discover any differences in fishing spread of the net with or without these ropes, the latter were removed for the rest of the observations[13].

THE NET

The observed net was of the usual Italian type used in commercial fishing by Mediterranean trawlers of 120 h.p.

The top and bottom parts of the Italian net differ greatly. The bottom has much less webbing, made of a much heavier twine, than the top part. The parts are connected in such a way as to permit a high degree of slackness in the bottom (lacing coefficient: c = 0·85 to 0·90). The codend is one tube-like piece of webbing, and the wing consists of one part, also common for top and bottom. The front edges of the belly are completely connected to the wings. At the centre of the mouth there are two wedges, upper and lower, sewed into long clefts in the top and bottom of the belly. Long hangings, (30 to 45 cm.), connect the webbing to headline and footrope. The wedges are also sewn into the belly by means of hangings. The net parts are never cut to shape but the whole webbing is made by hand and tapered, to reduce the size and number of meshes towards the codend. The Italian trawl net is much longer than most other types of trawl nets.

TEST RESULTS

The Opening Width

The method used in finding the approximate distance between the otter doors was based on measuring the distance between the warps at two particular points on board the vessel. Knowing the exact length of the warp, the spread was then calculated. This method, although not exact, suffices to obtain a rough appraisal of the fishing spread.

Calculations showed that the distance between the boards of the standard gear of *Hatzvi* varies from 60 to 70 m., and in the examined gear from 40 to 50 m.[16] To assess the angular difference between the net's wings in both cases, a comparison can be made between the isosceles triangles formed by the wings and the sweeplines and the line joining the two otter boards.

(1) Common gear: Distance between the boards—60 m. Length of the arm—220 m. (this includes the sweepline, the mudrope and the wing of the net).

Therefore the sine of $\frac{\alpha}{2}$ will be 0·14 and the angle itself will be about 16 degrees (α = angle between the two equal arms).

(2) Experimental gear: Distance between the boards 40 m.; the arm—112 m. (this includes the shortened sweepline and the wing of the net). The sine of $\frac{\alpha}{2}$ equals 0·18 and the angle itself about 21 degrees.

The difference between the common and the experimental gear, regarding the angles between the wings, calculated in this simplified way, is about 5 degrees. There is no reason to believe that this value makes a great difference in practice, causing basic changes in the shape and behaviour of the net in action.

All measurements and observations were carried out while the codend was empty. The current opinion of local fishermen is that a big catch in the codend increases the total resistance of the net. It is understandable that if the codend fills with mud, stones or any other heavy load, as often happens, the total resistance of the gear increases, the fishing spread decreases and in some cases the towing speed decreases as well. The reaction may be quite different if the codend fills with fish only. De Boer[9], who measured the trawl gear under water, by means of special instruments, expresses the opinion that a big catch may cause a decrease instead of an increase of the pull in the legs of a trawl but a normal catch would not influence the tension.

Influence of bottom conditions

All observations were made on a sandy bottom. Various beliefs and ideas about the influence of the type of the sea bottom on the behaviour of the trawling gear exist among the fishermen. The most common opinion is that on a soft muddy bottom the sweeplines dig into the mud, and move mole-like under its surface.

In spite of the differences between the actual fishing conditions and the conditions under which the study was made, the author believes that the over-all picture obtained of the Italian trawl net in action is sufficient to allow a preliminary analysis of the problem.

The Shape of the trawl net in action

Some facts concerning the shape of the net in action may be determined from the photographs and observations made by the divers (fig. 2).

(1) The curve of the footrope is much wider than the curve of the headline. This suggests that the overhang of the net is much smaller in action than it appears to be when the net is spread on shore.

(2) The wing forms a triangular wall, with its concave surface inwards. The height and the cross section of this wall increase from the danleno towards the junction with the body.

(3) The cross section of the net's body is ellipse-like, becoming more and more circular in form towards the codend.

(4) The after part of the codend forms a swollen ball, the diameter of which is larger than the diameter of the cylindrical throat (fig. 3).

(5) The fishing height, measured by the divers at the centre of the headline, is 90 to 120 cm.

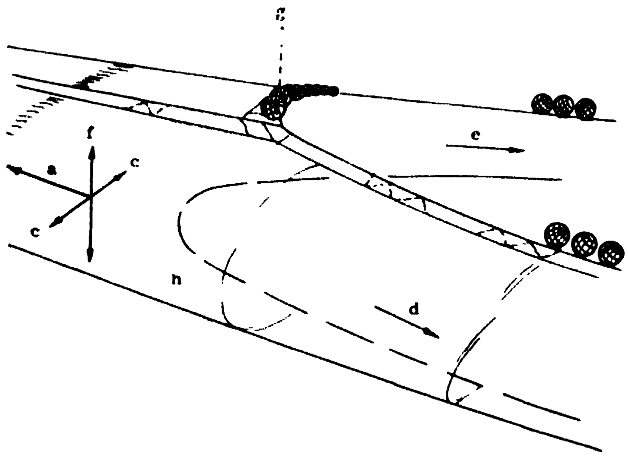

Fig. 2. Combined photograph-drawing of the Italian trawl net in action.

a = total net resistance.
c and f = spreading forces.
d and e = towing forces.
g = lifting force of the floats.
h = connection between the wing and the body.

The forces acting on the net

Forces acting on the Atlantic type trawl gear have already been calculated theoretically[3] and studies of various types of trawls are being made in some countries[9], [10], [20] and [21]. But up to the present no report has been received on attempts to measure these forces in the Mediterranean trawl gear. However, the experience of the fishermen and netmakers, the direct underwater observations, and the knowledge of the construction of the Italian trawl net, can provide an explanation in general terms. The scheme of these forces is given in figs. 2 and 3.

In the horizontal plane, three main forces are acting:

(1) *Total resistance of the net* "a" opposes the movement of the gear.

(2) *Towing force* "e", "d", acts at an angle α to the direction of movement.

(3) *Spreading force* "c" acts perpendicular to the direction of the movement and is a result of the action of the water stream on the webbing.

Although we cannot deal with the actual values of these forces because of the absence of any measured data, it is clear that the resulting force acts along the net, parallel to the movement. This force (fig. 3-AB) will be called in the following "*the parallel force*".

The spreading force acts on the webbing of the net from inside out in all directions, causing the net's body to expand (fig. 2-c and f). The action of all these forces together with the lifting force, if any, of the spherical floats (fig. 2-g), creates the final shape of the Italian trawl net while fishing. As whirlpools are formed by the net moving through the water, it is possible that additional mutual influences exist between them and the shape of the net.

The behaviour of the gear when towing is started

The divers found that when the net is released and the whole gear is loose, the height of the vertical opening reaches 4 or more metres, caused by the lifting force of the floats. But as soon as towing is started, the vertical opening of the net decreases rapidly and the tightened headline comes down to a height of about 1 m. As the trawl begins to move, a stream of water through the net body presses in all directions, which causes the body to swell. The after-end of the codend opens up into a ball and, being constructed from heavy webbing, causes a serious resistance. While the towing speed increases, the

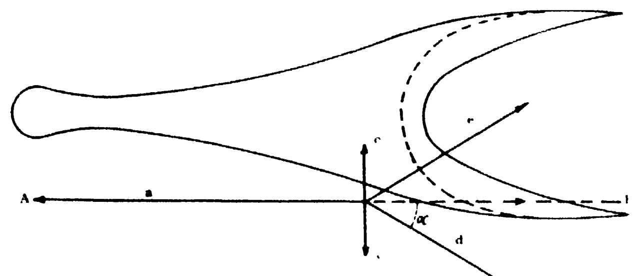

Fig. 3. Scheme of forces acting on an Italian trawl net.

a, c, e and d as above (fig. 2).
AB = parallel force, α = the angle at which the towing forces act.

Fig. 4. Top part of net while in action, under full towing strain.
A — distorted section of belly webbing, at rear connection of upper wedge.
B — distorted edge, due to wrong adjustment of hangings.
C and D — drawing show mesh angles.

parallel force increases and the lifting effect of the spherical floats decreases. As the Italian trawl net has no sidelines the elongation of the body, due to the resistance of the codend, is limited only by the webbing of the upper part. As the parallel force increases, the meshes close and the body of the net consequently becomes longer. The result is that the net body narrows and forms a flat, long funnel shape.

The lifting force of spherical floats

The headline of the experimental net was equipped with common spherical glass floats. The lifting force of these floats at usual towing speeds of about 3 knots seems to be almost negligible. This feature of the spherical floats has been described by various authors [3], [19], [22] and [23].

The opening height

The headline of the Italian trawl net lifts at regular towing-speeds to a height of 90 to 120 cm. The efficiency of the spherical floats is more than doubtful. The height of the wooden danlenos of the wings is 40 to 60 cm. only, and pictures show that they move at an acute angle towards the bottom. This means that their effective height is even less. It would seem that the water stream, while expanding the net, meets the belly webbing at a certain angle of attack and lifts the upper part of the net to the observed height.

The form of the meshes in various parts of the experimental net

Due to the angle taken by the camera, the angles of the meshes, as measured on a photograph, are not quite accurate (fig. 4). Those which appeared to be undistorted by the perspective were measured but the results are still valid only for a rough comparison of the shape of the webbing in the various parts of the net.

The length of the mesh bar is the only unchanging factor if the stretching of the twine caused by towing tension is disregarded.

All other qualities of the mesh (the length, the width, the mesh angle) change according to the action of outside forces, so that trigonometric and geometric formulae can be used in designing nets and analysing their action. For this purpose the hanging coefficients are convenient and in common use (figs. 5 and 6), for calculating the relations between the webbing and the ropes. Hanging coefficient $c_1 = \frac{b}{2a}$, (fig. 5), gives the relation between the mesh length (b) and the mesh size (2a). The co-efficient $c_2 = \frac{c}{2a}$ represents the relation of the mesh width to the mesh size. The bigger b, the bigger is c_1, the smaller c_2 and the mesh angle (fig. 6). The relation between these coefficients and the mesh angle can be calculated trigonometrically, or by means of measuring the angles on drawings (fig. 6). A table was published by Baranov[2] p. 168.

As seen from the underwater observations and photographs the mesh angles in the Italian trawl net vary from

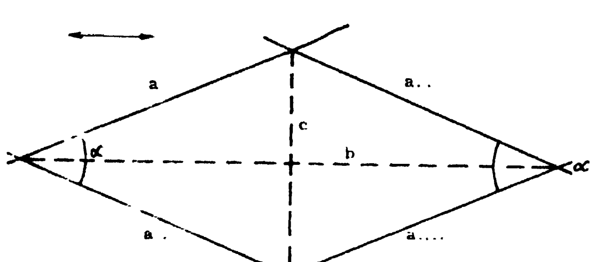

Fig. 5. Shape of a net mesh in working position.
a ., a . . ., a . . . ., a . . . . = bars of the mesh.
b = mesh length.
c = mesh width.
α = mesh angle.
The arrow shows the direction of movement. a . = a . . = mesh size. Hanging coefficients: $c_1 = \frac{b}{2a}$; $c_2 = \frac{c}{2a}$

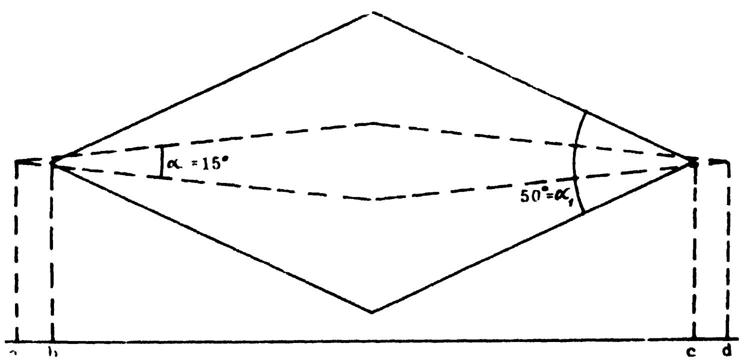

Fig. 6. Relation between coefficient of hanging c_1 and mesh angle α
ad = mesh length at $c_1 = 0{\cdot}99$; α = 15 degrees.
bc = mesh length at $c_1 = 0{\cdot}91$; α = 50° degrees.
ab + cd = the difference between the mesh length in both cases

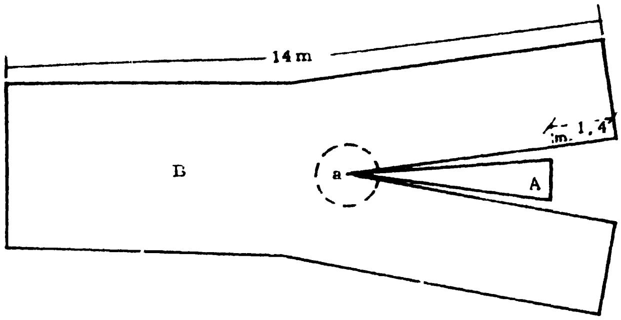

Fig. 7. The upper belly with the wedge adjusted into the cleft.

A — *upper wedge.*
B — *belly.*
a — *distorted sector of webbing.*

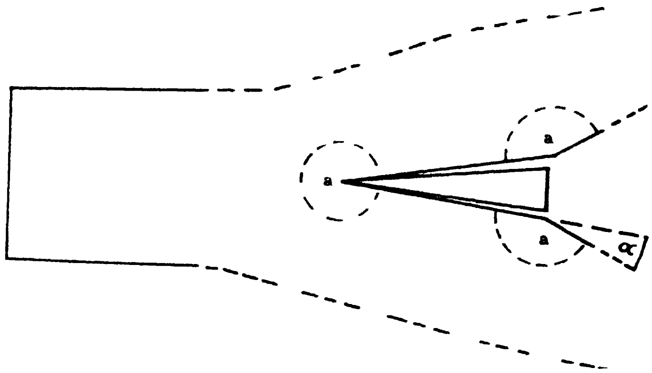

Fig. 8. Schematical view of the belly in action.

a — *sectors under distorting forces.*
α — *angle at which the belly is broken.*

wide open to completely closed. In the after part of the upper belly, and in the throat, the meshes are almost completely closed. The meshes in the central and the front parts are closed in the sides and open in the upper belly. In the central sectors of the belly and the upper parts of the wings, the mesh angle seems to be not less than 40 degrees, while in some places it reaches 80 degrees (fig. 4). The width of the webbing strips, the meshes of which are open, is at least 50 rows counting from the top edge downwards (fig. 4). Theoretically this fact should cause a shortage in the upper part of the webbing in relation to the mid and lower parts.

The strain in the upper part of the net

According to observations the mesh angle in the lower parts of the front half of the net is less than 15 degrees compared with the 50 degrees in the upper strips. The length of the mesh at 15 degrees, is only 1·7 per cent. shorter than the mesh size. The length of a mesh at 50 degrees is 9·4 per cent. shorter than the mesh size, (fig. 6). The difference in length between those parts of the upper and lower net where great differences in the mesh angle appear, should be approximately 8 per cent. particularly in the front half of the belly and in the wings.

In action, therefore, the front 7 to 8 m. of the upper belly, should theoretically be about 0·5 m. shorter than the lower belly. From actual experience this is not found to be true. The stretching of the twine in the upper net is a generally known fact. This can be seen when a new Italian trawl net is taken ashore for the first time for repairs and adjustment. The belly webbing is found to have lost its original form, and differences between the upper and lower parts are apparent, the former being longer than the latter. The fishermen cut triangular strips from the stretched sectors of the webbing, to give the belly its original rectangular form. This proves that there is a greater stretching force acting on the upper strips than on the rest of the webbing, and this causes an elongation of the meshes. The wide opening of the meshes is not due to a weaker parallel force acting on the top of the net, but to additional spreading forces affecting the sides of the belly (figs. 2 and 3).

It could be concluded that the increase in the angle of the meshes in the upper net is almost balanced by the stretching. In action, the strips with wide open meshes would be about 5 to 10 per cent. shorter than the parallel strips with closed meshes below. However, the actual stretching of the webbing in the top is less than 5 per cent. so that these two phenomena only balance each other in part. It seems, therefore, that in action the upper parti of the belly and of the wings are really a little shorter than the rest of the webbing, although the total strans over the top is stronger.

Consideration of the suitability of the Italian net design

The upper belly of the Italian net is a trapezium which is almost rectangular. In the centre of its front part there is a cleft 6 to 7 m. long. The shape is achieved by gradually reducing the number of meshes per row, and/or by decreasing the mesh size towards the throat. All edges are knitted straight and no shape cutting used. A triangular piece of webbing is laced in the cleft by means of thin lines, in order to enlarge the net mouth. This part is called the upper wedge (fig. 7-A). While adjusting this wedge into the cleft the natural shape of the belly webbing becomes distorted. Thus, a weak constructional point is produced near the posterior connection of the

Fig. 9. Net mouth in action.

AB — *opened meshes in upper strips of webbing.*
C — *sector under distorting forces.*
E — *edge of upper wedge.*
Df — *hangings of headline*

upper wedge (fig. 7-a). This place often tears, and the meshes here are always distorted, so that fishermen use various methods to avoid such damage but with relatively poor results. The methods used are: connecting the wedge to the belly by means of a long line running along the centre of the belly and reaching sometimes to the throat or even the codend, and/or using double twined webbing along the cleft.

In addition to the distortion, two more weak points are created on the upper edges of the belly where the headline, the wedge and the belly meet (fig. 8-a, fig. 9-c). The angle is clearly visible in the photograph, although the edge here was constructed straight (fig. 9). The fishermen waste a lot of fishing time repairing the torn mesh and hangings in this sector of the net.

The form the belly webbing takes in action is reconstructed in fig. 8. Comparing this figure with the construction plan, it is clear that the construction does not fit the shape the belly has when in action. The angle resulting from the distortion at the belly edges (fig. 8-α), was calculated as being approximately 20 to 30 degrees, depending on various factors, such as opening width, length of hangings, etc.

The same constructional defects appear in the lower part of the net along the lower wedge and the footrope. However, as there is less strain here and stronger twine is used, less damage is done than in the corresponding parts of the upper net.

In most parts of the net, the meshes are closed when the net is in action, so that the webbing partly loses its filtering action. In the after part of the belly, and in the throat, where the body of the net takes the shape of a tube, the meshes are so near to closed that substituting a non-filtering material for net webbing, e.g. canvas, would have only a slight influence on the behaviour of the gear. The poor filtering of the webbing results in increased resistance of the whole net.

The curves of headline and footrope in the sections connected to the wedges, are very broad, especially in the footrope (fig. 9). The fishermen make the hangings of the wedges shortest in the centre (less than 5 cm.), and their length is gradually increased towards the side of the wedge. The divers reported that the difference in length between the central and the side hangings is too great and causes increased tension in the centre of the wedge and some slack, in its sides.

Possibilities for improvements of the Italian net

A differentiation ought to be made between the term "improvements in the Italian trawl net" and the term "improvement of the Mediterranean trawl net". In the former, reference is made to small technical improvements in the present net, while conserving the characteristic pattern of its construction and behaviour on the sea bottom. In the latter, this pattern is rejected. The aim of the improvements in both cases is the saving of work and material, decreasing the net resistance to the water, increasing the catch in relation to the towing force invested and saving the young specimens of no commercial importance[17].

Few changes can be made in the Italian net without deviating from the accepted pattern. The vertical opening is definitely limited because the upper part of the body is 10 to 15 per cent. shorter than the bottom part The meshes in many parts of the net are closed due to the absence of side lines along the body, which would limit the stretching of the webbing (see page 220: Hybrid net).

Reduction of the amount of webbing

Decreasing the number of meshes in those parts of the webbing where the mesh is closed, without suitable changes in the parallel force, will not improve the mesh opening. The strain acting on the webbing will continue to keep the meshes closed, with the whole tube of the net body becoming thinner. Since the shape of the net mouth and its dimensions depend mainly on the hydrodynamical features of the body, any change in the size and shape of the body in action must produce parallel changes in the form and behaviour of the net. Therefore, only a limited decrease of the amount of webbing in the throat and the codend can be recommended and care must be taken to avoid exaggeration which can produce negative effects.

Reduction of the twine strength

The fishermen of the smaller trawlers (up to 120 h.p.), have upper parts made from light webbing as it is more efficient despite the fact that the thinner the twine the weaker and shorter living the net. For the bigger trawl nets, the light webbing proved too weak to resist the greater tension of the higher towing speeds of the larger vessels. Substituting the thin webbing by a stronger and heavier one, lowers the lifting abilities of the Italian net and reduces the catch.

Limits of the Italian pattern

It can be said that in the three most important aspects, namely: (1) saving in the amount of webbing; (2) lengthening the net's life by use of stronger twine without changing the material, and (3) increasing the fishing height, no full satisfactory results can be achieved, as long as the main pattern of the Italian net remains unchanged.

Experiments should be carried out with a shortened body and a flapper in the throat, and with synthetic twine, none of which has yet been tried.

Minor improvements of construction

Two different methods are suggested to decrease the damage due to the weak points in the upper edges of the belly and around the posterior connection of the wedge.

In fig. 10 the whole wedge is made much longer, and in fig. 11 only the cleft is made longer, while the

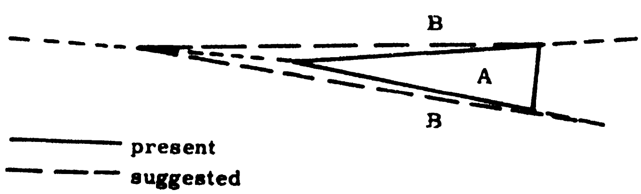

Fig. 10. Longer wedge to decrease distortion in belly webbing.
A = wedge. B = belly.

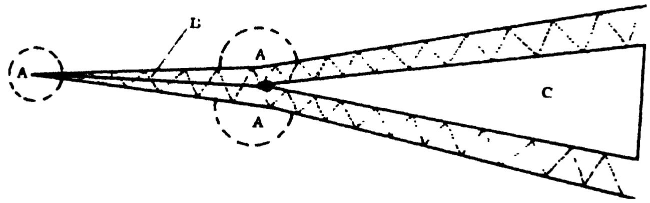

Fig. 11. Method of wedge adjustment, to reduce distortions in the belly webbing.

A – the weak points performed.
B – suggested additional hanging.
C – wedge.

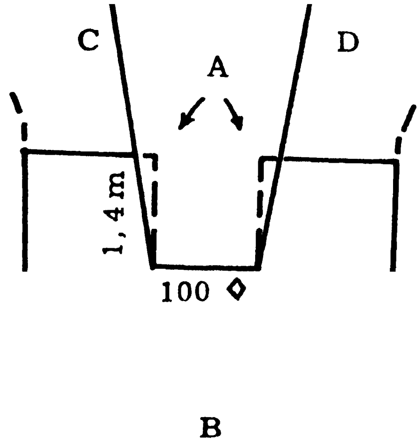

Fig. 12. Front edges of upper belly cut to shape.
A – triangular pieces to be removed.
B – belly.
C-D – wings.

hangings of both sides of the wedge unite behind its end and continue some metres, decreasing their length gradually. Although the use of these two methods will decrease the strain around the end of the wedge, the distortion in the edges of the belly will be even more pronounced than before (fig. 9-C.) Therefore, at the same time, the hangings which connect the headline to the belly (fig. 9—section CD), have to be gradually lengthened the longest hanging should be nearest to the wedge (fig. 9-C). This is already practised by some fishermen. Here the author would rather recommend, instead of making the hangings in the critical section longer, that the other hangings along the whole wing be shorter. This method of hanging was already successfully practised. The length of the hangings along the wing should not exceed 20 cm. (instead of 35 to 40 as used generally) but those along the critical section of the belly edge should be gradually lengthened till 40 cm. at the wedge.

The side hangings connecting the wedges to the ropes should not exceed 20 to 25 cm. (fig. 9-E).

A more radical solution would be to cancel the wedges altogether. For this purpose, however, the number of the meshes in the front edge of the belly must be increased by about one hundred. For this purpose a rectangular part of webbing (fig. 12-A) could be removed in order to form the mouth. This would simplify the construction of the Italian net without changing the principle of its action. The weak point around the wedge end disappears together with the wedge and its hangings. After cutting out two small triangular pieces of webbing (fig. 12-A), a form close to that appearing in action is given to the top of the net mouth.

It must be underlined that such small technical adjustments may improve the economy by reducing time and expense of maintenance but have nothing to do with increasing the efficiency of the Italian trawl net, for they do not change its towing resistance nor the size of its mouth. For more basic improvements the Italian pattern in the construction of a trawl net would have to be rejected.

Considerations about the suitability of other types of trawl nets

The long experience of making, and fishing with, the Italian trawl net, and the survey described above, has convinced the author that this net cannot form a basis for the development of an improved trawl.

Former experiences

From publications available in Israel we learn that experiments made in the Mediterranean proved that the Atlantic or northern types of nets were in all cases less efficient than the Italian, although in some trials they caught more pelagic fish[8].

Experimental trawling with the Atlantic gear in 1957 by the South African steam trawler, *Drom Africa*, yielded very poor results, taking into consideration the size of the vessel and her gear and the richness of the north-east Mediterranean where the trawling was carried out[18]. Some experiments were made by the late Dr. Lissner, Director of the Sea Fisheries Research Station, but the author did not succeed in getting enough information about them. A Yugoslavian fishing vessel, *Napredak*, arrived in Israel in 1953 to carry out experimental tuna fishing. This vessel, when the expected tuna did not appear, fished with an Atlantic type of trawl net but, although her power was 400 h.p., the catches were always less than those of the small Israeli trawlers until a net of Italian pattern was used. Experimental fishing was done by the Sea Fisheries Research Station in 1957 in the Bay of Tarsus with Portuguese gear on board the F/V *Lamerchav* (240 h.p.). The results were almost nil, and the trawling was stopped after two tows. At the same time and place, big catches were taken by *Lamerchav* and other Israeli trawlers fishing with their standard gear.

The Mediterranean needs an improved trawl net, which has all the features of the Italian net, is economic to construct and has a fishing height that will ensure catching fish swimming some metres off the bottom. The mesh should be large enough to avoid catching young fish of non-commercial size, as recommended in the survey carried out by the Sea Fisheries Research Station[14].

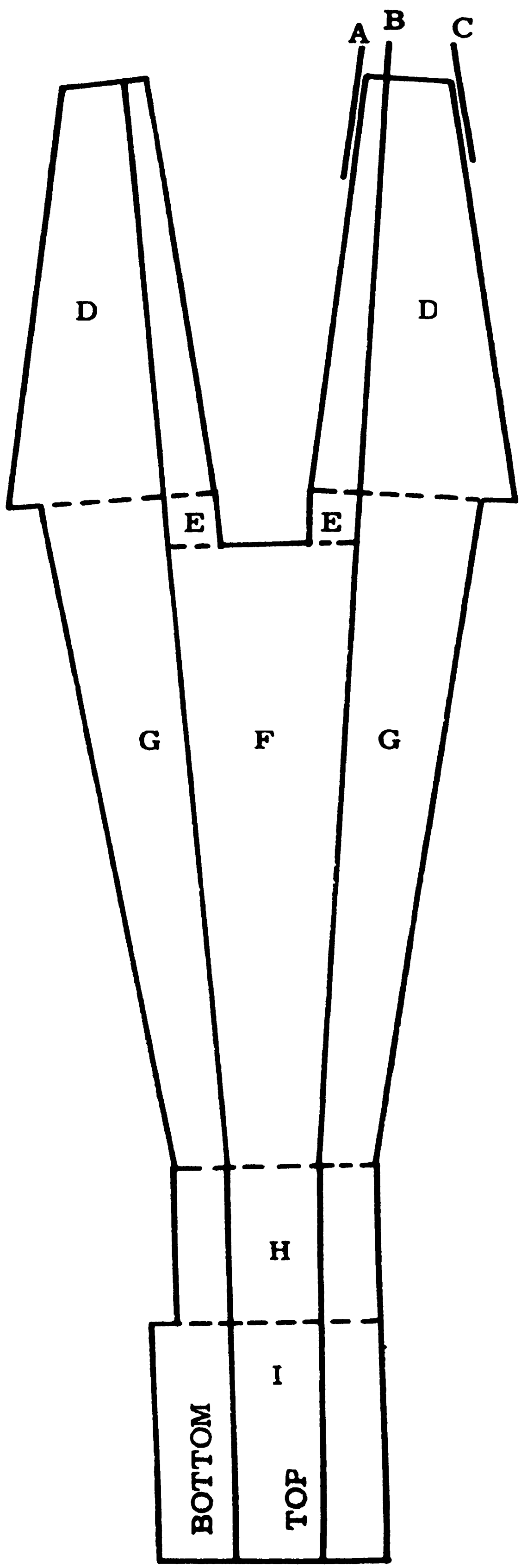

Fig. 13. Hybrid net, advanced type, as used on board F/V Shomria *(110 h.p.) Upper part.*

A — headline, 12 mm. ø hemp, 28 m. long.
B — sideline, 12 mm. ø hemp, 2 × 32 m. long.
C — footrope, 40 mm. ø hemp, 34 m. long.
D — wing, 140 reduced to 90 meshes, 110 rows, 100 mm. stretched
E — square, 40 meshes, 24 rows, 50 mm. stretched.
F — top, 170 reduced to 120 meshes, 300 rows, 50 mm. stretched.
G — side, 115 reduced to 80 meshes, 300 rows, 50 mm. stretched.
H — throat, 280 meshes, 60 rows, 40 mm. stretched.
I — codend, 300 meshes, 100 rows, 46 to 48 mm. stretched.
The rows are of full meshes (2 bars).
A flapper is sewn into the throat.

For the bottom part see fig. 1—F, G, I.

The hybrid net

During 1956 and 1957 four different vessels fished commercially with hybrid nets as well as with standard nets, and the hybrid nets had *at least the same catches* as the standard Italian nets. The important point is that a net constructed on a different pattern from the Italian can achieve satisfactory results[11,15]. The main principle of the hybrid net is that the towing forces are acting on the sidelines (seized to the side-seams) (fig. 13).

The top (F) is connected to the sidelines with a hanging coefficient c=0·88 to 0·90, and the sides (G) with a coefficient c= 0·95 to 0·97. The Italian pattern of the bottom parts below the sides is preserved. The loosely connected top part can be lifted by means of, for instance, Philip's trawl-planes, and reaches an opening height of 2·5 m. (twice that of the Italian net), as determined by the divers[1]. And this is achieved with less webbing in the upper part of the net.

Fig. 13 shows the plan of a hybrid net for 100 to 120

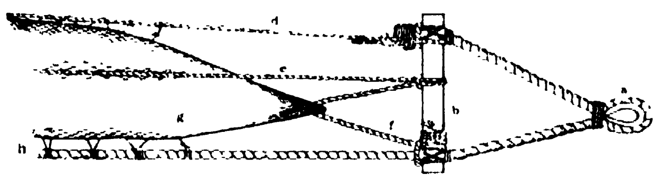

Fig. 14. Adjustment of wing tips to the wooden danleno in the hybrid-net. The height of the danleno is 70 to 80 cm.

a — thimble.
b — wooden danleno.
c — footrope.
d — headline.
e — sideline.
f — wing connecting rope.
g — wing webbing.
h — net to footrope connection (Italian) method.
direct net-to-rope connection.

h.p. trawler as now used by the F/V *Shomria.* (See also figs. 14 and 15).

FURTHER DEVELOPMENTS

The preliminary observations of the Italian trawl net, together with the theory of net construction[3], show the way for further development. The way suggested by the author is to remove the towing strain from the net webbing by the use of a rope skeleton sewn into the net.

Fig 15. Wing adjustment to iron pipe danleno in hybrid-net in action. Height of the danleno 80 cm.

- *a — triangular pipe danleno.*
- *b — swivel.*
- *c = footrope.*
- *d — wing connecting rope.*
- *e — sideline.*
- *f — headline.*
- *g — spherical glass floats, appearing here only for divers' convenience.*

Such constructional improvement will give back to the net webbing its original ability to filter the water and will save a lot of net material without decreasing the net size. Moreover, it will enlarge the mouth opening. These advantages have been proved in fishing with and underwater observations of hybrid nets. But the hybrid net is only a first step to the future Mediterranean trawl net. The meshes are closed in the after part of the body as in the Italian net. Waste of material and superfluous resistance are big in this net, too. In the suggested net the webbing will be free from the action of the parallel force. The relation between the webbing and the ropes can be calculated by the use of hanging coefficients. This will enable the constructor to design a net pattern suitable to the net shape when in action. Furthermore, in such a net all the meshes will be open and less webbing will cover a particular surface.

According to calculations made by the author, at least 64 per cent. of the webbing can be saved in those parts where the mesh angle does not exceed 18 degrees, if adjusted to the side ropes with a hanging coefficient $c = 0{\cdot}87$. This coefficient gives a mesh angle of 60 degrees.

The length of the whole net will be assured by means of sidelines preferably made of thin (12 to 14 mm.) combination rope, while the webbing will control only the swelling of the net. Such an improvement leads to: (a) saving of net material; (b) decreasing of resistance, and (c) liberating the top of the net from horizontal strain, thus enabling it to attain a larger opening height. It does not oppose, otherwise, the Italian principle of loose bottom parts. This net can be constructed of stronger (heavier) webbing, because its shape in action will be assured by the rope skeleton and the hydro-dynamic floats, and not only by the action of the water stream on the webbing, as seems to be the case in the Italian trawl net. The new net can be constructed of machine-made webbing.

CONCLUSION

A cheap, strong and efficient trawl net for the Mediterranean could be constructed as a result of technological surveys and experiments. The best way to develop such a net seems to be in rejecting the old pattern and shifting the towing strain from the webbing to ropes.

The proposed pattern could be equally applied to areas outside the Mediterranean where an increase in the fishing height may be of far greater importance.

REFERENCES

[1] Assaf, I. Underwater Observations of the Hybrid Net., Fishermen's Bulletin No. 9, Haifa 1956. (In Hebrew).

[2] Assaf, I. Personal information, 1956.

[3] Baranov, F. I. Theory and Calculations of Fishing Gear. Moscow, 1948. (In Russian).

[4] Bar-on, E. Personal information, 1956.

[5] Ben-Yami, M. A New Trawl Net. Fishermen's Bulletin No. 8, Haifa, 1956. (In Hebrew).

[6] Ben-Yami, M. The Design of the Hybrid Net Type B. Fishermen's Bulletin No. 9. Haifa, 1956. (In Hebrew).

[7] Ben-Yami, M. Preliminary Report on Experimental Fishing with a New Trawl Net. General Fisheries Council for the Mediterranean, 4th Meeting, Technical Paper No. 35, Istanbul, 1956.

[8] Bernstein, D. Three Experiments for increasing the height of the Head Rope. Fishermen's Bulletin No. 4, Haifa 1955. In Hebrew).

[9] De Boer, P.A. Trawl Gear Measurements obtained by Underwater Instruments. International Council for the Exploration of the Sea and North Sea Sub-Committee Comparative Fishing. No. 4, 1954.

[10] De Boer, P. A. Private correspondence, 1956.

[11] Crew of M. F. V. *Tzofia*—Preliminary Report on a New Type of Trawl Net. Fishermen's Bulletin No. 8, Haifa, 1956. (In Hebrew).

[12] Fried, Z. and Assaf, I. Aqua-lung Tests of the Italian Trawl Net. Fishermen's Bulletin No. 8, Haifa, 1956. (In Hebrew).

[13] Fried, Z. Underwater study of the Italian Type Trawl Gear.

[14] Gottlieb, E. and Oren, O. H. Savings Gear Experiments with Trawl Nets in Israel Waters. General Fisheries Council for the Mediterranean, Technical Paper No. 36, Istanbul, 1956.

[15] Hamburger, E. Preliminary Results on the Operation of the Hybrid Net, Fishermen's Bulletin No. 9. Haifa, 1956. (In Hebrew).

[16] Hamburger, E. Personal information, 1956.

[17] Kristjonsson, H. The scope for Technological Development in the Mediterranean Fisheries. General Fisheries Council for the Mediterranean, No. 2. Technical Paper No. 36, Rome, 1954.

[18] Lissner, H. and Hirsh, H. Experimental Fishing in the Bay of Alexandretta. Bulletin No. 1. Sea Fisheries Research Station, Haifa, 1948. (In Hebrew).

[19] Percier, M. A. L'ouverture du Chalut en Hauteur. Genera Fisheries Council for the Mediterranean, Rome, 1952.

[20] Schärfe, J. Geraete zur Messung an Schleppnetzen. Die Fischwirtschaft Heft 1 und 2, 1953.

[21] Schärfe, J. Dass Messen der Zugbelastung bei Schleppnetzen. Die Fischwirtschaft, Heft 2, 1955.

[22] Smislov, I. G. Analysis of Action of Spherical Trawl Floats, V.N.I.R.O. Works, Vol. XXX, Moscow 1955. (In Russian).

[23] Yacovlev, A. I. Results of Hydrodynamical Tests of Trawl Floats. V.N.I.R.O Works, Vol. XXX, Moscow, 1955. (In Russian).

FACTORS AFFECTING THE EFFICIENCY OF DREDGES

by

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Abstract

In this paper the various factors affecting the efficiency of the dredge are discussed. The depressive effect of diving plates allows an increase in the towing speed, and the angle of attack of the plates has an optimum value. The angle at which the teeth of the dredge travel over the bottom also has an optimum value, about 45 degrees, and the selective action of the teeth is a useful method of reducing the amount of trash taken. Preliminary attempts have been made to assess the absolute efficiency of the standard Manx scallop dredge and it was proved to be low.

Etude des facteurs conditionnant l'efficacité des dragues

Résumé

L'auteur examine dans cet article les différentes facteurs qui conditionnent l'efficacité de la drague. L'effet d'abaissement des plaques de plongée permet d'accroître la vitesse de remorquage, et il existe une valeur optimum de l'angle d'attaque des plaques. L'angle selon lequel les dents de la drague attaquent le fond, est optimum à 45 degré environ. Une bonne méthode consiste á tirer parti de l'effet sélectif des dents pour réduire la quantité de matériaux indésirables ramassés par la drague. Des essais préliminaires entrepris pour évaluer le rendement absolu de la drague "Manx" standard à coquilles St. Jacques ont montré que l'efficacité de ce modèle était faible.

Exposición de los factores que influyen sobrel a eficacia de los rastros

Extracto

En este trabajo se analizan los diversos factores que influyen sobre la eficacia de los rastros. El efecto de las planchas de inmersión permite aumentar la velocidad de arrastre de acuerdo con su àngulo de ataque hasta alcanzar un valor màximo. Por su parte, el àngulo de incidencia de los dientes de estas dragas cuando avanzan por el fondo del mar alcanza un valor óptimo a 45°, y la acción selectiva de ellos constituye un método útil para reducir la cantidad de desperdicios recogidos. So han hecho ensayos preliminares con objeto de evaluer el rendimiento absolute de los rastros para peregrinas o veneras utilizados corrientemente en la isla de Man, que resultó ser bajo.

THIS paper is intended for marine biologists as well as for commercial fishermen. Much of the discussion is of an elementary nature and over-simplified; qualifications should follow most of the statements. However, as dredges have evolved very slowly, and nearly always in an empirical manner, at least in Europe, it will perhaps make a starting point to discuss in a general way some of the problems involved.

Underwater observation of dredges in action shows that scallop dredges with rope warps have a tendency to skip over the bottom[1] and oyster dredges to slither. Increases in speed of tow above a low level tend to reduce catches. This can be overcome to some extent by fitting depressors or diving plates to the dredges. One such dredge for scallops has already been described[2]. The fitting of teeth to dredge bars improves performance in some cases, but makes the angle of attack of the blades more critical than without teeth. Tooth spacing is also important.

The shape of the catenary of a warp in the water will depend on the drag of the warp which will vary with the material. In general, a wire warp will have a forward and downward catenary, the weight in water being greater than the drag; a rope warp will have a backward and upward catenary, the drag being greater than the weight in water.

In the following discussion, the weight of the warp will be ignored, although it can be seen that a wire warp can increase the effective weight of the dredge and a rope warp can exercise considerable lift.

The normally used warp-depth ratio for dredging is 3:1. The actual length of warp required—disregarding the effect of the warp itself—will be determined by the drag of the dredge which is proportional to the velocity squared ($D = K_D V^2$), and by its weight in water. An increase in speed of tow necessitates a much increased ratio of warp to depth.

EFFECT OF DIVING PLATES

With a diving plate, another factor—lift—is introduced, which can act upwards (positive) or downwards (negative). In addition to the lift from a diving plate, induced drag occurs. Thus, there are two sources of drag, that from the dredge itself, called parasitic drag (D_p), and induced drag from the diving plate (D_i). As with drag, lift is proportional to velocity squared ($L = K_L V^2$). From fig. 1 it can be seen that although the negative lift from a diving plate increases the warp angle, increase in speed still decreases the warp angle and thus some more warp is required for a given depth. Parasitic drag should be kept as low as possible by the use of as large a mesh as possible and by avoidance of unnecessary large surfaces in the construction.

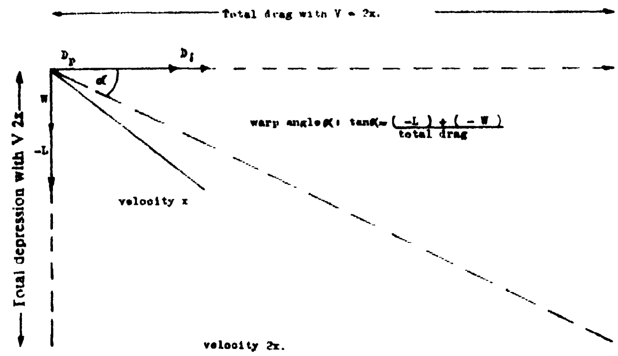

Fig. 1. The effect on warp angle of increasing speed of tow with diving plate. The sign of lift and weight show direction.

The lift/drag ratio is at its maximum at rather small angles of attack, the drag increasing, with increased angle of attack, quicker than the lift which, furthermore, increases only up to the point of stall. However, when the parasitic drag is high, the amount of negative lift needed for a given size of diving plate requires a bigger and, therefore, less efficient angle of attack.

A secondary effect of a diving plate is to help material into the bag of the dredge by deflecting upwards the waterflow at the mouth of the dredge. It has been observed that if the angle of attack of the diving plate is too great, more trash is retained. This may be explained by the eddies formed by the partial or complete stall of the plate resulting in a slowing down of the water flow at the mouth of the dredge, with a tendency for trash to accumulate in the front of the dredge bag (fig. 2).

The use of diving plates affects the stability of the dredge while it is in mid-water during shooting. A dihedral angle on the diving plate will give lateral stability about the longitudinal axis. Longitudinal stability is maintained by the point of tow. If negative lift is maintained on the plate with negative dihedral (anhedral) while shooting, righting moments occur when the dredge is disturbed laterally. If the plate gives a positive lift with negative dihedral angle the dredge will be turned over.

Fig. 3 illustrates the effect of negative dihedral and negative lift. When the dredge is disturbed laterally, weight continues to act vertically downward but the negative lift is inclined to the vertical. If the negative lift is split into its vertical and horizontal components, it can be seen that the horizontal component is acting to the right, causing a relative waterflow to the left, which

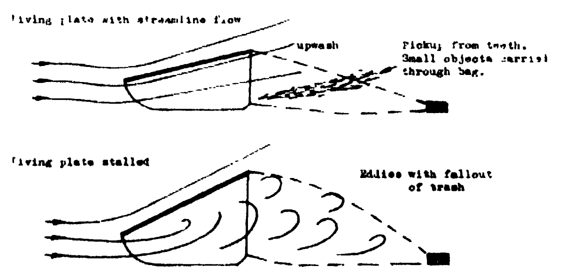

Fig. 2. Secondary effect of stalled diving plate. Eddies behind stalled plate can cause accumulation of trash in the dredge bag

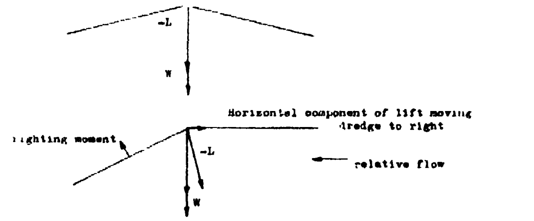

Fig. 3. Effect of dihedral. Temporary displacement of plate results in forces righting moments.

gives positive lift to the left plane and negative lift to the right plane, resulting in righting moments. However, if, as sometimes happens, when the tow is taken from the leading edge of the dredge and the warp is run out with restraint (fig. 4), the diving plate will give positive lift, turning the dredge on to its back; the forces are illustrated in fig. 5.

In fig. 6, a dredge designed for mussel and oyster fishing is shown with two alternative points of tow. When the forward points of tow are used, the dredge has positive lift and is unstable in mid-water if checked during shooting. This had the disadvantage that when the depth suddenly increased the dredge left the bottom and turned over. With the after points, a negative lift was always maintained and the dredge was completely stable and could be towed in mid-water without turning over.

THE EFFECT OF TEETH

Scallops normally lie recessed with the flat valve approximately in the plane of the bottom. On escallop dredges the teeth penetrate the bottom and get below the edge of the shell, thus lifting the scallops into the bag. There are, however, considerable secondary effects. It has been shown[1] that the teeth on scallop dredges give a highly selective effect, operating probably more efficiently than the selective effect of the meshes of the bag. Quantitative information on this effect is limited to date, but from my own data and from those of Mason (1953) the suggestion is that the sizes at which 50 per cent. are selected are between 20 per cent. and 50 per cent. larger than the tooth spacing. The teeth, furthermore, are also sifting out trash, i.e. smaller organisms, shells and small stones. This allows a much longer tow with an increased proportion of fishing time with the dredge on the bottom. For this screening action to be effective there must be clearance between the dredge bar and the bottom. With a shallow angle of attack of the teeth of the dredge, excessively long teeth are necessary to allow for sufficient clearance and penetration of the bottom. These are very easily damaged. With an angle of attack of the teeth approaching 90 degrees, shorter teeth can be used, but entry of the catch

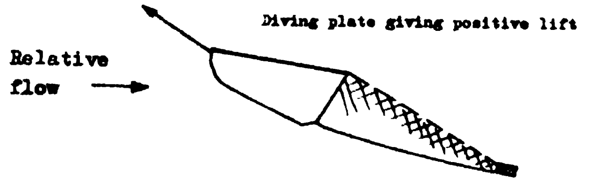

Fig 4. Diving plate giving positive lift during shooting when tow is taken from leading edge and warp is run out with restraint.

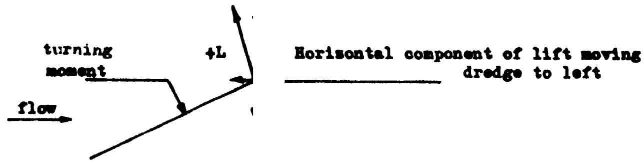

Fig. 5. Forces capsizing dredge during shooting when diving plate gives positive lift.

into the bag is impeded. Experiments done at Conway with a model dredge of about 0·5 metres span, with an adjustable tooth angle but uniform bottom penetration, have suggested that, at varying speeds, entry into the bag is not much impeded up to angles of 45 degrees. Within limits, higher speeds of tow allow steeper tooth angles to be used before passage of scallops over the teeth is impeded.

ABSOLUTE EFFICIENCY

The catching efficiency of dredges is low and will vary with the type of bottom. Coral gravel bottoms in Cornwall and near Port Erin, Isle of Man, at depths of about 20 metres, have been observed to be furrowed to a depth up to 10 cm. with 20 to 30 cm. between the crests of the ridges. The passage of a dredge effectively flattens this type of bottom. It can be seen that a dredge will have a low catching efficiency on a furrowed bottom because it will be either skimming the crests of the ridges and missing many of the scallops, or digging into the ridges and catching a lot of trash which will soon fill the dredge. An increase in efficiency will occur as the bottom is flattened by working. (It is often stated by scallop fishermen that catches increase on some grounds after some days of intensive working.)

Dickie[3] measured the efficiency of Canadian dredges by releasing marked scallops and afterwards dredging in the area, assessing efficiency by the estimated number encountered per tow and the actual number caught. He found an efficiency of from 5 per cent. to 12 per cent., depending on the ground worked. Walne[5] assessed the efficiency of a hand oyster dredge on slipper limpets (*Crepidula fornicata*) by comparing the catch of the dredge to the density of limpets as assessed by grab sampling. He found an efficiency of 16 per cent. Shelbourne[4] measured the efficiency of a winch-operated oyster dredge on slipper limpets by distributing a known number of limpets between poles on a clean intertidal area at low water and fishing between the poles at high water. He found this dredge to be 30 per cent. efficient. A special sampling dredge he devised had an efficiency of 60 per cent. However, although it might be quite possible to devise a dredge that was nearly 100 per cent. efficient for a short tow on a soft bottom, it does not follow that this will give the most economical fishing. This is clearly demonstrated by Shelbourne where the ratios of catch per distance run of 3·3, 1·0, 0·6 were obtained for the survey dredge, the winch-operated dredge and hand dredge respectively on oysters. The ratio of output of oysters per man day was 1·0, 1·1, 1·6 for the most, medium and least efficient dredges respectively. This was almost entirely due to the degree of selectivity, the least efficient dredge being most

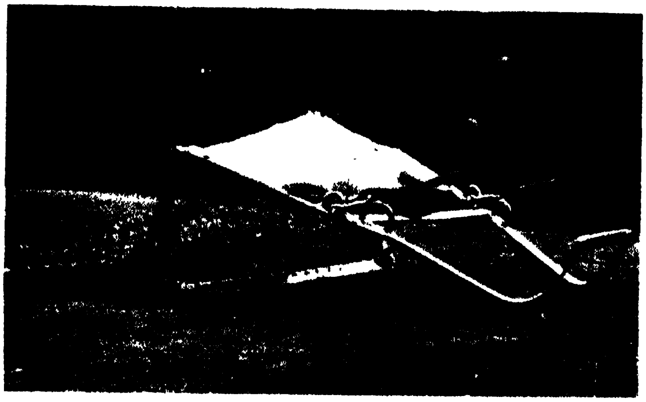

Fig. 6. Mussel and oyster dredge showing alternative tow attachments. Forward attachment results in mid-water instability when warp is checked. After points give complete mid-water stability.

selective and resulting in the highest daily catch of oysters on a "mixed" ground. Where the organisms to be caught are fairly sparse on the bottom, a high selectivity is as important as a high efficiency, otherwise the dredge fills too quickly with unwanted material and so has to be handled more frequently.

A preliminary attempt to measure the efficiency of a traditional scallop dredge was made at Port Erin, Isle of Man, with the aim of using the dredge as a quantitative sampling device and as a standard to which other dredges could be related. Using a self-contained breathing apparatus, the actual density of scallops was measured by collecting all scallops passing between the runners of a sledge towed slowly over a known distance. Dredge hauls of measured distances were made in the same area. If only commercial scallops, 11·5 cm., and upwards, are considered, diving showed these to be present at a mean density of 1 per 40 m.^{2} and the dredge covered 250 m.^{2} for every one caught, giving an efficiency of 16 per cent. for commercial scallops. The mean density of all sizes of scallops, found by diving on the bed being investigated, was 1 per 11 m.^{2} The dredge covered 130 m.^{2} of bottom for every scallop caught, giving an efficiency of 8·5 per cent. The selective effect of the dredge will cause this figure to vary with the size-distribution of scallops on the bed.

It must be emphasized that the range and scatter of these results was such that the only inference that can safely be made is that dredge efficiency is of a low order, probably between 5 and 20 per cent. with a higher efficiency when working on the larger scallops.

REFERENCES

[1] Baird, R. H. and Gibson, F. A. "Underwater Observations on Escallop (*Pecten maximus*) Beds." J. mar. biol. Ass. U.K. (1956) 35, 555-562.

[2] Baird, R. H. "A Preliminary Report on a New Type of Commercial Escallop Dredge". J. d. Con.Int., Vol. XX, No. 3, 1955.

[3] Dickie, L. M. "Fluctuations in Abundance of the Giant Scallop, *Placopecten magellanicus* (Gmelin), in the Digby area of the Bay of Fundy." J. Fish. Res. Bd. Canada, 12 (6), 1955.

[4] Shelbourne, J. E. "The 1951 Oyster Stock in the Rivers Crouch and Roach, Essex." Fish. Invest., Ser. II, XXI, No. 2.

[5] Walne, P. R. "The Biology and Distribution of the Slipper Limpet (*Crepidula fornicata*) in Essex Rivers." Fish. Invest., Ser. II, XX, No. 6.

TRAWL GEAR MEASUREMENTS OBTAINED BY UNDERWATER INSTRUMENTS

by

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Abstract

The Netherlands Fishery Inspectorate has devised a series of instruments for recording the behaviour of trawl gear, as follows: 1. *The Spread Meter*, to record the distance between the after ends of the otter boards or, if the boards are attached directly to the wings, the horizontal opening of the net. 2. *The Clinometer*, which records the tilt of the otter boards sideways as well as fore and aft. 3. *A Net height meter* for measuring the vertical opening of the net. 4. *An angle of attack meter*, for recording the angle of attack of the otter boards. 5. *An Hydraulic Dynamometer*, for measuring the pull of the legs between the boards and the net, and also for recording the tension in the warps on board the ship.

The author describes the evolution of the instruments and then gives some interesting results obtained by their use, for instance the relationship between warp length, the spread of otter boards, their tilt and angle of attack and the opening height of the net.

Tests were made using different kinds of floats on the headline, and it was found that, using no floats, the headline height was 1·2 m., while 10 spherical floats raised it to 1·9 m., 5 "Siamese-twin" floats increased it to 2·3 m., and 10 "trawlplanes" lifted it to 2·75 m.

Mesures effectuées sur des chaluts au moyen d'appareils sous-marins

Résumé

Le Service d'Inspection des pêches des Pays-Bas a mis au point les appareils suivants pour enregistrer le comportement du chalut: (1) un *écartemetre* pour enregistrer la distance séparant les extrémités postérieures des plateaux, ou, si ceux-ci sont fixé directement aux ailes, l'ouverture horizontale de filet. (2) Un *clinometre* qui enregistre l'inclinaison longitudinale et latérale des plateaux. (3) Un *Paravane avec manometre differentiel* pour mesurer l'ouverture verticale du filet: (4) un *appariel pour mesurer l'angle d'attaque* des plateaux. (5) Un *dynamometre hydraulique* pour mesurer la traction des bras reliant les plateaux au filet, ainsi que la tension des funes à bord du navire.

L'auteur décrit l'evolution des appareils et donne ensuite certains résultats intéressants obtenus par leur emploi, par exemple, les rapports entre la longueur des funes, l'ecartement des plateaux, leur inclinaison et leur angle d'attaque.

Des essais ont été exécutés avec différents types de flotteurs sur la ralingue supérieure, et l'on a constaté que la hauteur de la ralingue était de 1,20 m. sans flotteurs, de 1m 90 avec 10 flotteurs sphériques, de 2m 30 avec 5 flotteurs "freres-siamois", et de 2m 75 avec 10 " trawlplanes".

Mediciones en las redes de arrastre con instrumentos submarinos

Extracto

La Inspección de Pesca de los Países Bajos ha ideado los siguientes instrumentos para registrar la manera como se comporta una red de arrastre: (1) El *medidor de separación de las puertas de arrastre* para registrar la distancia que media entre los extremos posteriores de ellas o, cuando éstas se encuentran unidas directamente a las bandas, la anchura de la boca de la red. (2) El *clinometro* que mide la inclinacion de dichas puertas, tanto en sentido lateral como longitudinal. (3) El *paravan con manometro diferencial* para determinar la altura de la boca de la red. (4) El *medidor del ángulo de ataque* para registrar el angulo de ataque de las peurtas de arrastre. (5) El *dinamometro hidrdulico* para evaluar la tracción de las malletas y de los cables de arrastre a bordo del barco.

El autor describe en el trabajo, muy bien ilustrado con fotografias y esquemas, la evolución de los instrumentos y da a conocer algunos resultados interesantes obtenidos mediante su uso; por ejemplo, la relación entre la longitud de los cables de arrastre, la separación de las puertas, su inclinación y àngulo de ataque. Se hicieron pruebas con diversos tipos de flotadores distribuidos a lo largo de la relinga superior, encontràndose que al usar ninguno la altura de ésta llegaba a 1,2 m., mientras que con 10 flotadores esféricos subia a 1, 9 m., con 5 flotadores siameses ("Siamese-twin") a 2, 3 m. y con 10 "trawlplanes" a 2,75 m.

FILMS taken by frogmen, showing trawls and seines in action under water, have enabled fishermen for the first time to see the behaviour of their nets on the bottom and the reaction of the fish to the net.

Although helpful, underwater filming does not solve all the problems. It is also necessary to take measurements of the gear in action. For this reason the Netherlands Inspection of Fisheries has, during the past four years, developed several underwater instruments to record the behaviour of the gear in tow.

Extensive experiments have been made on board the Netherlands F.R.V. *Antoni van Leeuwenhoek* (fig. 1). These have led to many improvements in the instruments which, as they were designed for work in the Southern North Sea, only withstand pressures to a depth of 100 metres.

DESCRIPTION OF THE INSTRUMENTS

The instruments can be read to an accuracy of 1 centimetre, half a degree or 1 kilogram.

1. **A spread meter.** This records the distance between the after ends of the otter boards. If the boards are attached to the wings directly (without legs) this corresponds with the horizontal opening of the net.
2. **A clinometer.** This records the tilt of the otter board sideways as well as fore and aft.

Fig. 1. The Netherlands F.R.V. Antoni van Leeuwenhoek.

3. **A net height meter.** This records the vertical opening of the net (Headline or kite).
4. **An angle of attack meter.** This records the angle of attack of the otter board.
5. **An hydraulic dynamometer.** This records the pull in the legs between the otter board and the net or the pull on the warps on board ship.

SPREAD METER

The spread between the otter boards was first measured by reading the angle between two rods clipped on the warps. At the same time, a length of twine was attached to one of the otter boards, the other end being wound round a small barrel mounted on the other otter board. The barrel was pulled down by springs against two wooden brake cleats. Pull on the twine lifted the barrel from its brakes so that twine unreeled according to the spread of the otter boards and then braked again. In this way, the maximum spread could be measured.

However, the average spread measured by these two methods differed by about 6 metres, so a much more accurate instrument had to be developed.

First it was necessary to determine the curve in a steel wire of 3 mm. diameter and 12, 16, 20 and 24 metres length pulled through the water at speeds of 2, 3, 4 and 5 knots, and carrying longitudinal loads of from 0 to 500 kg. Then graphs were drawn for each speed, giving the difference in lengths at certain loads between the curved wire and a straight line, viz. the actual distance between the otter boards.

Accepting an inaccuracy of 1 per cent. and with an expected spread between the otter boards from 12 to 16 metres, it was found necessary to have a pull of 11 to 15 kg. on the wire when travelling at a speed of 3 knots.

This pull is provided by trawlplanes attached to the free end of the wire. Tests in the towing tank in Wageningen showed that 3 trawlplanes on a 3 mm. wire produced a load of 16 kgs. at 3 knots. In practice, however, this pull was too much for the wire, which had to be renewed frequently because of kinks and flattening where it went over the guiding reels. So, only 2 trawlplanes, which exerted a load of about 10 kg., were used although this increased the error to 2 per cent. in the spread reading.

At a speed of 5 knots, the pull of 2 trawlplanes is 42·2 kgs. and for 1 trawlplane about 20 kg., which is double the amount that can be used for 3 mm. diameter wire. The new spread meter therefore cannot be used for speeds over 3 knots without renewing the wire after every haul or using a stronger wire and recalculating all the data.

The spread meter works as follows: a 3 mm. diameter steel wire is fastened to the aft part of one otter board and passes over guiding reels through a hole in the aft part of the other otter board. As shown in fig. 2, the wire then passes (actually in two turns) over a wheel and over another set of guiding reels to the two trawlplanes (not in the figure).

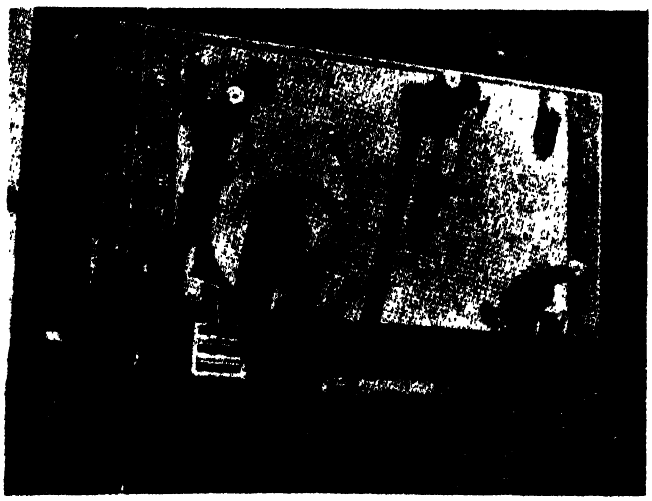

Fig. 2. The baseplate of the spread meter showing arrangement of wire and rolls.

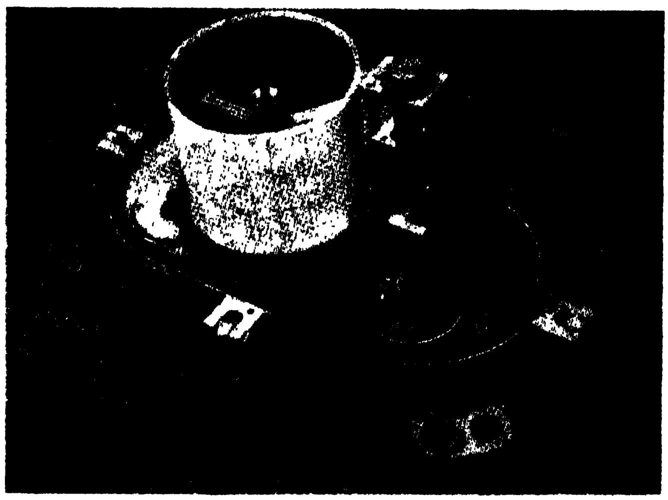

Fig. 3. The recording device of the spread meter.

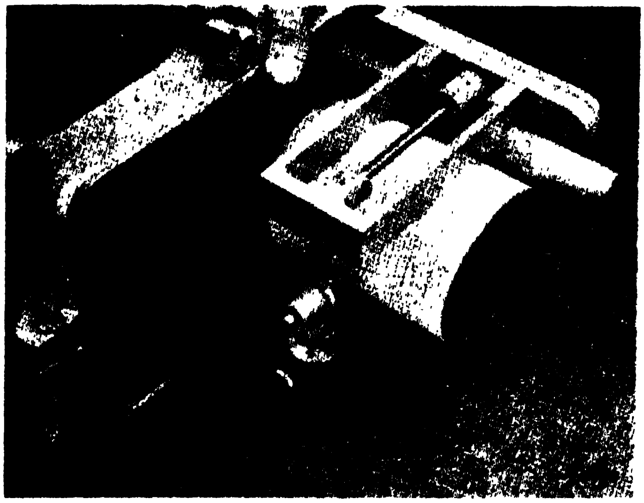

Fig. 4. Clinometer, showing arrangement of pendulum and recording device.

In towing, when the distance between the otter boards increases or decreases, the wheel turns one way or the other and so registers changes in the spread.

A recording device is attached to the wheel as shown in figs. 3 and 5.

The distance between the otter boards is measured before shooting and added to the distance read on the meter, the total being the spread ± 2 per cent.

CLINOMETER

The clinometer mainly consists of a pendulum arm, free to swing in a vertical plane, and a clockwork paper recorder. Changes in the tilt of the otter board are marked by a stylus on the pendulum arm, which carries a weight that can be moved up or down to regulate the sensitivity. Oscillations are damped by attaching the pendulum to a horizontal spindle, which operates a piston rod in two air cylinders (fig. 4). Two vent screws regulate the escape of air in the cylinders.

The apparatus is shown, together with the spread meter, in figs. 5 and 6, attached to the otter board in operation position to determine the sideways tilt of the otter board. By unscrewing the sole plates, it can be fixed in a position at right angles to measure the fore and aft tilt of the otter board. The range is ± 45 degrees.

NET HEIGHT METER

The height of the headline is established by using a differential manometer to measure the difference in hydrostatic pressure between the bottom of the net and the centre of the headline (fig. 7).

A tank (fig. 8) is attached to the footrope. It has a hole at one end while the other is connected to a plastic tube, with an inside diameter of 3 mm. The tube runs along the headline upwards to a paravane which has a buoyancy of 4 kg. and is towed by a steel wire attached to the centre of the headline. A second tank (an ordinary 8 in. float with a hole at the bottom) is fastened to the middle of the headline, and is connected by a short plastic tube to the paravane.

When the net is shot, the water enters and compresses the air in the tanks and in the plastic tubes. The submerged capacity of the tanks is such that they only half fill with sea water.

The two plastic tubes inside the paravane are connected with one pair of bellows each, welded to a steel plate, which moves out of its zero position if the pressure in one pair of bellows is more than in the other. A stylus records the movements. The paravane is shown in fig. 9, while fig. 10 shows it with the head off, disclosing the differential manometer and paper recorder.

As this apparatus measures the difference between the water levels in the two tanks, only that difference can give rise to inaccurate readings. If excess seawater enters one tank by accident, the inaccuracy will not be more than 5 cm. If the tanks are lowered carefully, the

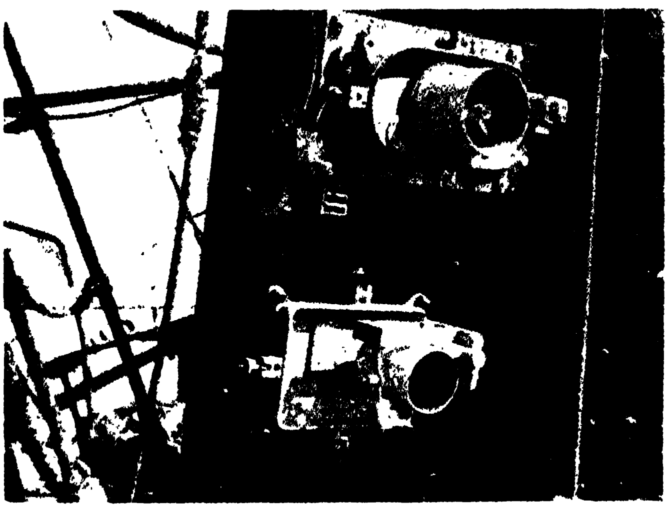

Fig. 5. Spread meter (top) and clinometer (below) attached to the otter board. Without underwater casings.

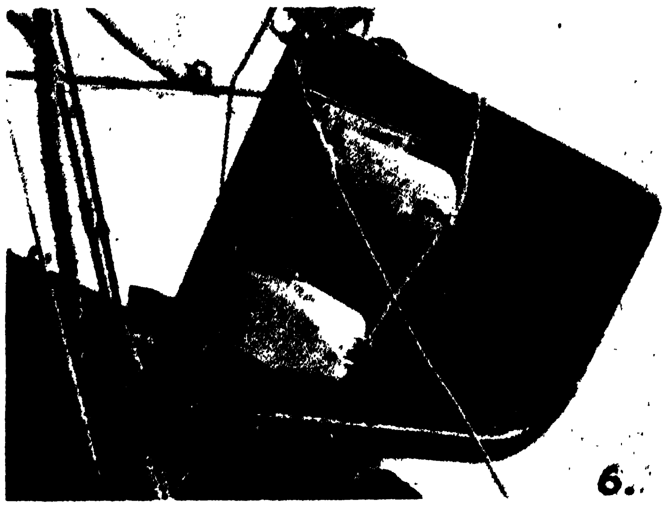

Fig. 6. Spread meter and clinometer ready for operation

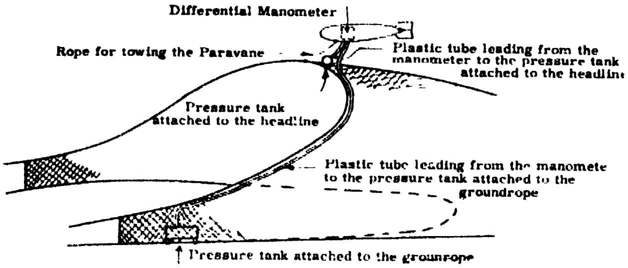

Fig. 7. Net height meter. Arrangement of the different parts at the net opening.

Fig. 8. Measuring tank fixed to the footrope, showing the hole for entrance of pressure and the connection of the plastic tube.

maximum error, therefore, will not be more than 10 cm.

The paravane is lowered at the same time as the headline, with the towing wire and plastic tubes connected to both sides. When the paravane is afloat the veering wire is disconnected at a length of 4 metres, a small plastic float being attached to the end. This can be picked up easily when the net is hauled again.

As the first paravane could be used only between depths of 15 and 30 metres, measuring a maximum height of 5 metres, another was developed on the same principles, designed to withstand an outside pressure of 10 atmospheres.

A new type of differential manometer divided in two partitions by a large brass diaphragm on a rubber disc, has been used with this paravane. Movements are marked on a recording drum by a stylus mechanism. The paravane can be used at all depths up to 100 metres, measuring a maximum height of 10 metres.

ANGLE OF ATTACK METER

If a rod is attached to an otter board and suspended to move in horizontal and vertical directions, the free end sliding over the ground will adopt the towing direction of the otter board.

This is the principle underlying the angle of attack meter.

A steel tube, about 2 metres long, and weighted at the end with lead, is connected by a lever with a turning disc operating in a sole plate attached to the otter board.

Fig. 11 shows the registration apparatus mounted on the sole plate. The complete instrument fixed to the otter board ready for operation is shown in fig. 12.

DYNAMOMETER

Tension in the warps varies considerably with the movement and change in direction of the ship, and with the movements of the otter boards over uneven ground. For measuring the pull on the warps and other parts of the gear, two types of dynamometers were tested.

The principle of the first dynamometer is the variation in electrical resistance of a thin wire when elongated. Fig. 13 shows this tension dynamometer fixed between the bollard and the warps. The electronic tension meter on which the pull can be read in kg., is shown underneath the dynamometer. This apparatus proved to be much too sensitive for use.

Measurements between the otter boards and the net were made by using a hydraulic dynamometer (fig. 14)

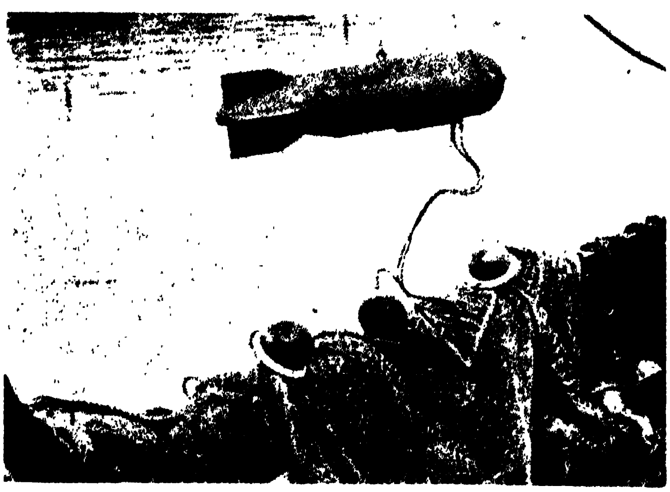

Fig. 9. The paravane of the net height meter ready for operation.

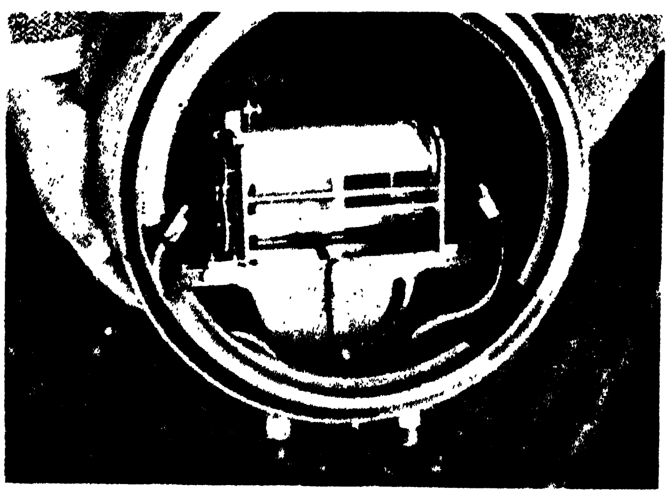

Fig. 10. Inside view of the paravane.

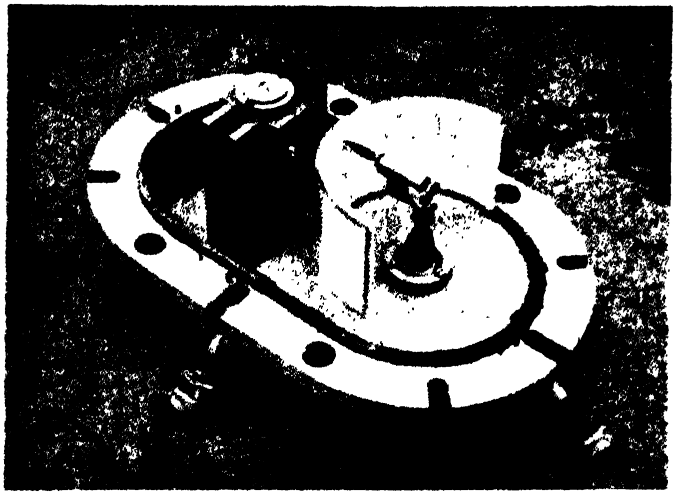

Fig. 11. Angle of attack meter, inside view.

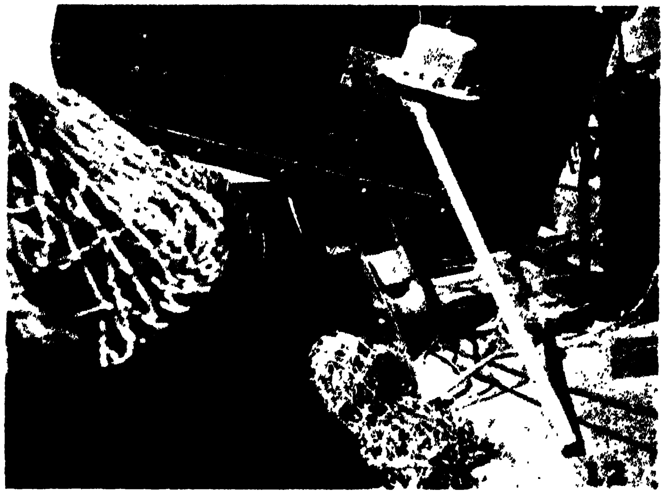

Fig. 12. Angle of attack meter attached to the otter board in working position.

attached to the upper leg between the otter board and the wing of the net. This dynamometer, attached to a bracket mounted to the aft side of the otter board, consists of an oil cylinder, with piston rod and piston which compresses the oil in the cylinder. The cylinder is connected with the registration apparatus by a high pressure rubber tube. A plug regulates the sensitivity. The pressure, which is proportional to the pull, is measured by a spiral hollow tube moving a stylus, which is supported to prevent bad recording when the otter board bumps. The recorder is mounted in a vertical position so that ink can be used instead of a pencil, which proved to be too unyielding.

The best results from the instruments mentioned are obtained when trawling over even ground and when the wind force is not more than 3 to 4. These conditions apply to even bigger ships than the *Antoni van Leeuwenhoek*.

RESULTS

Instruments 1 to 4 have been used together, or in different combinations, in a number of experiments. The hydraulic dynamometer has been used separately in more recent trials.

The depth was noted during each haul and the ratio of the length of the warps to the depth was determined, while the distance travelled per haul over the ground was calculated to find out the strength of the tide. Wind and sea conditions were noted as well.

A manila trawl, with a headline length of 20·8 m., a footrope of 25·2 m., and with 8 cm. meshes in the codend, was used. The dimensions of the otter boards (fig. 15) were 1·10 × 2·10 m. (weight 209 kgs. each). The wings of the net were attached to the otter boards without legs, while 10 trawlplanes of 8in. diameter, 1 m. apart, were attached to the headline, 5 to each side of the middle. The upper tank, plastic tubes and towing wire of the paravane were fixed to the centre of the headline.

Hauls were made always with the running tide and with a constant number of propeller revolutions, giving the ship a fishing speed of 1·7 to 3 knots over the ground.

Experiments took place from 5th May to 4th July 1953, over smooth bottom between Scheveningen and Katwijk at a mean depth of 17 metres. Hauls lasted

Fig. 13. Electronic dynamometer in action.

Fig. 14. Hydraulic underwater dynamometer attached to the otter board in working position.

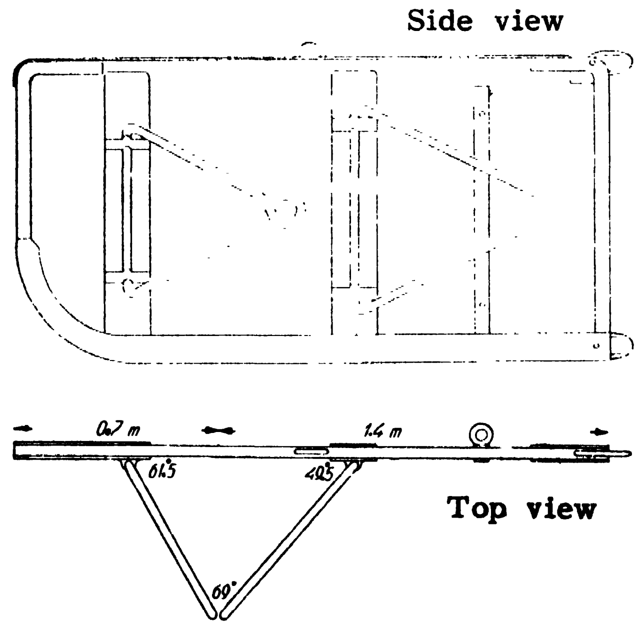

Fig. 15. Schema of the otter board used.

one and a half hours, during which the warps were lengthened by veering about 7·5 fathoms every 15 minutes.

SPREAD

A record of the spreadmeter is shown in fig. 16. For convenience the scale of the total spread has been given at the bottom of the diagram. The distance between the otter boards measured on board was 9·45 m. The zero-position of the stylus before lowering the otter boards is indicated by a thick short arrow. The recording is unsteady at first but becomes nearly constant as the gear settles on the bottom. As the warps are lengthened by about 7·5 fathoms, the spread increases. The periods of shooting and hauling are indicated with arrows on the left of the diagram.

Conclusion: the spread will increase by lengthening the warp.

TILT

Fig. 17 gives a clinometer record for one haul. The first line shows an outward tilt about 16·5 degrees when the otter board is hanging in the gallows. When lowering, the tilt is unsteady, but becomes steady after a short settling period. The otter boards take a more upright position as the warps are lengthened and finally tilt inwards and become unstable when the warps become too long. The average tilt with the different lengths of warp can be read on the right of the diagram, while on top the arrows give the periods of shooting and hauling.

Conclusion: the otter boards will tilt from outwards to inwards, becoming more unstable, as the warps are lengthened.

HEIGHT OF THE NET

Fig. 18 shows a record of the net height meter. The conspicuous peaks indicate that the height of the net is temporarily increased during the veering of the warps. The periods of shooting and hauling are shown by arrows. The large peaks are formed when the net hangs from the side of the ship.

Conclusion: the height of the net decreases with increase in warp length.

ANGLE OF ATTACK

A record of the angle of attack meter is shown in fig. 19. During the periods of shooting and hauling, the position of the otter board is uncontrollable. The periods of veering of the warps are indicated on the left of the diagram. Even if the angle of attack of the otter boards for the different lengths of the warp are rather variable, it is possible to read a reliable average, indicated on the left in degrees.

Conclusion: by lengthening the warps, the angle of attack decreases.

The recordings of the tilt, the height of the net and the angle of attack (figs. 17, 18 and 19) show great peaks when the warps are veered.

It appeared that, during the veering of the warps, the otter boards tilted, on average, 23 degrees inwards, while the angle of attack diminished by 8 degrees and the height of the net increased by 35 cm. In fig. 20 the position of

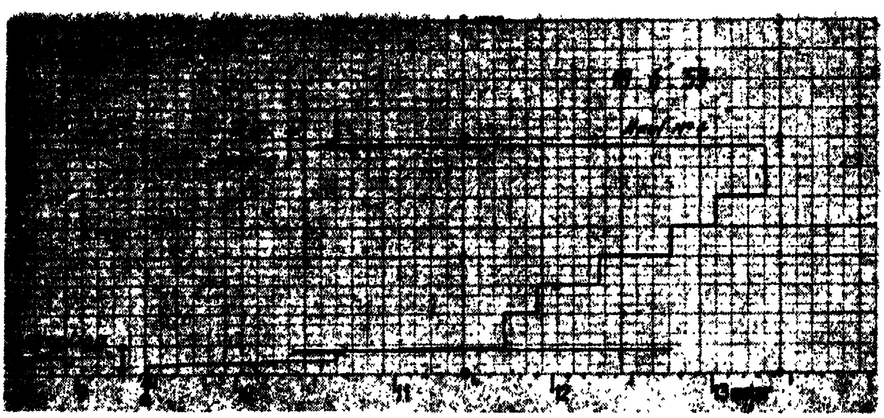

Fig. 16. A record of the spread meter.

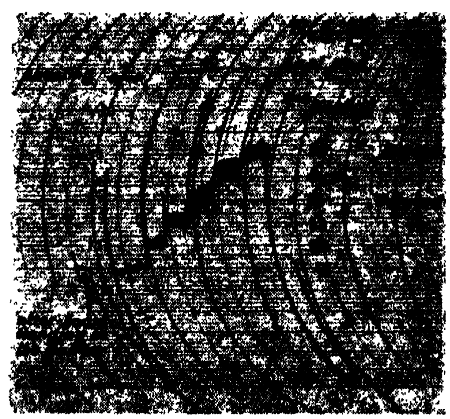

Fig. 17. A record of the clinometer.

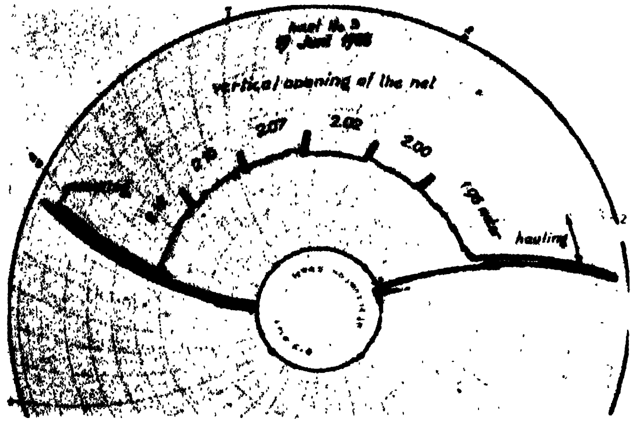

Fig. 18. A record of the net height meter.

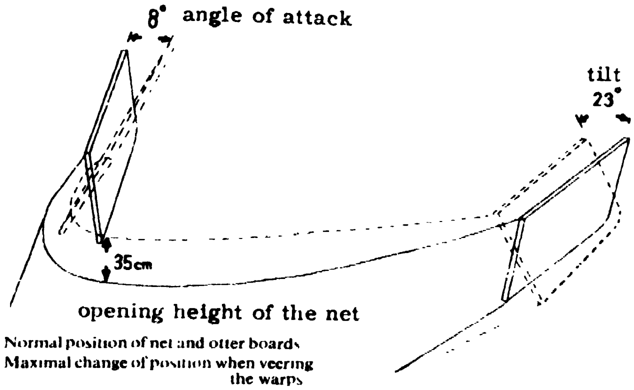

Fig. 20. Schematic drawing, explaining the behaviour of the otter boards and the net opening when veering the warps.

the otter boards, drawn in dotted lines, indicate the situation during the veering of the warps, from which the conclusion can be made that there is more slack in the headline, which will be lifted by the floats.

There are peaks also on the other side because of the sudden braking of the warps after veering, in which case the opposite action occurs, but, with gradual braking no peaks appear.

INFLUENCE OF THE INSTRUMENTS ON THE GEAR

The paravane has a buoyancy of 4 kg., equal to that of a spherical float of 8 in. diameter, while the clinometer has a buoyancy of 0·8 kg. The new paravane was given a buoyancy of 8 kg. It may be accepted that these instruments will not affect the gear in any way.

Since the spread meter, the angle of attack meter and the clinometer are mounted on the aft side of the otter boards where, as the film "Trawls in Action" shows, great whirls are created, the water resistance of these instruments is not likely to affect the action of the otter boards. But the angle of attack meter weighs 9 kg. and the spread meter 5 kg. At a speed of 3 knots, 2 trawlplanes pull with a force of 10 kg. on the wire of the spread meter. It had, therefore, to be determined what influence these instruments had on the gear, separately and in combination.

The instruments were distributed over both otter boards (see Table I) in 9 series of hauls.

Before starting *h* and *i*, the warps had to be renewed and shortened and since differences in lengths of warps produce different readings, series *h* was made a repetition of series *d*, so that *h* and *i* could be compared.

The net height meter and the clinometer were used during all these hauls. A comparison of the data obtained shows that the instruments exerted no influence whatsoever on the operations of the otter boards. Even the strain on the wire of the spread meter had no influence on the angle of attack and the tilt of the otter boards.

However, the height of the net became 2·20 m. when the spread meter was used, compared with 2·12 without it (see Table IV). This corresponds to a decrease in spread of about 52 cm. (calculated from Table II) on an average spread of 12·89 (see Table IV), an error of nearly 4 per cent., which must be added to the measured spread. As already mentioned, by using 2 trawlplanes, 2 per cent. has to be subtracted for the bend in the wire, so the actual distance between the aft parts of the otter boards will be the measured distance plus 2 per cent., in this case 12·89 m. + 2 per cent. = 13·15 m.

Fig. 19. A record of the angle of attack meter.

INFLUENCE OF THE LENGTHS OF THE WARPS

After determining the influence of the instruments on the gear, the average was taken of the results obtained

TABLE I

Series	Spread Meter on	Attack-Angle meter on	Clinometer on	Number of hauls
a.		Aft otter board	Front otter board, sideways	7
b	Front otter board	Aft otter board	Front otter board, sideways	9
c.		–	Aft otter board, sideways	6
d.		Aft otter board	Aft otter board, sideways	9
e.	Front otter board	Aft otter board	Aft otter board, sideways	8
f.	—		Front otter board, fore and aft	2
g.		-	Aft otter board, fore and aft	3
h.	-	Aft otter board	Aft otter board, sideways	8
i.	—	Front otter board	Front otter sideways	9

TABLE II

Length of the Warps in m.	Depth in m.	Ratio between Length of Warps and Depth	Angle of Attack	Tilt outwards (o) or inwards (i)	Tilt fore (f) or aft (a)	Spread in. m.	Height of Net without Spread Meter in m.	Height of Net with Spread Meter in m.
67·21	17·04	3,9	35·2°	12·5° (o)	3·4° (f)	12·26	2·19	2·31
81·05	17·03	4,8	32·7°	7·0° (o)	2·5° (f)	12·53	2·17	2·26
94·85	16·97	5,6	28·4°	1·0° (o)	1·7° (f)	12·83	2·13	2·21
108·67	17·01	6,4	25·0°	4·4° (i)	0·6° (f)	13·14	2·08	2·15
122·42	16·96	7,2	22·2°	8·9° (i)	0·3° (a)	13·34	2·02	2·10
136·17	16·87	8,1	20·1°	12·5° (i)	0·5° (a)	13·40	1·97	2·05

TABLE III

58·50	17·10	3,4	37·0°	5·9° (o)	—	—	2·26	—
72·00	17·00	4,2	34·3°	9·0° (o)	—	—	2·19	—
85·50	16·95	5,0	30·9°	3·3° (o)	—	—	2·16	—
99·00	16·90	5,9	28·6°	1·7° (i)	—	—	2·12	—
112·50	17·10	6,6	26·2°	5·3° (i)	—	—	2·10	—
126·00	17·30	7,3	24·9°	8·8° (i)	—	—	2·08	—

from series a to g, and the results are given in Table II, while Table III gives the averages of the hauls in h and i.

The following conclusions can be drawn from Tables II and III. By lengthening of the warps:

1. the angle of attack decreases;
2. the otter board tilts from outward to inward;
3. the otter board tilts from forward to aftward;
4. the spread increases;
5. the height of the net decreases.

We can also say that, if the depth decreases with a fixed length of warp, the same will happen as mentioned above. If the depth increases, the opposite will occur.

RATIO BETWEEN WARP LENGTH AND DEPTH

The effective spreading surface of the otter board is greatest when it takes up a position perpendicular to the bottom, i.e. when the sideways tilt of the otter board is zero.

Interpolating the data in Table II and III for a tilt of 0 degrees, the result is given in Table IV.

The small differences between the sets of values are caused by a smaller ratio between the lengths of the warps and the depth, by small errors in the readings due to differences in current, wind force, swell and slight changes in the depth, and by small instrument errors.

However, the results are sufficiently accurate to show that, while fishing at a depth of 17 metres with an upright otter board, the angle of attack is about 28·5 degrees the height of the net just over 2 metres and the spread 12·89 m. + 2 per cent. = 13·15 metres. For an upright position of the otter board the length of the warps must be about 5·1/2 times the depth.

INFLUENCE OF LEGS

Two additional series of hauls have been carried out with the same gear but with a fixed length of the warps.

In the first 7 hauls, legs of 3·60 m. length were used between the otter boards and the net; in the second series of 4 hauls the wings of the net were coupled to the otter boards directly. The tilt of the otter boards was not determined.

The average readings for these series are given in Table V.

These results are represented diagrammatically in fig. 21 (gear with the legs shown by dotted lines).

In fishing with legs, the angle of attack is decreased and the spread of the otter boards is increased, but not the spread of the net, so there is more slack in the headline, and the height of the net is increased by 41 cm.

INFLUENCE OF DIFFERENT TYPES OF FLOATS ON THE OPENING HEIGHT

With the same gear as mentioned above, using 3·70 m. legs between the otter boards and the net, the height of the net without any floats was 1·20 m., or 10 cm. more

TABLE IV

From Table	Length of the Warps in m.	Depth in m.	Ratio between Length of Warps and Depth	Angle of Attack	Spread in m.	Height of Net without Spread Meter in m.	Height of Net with Spread Meter in m.
II	96·9	16·98	5,7	27·8°	12·89	2·12	2·20
III	94·7	16·92	5,6	29·4°	—	2·13	—

TABLE V

With or without Legs of 3·60 m.	Length of the Warps in m.	Depth in m.	Ratio between Length of Warps and Depth	Angle of Attack	Measured Spread in m.	Height of Net in m.
With	95·45	15·2	6,3	26·0°	14·54	2·76
Without	95·45	16·2	5,9	31·5°	13·43	2·35

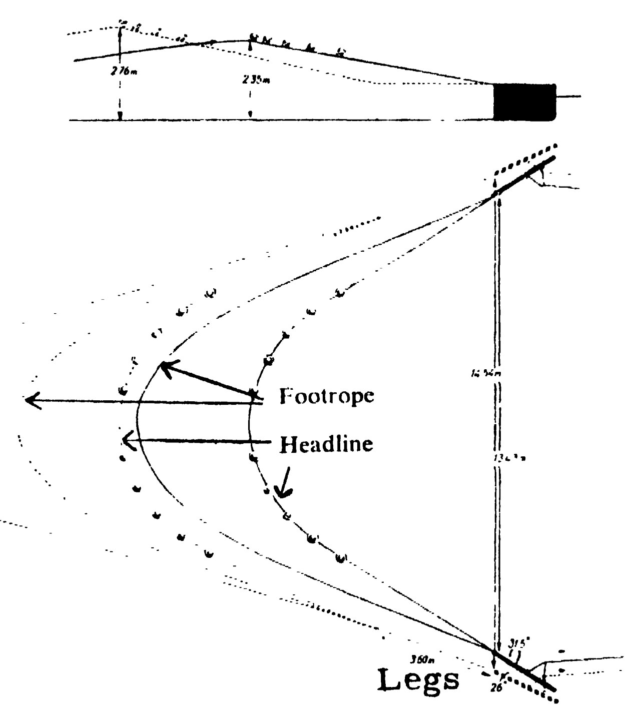

Fig. 21. Schematic drawing showing the influence of short legs on the net opening.

than the height of the otter board. With 4 to 6 spherical 8 in. floats, the increase in height was not more than 30 cm., while with 8 floats the lift was considerably more, being about 55 cm. (total height 1·75 m.). A kite (with two small glass floats mounted on it) was used with the 8 floats, but it provided no increase in height.

Comparative trials were carried out with 10 spherical 8 in. floats, 5 Phillip's Siamese-twin floats and 10 Phillip's trawlplanes, all having a diameter of 8 in. Strips of about

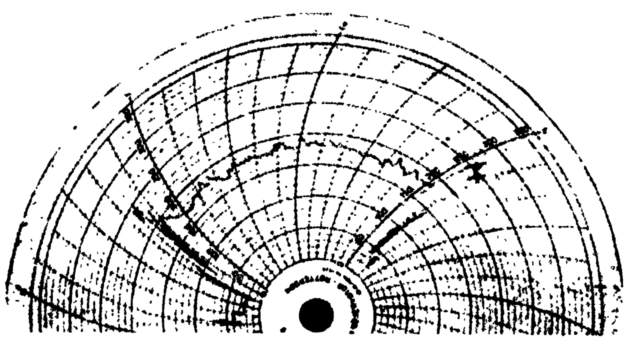

Fig. 22. Record of the underwater dynamometer between otter board and upper leg, rough sea.

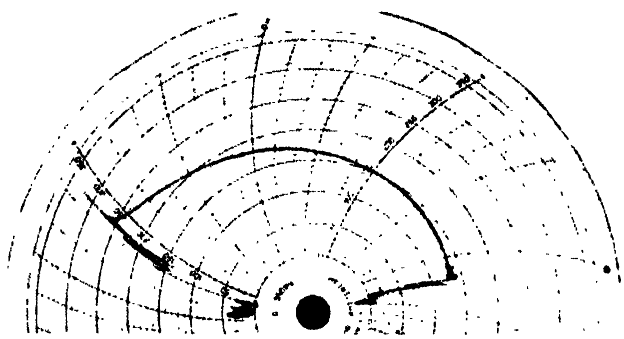

Fig. 23. Record of the underwater dynamometer between otter board and upper leg, in a calm sea. The pull decreases due to the net being choked by a big catch of colony-building Hydrozoa.

7 cm. width were out off the sides of the half circular plates on the Siamese-twins, giving them a winglike shape, which reduced resistance and increased buoyancy.

The results were:

10 spherical floats	.	height of headline 1·90 m.
5 Siamese-twins	.	height of headline 2·30 m.
10 trawlplanes .	.	height of headline 2·75 m.

PULL ON THE LEGS AND AMOUNT OF CATCH

The hydraulic dynamometer has only been used submerged between the otter boards and the net, and only a limited number of hauls have been made. In fig. 22 a diagram is given showing a tension of about 180 kg. in the upper leg. During this haul the sea was rather rough, with a wind force 4.

During another haul with very calm weather (fig. 23) the pull decreased from 250 to 130 kg. The same happened in 6 consecutive hauls although in earlier and later trials a fairly constant tension was recorded. The reason was found in an enormous number of colony-building Hydrozoa which gradually choked the net during fishing. The net was cleaned before each haul.

On the assumption that the specific gravity of fish is practically the same as the specific gravity of the water, the strain in the legs should be unaffected by the catch, especially if most of the fish are swimming with the net. But eventually the codend becomes choked by the fish and starts to overflow. This may result in a decrease, not an increase, of the pull. Therefore, a dynamometer between the otter board and the net may give an indication of the amount of catch.

This is in contradiction to a claim by an American manufacturer of dynamometers, published in the "Atlantic Fisherman", Vol. 30, No. 6, p. 35, July 1949, and it is suggested that the rate of catch may be determined *by a decrease in the tension* on the warps or the legs.

STUDIES ON TWO-BOAT TRAWLS AND OTTER TRAWLS BY MEANS OF MEASURING INSTRUMENTS

by

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Abstract

The authors have analyzed the change in shape of the net during shooting and towing by the use of instruments and this paper deals with the results of their experiments so far as the two-boat trawl and the otter trawl are concerned. The automatic net-height meter was used to ascertain the height of the headline and the wings and the footrope indicator to assess the shape of the footrope during the various phases of the fishing operation. Improvements were made to the two-boat trawl, as a result of the tests and the authors claim that by raising the headline by 1·5 metres the catch was increased by nearly 50 per cent. With the otter trawl the shape of the net was observed from the time it was put overboard until it was on the sea bottom, and the time taken for the warps and net to assume their correct position was calculated.

Etude, au moyen d'instruments du chalut à deux bateaux et du chalut à plateaux

Résumé

Les auteurs ont étudié au moyen d'instruments de mesure, le changement subi par la forme du filet pendant les opérations de mise à l'eau et de remorquage et exposent dans cet article les résultats de leurs expériences obtenu avec des chaluts à deux bateaux et des chaluts à plateaux. Ils ont utilisé l'appareil automatique à mesurer la hauteur du filet pour déterminer la hauteur de la corde de dos et des ailes, et l'indicateur de bourrelet pour mesurer la forme du bourrelet pendant les différentes phases des opérations de pêche. Les résultats des essais ont permis d'améliorer le chalut á deux bateaux, et les auteurs déclarent avoir obtenu une augmentation de près de 50 pour cent des quantités pêchées en élevant de 1·5 mètres l'ouverture de gueule du chalut. En ce qui concerne le chalut à plateaux, les auteurs ont étudié toutes les positions successives prises par le filet depuis le moment de sa mise à l'eau jusqu'à celui où il a pris sa forme normale sur le fond, et ils ont calculé le délai nécessaire aux funes et au filet pour prendre leur position correcte.

Estudios mediante instrumentos de las parejas y arrastreros que pescan con artes de puertas

Extracto

En este trabajo los autores estudian, mediante instrumentos de medida, los cambios que experimenta la forma de una red de arrastre durante el calamento y la recogida, y analizan los result a dos de sus investigaciones con embarcaciones que pescan en parejas y usand redes de arrastre du puertas. Durante las diversas etapas de estos estudios se usaron el medidor automático para evaluar la altura de la relinga superior y de las pernadas, y el indicador de la relinga inferior para determinar la forma de este cable durante las diversas fases del lance. En el caso de la pesca con parejas, se pudieron introducir mehjoras de acuerdo con los resultados obtenidos en las pruebas, afirmando los autores que al aumentar la altura de la boca de la red, 1·5 m., el volumen de las capturas experimentó un incremento de casi un 50 per cent. En el caso de la red de arrastre de puertas se estudio cada estado del arte desde el momento de lanzarlo al agua hasta que tomó la forma definitiva sobre el fondo del mar, calculándose el tiempo que demoraron los cables de arrastre y la red en tomar la posición correcta.

THE AUTOMATIC NET HEIGHT METER

THE recorder (A) and the guide part (B) are both equipped with bellows (C_2 and C_1) which are connected by a vinyl pipe (F) filled with oil. The antipressure vinyl pipe (G) equalises the air pressure inside the recorder and guide part in order to avoid temperature effects. The recorder is fixed to the footrope and the guide part to the point to be measured. The two bellows measure the difference in hydrostatic pressure between the measuring point and the footrope which is recorded in the usual way by a pointer (E) writing on a chronograph (D) (fig. 1).

Three types of such net height meters have been developed which are all of sturdy construction to stand rough handling, and which are small and light enough to exclude any influence on the net to be measured. They have a working range of 0 to 150 m. water depth, a measuring range of 0 to 7 m. and an accuracy of 5 cm. with a sensitivity of 2 cm. The newest of these instruments used since 1957 is shown in fig. 2.

THE AUTOMATIC FOOTROPE INDICATOR

This instrument consists of a handle which can freely turn on a vertical axle and which, due to the bottom friction of its resistance plate, is kept in towing direction during action of the trawl. The position of this handle is continuously recorded on a chronograph which is attached to the footrope in a water and pressure tight casing (fig. 3). By attaching several of such instruments distributed over the footrope the curvature it takes during trawling and its variations can be determined.

TWO-BOAT TRAWLS

Opening height. A diagram of the trawl which was tested is given in fig. 5.

Table I shows that the net sinks to the bottom with a speed of about 0·3 m./sec. and the warps are veered at about 3·1 to 4·2 m./sec. It is also shown that before towing really starts the net opening is much higher than during trawling.

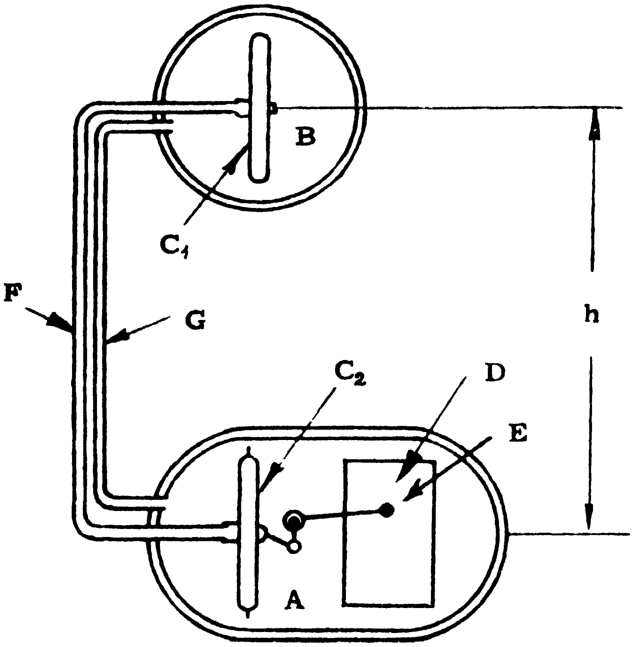

Fig. 1. Principle of the recording net height meter. A Recorder; B – Guide part; C_1 – Bellows (guide); C_2 – Bellows (recorder); D – Chronograph; E – Pointer; F – Liquid pipe; G – Air pipe.

TABLE I

Experiment No.	Time from throwing the net overboard until it reaches the bottom	Time for paying out 750 m. warp	Height of net-entrance immediately after reaching the sea bottom	Sea-depth
1	3 min.	3 min.	6·28 m.	51 m.
2	3	4	5·55	55
3	3	3	5·70	52
4	3	3	6·28	57
5	3	3·5	6·30	51

Fig. 2. Newest type of recording net height meter.

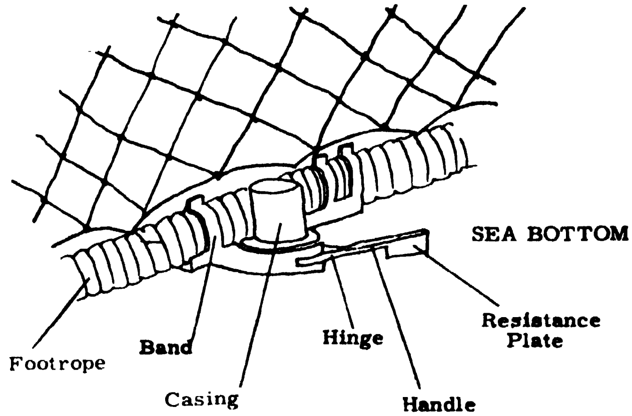

Fig. 3. Principle of the recording footrope indicator.

There are two ways of shooting this gear (fig. 6) which have been found to influence the time needed from starting towing until the net opening acquires its stable height. With the V-type manoeuvre it takes less time than with the U-type where, furthermore, the opening decreases to a minimum before it becomes stable (Table II).

With about 750 m. warp length, 300 to 400 m. distance between the two towing boats is considered to be convenient. Fig. 7 shows that even up to about 500 m. distance no significant effect to the opening height occurred. The variation is due to the changing tidal current influencing the actual towing speed.

To improve the opening height, the construction of the original net was changed as shown in fig. 8. These changes concern increase of webbing mainly around the net opening, the relation between headline and footrope lengths which shifts the main pull to the footrope, and the flapper attached in such a way that it can open completely during towing. A comparison of the values

TABLE II

Experiment No.	Time from start of towing to stable net-opening	Minimum height of net opening	Height of stable net opening	Type of setting
1	12·5 min.	1·43 m.	1·82 m.	U
2	14	1·00	1·55	
3	8	1·48	2·14	
4	1	1·68	1·68	V
5	5	1·30	1·30	

Fig. 4. Recording footrope indicator.

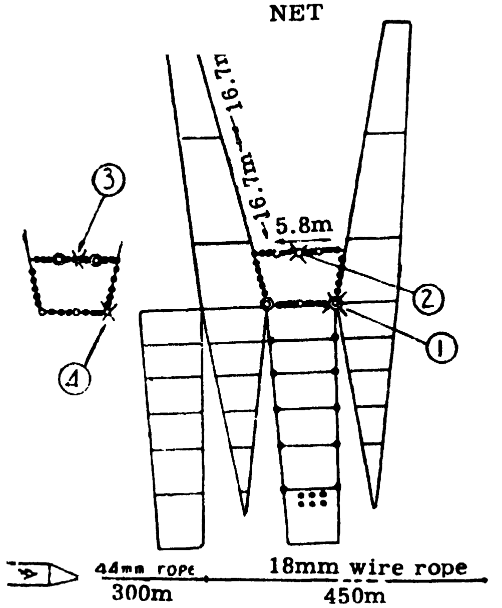

Fig. 5. Diagram of two boat trawl tested with indication of the measuring points for the net height meter (1 to 4). O = Glass float, 30 cm. diameter; O = Glass float, 18 cm. diameter; ● = Glass float, 15 cm. diameter; ⌣ — Chain.

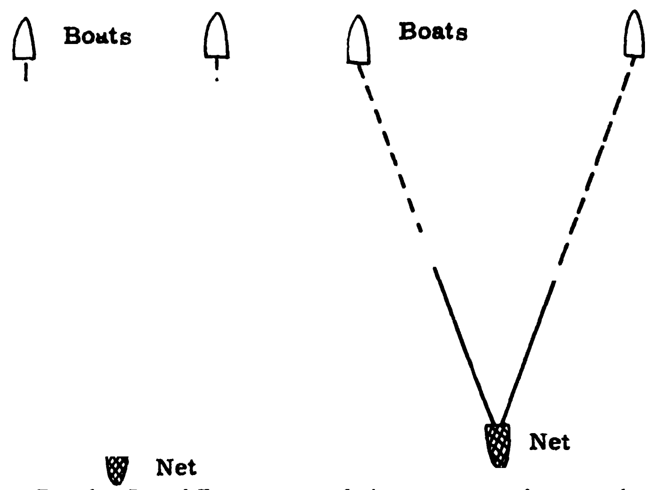

Fig. 6. Two different types of shooting a two boat trawl.

of opening height of the original design with the new design proves that a considerable increase of about 1·5 m. or 75 per cent. could be obtained (fig. 9).

With increasing towing speed the opening height decreases considerably at all points measured, e.g. middle of headline bosom, quarter point and middle of wing. The main reason for this is considered to be the decrease in buoyancy of the floats caused by their towing resistance. Without any floats, the opening height was only 0·6 to 0·8 m.

The graphs in fig. 10 show that the influence of the distance between the trawlers on the opening height increases with the towing speed. With a towing speed of 2·3 to 2·5 knots the most satisfactory distance between the trawlers in regard to the opening height is 300 to 350 m. under the given conditions.

CURVATURE OF THE FOOTROPE

The curvature of the footrope was measured at five points (fig. 11, a to e) by means of the footrope indicators

TABLE III

Ex. No.	*Distance between the boats*	*Towing Speed*		*Height*		
		Boat	*Net*	*The Middle of the headline bosom*	*The quarter point*	*Difference*
1-1′	420 m.	2·2 kt.		3·3 m.	2·15 m.	1.15 m.
	370 ,,			3·9 ,,	2·4 ,,	1·5 ,,
2-2′	300 ,,	2·5		The middle point of the wing. 1·7 m.	1·9 ,,	0·2 ,,
	500 ,,			1·7 ,,	2·0 ,,	0·3 ,,
3-3′	400 ,,	2·2 ,,		3·4 ,,	3·0 ,,	0·4 ,,
	600 ,,	2·1 ,,		3·2 ,,	2·9 ,,	0·3 ,,
	300 ,,	2·3 ,,		3·7 ,,	3·15 ,,	0·55 ,,
	500 ,,			3·5 ,,	2·95 ,,	0·55 ,,
4-4′	280 ,,	3·5 ,,		0·65 ,,	0·35 ,,	0·3 ,,
	400 ,,	3·3 ,,		0·6 ,,	0·3 ,,	0·3 ,,
	300 ,,	2·66 ,,		0·8 ,,	0·4 ,,	0·4 ,,
5-5′	300 ,,	1·66 ,,		5·3 ,,	3·0 ,,	2·3 ,,
	350 ,,	1·6 ,,		5·7 ,,	3·05 ,,	2·65 ,,
6-6′	320 ,,	1·6 ,,		5·5 ,,	3·1 ,	2·4 ,,
7-7′	530 ,,	1·66 ,,	0·3 kt.	5·2 ,,	2·95 ,,	2·25 ,,
	530 ,,	1·8 ,,	0·6 ,,	5·3 ,,	3·05 ,,	2·25 ,,
	530 ,,	1·86 ,,	1·0 ,,	4·85 ,,	2·80 ,,	2·05 ,,
8-8′	380 ,,			4·3 ,,	2·6 ,,	1·7 ,,
	270 ,,			5·0 ,,	2·85 ,,	2·15 ,,
	450 ,,	2·4 ,,		3·6 ,,	2·45 ,,	1·15 ,,
	350 ,,			4·45 ,,	2·8 ,,	1·65 ,,
	400 ,,			3·5 ,,	2·35 ,,	1·15 ,,

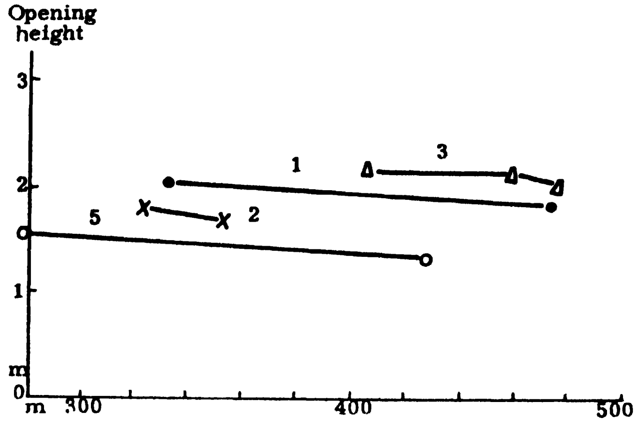

Fig. 7. Relation between the distance of the two trawlers and the opening height of the net.

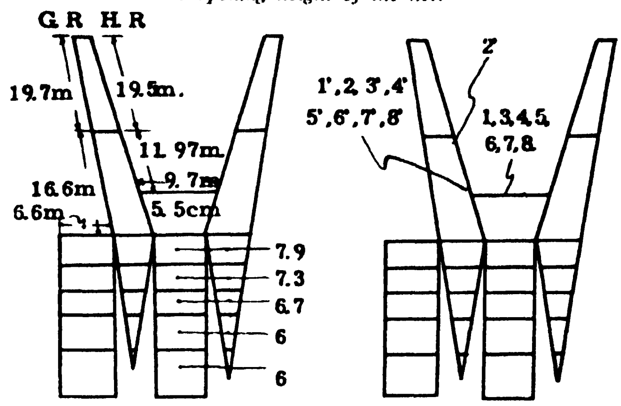

Fig. 8. Diagram of the improved net for a higher opening with indication of measuring points for different experimental hauls.

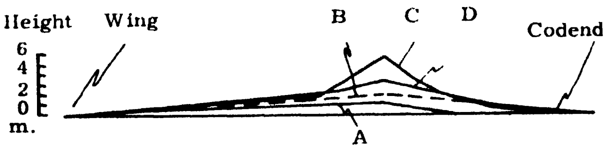

Fig. 9. Comparison between the original net and the improved one. A = Net without floats; B = Original net, 2·3 knots towing speed; C = Improved net, 1·7 knots; D = Improved net, 2·3 knots towing speed.

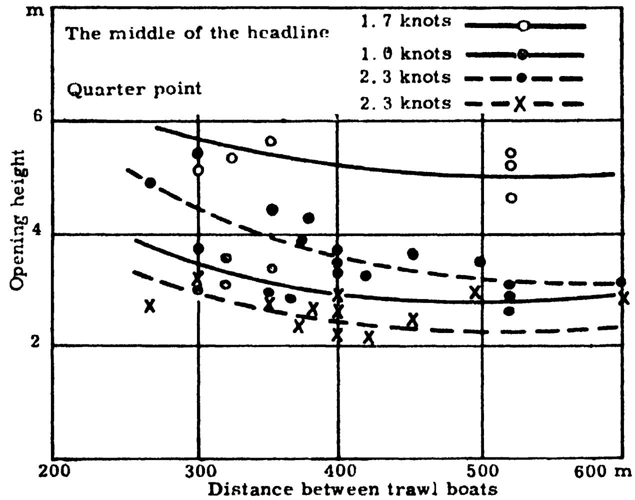

Fig. 10. The effect of towing speed on the influence of the distance between the trawlers on the opening height.

described below. An example of the recordings is given in fig. 12.

It was found that the footrope settles to a stable curvature in 10 to 12 minutes with the U-type of shooting and in 2·5 to 5 minutes with the V-type of shooting, after towing is started.

The angles formed at the five measuring points and the distance calculated accordingly between the respective points for different distances between the trawlers are given in Tables IV and V. The magnitude of the change in distance between the vessels explains the influence on the opening height discussed above.

TABLE IV

Distance between the boats	*Angle of the Footrope and Towing Direction* a	b	c	d	e
400 m.	26·5°	32·5°	34°	38°	46°
450	35	35	37·5	46	52
500	32	36	38	53	55

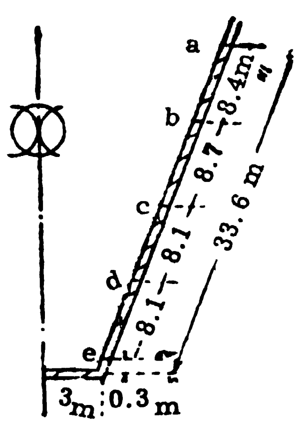

Fig. 11. Measuring points for determining the curvature of the footrope.

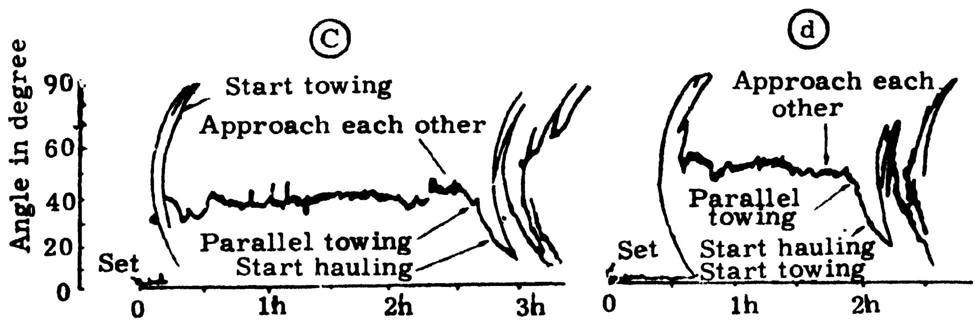

Fig. 12. Example for the recordings of the footrope indicators.

TABLE V

Distance between the boats	*Distance between wing tips*	*Span of foot-rope bosom (6 m. long)*	*Depth of footrope curvature*
400 m.	41·1 m.	5·1 m.	29·3 m.
450	45·6	5·4	27·8
500	48·6	5·5	26·3

Just before hauling the two boats approach each other and then tow for a short while parallel and at about 10 m. distance to force the whole catch into the codend. The changes in the curvature of the footrope during this manoeuvre is shown in Table VI and fig. 13. For the stages 1, 2, and 3 the distance was 500, 450 and 400 m. respectively. The stages 4, 5, 6 and 7 refer to the approaching, and 8, 9, 10 and 11 to parallel towing with reduced distance (about 10 m.). In addition to the quantitative data given it was found that after about 10 minutes the footrope has settled in a stable curvature according to the reduced distance between the trawlers and that extending the time of parallel trawling to get the warps parallel would be useless.

OTTER TRAWL

Measuring experiments with this trawl by means of net height meter and footrope indicator are being carried out in the Yellow Sea since 1953. The construction of the net in question and the measuring points for different experiments are given in fig. 14.

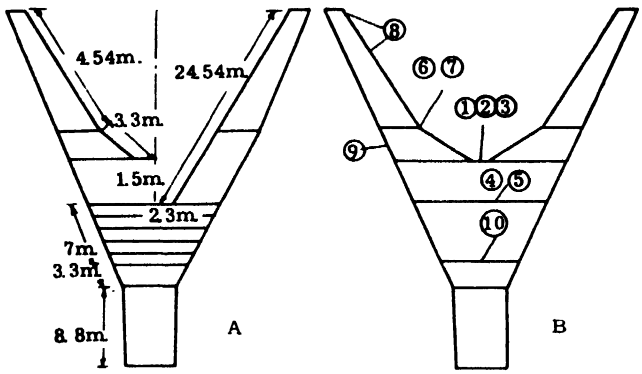

Fig. 14. One boat otter trawl net used during the measuring experiments. A – Construction; B – Measuring points for the net height meter referring to the different experiments.

For measuring the opening height an improved meter was used with which two points of the net height could be measured simultaneously. An example of the readings obtained is given in fig. 15.

The behaviour of the trawl and the variation of the distances between different parts, as well as the angles of net, sweep lines and warps during the shooting operation have been studied thoroughly. Fig. 16 is one example of the configurations drawn according to the measurements obtained. It was, for instance, found that the otter boards reach the bottom first and the net follows some time later.

Measurements during trawling have been made with

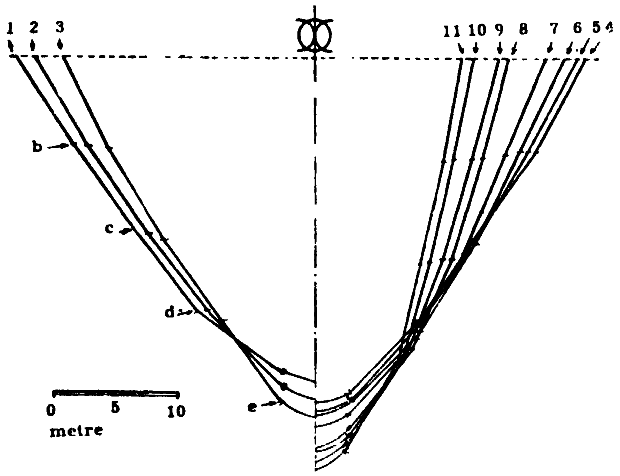

Fig. 13. Shape of the footrope, as calculated from the angle measurements, the trawlers keeping different distances.

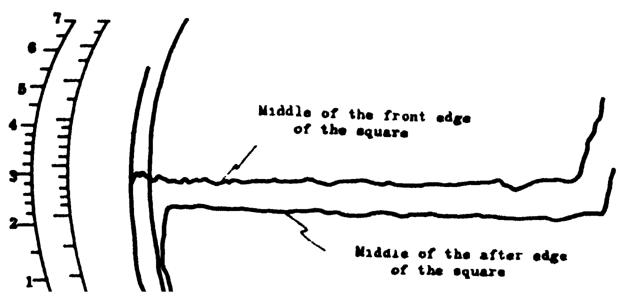

Fig. 15. Example of the records of the net height meter measuring two points of the net height simultaneously.

TABLE VI

Angle between footrope and towing direction

Time Ex. Mark	*Mins.* 0	1	2	3	4	5	6	7	8	9	10
a	27·5°	27·5°	27·5°	28·5°	30·0°	28·0°	27·5°	27·0°	26·0°	25·0°	24·0°
b	32·5	34	34	34·5	33·5	32·5	30·5	29·5	27·5	27·5	22·5
c	34	34	34·5	35	35·5	36	34·5	32·5	32	31	28·5
d	43·5	43·5	43·5	43·5	43·5	43·5	42	43	44·5	43	43
e	46	45	45	45	45	45	46	46·5	47	48	49·5

N.B. Initial distance between the boats: 400 m.

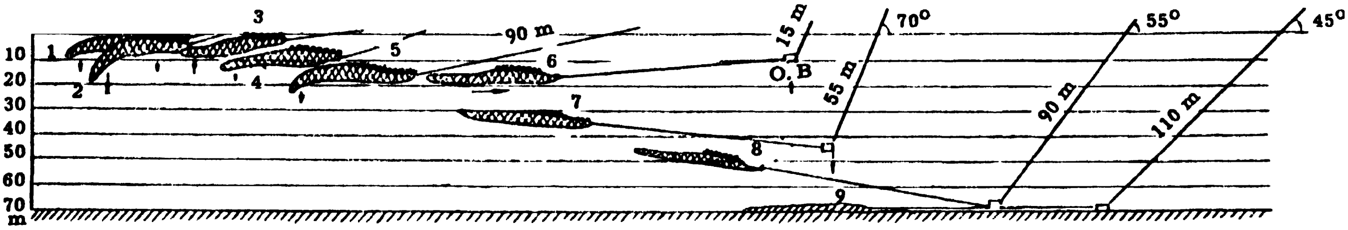

Fig. 16. Behaviour of the trawl during shooting.

a trawl of the following dimensions under following conditions:

Headline 38·9 m. Footrope 53·6 m. Sweep lines 90 m.; Warp length 250 m. Water depth 70 m. Warp angle to horizontal 13 degrees, Towing speed 2·5 knots, Bottom mud, Wind fair, 10 glass floats 26 cm. diameter on headline bosom, 19 glass floats 20 cm. diameter on each wing.

The results are given in Table VII and fig. 17.

The height of the wings and the square is obviously unsatisfactory. The main reason for this is the fact that with these trawls the main pull acts on the headline. If, by changing the length relation between headline and footrope the pull would be shifted to the footrope, it may tend to cut into the bottom, This could be overcome by means of a suitable bobbin footrope. Furthermore, the suitability of the net construction has to be checked including the flapper which in the present form tends to restrict the proper water flow into the codends.

When the trawler changes course the speed of the net and the horizontal opening decrease. Consequently the vertical net opening height increases because of the reduced resistance on the floats and the slack in lines and webbing.

The influence of wind direction was found to be very noticeable. The opening was much higher with head wind than with fair wind (Table VIII). Furthermore, with head wind the opening height oscillated considerably while with fair wind it was stable. This effect, of course, is caused by the influence of wind and water on the towing speed and movements of the trawler.

As in the case of trawling for flat fish in Bristol Bay, the opening height gradually increases with the accumulated catch. This effect is due to the reduction in towing speed and opening width resulting in an increase of resistance. During the present experiments similar observations have been made. An example is given of the recorded heights in fig. 18. During this haul the catch amounted to 6,000 kg.

TABLE VII

Measuring Points	*Vertical distance from footrope*
Wing point 1	0·72 m.
Wing point 2	1·39 m.
Wing point 3	1·82 m.
Wing point 4	1·93 m.
Middle of headline bosom	2·03 m.
Middle of after edge of square	1·93 m.
Middle of front edge of throat	1·65 m.
Middle of front edge of codend	1·50 m.

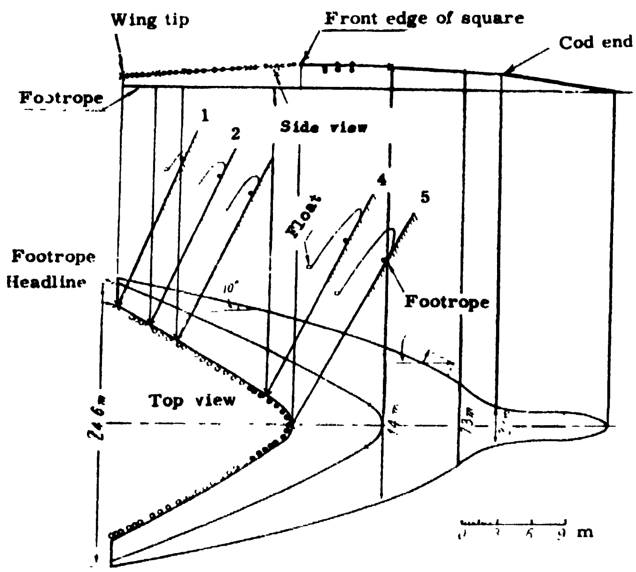

Fig. 17. Shape of the net as found by means of the net height meter.

TABLE VIII

The Net Height when Towing with Head and Fair Wind

Measuring Point	*Average height with head wind*	*Average height with fair wind*
Middle of headline bosom	2·6 m.	1·8 m.
Middle of after edge of square	2·4 m.	2·1 m.
Quarter point	2·25 m.	1·8 m.

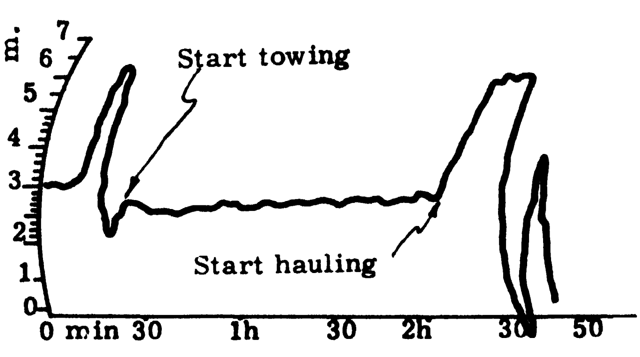

Fig. 18. Record of net height meter attached to the middle of the headline bosom, showing the influence of increasing amount of catch.

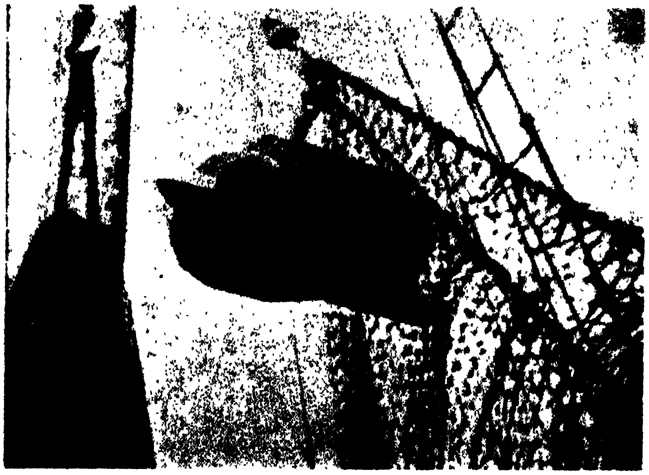

Fig. 19. The wing shaped float.

As the buoyancy of the glass floats is considered to be unsatisfactory at higher towing speeds, experiments were carried out with the addition of wing shaped floats (fig. 19). Results are given in Table IX.

It was found that the usual net covering of the glass floats is unfavourable, and plastic floats with a smooth surface give better results. The wing shaped floats are superior because of their hydrodynamic lifting power. In order to make the best use of this lifting power, sufficient surplus of webbing should be provided in the net mouth to allow for a high opening.

COMPARISON OF BOTH METHODS

Table X and fig. 20 give a comparison of two-boat and one-boat trawling. In two-boat trawling the duration of a voyage is 20 to 30 days. In the East China Sea, otter trawling is excellent for catching hair tail or prawn and two-boat trawling for guchi (*Nibea argentata, Pseudosciaene manchurica, Nibea nibe*, etc.).

TABLE IX

	With glass floats alone	*With glassfloats and wing-shaped floats in addition*
Height of net opening	1·60 m.	2·95 m.
Height of left quarter point	1·35 m.	2·20 m.
Towing speed	3·7 knots	3·7 knots

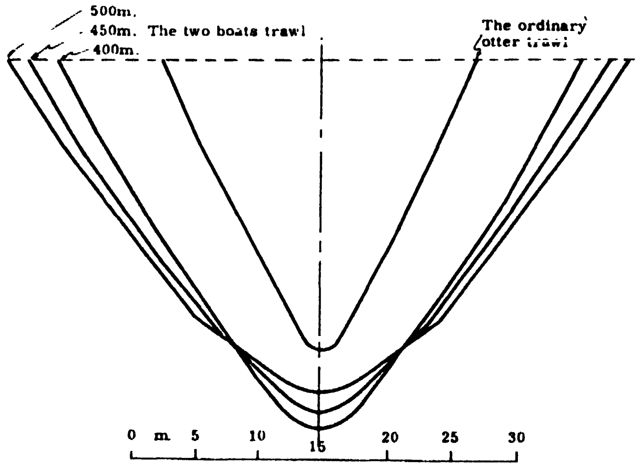

Fig. 20. Curvature of footrope and opening width of the one boat otter trawl in comparison with the two boat trawl at different distances between the towing boats.

	Two boat trawl	*Otter trawl*
Depth	*54 m.*	*95 m.*
Warp length	*750 m.*	*300 m.*
Sweepline length	—	*90 m.*
Footrope length	*74 m.*	*53 m.*
Towing speed	*2 knots*	*3 knots*
Angle between warps	—	*12·5 degrees*

TABLE X

Items	*Two-boat Trawling*	*Otter Trawling*
Boat	60 to 100 tons (couple)	200 to 1,000 tons (single)
Engine	200 to 300 h.p. (diesel)	500 to 800 h.p. (diesel)
Distance between the parts on touching the bottom	Hawsers 150 to 200 m.	Otter boards 60 to 70 m.
Wing spread	40 to 50 m.	25 to 30 m.
Height of net opening	Max. Min. Mean 4·0 m. 1·3 m. 3·5 m.	Max. Min. Mean 2·95 m. 1·4 m. 1·9 m.
Towing time	1·5 to 2·0 hour	3 to 4 hour
Towing speed	1·7 to 2·6 knots	3 to 3·6 knots
Deck machinery	2 gurdies	1 winch
Fishing areas	Yellow Sea, East and South China Sea	Yellow Sea, East and South China Sea.

THE USE OF ECHO-SOUNDING AS A MEANS OF OBSERVING THE PERFORMANCE OF TRAWLING GEAR

by

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Abstract

Several echograms showing traces of pelagic trawling gear in action are discussed. Besides measurements of the depth of the gear and the height of its opening, the position of the danlenos and otter boards in regard to the net opening can be observed, as well as the slope of the legs and bridles and the position of the net bag itself. From these experiments it is suggested that echo-sounding could be a valuable help in studies directed towards the development or improvement of pelagic trawling gear.

L'emploi du sondage par ultra-sons comme moyen d'observer le travail du chalut

Résumé

Plusieurs échogrammes montrant des tracés de chalut pélagique en action sont examinés. Outre les mesures de la profondeur de l'engin et de sa hauteur d'ouverture, la position des guindineaux et des plateaux par rapport à l'ouverture du filet peut être observée, de même que la pente des câbles et des bras et la position du filet proprement dite. D'après ces expérences, il est suggéré que le sondage par écho pourrait être une aide de valeur dans les recherches pour le développement du chalut pélagique.

Uso de los sondeos a eco como medio para observar el rendimiento de las redes de arrastre

Extracto

Se analizan varios ecogramas de los trazos obtenidos con redes de arrastre pelágicas. Además de la medida de la profundidad del arte y la altura de la boca, puede observarse la posición de los calones y puertas con respecto a la abertura de la red, la inclinación de los cables que unen los extremos de las pernadas con las puertas y los piés de gallo, así como la posición del cuerpo del arte.

De estos ensayos se llega a la conclusión que el sondeo ultrasonoro puede ser de gran ayuda para los estudios destinados a desarrollar o perfeccionar las redes de arrastre pelágicas.

RECENTLY attempts have been made to accelerate the development and improvement of trawling gear by using measuring instruments. The problems connected with this new approach, such as, for instance, identifying those important characteristics of a trawl which should be measured, and the different ways of doing this without affecting the behaviour of the gear, need not be dealt with here. Instead, only one of the numerous measuring or observing methods will be discussed, the echo-sounding method.

To the author's knowledge, the first experimental observations of a trawl in action by means of an echo-sounder were carried out by Wood and Parrish (Journ. de Conseille 17, 1950, pp. 25 to 36) in 1949. They used the sounder from a rather big boat which was towed by the trawling vessel and in this way operated over the gear.

The writer, as an employee of the German "Institut für Netz- und Materialforschung", has since 1953 used a motor-driven rubber boat about 16 ft. long and 7 ft. in beam, with a battery-driven echo-sounder (Atlas-Werke AG, Bremen, Type SH 37 tr, 4 AZ 42 d tr.). The main advantage of this boat is its good manoeuvrability and the unlimited possibility of circulating freely. Numerous observations on trawling gear were carried out with this equipment, mainly to define the opening height of bottom trawls and their contact with

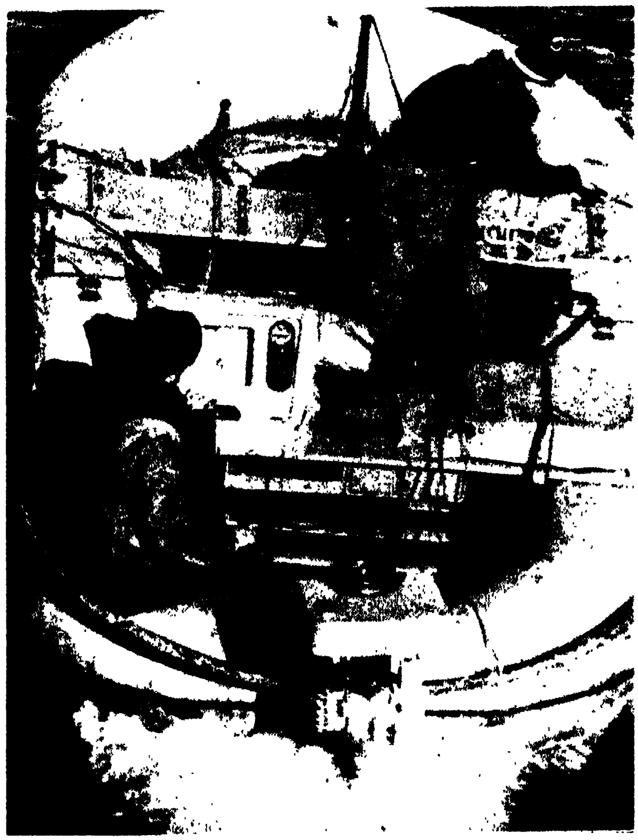

Fig. 1. The motor-driven rubber boat used by the "Institut für Netz- und Materialforschung" for echo-sounding observations. (Photo—Bodo Ulrich)

* Formerly of Institut für Netz- und Materialforschung, Hamburg.

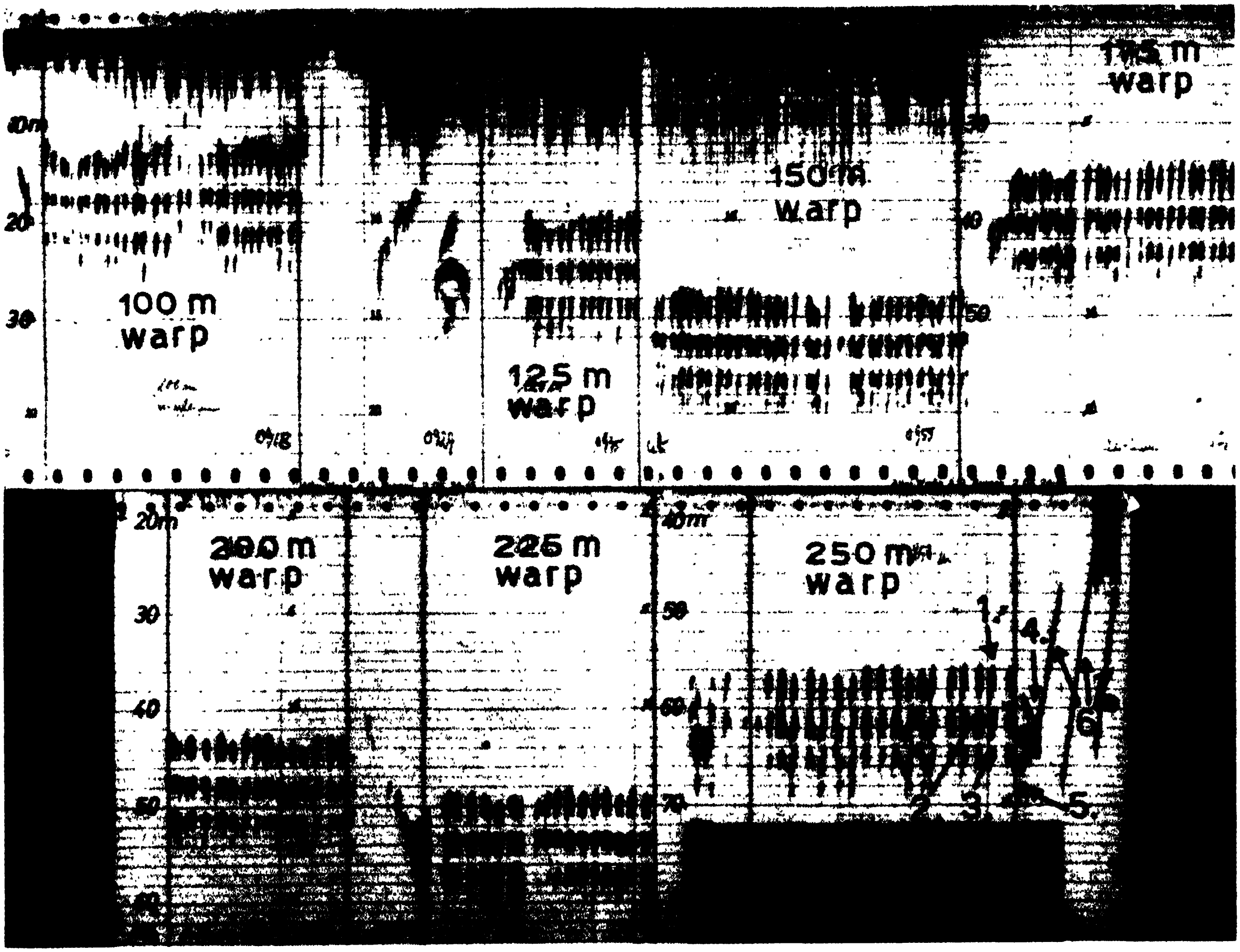

Fig. 2. Echogram showing the influence of the length of the warps on the depth of the gear and the height of the net opening. 1. Headline; 2. Lastriches; 3. Footrope; 4. Otter Board; 5. Weight in front of the lower wingtip; 6. Warp.

the ground, but also on the behaviour of fish coming near such gear.

Later, the equipment proved of even higher value for studies directed towards the development of pelagic trawls. The following echograms were taken during pelagic trawl experiments carried out with the German Fisheries Research Vessel *Anton Dohrn* in June 1957, in the Baltic Sea. Three one-boat pelagic trawls were tested, all being equipped with hydrofoil otter boards, but with different nets and different riggings. As only the suitability of the method will be discussed, a description of the gear is not needed.

DEPTH OF THE NET AND OPENING HEIGHT

Two important characteristics of a pelagic trawl can be very easily, and also exactly, measured by echo-sounding: the actual depth of the net and the opening height. Fig. 2 shows the changes in these characteristics connected with the increasing length of the warps. With this gear, under the conditions in question, a lengthening of the warps by 25 m. caused an increase in depth of 6 to 8 m. Furthermore, with increasing warp length, the opening height decreased in favour of the opening width. With 100 m. warp length the opening height was 10 m. whereas with 175 m. and more it decreased to only 8·5 m.

POSITION OF THE LASTRICHES

Besides the headline and footrope, the lastriches also give good traces. They appear in all sections of fig. 2 and both are in the same or almost the same depth, except the last section, where a difference of nearly 1·5 m. is shown. In this case, the length of the warps was not equal. It was observed that an inequality of about one fathom may cause the net to assume an oblique position, with the lastrich connected with the shorter warp being as much as 3 m. higher than the other lastrich.

POSITION OF THE OTTER BOARDS

Furthermore, the last section of fig. 2 shows that with this gear, under the given conditions, the position of the

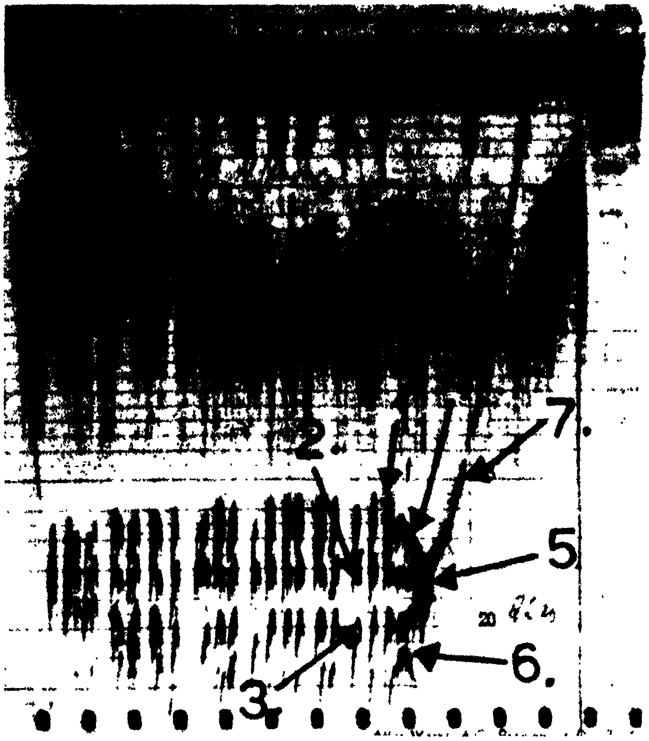

Fig. 3. Echogram of the same gear as in fig. 2, showing the slope of the legs. 1. Headline; 2. Lastriches; 3. Footrope; 4. Legs; 5. Otter Board; 6. Weight; 7. Warp.

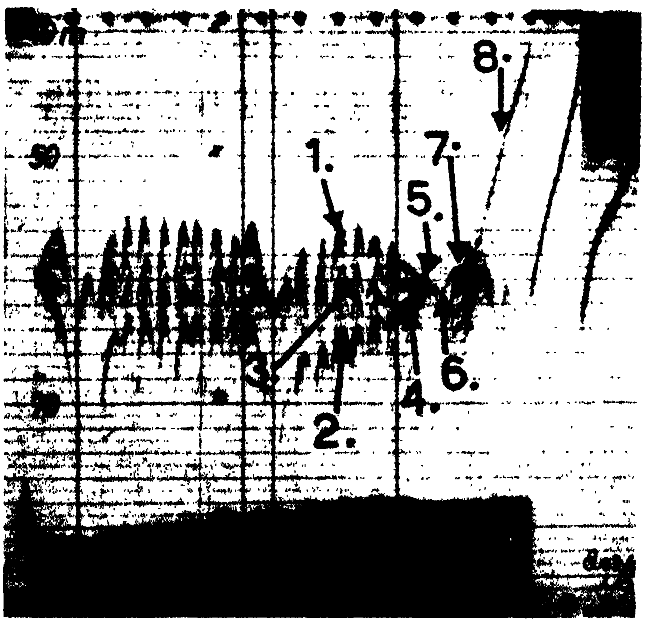

Fig. 4. Echogram of another gear with four legs, danleno and bridle. 1. Headline; 2. Footrope; 3. Lastriches; 4. Legs; 5. Danleno; 6. Bridle; 7. Otter Board; 8. Warp.

Fig. 5. Echogram of a third gear with only two legs, showing the slope of the legs and the position of the net. 1. Headline; 2. Footrope; 3. Legs; 4. Weight; 5. Otter Board; 6. Warp; 7. Net.

otter board was not level with the middle of the net opening, but it travelled about 2 m. deeper.

SLOPE OF THE LEGS

During another observation of the same gear, more care was taken to establish the slope of the legs (fig. 3). Coming from astern, the sounding boat was steered accurately over the legs to the otter board and then up the warp. Here the otter board is also about 2 m. below the middle of the net opening. Consequently, the legs have a down-going tendency, especially the lastrich one. A good trace is given by the heavy weight, which is fixed to the leg a short distance in front of the lower wing tip to keep it down.

Fig. 4 shows traces of another gear equipped with four legs to each wing, danleno and bridle. The record shows that the danleno travelled about 1 m. below the middle of the net opening. The bridle is not well recorded. The otter board obviously had the same depth as the middle of the net opening. The clear reproduction of the four legs, in this case, has a special interest. When the net was hauled in, it appeared that both lastrich legs of this side of the gear were broken, causing the net to be completely torn. The echogram proved that this damage had not occurred before hauling and the measured values could safely be relied upon. Likewise, the echo-sounding method can be successfully used to check the performance of a gear during trawling operations.

POSITION OF THE NET

Fig. 5 shows traces of the third gear which was equipped with two legs from each wing to the otter boards. Besides the depth of the different parts of the gear and the height of the net opening, the slope of the legs and the weight keeping down the lower wing can easily be recognised. In this case, the influence of the towing speed on the slope of the legs is obvious. At lower speed (left) they have a greater slope, and at higher speed (right) they are almost stretched. The position of the otter board to the net opening is naturally influenced by the speed. At lower speed, the board is almost at the same depth as the middle of the opening, but at greater speed it travels about 2 m. higher. The most interesting feature of this record is the trace of the net (right). It shows that the net has no horizontal position at all. To control this, the sounding boat, coming from astern, was steered over the whole net from the codend to the opening and then followed one pair of legs to the otter board and up to the warp. It showed that, with this gear, under the given conditions, the codend travelled at almost the same depth as the footrope and, consequently, about 5 m. below the middle of the net opening. Furthermore, this record shows that in these cases the headline exceeded the height of the upper wingtip by about 1·5 m. (right, higher speed) to about 2·5 m. (left, lower speed) whilst the depth of the footrope did not seem to differ much in relation to that of the lower wingtips. The reason for this may lie in the fact that heavy weights were keeping down the lower wings, whilst the upper wings had no additional lifting device.

Although incomplete, these examples clearly indicate the value of the echo-sounding method for a quick test of the technical performance of certain characteristics of pelagic trawls. Such a test provides an objective background for estimating the probable catching ability which, as a second step has, of course, to be proved by real fishing.

Hydrofoil otter board being tested on a small research vessel. The instrument attached is a recording angle of attack meter. —Photo FAO.

Oval otter board of Russian design with angle of attack meter attached. The cover is removed showing the circular recording paper and the stylus in zero position. Above the board a surface dynamometer attached to the gallows is used for measuring the pull on the towing warp. —Photo FAO.

EXPERIMENTS TO DECREASE THE TOWING RESISTANCE OF TRAWL GEAR

by

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Abstract

In comparison with a common German herring bottom trawl, a gear of quite the same size and characteristics but with hydrofoil otter boards (Süberkrüb) and a lighter net bag made of Perlon twine was tested. The towing resistance of the latter gear proved to be about 30 per cent. lower than the former. About 80 per cent. of this decrease was due to the boards and about 20 per cent. to the lighter net. This remarkable amount of decrease in towing resistance obtained in such a simple way is suggested as being a suitable way for improving the economy of trawling.

Expériences pour la diminution de la résistance de remorquage des chaluts

Résumé

On a comparé un chalut de fond ordinaire allemand pour le hareng avec un engin de même taille et de mêmes caractéristiques mais ayant des plateaux à surface hydrodynamique (Süberkrüb) et un sac plus léger fait de fils de Perlon. La résistance de remorquage du second engin s'est montrée inférieure d'environ 30 per cent. à celle du premier. Environ 80 per cent de cette diminution était due aux plateaux et environ 20 per cent. au filet plus léger. Cette diminution remarquable de la résistance de remorquage obtenue d'une manière simple est proposée comme moyen convenable pour améliorer l'économie du chalutage.

Experimentos para disminuir la resistencia que las redes de arrastre oponen al remolque

Extracto

Se efectuaron diversas pruebas a fin de comparar una red de arrastre de fondo para arenque, como las empleadas correintemente en Alemania, con una de igual tamaño pero más liviana que tenia puertas con superficies hidrodinámicas y cuerpo de perlón.

Este último arte opuso un 30 per cent. menos de resistencia que la primera. El 80 per cent. de esta disminución se debió a las puertas y el 20 per cent. al cuerpo de la red que era más liviano. Esta notable reducción obtenida de manera tan sencilla, podria servir para aumentar las economías en la pesca de arrastre.

FOR optimal economy in trawling, the towing resistance of the trawl gear should be as low as possible. It is well known that the commonly used plane otter boards are very unsatisfactory from a hydrodynamic point of view. Moreover, nets of manila or sisal, i.e. natural fibres, have to be made of thicker twine than those of synthetic fibres (e.g. nylon or Perlon). So, two simple ways are open to decrease the towing resistance of trawl gear:

1. Hydrofoil otter boards.
2. Nets made of thinner synthetic twine.

To test the effect of these changes in the German herring bottom trawl, measuring experiments were carried out with the Fisheries Research Vessel *Anton Dohrn*, during June 1957, in the Baltic Sea.

These experiments consisted of measurements of:

(a) Towing resistance of the complete gear.
(b) Towing resistance of that part of the gear behind the otter boards. The difference between (a) and (b) gives the share in total towing resistance of warps and otter boards.
(c) Towing speed.
(d) Distance between the otter boards.
(e) Height of the net opening.
(f) Angle of attack of the otter boards.
(g) Angle of attack of the kites.

Weather, course, depth, bottom conditions, propeller revolutions, "cutoff" and boiler pressure, were also taken into account.

Of the total of 27 tows, 17 had to be rejected because of changes in weather or bottom conditions, unsatisfactory conformity in the size of the gear opening or damage to the gear, such as broken lines or torn net. Of the remaining 10 tows, 5 were made with each of the two following types of gear:

1. Common German herring bottom trawl with 160 ft. ground rope, manila net and common otter boards (see fig. 1). (Hereafter called "Common gear.")
2. German herring bottom trawl rigged in the same way with a net of the same construction and size but made of thin Perlon, and with "Süberkrüb" otter boards (see fig. 2). (Hereafter called "Experimental gear.")

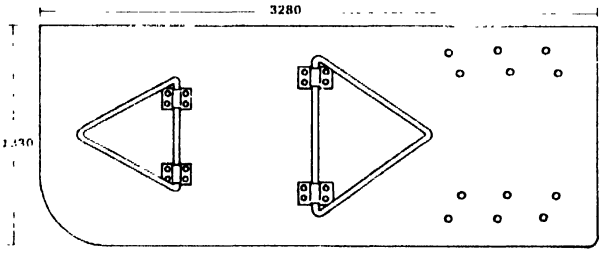


Fig. 1. Construction drawing of the common Otter-board.

RESULTS

The measurements were made at a water depth of 80 to 100 m. on a rather hard clay bottom and with 225 fathoms of warps (22 mm. diam.).

The angle of attack of the otter boards was ascertained from the traces caused by the bottom friction on the iron shoe plates of the boards. These traces give good average values which were found to be as follows:

Common otter boards about 35 degrees
"Süberkrüb" otter boards about 12 to 15 degrees

These values are almost optimal for both types of boards (see fig. 3).

According to the "Göttinger Messungen", and with regard to the influence of the water only, the following values are calculated for resistance and shearing force at 3·8 knots towing speed:

	Towing Resistance	*Shearing Force*
Common otter board	0·8 tons	1·1 tons
"Süberkrüb" otter board	0·2 tons	1·1 tons

This shows a decrease of resistance with the "Süberkrüb" type of boards of 1·2 tons (for both boards) or 75 per cent. compared with the common boards. But this calculation neglects the influence of the bottom friction, which should be higher for the common boards with their long lower edge. The measurements actually showed a difference of 1·6 tons. The 0·4 tons exceeding the calculated value is at least partly due to the lower bottom friction of the "Süberkrüb" boards under the existing bottom conditions.

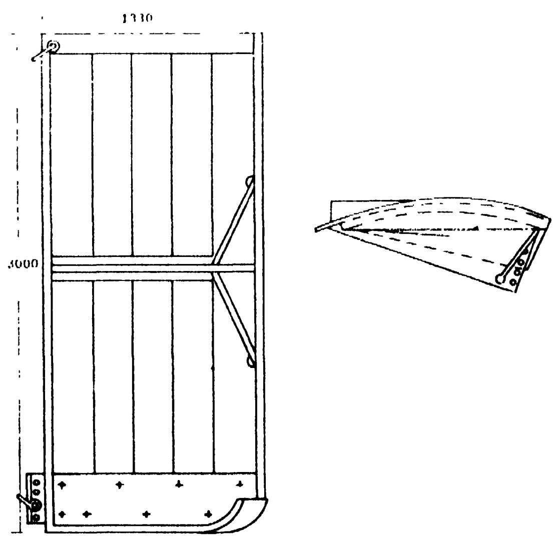


Fig. 2. Construction drawing of the "Süberkrüb" Otter board used in the experiments.

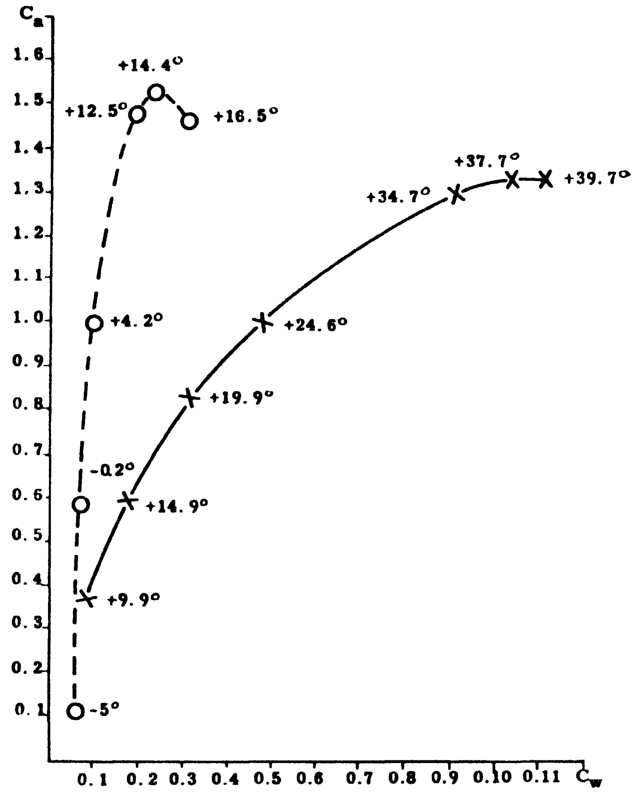


Fig. 3. Buoyancy coefficients (C_a) and Resistance-coefficients (C_w) for a common Otterboard (——) and the "Süberkrüb" Otter board (- - - -) used in the experiments.

The size of the net opening should be as similar as possible for both types of gear. The width of the opening was not really measured. Instead, the distance between the two warps 1 m. behind their cross-over in the slip-hooks was controlled. This, of course, does not give accurate values, but is, at least, a basis for comparing the opening width of equally rigged nets. This is an old fisherman's method for controlling the behaviour of the boards. The following values were obtained:

	Distance of the Warps	*Calculated Distance of the Otter Boards*
Common gear	11·5 — 12·0 cm.	about 48 m.
Experimental gear	13·5 — 14·0 cm.	about 55 m.

The slight difference indicates that the shearing power of the "Süberkrüb" otter boards was too strong, at least for the light Perlon net. As the most simple way to decrease the shearing power, it was suggested that the angle of attack should be made smaller, but as this could lead to fouling the gear when shooting, it was not tried. It was not possible to reduce the size of the boards on board ship, so this difference was accepted as of no great importance.

The opening height was measured by means of an echo-sounder, installed in a motor driven rubber boat. The following values were obtained:

	Distance from the Bottom		
	Headline	*1st Kite*	*2nd Kite*
Common gear	3·0—3·4 m.	7·0 m.	12·0 m.
Experimental gear	2·5—3·5 m.	6·0—7·5 m.	10·0—12·0m.

Because of the greater width of the net opening, the false headlines of the experimental gear had to be slightly lengthened. The conformity thus obtained in the net openings was regarded as satisfactory.

The angle of attack of the kites was measured by the jelly-bottle method. The values lay between 28 degrees and 34 degrees, a favourable range.

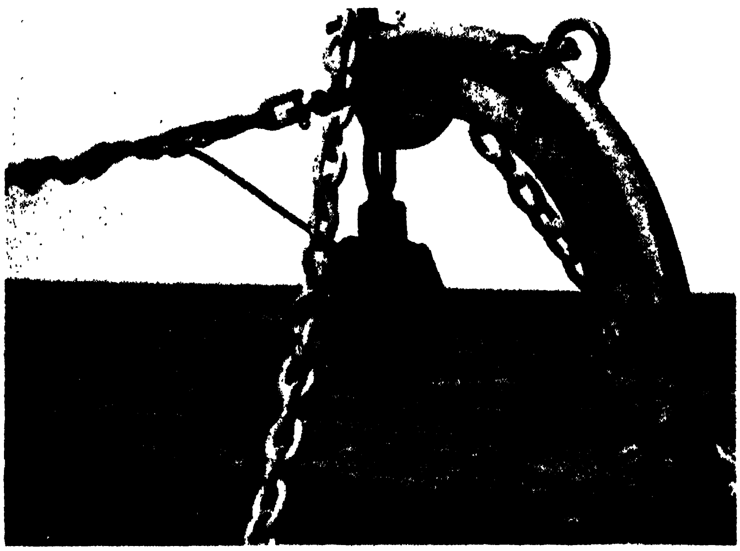
Despite efforts to keep the same **towing speed** in all experiments, a deviation between 3·6 and 4·1 knots could not be avoided. The measured values of the towing resistance, therefore, had to be converted to an average speed of 3·8 knots assuming, as conventional, the resistance being proportional to the square of the speed. The speed was measured by means of a "Kempff" resistance log.

The towing resistance was measured on both warps, close behind the sliphook (total resistance), as well as on both bridles, close behind the otter boards (resistance mainly caused by the net). As warps, bridles, danlenos, legs, kites and false headlines were the same for both gears, differences between the measured values are due to the otter boards and the net bag. Converted to a speed of 3·8 knots, the following average values were found (the range of deviation is shown below in brackets).

This comparison shows a very remarkable difference, the experimental gear offering about 30 per cent. less resistance. Of this 30 per cent. about 24 per cent. was due to the hydrofoil shape of the boards and about 6 per cent. due to the lighter net.

This decrease of towing resistance means that, with the same engine power, the experimental gear could be towed about 0·7 knots faster (i.e. at 4·5 knots) than the common gear (3·8 knots), or its size could be increased by about 30 per cent. or, thirdly, a corresponding amount of fuel could be saved.

			Resistance				
	Propeller	*Cut off*	*Total*	*Otter board and warps*		*Net with lines, danlenos and warps*	
	Rev./min.	%	*Tons*	*Tons*	%	*Tons*	%
Common gear	82	52-54	6·7 (6·0—7·3)	2·5 (2·1—3·0)	37	4·2 (3·9—4·4)	63
Experimental gear	74	50 Main valve partly closed	4·7 (4·5—5·1)	0·9 (0·7—1·0)	19	3·8 (3·0—4·1)	81



Dynamometers for the determination of the towing resistance of trawl gear. Left: surface dynamometer in working position measuring the pull on one towing warp. Right: simultaneous calibration of four underwater and two surface dynamometers against a master instrument on board a small research vessel. The necessary pull is provided by a turnbuckle handled by the person in the background. Photo FAO.

ON THE RELATION BETWEEN OTTER TRAWL GEAR AND TOWING POWER

by

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Abstract

This paper deals with the relation between trawling gear and towing power. The author presents data he has gathered on the subject in India and Japan but stresses that his deductions are based on preliminary observations which need to be verified by further investigations.

The formulae he submits are for calculating the size of trawl nets and boards, and the weight of the boards in relation to the H.P. of the engine, the size of the boards in the relation to the size of net, and the 'ength of the warps in relation to fishing depth.

Sur la relation entre le chalut à plateaux et la puissance remorquage

Résumé

On dispose de très peu de renseignements concernant la relation entre les dimensions des plateaux de chalut, la taille du chalut et la puissance de remorquage nécessaire.

En s'appuyant sur les observations et données provenant de différents bateaux de pêche, l'auteur a établi une série de formules pour calculer: (a) les dimensions des plateaux de chalut d'après la puissance du moteur, (b) les dimensions du filet d'après la puissance du moteur, (c) le poids des plateaux d'après la puissance du moteur, (d) les dimensions des plateaux de chalut d'après calles du filet, (e) la longueur des funes de chalut d'aprés la profondeur de pêche.

Relación entre la red de arrastre de puertas y la potencia emleada en el arrastre

Extracto

Se dispone de muy pocos datos sobre la relación que existe entre las dimensiones de las puertas de arrastre, el tamano de la red y la potencia requerida para el remolque:

Basándose en las observaciones y datos tomados en diversos barcos pesqueros, el autor ha desarrollado una serie de formulas para calcular: (a) el tamaño de las puertas con relación a la potencia del motor, (b) el tamaño de la red con relación a la potencia del motor, (c) el peso de las puertas de arrastre con relación a la potencia del motor: (d) el tamaño de las puertas de arrastre con relación al tamano de la red, (e) la longitud de los cables de arrastre con relación a la profundidad de pesca.

IT is a well-known fact that bigger boats use bigger trawls. But there exists no information about the common relation between size or engine power of the trawler and the size of the trawl gear and between the size of the trawl net and the size of the otter boards. Therefore, data has been collected mainly from trawlers in India and also from a few Japanese trawlers which are presented below.

RELATION BETWEEN ENGINE POWER AND SIZE OF OTTER BOARDS

Fig. 1 shows that in the common use the area of the otter boards is proportionate to the h.p. of the engine. If the area of one otter board is called S″ and the h.p. of the engine P, the relation found can be expressed by the following equation:

$$S'' = 0{\cdot}105\ P + 4$$

The ratio between the length and the width of the otter boards usually is 2 : 1 approximately. If B denotes the width, the length will consequently be 2B. Then B can be calculated by means of the following formula:

$$B = \sqrt{\frac{0{\cdot}105\ P + 4}{2}}$$

SIZE RELATION BETWEEN OTTER BOARDS AND NET

The hydrodynamic resistance of the net and the boards is proportionate to their area. Assuming that the otter boards of the trawls included in the collection data are being worked at approximately the same ratio of lift to drag, not only the lift needed for keeping the net mouth open but also the resistance of the otter boards should be proportionate to the size of the net.

The size of a trawl net is usually represented by the length of the headline. For purpose of comparison, therefore, the area of a trawl net can be represented by the square of the headline length.

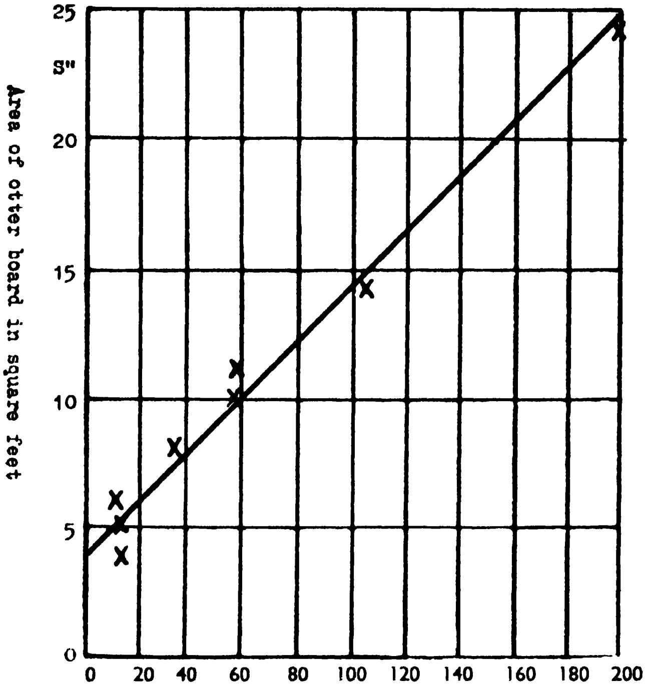

Fig. 1. Relation between h.p. of engine and area of one otter board.

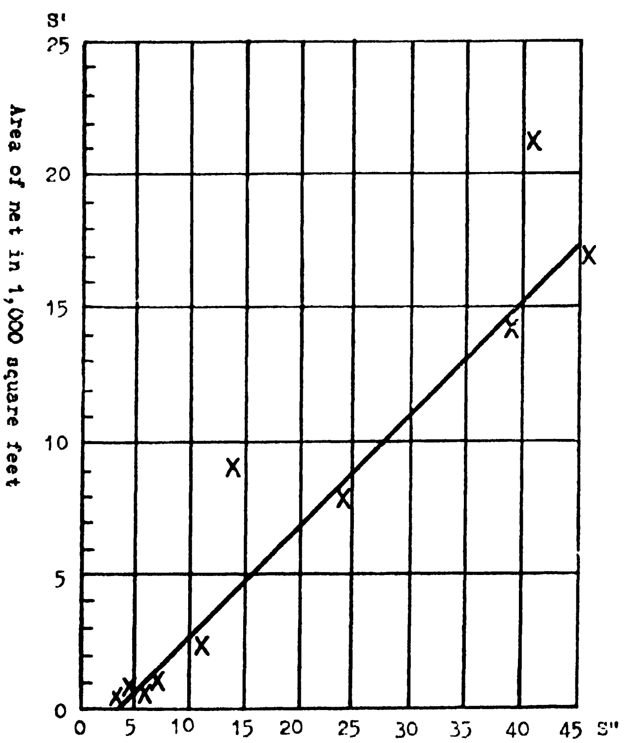

Fig. 2. Relation between area of one otter board and the area of the net.

The relation between the area of the otter boards and this expression of the area of the nets, is given in fig. 2.

If S″ denotes the square of the headline length, the values found can be expressed by the following equation:

$$S' = 415\ S'' - 1000$$

RELATION BETWEEN THE ENGINE POWER (H.P.) AND THE SIZE OF THE NET

Using the equations given above, the relation found between the h.p. of the engine and the size of the net can be expressed by the following equation:

$$L = \sqrt{43{\cdot}6\ P + 660}$$

where L is the length of the headline and P the h.p. of the engine.

WEIGHT OF THE OTTER BOARDS

The weight of the otter boards was found to be proportionate to the h.p. of the engine and to the cube of the expression $\frac{a + b}{2}$ where a is the length and b the width of the board.

The findings shown graphically on logarithmic paper

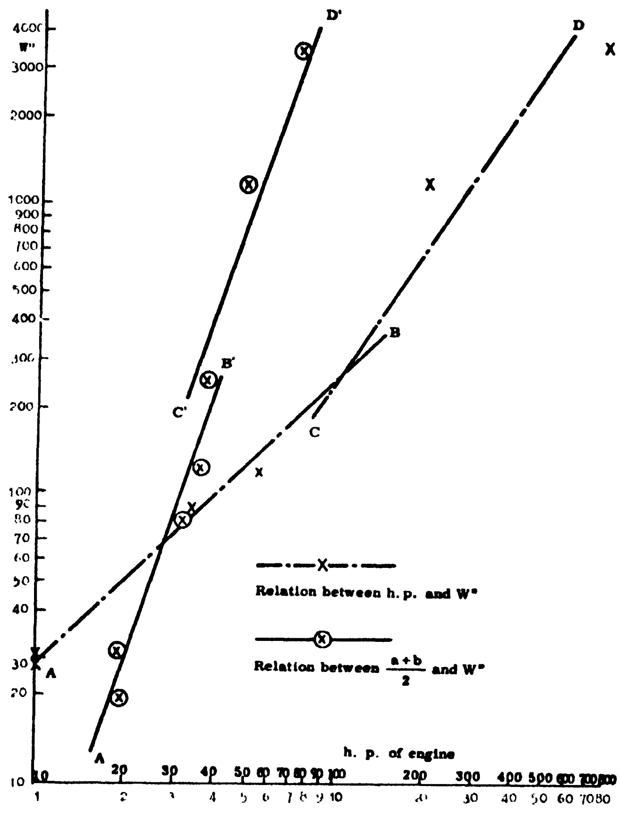

Fig. 3. Relation between h.p. of engine and weight of one otter board and relation of average length of otter board in feet and the weight of the board.

in fig. 3 can be expressed by the following equations:

Up to 100 h.p. $W''=2{\cdot}7\ P$

100 to 66 h.p. $W''=6{\cdot}5\ P \quad 400$

Up to 4 ft. average size of board $W''=3{\cdot}2\left(\frac{a+b}{2}\right)^3$

More than 4 ft. average size of board $W''=7\left(\frac{a+b}{2}\right)^3$

where W'' is the weight of the board (lbs.), P the h.p. of the engine and $\frac{a+b}{2}$ the size of the board (ft.).

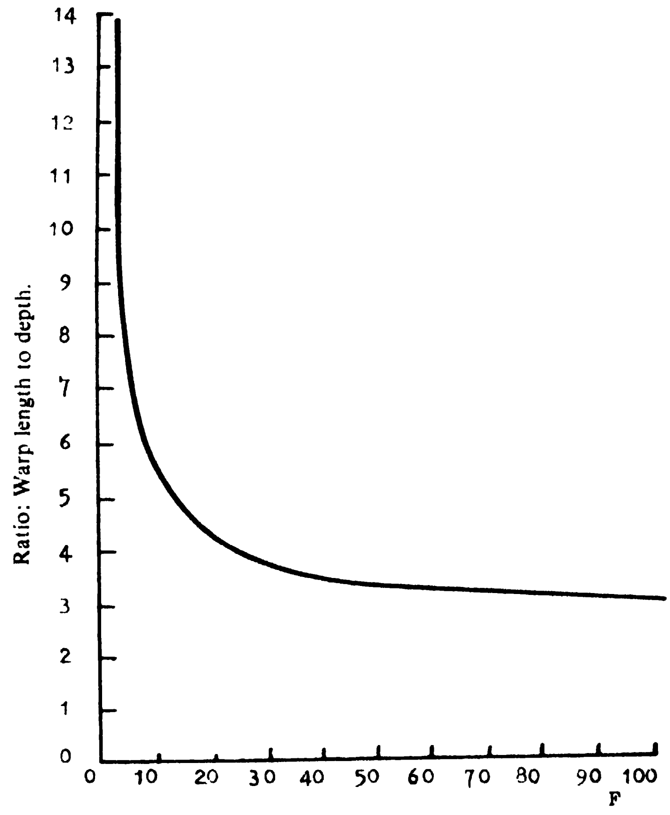

Fig. 4. Relation between the water depth and the ratio of warp length to water depth.

RELATION BETWEEN WARP LENGTH AND WATER DEPTH

Fig. 4 represents the relation between the depth of water and the length of warp for trawling at different depths. The curve is a hyperbola from which the following approximate equation can be deduced:

$$F=\left(3+\frac{25}{D}\right)D$$

Modern Mediterranean stern trawling vessel.

STUDIES TO IMPROVE THE EFFICIENCY OF OTTER BOARDS AND TRAWL FLOATS

by

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Abstract

This paper describes studies made on models of otter boards and trawl floats. Several types with different profiles were designed. Importance was given to the smoothness of their surface and stability. Two types of floats were made and tested, a hydrodynamic plastic float acting as kite and tied to the headline, and an elevating hood which acts directly on the square and the headline. Diagrams of the resistance and lift of these devices are given.

Recherches pour améliorer l'efficacité des plateaux et flotteurs de chalut

Résumé

Ce travail relate les recherches effectuées avec des maquettes de plateaux et de flotteurs de chalut construits selon le principe de similitude mécanique et essayés sous une pression de 60 à 80 kg./cm^2.

Plusieurs types de plateaux avec différents profils ont été conçus, et on a attaché beaucoup d'importance au poli de leur surface et à leur stabilité. Les types suivants de flotteurs de plastique ont été fabriqués et essayés: (1) un flotteur hydrodynamique de plastique attaché à la corde de dos par de courtes chaines pour éviter l'emmêlage et (2) un système élévateur hydrodynamique relié directement au grand dos et à la corde de dos pour soulever ce câble. Dans l'article on trouve aussi des courbes sur la résistance de ces dispositifs pendant le chalutage, etc.

Estudios para mejorar el rendimiento de las puertas y flotadores en la red de arrastre

Extracto

En este trabajo se describen los estudios hechos con nuevos tipos de puertas de arrastre y flotadores construidos según la ley de similitud mecánica y sometidos a pruebas de remolque a presiones que variaban entre 60 y 80 kg. por cm^2.

Se estudiaron varios tipos de puertas con perfiles diferentes, dando gran importancia a la continuidad de la superficie y a la estabilidad; además se ensayaron los siguientes tipos de flotadores de material plástico: (1) un flotador hidrodinámico atado a la relinga superior mediante cadenas cortas para evitar que se enrede con el arte; y (2) una "cofia" o dispositivo elevador hidrodinámico unido directamente a la visera y a la relinga superior a fin de hacerla subir. En el artículo también se incluyen gráficas sobre la resistencia de estos dispositivos durante el arrastre, etc.

FISHING gear is a determining factor in the development of fishing but little progress has been made in research and development, probably because of the difficulties to be overcome in investigating the underwater behaviour of nets and gear.

An old boat with a modern net, with the same crew and in equal conditions, can sometimes compete with a new boat equipped with a low yield net. When developing the fishing unit as a whole, one must improve not only the boat but also the main and direct means of capture, the net. This is indicated in Italy, where the catch of fish remains at the same level, despite increased number and tonnage of boats and their engine power, and the increased cost of operations.

Fuel, for example, accounts for about 40 per cent. of the total operating expenses, but it is now easy to design high efficiency hulls using technical data in "Fishing Boat Tank Tests" and "Fishing Boats of the World", both published by F.A.O., and so cut fuel costs. But trawl nets and gear are still made by rule of thumb, based on practical experience, and not on hydrodynamic laws. However, technicians in many countries have been studying how to increase the horizontal and vertical openings of the mouth of the trawl by the use of otter doors and floats.

OTTER BOARDS

The boards are rectangular sections which have badly finished surfaces because of the frame, reinforcements, nuts, etc.

Resistance to towing at a determined speed depends upon the area and angle of attack and is influenced by the finish of the surface and the density of the media. But, in the majority of cases, these factors are completely ignored. The dimensions, weight and angle of attack of the otter doors vary considerably not only in different countries but also in the same fishing port.

By applying elementary laws of mechanics, it should be possible to construct accessory trawling equipment of improved efficiency, and for purposes of experiment we built three models of otter doors (see fig. 1).

Door "a", similar to the conventional boards now in use, is made of wood with metal reinforcements. Door "b", designed in the style of an aeroplane wing section with flat and convex areas, is made of cast or plate iron and plastic material. Door "c" is similar to "b", but the shearing area is concave. Tests with the models were made in a calm sea—zero Beaufort scale—and the towing effort was measured with a dynamometer. The graph in fig. 1 shows the behaviour of the three models towed at different speeds of up to 2·5 metres per second. At 1·54 metres (about 3 knots) the resistance of door "b" was 6·2 kg. while that of "a" was 9·9 kg. which is almost 60 per cent. more.

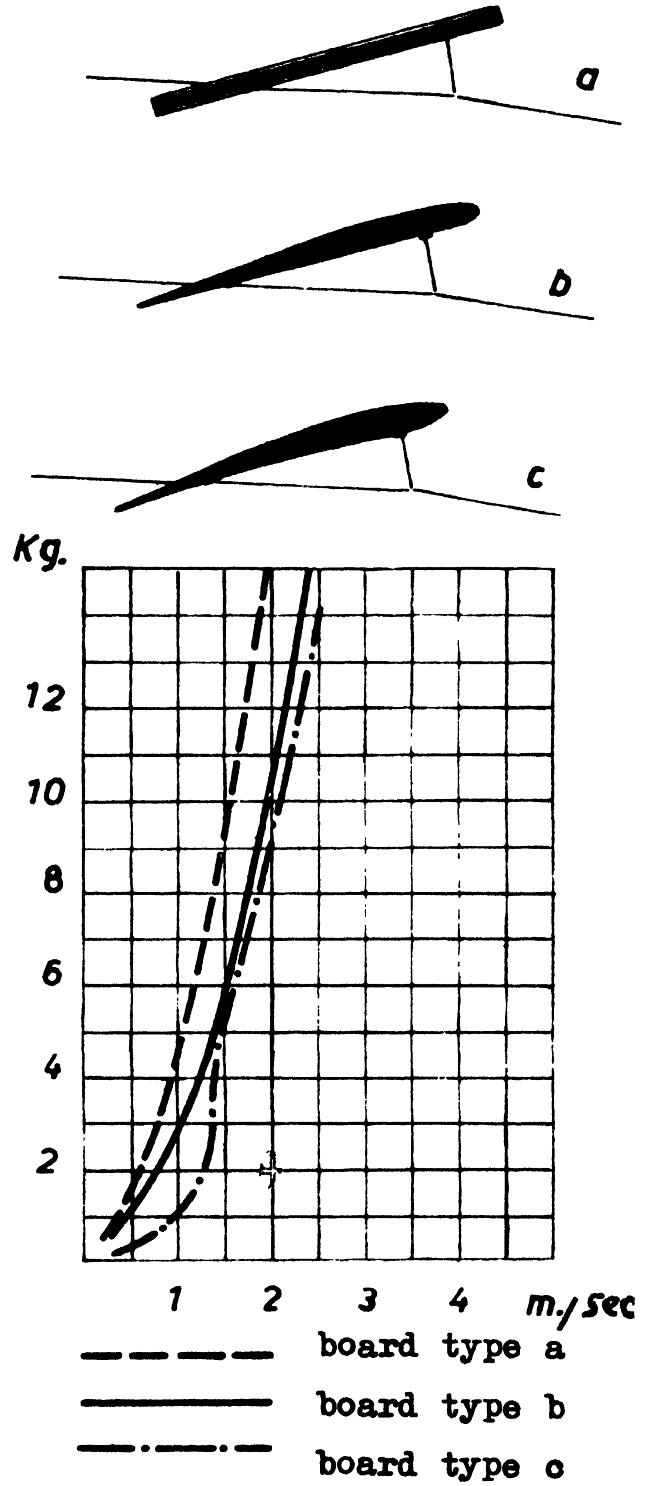

Fig. 1. Profiles of trawl boards and graph of performance.

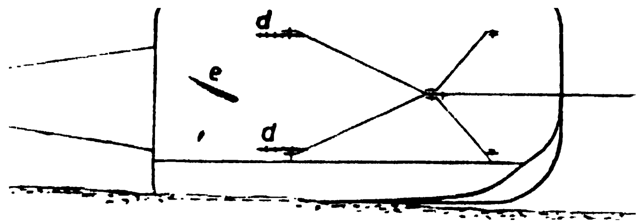

Fig. 2. Adjustment of the angle of attack on the otter boards.

Door "c" offered even less resistance but the spreading power was less because of the concave shearing surface which made the door less efficient. The smaller resistance of the new doors is due to the hydrodynamic shape of the longitudinal section and to the finish of the surfaces. The protuberances on the conventional doors extend through the turbulence layer which is very thin because of the low Reynolds number. The results of the tests and the graphs possibly contain some mistakes, but these can only be eliminated by making tank tests.

To vary the shearing power of the trawl board, the angle of attack may be changed by using different holes in an iron plate "d" (fig. 2) for fixing the brackets, or by changing the points of attachment of the towing cables on the back of the boards.

We also studied the problem presented when the otter door falls flat on the bottom or gets wedged when turning on end. This is dangerous on muddy ground and often results in the loss of the net. The fins (fig. 2, "e"), are meant to act as stabilizers; they push the front up and the rear down and make the door rest on its after end. The doors may also fall flat because of a momentary interruption in the tension of the towing cables which may easily go slack in a head sea. If the doors fall inwards the damage is not serious, but when they tilt down outwards they get wedged in the bottom when the tension returns in the towing cables and soon the cables snap. An important characteristic of the new trawl doors is that they remain vertical in all circumstances, except on becoming entangled in reefs, etc.

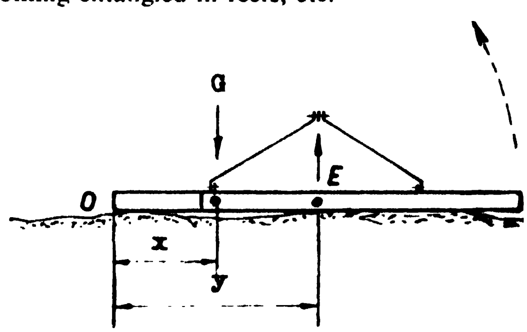

Fig. 3. Forces acting on the otter board.

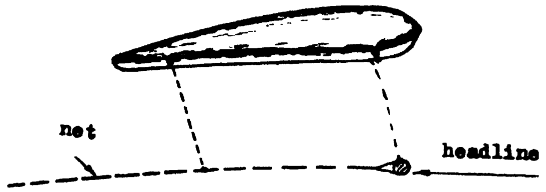

Fig. 4. Position of the plastic kite on the headline.

The centre of gravity "G" has been placed very low in the door (fig. 3) while the centre of lift "E" has been placed very high so that the product of weight "G" times the distance "X" from the point O (tilting moment), is less than the product of the lift "E" times the distance "Y" from point O (lifting moment). During the experiments it was noticed that each time the submerged door fell flat on the bottom, it turned back to the vertical position again.

The new door models studied showed the following advantages:

(1) they offer smaller resistance;
(2) they do not fall flat;
(3) they are less liable to dig into the bottom;
(4) they should last longer.

During this study we were unable to tow the door models at the speed corresponding to mechanical similarity, because at a low speed they do not spread out well and advance with irregular movements. Although we were unable to establish the resistance of full-scale doors, we got enough facts to establish the marked differences among the three models.

FLOATS

Glass balls are generally used to increase the height of the mouth of the trawl net, chiefly because of their good resistance to pressure and their low cost. New types of floats, metallic or made of other materials, are being used in many countries. They may be spherical, with reinforcement rings, or similar to kites. It is known that spheres have a high coefficient of resistance and with

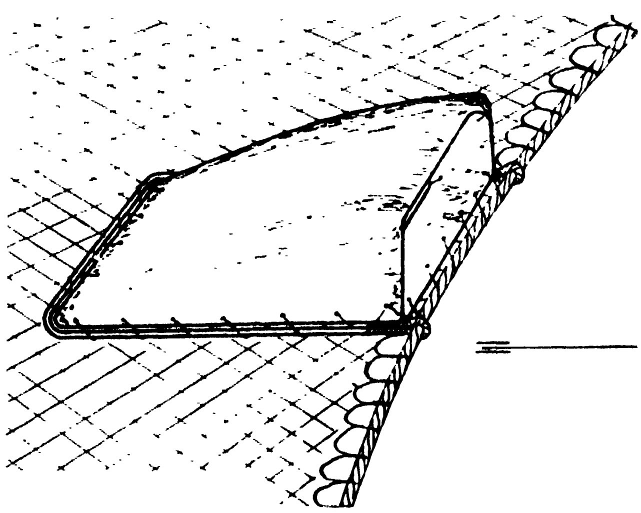

Fig. 5. Elevating hood.

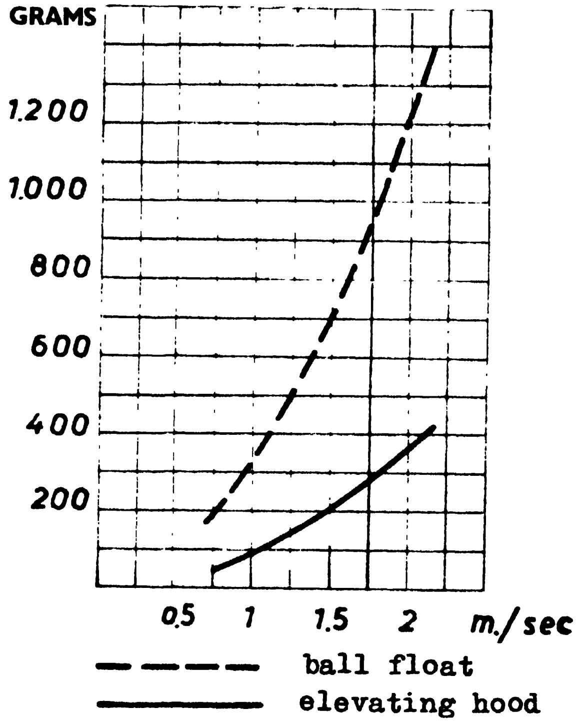

Fig. 6. Comparison between towing resistance of a ball float and the elevating hood.

increasing speed they lower the headline. Kites would avoid this disadvantage and we have built a plastic float (fig. 4) with a hydrodynamic section. In operation, we tied it to the headline with chains to avoid entangling. We found this device offered a very low resistance to towing compared with the spherical floats and had a fairly good lifting power. Reinforcements of the same material were used to resist the hydrostatic pressures. Kites are more expensive than the ball type floats, but the extra cost should be offset by increased catches.

LIFTING DEVICE FOR TRAWL NETS

The study of the hydrodynamic floats revealed certain disadvantages while trawling, so a "lifting device" (fig. 5) (similar to a prompter's box) was built. It was attached to the top of the net at the back of the headline to increase the opening of the mouth without offering excessive resistance.

The most important advantage of this lifting gear is that it is firmly attached to the trawl net, which makes efficient operation possible and facilitates handling.

The top of the lifting device slopes down towards the net to form an angle of attack in the direction of the advance. The walls are also of hydrodynamic profile and offer a minimum of resistance. As in the case of the kites, higher speeds increase the lifting power of the device and because of its smaller coefficient of resistance less towing power is needed than in the case of spherical floats.

The graphs (fig. 6) compare tests of this lifting device with those of a ball float, and show the respective resistances for the same area and speed. The new lifting device withstands 60 to 80 kg./cm.^{2} hydrostatic pressure.

SIMPLE DEVICES FOR STUDYING THE GEOMETRY OF VARIOUS GEARS AND FOR RELATING SOME COMMERCIAL FISHING OPERATIONS TO THE EXISTING WATER MOVEMENTS

by

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Abstract

The usual method of studying the underwater behaviour of fishing gear is by the use of highly technical instruments operated by equally highly skilled technicians. In this paper, the author describes some of his extremely simple ideas for measuring the speed and direction of bottom currents which undoubtedly play a big part in the successful operation of many kinds of fishing gear. The principle upon which the indicators are designed is a simple one. Hot gelatine is introduced into suitable containers which can be fixed to various parts of the fishing gear, and after some time, the lower sea temperature solidifies the gelatine and, from the angle of the "gel" in relation to its container, much information can be deduced. The aim of this work has been to produce cheap and effective instruments which can be used by the fishermen themselves while they are actually fishing, and some typical results have shown that a trawl was not being towed immediately astern of the ship but slightly to starboard, and also that one otter board fished a little deeper than the other.

Dispositifs simples pour étudier la géométrie des engins de pêche, et établir les relations entre les opérations de pêche industrielle et les mouvements des eaux

Résumé

La méthode généralement adoptée pour l'étude du comportement des engins de pêche sous l'eau consiste en l'emploi d'appareils très complexes manoeuvrés par des techniciens hautement qualifiés. L'auteur expose dans ce document quelques idées permettant de mesurer d'une façon extrêmement simple la vitesse et la direction des courants de fond qui jouent incontestablement un rôle important dans le bon fonctionnement d'un grand nombre de types d'engins de pêche. Le principe d'après lequel les appareils de mesure sont conçus est très simple. De la gélatine chaude est versée dans des récipients de forme appropriée qui peuvent être fixés à différents points de l'engin de pêche; après un certain temps, la gélatine refroidie par l'eau de mer, se solidifie, et l'angle que forme la surface solidifiée avec le récipient permet de déduire un grand nombre de renseignements. L'auteur a cherché à réaliser des appareils peu coûteux et efficaces susceptibles d'être utilisés par les pêcheurs eux-mêmes pendant la pêche; ils ont permis entre autres de constater qu'un chalut n'était pas remorqué dans l'axe du navire mais légèrement sur babord, et aussi qu'un plateau de chalut était un peu plus enfoncé que l'autre.

Dispositivos sencillos para estudiar la geometría de los artes pesqueros y relacionar algunas operaciones de pesca comercial con los movimientos del agua

Extracto

El método corriente para estudiar la manera como los artes de pesca se comportan en el agua consiste en usar instrumentos muy técnicos manejados por personal altamente especializado. En este trabajo el autor describe algunas de las ideas extremadamente sencillas puestas en práctica para medir la velocidad y dirección de las corrientes junto al fondo del mar que, indudablemente, juegan un papel de gran importancia en el éxito del funcionamiento de muchos tipos de artes de pesca. El principio que rige a estos indicadores es sencillo: se introduce gelatina caliente en envases adecuados que pueden fijarse a las diversas partes del arte, a fin de que después de cierto tiempo la baja temperatura solidifique a la gelatina, lo cual permite deducir gran cantidad de información del ángulo del "gel" en relación con el recipiente que lo contiene. El objeto de este trabajo es producir instrumentos baratos y efectivos que el mismo pescador pueda usar durante sus faenas. Entre algunos resultados típicos obtenidos con ellos figura la indicación de que una red de arrastre no se encuentra directamente detrás de la popa del barco, sino ligeramente hacia el costado de estribor y, también, que una puerta se halla a una profundidad ligeramente mayor que la otra

THERE are fishing methods and gear of commercial importance such as bottom trawling, gillnetting and longlining, which are much affected by the strength and direction of underwater currents as they may influence the distribution and behaviour of the fish and the operation of the gear. Fishermen agree that, in certain cases, advance knowledge of the current prevailing at the fishing depth would be a great advantage. Therefore a very simple current-meter for use by fishermen has been developed and constructed, suitable for measuring underwater currents without anchoring the fishing vessel. It can be used in any depth up to 150 metres.

It is only necessary to throw overboard a long stick, weighted at both ends. A thin hauling-in line is attached to one end and a small buoyant Pyrex bottle tethered at the other by a short length of twine. The bottle is part filled with a hot gelatine solution on which floats a circular compass. The bottle is canted by any current and the jelly sets solid at a certain slope, gripping the compass. The magnitude of the slope provides information on the speed and the compass reading on the direction of the current.

GILLNETTING

The direction in which gillnets have fished can easily be learnt by lashing to the net a bamboo with a Perspex tube full of hot gelatine solution. The tube is sealed at each end with a solid rubber ball through which (and along the axis of the tube) runs a slender brass rod. At the outer end of each ball is a washer and a travelling wing nut, so that the tube can be sealed. A disc of magnetised ceramic hangs from a short nylon twine midpoint of the rod (inside the tube). The disc, which carries north and south marks, orientates itself resolutely into the magnetic meridian. It is easy to arrange for the gelatine solution to remain fluid long enough in cold water by enclosing the Perspex tube within a wider tube of polythene filled with hot water.

LONGLINING

Fishermen who longline for halibut off the Faroes and in Denmark Strait would like to know how the deep currents strike their lines. With this they could build up a body of knowledge connecting current strength and direction with tidal state, as represented by hours before or after high water at a port of reference. Then they would know when to fish safely near the edge of a bottom declivity at places where uprising water is held to produce good feeding conditions.

There is a very easy way in which the longline fishermen can collect such information. All that is necessary is to fix a small yardarm to his hand/anchor line just above bottom (one simple tie of a lanyard) and hang from it a bottle half filled with hot gelatine solution and half with hot coloured oil. A brass rod screwed into the underside of the bottle's cap runs down the axis of the bottle and carries a directional disc hung from a nylon thread at its free end. Any current will cant the bottle and a sloped frozen interface of known direction will give information about speed and direction of the bottom current when the lines are hauled. Sensitivity is increased by pushing a tight-fitting polythene "cuff" on the bottle, and trailing a tassel from it.

A very simple valve is used to avoid bottle breakage if the pre-heating is too severe, and for interior/exterior pressure equalisation when the hot liquids chill and contract deep in the sea.

GEOMETRY OF FISHING GEAR, PARTICULARLY TRAWLS

Until fully reliable telemetering devices are available for use from ordinary fishing vessels, it is perhaps of value to make observations by using some very elementary gelatine solution devices which present evidence of how towing cables sloped during a tow, their azimuth, the shape and height of a headline, and so on. The slope of a towing cable can be studied by fixing to it (by means of stretched "garters" cut from a motorcar tyre inner tube) cylinders of clear Perspex filled with gelatine solution and each containing a rolling inclinometer. This is contrived from a schoolboy's celluloid protractor mounted on a rod running through the cylinder and weighted so as to remain always pendulous. A weighted pointer registers the slope of the cylinder. The correct slope is registered whatever the aspect of the cylinder on the cable—whether below, above or to either side. The jelly sets and grips the pointer at its protractor reading, thus making a record of cable slope.

In the same way, the shape taken up by a trawl headline during the tow can be easily ascertained. We used six cylinders fixed at intervals along the headline of a very big trawl to establish the slope at each of the points. To measure the opening height, a similar tube was fixed with one end to the middle of the headline, and a length of rope and plummet (longer than the expected headline height) attached to its lower free end. During the tow the line pulls tight and draws the tube into alignment. The liquid interface in the bottle becomes "frozen" so that, on hauling, one learns the headline height by multiplying a known length (tube + rope) into the cosine of the angle of slope realized.

A more ambitious version of the simple Perspex cylinder has a ring aircraft compass in its pendulum so that the direction of the obliquity as well as the slope of a net or cable is learnt.

By using several such devices, it has been possible to measure the angle of divergence of a pair of trawl warps and something of the distribution of direction along them. It would doubtless be easy to glean such information of value by using a number of these simple instruments.

Fig. on left shows a jelly compass bottle as it would appear to a frogman who viewed it tethered down in a current running ESE at 1 2/5 knots. Fig. 2 shows the same bottle when brought inboard after use and stood upright for slope measurement.

Leaflets issued by the National Institute of Oceanography, Wormley, Surrey, England, giving details of the simple current measuring apparatus are: for temperate waters NIO/4795 and for tropical waters NIO/4858.

Fig. 1.

Fig. 2.

A RESEARCH ON SETNETS

by

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Abstract

Bad weather and strong tides cause damage and heavy losses to the setnets used in Japanese waters. Using current meters the author carried out experiments with various kinds of nets for the purpose of reducing these losses by improving the shape and construction of the nets.

In this paper some data is given on the influence of currents on the net shape and the author claims that the submerged setnet is less influenced than the floating one. Other advantages claimed for the submerged net are economy in labour and material, and higher catchability.

Recherches sur les filets fixes

Résumé

Depuis longtemps, les pêcheurs japonais subissent de lourdes pertes à leurs filets calés causées par le mauvais temps et les grandes marées, et l'auteur essaie de réduire ces pertes par l'amélioration de la construction de l'engin. Dans ce but, il a fait des expériences avec diverses variétés de filets. Dans ce travail, quelques résultats concernant la forme des filets sous l'influence de la direction et de la vitesse du courant sont enregistrés, et l'auteur déclare que le filet-trappe fixe immergé est meilleur que le filet-trappe ordinaire à cause de l'économie de matériau et de main-d'oeuvre, la possibilité de le caler sur les lieux de pêche où la vitesse du courant est relativement élevée, et sa plus grande capacité de capture.

Investgación sobre Redes "trampas"

Extracto

Como durante muchos años los pescadores japoneses han perdido gran cantidad de redes "trampas" a causa del mal tiempo y altas mareas, el autor trata de reducir las pérdidas mejorando su construcción. Para lograr este objeto se hicieron experimentos con varios tipos de artes, registrándose en este trabajo algunos resultados sobre la influencia de la dirección y velocidad de la corriente. El autor afirma que las redes "trampas" de fondo son mejores que las comunes a causa de: la economia de materiales y mano de obra, la posibilidad de calarlas en bancos pesqueros donde la velocidad de la corriente es relativamente alta y la mayor capacidad de pesca.

CHARACTERISTICS AND POSSIBILITIES FOR IMPROVEMENT

THE immobility which is characteristic for setnets has made it very difficult to make any notable improvements to this gear, which is based on the principle of inducing the fish to enter the trap after leading them to it by obstructing their normal route. After more than thirty years' development of this typical Japanese type of gear, there is still scope for improvement. More thorough research is needed on the behaviour of the fish, and on the physical characteristics of the net construction before really effective improvement can be expected. Bad weather and high tides have for many years caused severe damage and loss of gear. Efforts are being made to prevent this loss of material and labour by improving the construction of the gear, by reduction of the diameter of twine and ropes, and by reducing the tension on the webbing by decreasing the buoyancy of floats and the weight of sinkers.

The most effective way of preventing loss and damage is to completely submerge the usual type of floating setnet so that it becomes a submerged or bottom setnet.

The fish caught in the submerged setnet are mostly of the demersal kind, but many species of fish which normally swim in the upper layers are also caught. In fact, many so-called pelagic species are frequently found near the sea-bottom, especially when they come near to the coast.

In fact it is even possible to catch such pelagic fish as salmon, sea-trout, sardine and mackerel with the submerged setnet.

Some advantages of the submerged setnet over the floating type are: economy in material and labour: less chance of damage by tide and swell, because of reduced resistance in the water. The reduced resistance at the same time allows the net to be used in stronger currents. With the floating type of net, the trapped fish often escape from the bag over the floatline which becomes submerged in bad weather or strong tides; this is avoided in the improved type of net, where the fish are completely enclosed.

When constructing a floating setnet the buoyancy on the floatline is made as great as possible to prevent the net being submerged under the influence of the tide current. On the other hand, the submerging of the net can also be avoided by decreasing its resistance to water

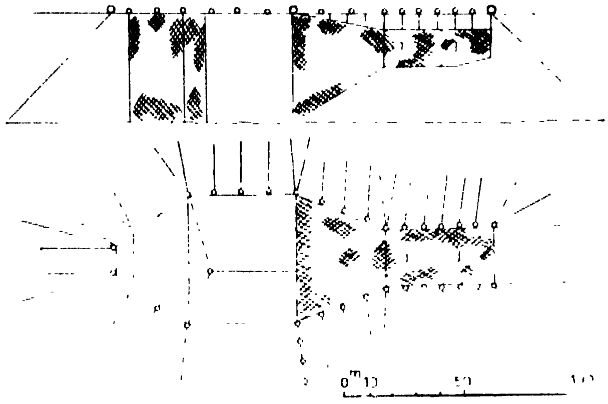

Fig. 1. Surface setnet with submerged bag for Yellow-Tail.

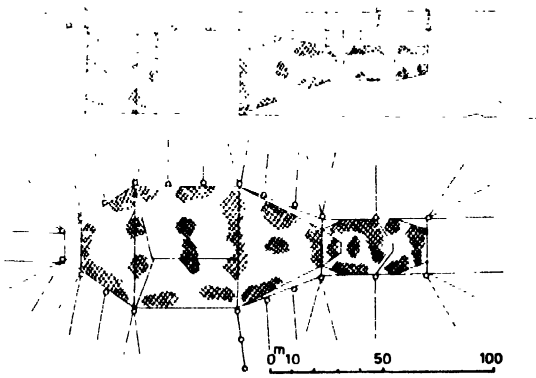

Fig. 3. Submerged setnet with one bag in midwater.

currents and waves. With the setnet for yellow-tail the buoyancy of the floatline is decreased so that the floats are allowed to submerge in heavy weather or strong tides; this is because the fish usually stay well below the surface. However, a certain amount of fish does escape over the floatline whenever it submerges.

With the double-trapping net, one of the recent new types of setnets, the trapped fish is induced to enter a box-net by passing through a funnel. Once inside the box-net the fish cannot escape as they are completely enclosed. This retaining feature of the double-trapping net has been incorporated in the submerged setnet.

CLASSIFICATION OF TYPES

The construction of setnets can be divided in two groups. In the first group there are two kinds, the first of which has the ante-chamber and the front shoulder of the funnel buoyed up so that the floatline is at the surface, while the rear end of the funnel and the entrapping bag are completely submerged.

Another way is to have the whole net submerged while the floatlines are held up partly by submerged floats and partly by surface buoys (fig. 3).

In both cases the webbing is suspended from the floatline and held down by sinkers so the nets could be called surface- and midwater setnets.

In the second group, the sinkers keep the net on the sea-bottom and the webbing forming the walls of the net, as well as the top parts of funnels and bags are held up by the buoyancy of the floats. The main difference is then that whereas in the first group the net is hung from its floats, in the second group the net is buoyed up from its sinkers (fig. 4).

The buoys used at the surface function as markers, or for lifting the submerged net, and have nothing to do with the floating or buoyancy of the net.

This group can be called bottom setnets and is of different construction. In fig. 4 the net has two wings and one bag; the fish is led straight to the entrapping bag, through the funnel. In other constructions, as in figs. 5 and 6, the net has two funnels and two bags but only one leader.

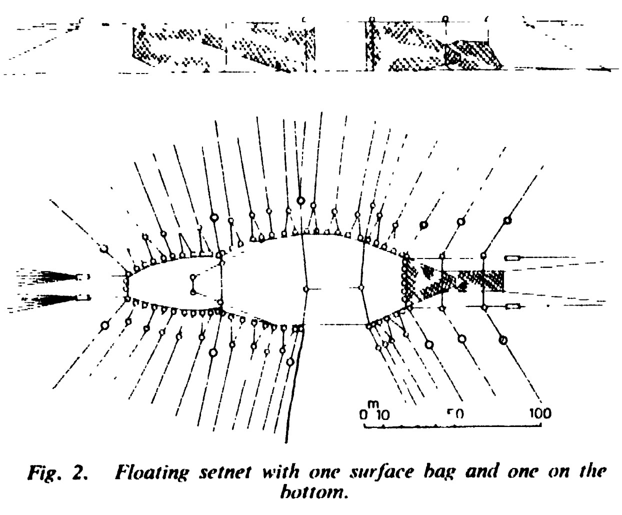

Fig. 2. Floating setnet with one surface bag and one on the bottom.

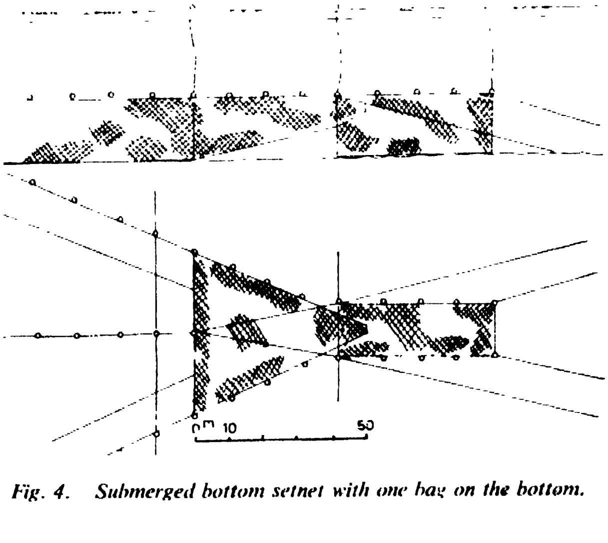

Fig. 4. Submerged bottom setnet with one bag on the bottom.

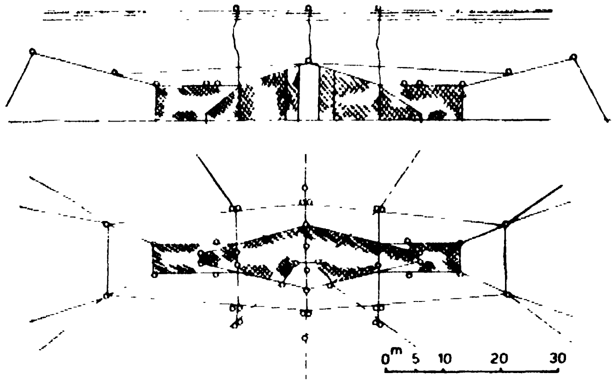

Fig. 5. Improved bottom setnet with two bags for salmon.

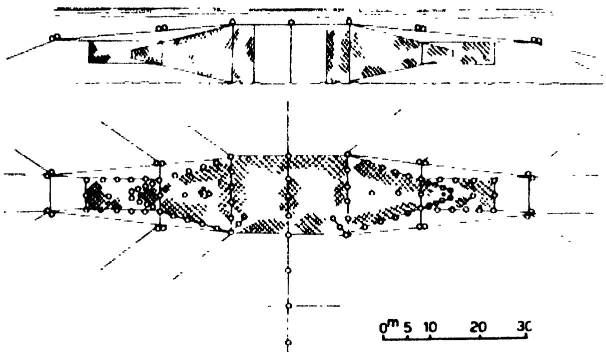

Fig. 6. Improved submerged salmon and trout setnet with two bags in midwater.

The table below shows the relations between the buoyancy, sinker weight and the fixing power of the nets classified according to the above grouping.

THE EFFECT OF DIRECTION AND SPEED OF CURRENT ON THE SHAPE OF SETNETS

The influence of speed and direction of current on the webbing structures of several types of setnets was investigated by the author, resistance of the webbing and the holding power of the sandbags were examined and measured; some merits and defects in the construction being ascertained.

Almost all the above mentioned nets, though there is a slight difference, usually take a forward-bent position against the flow of tide. The bagnet, funnel and the ante-chamber all bend inwards on the up-tide side, while on the lee-tide side they tend to balloon outwards. The deformation is more side pronounced on the up-tide side than on the lee-tide of the tide.

The lifting movement due to current influence of the ante-chamber floor section of the nets in Group I, was also examined and very little lifting was observed in the case of the nets classed under 1-a, which are left and right symmetrically constructed nets. However, with the increase of the current velocity the bag on the uptide side was pushed down to the sea bottom. In other nets, a lifting movement was generally caused by a current velocity of 13 to 38 cm./sec. ($\frac{1}{4}$ to $\frac{3}{4}$ knot). The lifting occurred in both tidal directions; when the tide was directed towards the ante-chamber as well as when it was directed towards the bag.

With the 1-b category net, the current directed towards the bag had more effect than when directed in the ante-chamber. In both cases, the floor of the net lifts completely at a current rate of from 40 to 45 cm./sec. ($\frac{3}{4}$ to $\frac{7}{8}$ knot).

The deformation of the shape of the net increases as the rate of tide increases until a position arises where the webbing itself precludes the fish from entering the

TABLE I

Category	*Net*	*Type of Net*	*Buoyancy F. ton*	*Fixing Power B. ton*	*Sinking Capacity W. ton*	*B/F*	*F/W*	*F-W*	*F-W/W*
	A	Yellow-tail Middle-layer Setnet I	15·3	82·7	2·57	5·4	5·95	12·73	4·95
	B	„ „ „ II	15·3	124·0	2·81	8·1	5·44	12·5	4·45
	C	„ „ „ III	11·2	85·0	2·81	7·6	3·98	8·4	2·99
(1-a)	D	„ „ Revised A type	12·2	122·0	2·25	10·0	5·42	9·95	4·42
	E	Improved Salmon and Trout Setnet B	0·5	8·8	0·37	18·0	1·32	0·12	0·33
	F	Setnet with Bottom Bag	13·8	65·0	3·83	4·7	3·6	9·97	2·6
	G	Bottom Gourd-shaped Net	0·63	4·6	0·15	7·3	4·2	0·48	3·2
(1-b)	H	Yellow-tail Middle-layer Setnet Revised B type	6·2	60·0	2·08	9·7	2·96	4·12	1·98
	I	Trapping Type Bottom Setnet	0·28	1·18	0·71	4·22	0·395	−0·43	−0·61
2(-a)	J	Ordinary Bottom Setnet	0·26	0·82	0·53	3·16	0·49	−0·27	−0·51
	K	Bottom Setnet for Cod	0·20	0·98	0·44	4·9	0·45	−0·24	−0·55
	L	Improved Bottom Setnet	0·14	1·85	0·16	13·2	0·87	−0·02	−0·13
(2-b)	M	Improved Salmon and Trout Setnet A	0·31	8·8	0·37	28·4	0·84	−0·06	−0·16
	N	Improved Salmon Bottom Setnet	0·58	5·25	1·15	9·05	0·50	−0·57	−0·5
	O	Yellow-tail Bottom Setnet	0·50	25·5	0·64	51·0	0·78	−0·14	−0·22

bag. This limiting tidal rate depends on the direction in which the net has been set.

With the group of nets under 1-a, which have a right and left symmetrical construction, it was observed that when set into the tide, the limiting current speed was 38·6 to 51·4 cm./sec. ($\frac{3}{4}$ to 1·0 knot), while in the opposite direction the net remained fixed beyond this rate of tide.

With the revised A type fitted with single bagnet, the current velocity needed to lift the enclosing walls was found to be 25·7 to 50 cm./sec. (about $\frac{1}{2}$ to 1·0 knot), while the bag end was lifted already at 19 to 38 cm./sec. ($\frac{3}{8}$ to $\frac{3}{4}$ knot). Both these nets are of the single bag type.

With the revised B type (1-b) the current speed needed to lift the enclosing walls was found to be 50 cm./sec. (about 1·0 knot) and for the bag end 45 cm./sec. ($\frac{7}{8}$ knot) respectively.

In the second group the 2-a category nets showed little deformation when the current entered at the ante-chamber, but when the current set in the opposite direction, they were easily deformed. In the first case the bagnet began to be lifted off the sea-bottom at 38 to 51·4 cm./sec. ($\frac{3}{4}$ to 1·0 knot), the entrance of the net was closed and the height curtailed to $\frac{1}{4}$ of the original.

When the current pressure was acting directly on the bagnet, the entrance of the bag was already closed at 26 cm./sec. (about $\frac{1}{2}$ knot); at 38 cm./sec. ($\frac{3}{4}$ knot) the net was near to collapsing. In case of the 2-b category nets, strong deformation was observed over the whole net when set in up-tide direction, while in lee-tide deformation was less, and even at a current velocity of 26 cm./sec. (about $\frac{1}{2}$ knot), the height of the floatline and the form of the net remained the same, only being bent forward; at 38 cm./sec. (about $\frac{3}{4}$ knot) there was some decrease in the height of the net; and at 51·4 cm./sec. (1·0 knot) the height decreased to about one half. Except where small sinkers were used, only slight lifting up of the net bottom was observed. Fish were still being caught even at a current rate of 38·6 to 51·4 cm./sec. ($\frac{3}{4}$ to 1·0 knot) when set in up-tide direction, and at 51·4 cm./sec. in the lee-tide direction.

DISCUSSION OF RESULTS

By comparing the above mentioned net-constructions with the ordinary setnet, the following differences were observed.

1. With the ordinary type net, during low tidal rates the huge surplus buoyancy prevents the floatline from being submerged; whereas with the nets under category 1 even a small current velocity sinks the floatline.
2. With the ordinary type of net, the ante-chamber starts to be lifted from the sea-bottom at 13 to 37 cm./sec. (about $\frac{1}{4}$ to $\frac{3}{4}$ knot); the funnel at 26 to 32 cm./sec. (about $\frac{1}{2}$ to $\frac{5}{8}$ knot); and therefore the net is easier to be lifted when the current is directed towards the ante-chamber than when directed towards the bag. With Group 1 nets, which have only one bag, the net-bottom of the ante-chamber lifted at the same current velocity as that for the ordinary one. But with Group 2 nets this was not observed.
3. With the ordinary Setnet, the limit of "current velocity" which causes deformation, differs according to the direction of the current. This limit was found to be 38 cm./sec. ($\frac{3}{4}$ knot) for ante-chamber direction and 26 cm./sec. (about $\frac{1}{2}$ knot) in the case of bag direction.

The single-bag net construction showed the same tendency as the ordinary trap net; whereas Group 2 nets can stand stronger lee-tides.

REFERENCES

[1] Miyamoto, H. Study on the Setnet, The Bulletin of the Toka Regional Fisheries Research Laboratory No. 2. January 1951

[2] Kanamori, M. A Tentative Experiment on the Improvement of the Yellow-tail Setnet. (Preliminary Report). Memoirs of the Faculty of Fisheries, Kagoshima University, Vol. 1 (1950).

[3] Kanamori M. and Enami S. Studies on the Improvement of the Yellow-tail Setnet I, On Model Experiments with a Floating Setnet. Vol. 2, No. 1 (1952).

[4] Kanamori, M. and Enami S. Studies on the Improvement of the Yellow-tail Setnet II, Model Experiments with Setnets of Various Constructions. Vol. 4 (1955).

[5] Kanamori, M. Studies on the Improvement of the Yellow-tail Setnet IV, Model Experiment with a Setnet furnished with Sea Bottom Bagnet. Vol. 5 (1956).

[6] Kanamori, M. Studies on the Improvement of the Yellow-tail Setnet V, Model Experiment with two different kinds of Bottom Setnets.

SPECIFICATION OF FISHING GEAR

by

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Abstract

To be complete and useful, the description of a fishing net should include well-defined data. In this paper some general rules are proposed, with a view to possible unification of the methods for measuring.

The twine is defined by the material used, by either metric number (or other numeric system) or useful length per kilogram, and by strength. The direction of the mesh in the webbing should be noted. The mesh size should be denoted by the length of one bar (halfmesh). The length of a piece of webbing should be measured on the stretched webbing. The width is expressed by the number of rows or meshes. Increase or decrease should be denoted by the gain or loss of meshes per row. When joining webbing of different mesh size, the method of joining and the ratio of meshsize should be defined. The length of footrope and headline should be stated; the hanging of the net should be expressed by the percentage of hanging-in and the amount of intake between ties. Accessory fittings for the net should be described in detail, i.e. material and diameter of ropes, the buoyancy of floats and the weight of sinkers.

Les spécifications des engins de pêche

Résumé

La description d'un filet pour être complète et utile doit comporter une série de renseignements bien définis. Dans ce travail, l'auteur propose quelques règles générales qui seraient susceptibles d'unifier les méthodes de mesure existantes.

Le fil est défini par le textile utilisé, par son numéro métrique (ou autres systèmes de quotation équivalente) ou par sa longueur utile par kilogramme, et par sa resistance. Le sens du filet doit être signalé. La dimension de maille est donnée par la mesure du côté de maille (entre deux noeuds). La mesure de la longueur d'une nappe s'effectue sur la nappe considérée, étirée. La largeur d'une nappe est exprimée par le nombre de rangs ou de mailles. Les diminutions ou augmentations sont signalées par les pertes (ou gains) de mailles par rang. Le collage de nappes de caractéristiques différentes est défini par le procédé de couture et par le rapport des mailles. Le caractère d'un filet est obtenu surtout au montage. Les ralingues doivent être décrites avec leurs dimensions: le montage final du filet doit être exprimé par le pourcentage d'armement et par le nombre de mailles entre deux ligatures. Les accessoires du filet doivent être décrits en détail: matériau et diamètre des cordes, flottabilité des flotteurs, poids du lest.

Especificaciones para artes de pesca

Extracto

Para que la descripción de una red de pesca sea completa y útil debe contener datos precisos. Con este objeto, en el trabajo materia del presente extracto se proponen algunas normas generales con miras a la posible normalización de los métodos de medida e incluyen algunas definiciones.

El hilo se designa, según el material usado, mediante la numeración métrica (u otro sistema de medida) o según la longitud utilizable (en kilgramos) y de acuerdo con la resistencia. Además debe anotarse el sentido en que corren las mallas en el paño. La longitud de éstas se determinará por la distancia entre dos nudos contiguos (media malla o lado del cuadrado). El alto y el ancho del paño se expresarán por el número de hileras y corridas de mallas en esos sentidos. El aumento o disminución se dará a conocer por el menor número de éstas últimas en las hileras. También es necesario describir los métodos usados para unir paños de mallas distintas, la relación que guarda el tamaño de ellas, la forma de las redes durante la tejedura, y la longitud de las relingas superior e inferior. La manera de armar el arte a lo largo de estas cuerdas se expresará según el tanto por ciento de colgadura y el número de mallas embebidas. Por último es necesario describir, en detalle, los accesorios que entran en una red de pesca, por ej.: materiales y diámetro de las cuerdas, flotabilidad y peso de los flotadores y plomos, respectivamente.

THE diversity of terms and definitions used by fishermen and manufacturers when describing fishing gear causes much confusion, delays and expense. In the French fishing industry there is urgent need for agreement on definition of the terms used in the trade and the present paper, while giving some principles of gear construction, also contains proposals for unification of terms and definitions.

TYPE AND SIZE OF TWINE

These have been described in other papers, but when ordering synthetic materials the following specifications must be given:

(a) trade name and/or chemical composition;
(b) whether staple or continuous multi-filament;
(c) whether bonded or coloured.

In France, the size of natural fibres is denoted by their metric number, which gives the length per kilogram of yarn and the number of yarns in the twine. For synthetics, the manufacturers give the size of yarn in denier but also usually indicate the runnage per kilogram and the breaking strength, which is much more useful to the netmaker. When ordering a net, the twine should be specified: by its Nm, Ne, etc., or by the runnage per kilogram and its breaking strength.

WEBBING

Three distinct types of knots are commonly used in machine-made webbing at present (fig. 1):

(a) single or double sheet-bend;
(b) flat knot;
(c) knotless net.

As webbing can be used in two different directions, it is always necessary to indicate the direction of "lay" ("with or across the knot"). The sign ⟷ could be used to indicate the direction which tightens the knots. This is important in the case of seine nets, gillnets, etc., and particularly with synthetic fibres, where the knots will tend to slip if the tension is applied in the wrong direction. Mesh size can be given in stretched mesh or in bar length, but in each case the unit should be mentioned. It is more correct to measure several meshes (at least five) and divide by the number measured, and it would seem more logical to use the bar size as this is the basic unit of webbing. Strips of machine-made webbing are manufactured with the lay or against the lay, according to the type of machine; in the first case the lint has a constant width, while in the second case it has a constant depth. As a mesh is composed of two rows, and a section of webbing must be defined in two directions, it would be advisable to express width in the number of meshes and depth in the number of rows. To avoid confusion with the sign for "metres", it is advisable to use # as an abbreviation for "meshes". The length and width of sections should be expressed in stretched condition, which will be the same as the number of meshes multiplied by the mesh size.

SHAPE

In handmade nets, the pieces are fashioned by inserting baitings or creases. This is done with machine-made webbing by cutting points and bars, the cutting sequence could be indicated as in the morse code. For example, · could indicate 1 bar 1 point. However, for comparison purposes between handmade and machine-made

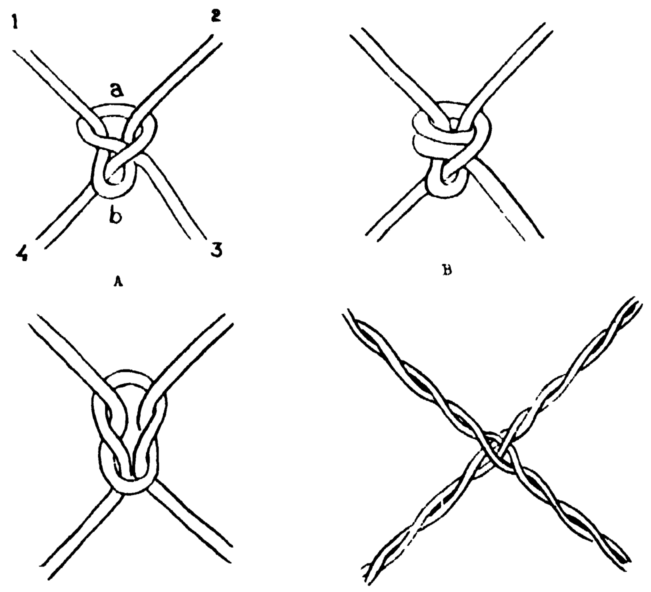

Fig. 1.

A. Sheet-bend.

B. Double sheet-bend.

C. Flat knot.

D. Knotless net.

TABLE I

Cutting sequence of webbing

Decrease	*Cutting*	*Symbol*
1 mesh every 2 rows	All bars	— — — —
1 " " 3 "	4 bars 1 point	·
1 " " 4 "	2 bars 1 point	- - ·
1 " " 5 "	2 bars 1 point and twice 1 bar 1 point	· · ·
1 " " 6 "	1 bar 1 point	·
1 " " 8 "	2 bars 3 points	· · ·
2 meshes " 5 "	8 bars 1 point	- - ·
2 " " 7 "	8 bars 3 points	· · ·

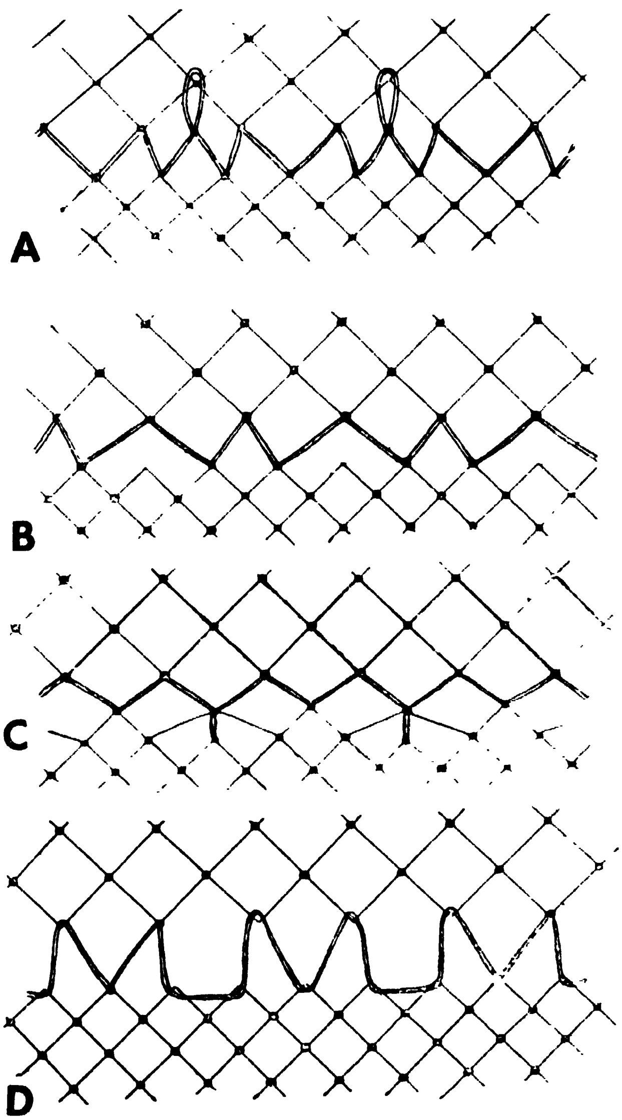

Fig. 2. Joining of webbing.

A. With increase every third mesh.

B. Leaving third mesh free.

C. Baiting every third mesh.

D. By threading-on.

nets, it appears to be more logical to indicate the shape by giving the numbers of rows per baiting. In that case, the example above would be denoted by: 1/6 or one baiting per 6 rows. Table I gives conversion values for the three systems.

It may seem unnecessary to indicate the baiting sequence when the top and bottom widths and height of a piece of webbing are indicated; but in the case of a trawl wing one cannot deduce from this the full baiting rate as it is not the same for the whole wing (fig. 3).

ASSEMBLY OF THE NET

Strips of different mesh size are often joined together, which can be done in different ways as shown in fig. 2 (for a take-up of 2/3).

Also in this case it would be advantageous to have standard ratios of take-up, such as the sequence 1/2, 2/3, 2/5, 3/4, 3/5, 4/5, 5/6...... 9/10. This would simplify the work of the netmaker.

During the assembly of the nets, the webbing is hung on framing lines by hangings which take up individual, or a certain number of, meshes. Before hanging, the webbing is normally given a self-edge for local strengthening and this should be noted on the plan. In France, the size of leadline, floatline, headline, etc., is expressed by the number of yarns to the strands and the number of strands in the rope or simply by the diameter. The hanging operation determines the opening of the meshes or the looseness in the webbing. If the webbing is hung on a line which is 73 per cent. of the stretched web length, the meshes will be squared.

The looseness of the webbing has a great influence on the fishability of the net, and must be specified on net plans.

The following specification for a sardine driftnet illustrates a method of expressing the hanging in terms of the mesh bars.

Length of net	55 metres, stretched
Depth ,, ,,	800 meshes
Leadline	3 meshes per 4·1/2 mesh bars
Floatline	3 meshes per 4·1/4 mesh bars

The hanging coefficient is here:

Leadline : $\frac{4\cdot 5 : 100}{3 \cdot 2}$ 75 per cent. (i.e. 25 per cent. slack).

Floatline : $\frac{4\cdot 25 : 100}{3 \cdot 2}$ 71 per cent.

Although this method is simple and gives complete information, it is better to express the ratio of hanging by giving the length of line as a percentage of the stretched webbing hung on the line.

FLOATS AND SINKERS

With the introduction of new materials, many types of floats are available. Hollow and sponge floats of plastic material, and metallic floats, are now increasingly used instead of cork and glass floats. As the buoyancy of these floats changes with their size and weight, in the case of hollow floats, and with size and density, in the case of sponge plastic, size alone is no longer an indication of the buoyancy of a float. The principal characteristics are given in Table II for the main types used in France. When the floats are uniformly divided over the whole floatline, it will be sufficient to specify the total number. If, however, as in the case of trawls and roundhaul nets, the floats are not uniformly distributed, the plan should include details of their distribution.

In the case of sinkers, the distribution of the weight

TABLE II

Characteristics of Net Floats

Material	*Shape*	*Dimensions in cm.*	*Weight in gr.*	*Density*	*Volume in cc.*	*Buoyancy in gr.*
Cork	Six-sided prism	10 × 10 × 2 hole of 1·3 cm.	40	0·20	197	150
Cork	Cylinder	7 in ø 4 in height hole of 2 cm.	27	0·20	135	100 — 110
Cork	Cylinder	6 in ø 2·5 in height hole of 1 cm.	11·5	0·20	60	50
Cork	Cylinder	4·15 in ø 2·5 in height hole of 0·8 cm.	6	0·20	30	25
Expanded Polystrene	Cylinder	7 in ø 4 in height hole of 1·2 cm.	18	0·12	150	130
Expanded Polystrene	Sphere	7 in ø hole of 1·2 cm.	20	0·12	155	145
Expanded Polystrene	Cylinder	5·4 in ø 2 in height hole of 0·8 cm.	4	0·12	30	25
Sponge Plastic	Cylinder	7 in ø 3·5 in height	25	0·20	123	100
Glass	Sphere	14 in ø	600		1,400	800
Plexiglass	Sphere	10 in ø	125			375
Aluminium	Sphere	20 in ø	1,200		4,100	2,900

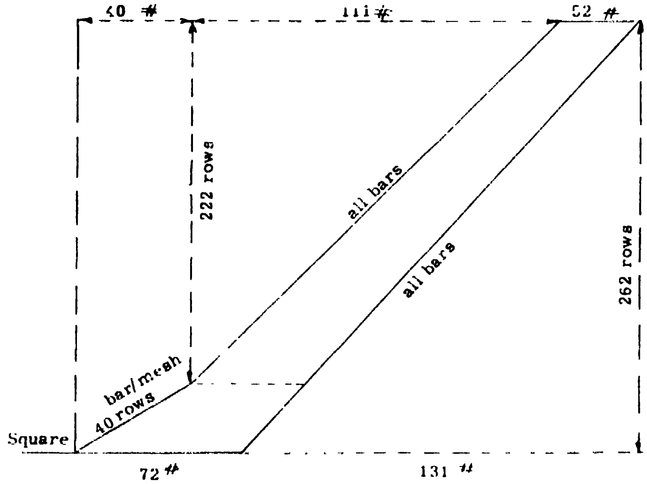

Fig. 3. The cut of a lower wing.

along the line, and the size and weight of sinker used, should be indicated. When the distribution is not uniform, this should be denoted by weight per metre in each section. The weight and method of attachment should also be given when chain is used.

SIZE OF FISHING GEAR

In France, the size of a net is usually given in terms of length of the floatline and, in the case of trawls, the length of the headline. This leads to confusion as such lengths provide no comparative size of the gear.

GILLNETS

The size of these nets should also include, apart from the length of the floatline, the depth in stretched mesh measure and the hanging percentage.

ROUNDHAUL NETS

French seines and lamparas are between 120 and 250 m in length. The depth is usually given in fathoms or metres of the breastlines, although these lines alone give no information on the working depth of the net. Furthermore, none of these measures give an indication of the bulge formed by the net in action, although this is one of the important factors of roundhaul nets.

Descriptions of roundhaul nets should therefore include:

- Length of float- and leadline
- Length of breastlines
- Number of meshes in depth and length of the main body of the net.
- Hanging percentages.

TRAWL NETS

Usually the size of a trawl net is given by the length of the headline. The net is composed of top and lower wings, the square, top and lower belly, throat and codend. The lower wings are longer to compensate for the square in the top half of the net. The bosom meshes of the square are hung to the middle of the headline, with the top wings on each side, while the bosom meshes of the belly bottom are hung to the fish line (bolchline), with the lower wings on each side, and the fishline is fastened with slack to the footrope. The hanging percentage of these net parts to their framing lines differs from netmaker to netmaker, so that for the same type of net the length of identical lines can differ greatly. This means that a net having small wings and a large bosom could have a bigger opening than a net with large wings and a small bosom mounted on the same length of headline. The wings are only an extension from the net to the boards and are really no part of the net funnel.

It appears, then, that the logical way to express the size of a trawl would be in the dimensions of its square, as this provides a truer comparison with other trawls.

Hauling nylon salmon gillnets in British Columbia. The nets are wound on a power-driven reel.

THE SIZE SPECIFICATION OF TRAWL NETS IN POLAND

by

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Abstract

For many years trawls have been described by the length of their headline or footrope, although these are by no means completely satisfactory indices of the characteristics of the gear. Today there is a greater need for a more systematic division of trawls and Poland has already adopted a more rational method of describing them, in terms of the headline and half the circumference of the belly's inlet.

Détermination de la dimension des chaluts en Pologne

Résumé

Les chaluts sont classés depuis de nombreuses années d'après la longueur de leur corde de dos ou de leur bourrelet bien que ces éléments ne constituent pas des caractéristiques satisfaisantes de l'engin. Le besoin se fait actuellement sentir d'une classification plus systématique des chaluts, et la Pologne a déjà adopté une méthode plus rationnelle fondée sur la longueur de la corde de dos et la demi-circonférence de l'ouverture du corps du filet.

Determinación del tamaño de las redes de arrastre en Polonia

Extracto

Durante muchos años se han descrito las redes de arrastre por la longitud de las relingas superior o inferior, aunque estas medidas no indican en forma completamente satisfactoria las caracteristicas de los artes. En la actualidad es muy necesario clasificar en forma sistemática a este tipo de redes, y Polonia ya ha adoptado un método más racional para describirlas según la relación de la relinga superior y la mitad de la circumferencia del cuerpo del arte, inmediatamente detrás de la visera.

CONSIDERABLE differences exist in descriptions of the size of trawl nets. Measurements are given in feet or metres, according to the country of origin, and the size indicators used may be the length of the headline, the footrope or some other combination of trawl dimensions, but the comparison of trawls by means of such indicators as these is quite impossible unless other important dimensions are known.

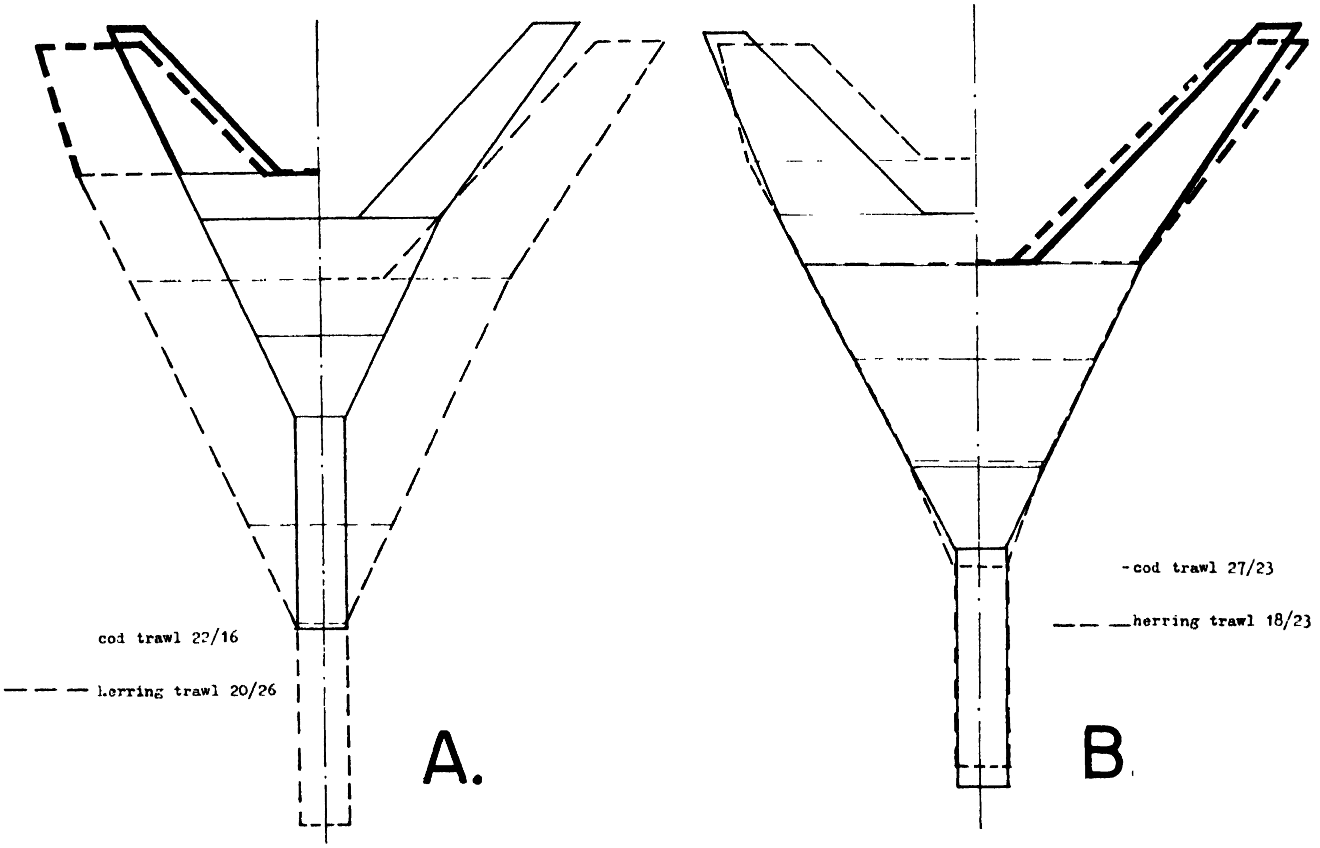
In the early days of trawl designing the size indicator was more of a name for the trawl than a true definition of its size. Today, however, there is a greater need for a systematic specification of trawl nets, and a comparative size indicator is essential in international exchange of ideas as well as in technical literature.

The length of a headline consists of the joint lengths of both upper wings and of the bosom. The length of the bosom is small, in comparison with the length of the upper wings, and there is only a slight difference in the lengths of the bosoms of various trawl nets. In other words, the difference in length of the headlines is decided primarily by the length-difference of the upper wings. For example, two English trawl nets—the Small and Big Granton—are marked by size indicators 80 and 100 feet. The length difference of their upper wings (jointly) equals 20 feet, which is the same as the difference between their size indicators. The bosom and all other parts of these nets are the same. Fig. 1A shows that trawl nets with long upper wings actually can be smaller than those with shorter wings. This also indicates that one cannot deduce any closer dependence between the lengths trawl. upper wings and the dimensions of other parts of a of the One can consider the body (belly and codend) as the main part of a trawl net which may be proved by the beam-trawl, which has no upper wings at all.

The problem of using the length of the footrope as an indicator is similar. The best evidence is found in fig. 1B where two trawl nets are shown with similar bodies but with very different lengths of lower wings. The drawing proves that the trawl with longer lower wings must not be bigger, as one might expect from the length indicator of the footrope. It therefore seems misleading to specify the size of the whole gear from data characteristic only for one part.

The proper size indicator for trawl nets, therefore, should include some reference to the dimension of the body in addition to the numerical value of one of the common indicators. Such an indicator was worked out by the author in the Polish sea fishery in 1953.

The length of the headline is used to define the part framing the mouth of the trawl, and the circumference of



Comparison of existing trawl net types, showing insufficient interdependence between the length of the upper wings (A) or the lower wings (B) and the size of the body. The examples are taken from the Album of Polish Cutter Trawls. The drawings are based on a mesh opening coefficient 0,7.

the front edge of the belly to define the dimension of the body. The reason is that this is a dimension closely connected with structural calculations of the net's size, upon which depends the amount of water filtered. Besides, the dimension of the front edge of the belly is a deciding factor (within certain limits) for all other dimensions of the body, with the exception of the size of the meshes.

The following indicator rules for trawl nets have been proposed:

(1) The length unit is the metre;

(2) The length of a headline is the length of the part of the rope to which webbing is attached;

(3) The circumference of the front edge of the belly is measured with the meshes stretched, or calculated by multiplying the number of edge-meshes by the double bar length;

(4) The size indicator is expressed by a fraction, the numerator being the length of the headline (m.), and the denominator being the length of *half* of the circumference of the belly's front edge. This indicator is used in practice and fully meets the requirements of the industrial fishery in Poland.

LITERATURE

Achlynow, I. J.—Ustroistvo trala i technika tralovovo lova. Moskwa 1954.

Davis, F. M.—An account of the fishing gear of England and Wales. Fishery Investigations, Ser. II, vol. XV, No. 2, 1936.

Klimaj, A., Bruski, Z., Netzel, J.—Wloki kutrowe i ich eksploatacja. Warszawa, 1956.

Okoński, S., Sadowski, S.—Album wloków kutrowych.

Schnackenbeck, W.—Schleppnetze—Hanbuch der Seefischerei Nordeuropas, Band IV, Heft 1/2, Stuttgart 1942.

Wojnikanis-Mirskij, V. M.—Technika promyszlennogo rybolowstwa. Moskwa 1953.

Żebrowski, Z.—Rybolówstwo—Przemysl Trawlerowy. Fleetwood 1943.

Zebrowski, Z.—Rybolówstwo Morskie—Narzedzia polowu. Gdynia 1949.

Zebrowski, Z.—Wloki trawlerowe. Warszawa 1954.

Prüffer S., Sienkiewicz, W., Zebrowski, Z.—Podstawowe wiadomości z praktyki sieciarskiej. Warszawa 1954.

DISCUSSION ON RATIONAL DESIGN OF FISHING GEAR

Mr. J. O. Traung (FAO) Rapporteur: The development of fishing gear has been based simply on common sense and the visual observations of fishermen and net-makers.

The last ten years have seen the introduction of engineering theories and the systematic testing of gear to determine the factors which influence the size of the catch. Test methods and the design of specific instruments to determine the behaviour and quality of individual parts of the gear have been developed.

The actual introduction of engineering theories in fisheries is not difficult, but is hampered by the fisherman's attitude. The fishermen mistrust these theories; he is convinced that as he does the fishing, he knows best what is required of his gear. The engineer himself is liable to disregard the experience and the knowledge of the fisherman and, although both want to improve the gear, they find no common ground of contact. A second problem is the attitude of biologists towards technicians. Biologists have long had an intimate knowledge of the fisheries and are sceptical of engineers who misuse fisheries terminology. When talking to fishermen it is necessary to use simple language. All too often engineers use mathematical formulae and technical expressions which are incomprehensible to the layman.

A few important points need mentioning here, such as the resistance of gear to waterflow, which increases as the square of the speed. Trolling at, say 2 knots, the trolling line having a resistance of 10 lb., may be found to work successfully. If, however, the speed is doubled to 4 knots, the resistance of the line will increase 4 times, to 40 lb. The resistance might be even higher, because some of the details in trolling gear, such as the sinkers, might change their position, causing an increase more than by the square on the speed If the speed of this trolling gear is increased to 6 knots, the resistance will be 9 times higher than at 2 knots, that is, 90 lb., in which case the line may break, and the gear be lost.

It is very important, therefore, to determine the speed exactly when talking of resistance, because if the trolling line has about 20 lb. resistance, this is in relation to quite specific speed. That speed must be accurately stated, otherwise the resistance figure given may be misleading.

Another important engineering law is that covering the behaviour of buoyant objects when moving through the water. This embraces the whole complexity of hydrodynamic behaviour of trawl boards, depressors, kites and floats, and it is important that studies of such bodies should be conducted over a sufficient speed range.

Phillips describes how he was misled when designing his trawl floats with the help of observations by frogmen. The tests were carried out at reduced speed to protect the frogmen, but, at normal operating speed, the floats behaved quite differently.

Fishing gear should be studied over the full speed range, one important object being to obtain results which are comparable with other tests. In the papers under consideration, certain trawling tests were done at 3 knots, some at 3·7 and others at 2½ knots. If this testing had been done over a speed range, it might have been possible to pick out the resistance at certain speeds and compare the different gear.

Furthermore, if a certain gear or a certain gadget to a gear is tested within a certain speed range, the different test points will not always lie on an even curve. It is best to obtain many test points to arrive at reliable average values.

A few papers cover tests with models of fishing gear. In this I want also to include tests of parts of fishing gear carried out with full-scale models as these produce the most accurate results. Such testing of parts of the gear will help us in assessing the efficiency of a complete gear.

Kawakami reports on a number of Japanese model tests with fishing gear. Miyamoto's tests with different types of webbing are very interesting.

Albrechtson has made similar tests with webbing in the test tank in Gothenburg. The Japanese have made tests with pieces of nets, to arrive at figures for the resistance of webbing at different angles of attack. We do not know sufficient of the flow characteristics of complete nets. One thing, however, is evident: if one type of webbing has less resistance to waterflow in the tank it will also have less resistance when fitted into a complicated net, where the flow conditions can be quite different.

Model tests of fishing gear can actually be carried out in many different types of establishments. There is the ship tank, a long channel with a water depth about half its width. It is equipped with a carriage which moves along it at variable speeds, towing a model. A dynamometer registers precisely the resistance of what is being towed, and it is easy to obtain the exact resistance at different speeds. Unfortunately, ship model tanks are usually very expensive to use, but in many countries there are University tanks for the use of students and these could be quite useful for fishing gear research.

Fishing gear is normally totally submerged and does not set up surface waves, so that wave resistance does not have to be taken into account. Relatively large models could therefore be used also in university tanks, although the tanks are only 10 to 20 ft. wide.

Another type of tank is that where the model is in fixed position and the water circulates around it. Such tanks, as described by Narasako and Kanamori, are suitable for observation of many types of fishing gear, especially stationary ones. These tanks are less efficient for bottom trawls because there is no friction of the gear on the ground. Circulating water tanks are also being used in testing ship models, and there are to my knowledge two such tanks in Europe, one in Genoa and one at the University of Delft.

Ship model testing has been carried on for about 80 years, but there are still very great difficulties in extrapolating the results from the model to the full ship. At the 1957 International Towing Tank Conference in Madrid, it was found impossible to reach a scientific agreement as to how this best could be done and a compromise had to be found.

The fact that the submerged gear is not rigid, resulting in varying friction lengths and friction forms, complicates the extrapolation of model results. I believe that extrapolation model results of gear will not be exact until many have been tried and the results compared with full scale gear performance, in order to find basic data for extrapolation. Meanwhile much can be learned from comparative model tests, especially on the behaviour of nets in the water.

Kawakami and Dickson both agree that model tests are easier and cheaper than full-scale tests. I would like to add that, with the help of model tests, it is possible to test "bad" designs. By studying these "bad" designs we will know what to avoid. Nobody would want to design a bad full scale fishing net. Model tests have another advantage. Model testing work could be done in wintertime, when weather conditions are unfavourable for full-scale work with exact measurements. Gear technologists should not avoid rough water, but under certain weather conditions it would be impossible to get, for instance, exact dynamometer readings.

The Japanese have contributed much in the use of complete models. Kawakami's paper describes the method in general. Takayama and Koyama describe how a certain trawl was improved by the use of a 1:30 model.

The Japanese use small models, but Dickson is more conservative and wants large models. This is completely in line with his countryman, Froude, who, about 100 years ago, was the first man to solve the way of testing ship models. Froude tested very large ship models of about 20 ft. (6·1 m.) in length, and met with relatively small problems in extrapolating the results. With today's extended knowledge of laminar and turbulent flow, etc., a school using models as small as 5 ft. has developed in shipbuilding, but many people still consider these 5 ft. models too small. This remark may illustrate the importance of the proper model scale for the purpose in question. Dickson and the Japanese have two different ways of looking upon model tests. When a fishing net is reduced to, say, 1:8 scale, it is very difficult also to reduce the meshes and the thread diameters correspondingly to make the model scale absolutely true in every detail Therefore, one can have a length scale 1:8 but a mesh scale of only 1:4. This procedure has been followed both by the Japanese and Dickson.

The difference comes when reducing the speed. Assuming a full scale speed of 3 knots, Dickson says "Well, we take the length scale and we reduce the speed scale correspondingly", and he gets 1 knot. The Japanese take the mesh scale and they get about 1½ knots. Naturally, considering that the resistance depends on the square of the speed, the ½ knot makes a difference.

In addition to testing fishing gear in a ship's tank, one can also use other means, as, for instance, Albrechtsson did when testing shearing devices and nets in the flow of a creek, from a bridge. This is not only a very useful but also a very cheap method even if speed regulation is impossible and speed determination difficult.

There are several methods of studying underwater operation of fishing gear. First we have the sensory method, that is, to study the angle and inclination of trawl wires, to feel the vibrations of the trawl wire, to listen to the engine, to watch the r.p.m. of the engine, to study scratches on the trawl door and gear, and to study stresses or tears in the webbing, interpreting these observations with the help of experience and common sense. These are the methods commonly used by the fishermen.

Then comes underwater observations, either visually through clear water in shallow depths, or by frogmen, using cameras, and direct hand measuring. Speed, however, must often be reduced. Frogmen are not always fishermen or technicians and have difficulties getting across their observations for the scientists. British underwater films are mentioned in several papers, and Ben-Yami describes some very complete tests.

Fishing gear can also be studied by echo sounding. Schärfe describes what kind of results can be obtained by operating with a small sounding boat over the gear. Television has opened up enormous possibilities in fishing gear research.

Carrothers describes how jelly bottles can be used to measure the slope of trawlwarps, headlines, etc. They can also be used for measuring the shape and position of passive gear such as longlines, gillnets, etc. under actual fishing conditions and thus supplement direct observation by television or frogmen.

When making a study of the trawl in action, the two main things to be determined are the speed and the resistance, this quite apart from headline heights and the distance between trawl boards. The speed, I feel, should be measured exactly and not just estimated. It should also be specified whether the indicated speed is that of the vessel through the water or the speed of the trawl over the ground. This is important not only because of differences in current speed and direction between the surface and near bottom waters, but also because of the bottom friction of the gear. For measuring the speed over the ground, Decca navigation equipment should be a good tool. Near the coast, the usual means of terrestrial navigation can be applied.

The ship's speed through the water at the surface can be determined by rail logging or with the usual handlog. Better accuracy is obtained by towing a small resistant body, specially designated and calibrated. The speed is then determined from the resistance of that body. That is done in the Kempf log, used by Schärfe.

Another method is represented by pressure logs, such as mentioned in Eddie's paper.

Finally, the propeller logs must be mentioned which, in high quality construction, are in common use as current metres. The Chernikoff Log is one example. This system could also be used in the way biologists do in connection with plankton nets, to measure the actual speed of the trawl net by attaching the instrument to the trawl itself and have the measurements recorded, or preferably transmitted, to the ship for immediate observation.

With regard to measuring resistance, Dickson describes a removable dynamometer of an interesting type which can be fitted to the trawl warp. This type of dynamometer works on the principle of measuring the pressure which the warp exerts on the instrument. Another way to measure the pull without cutting the warp is to use electric strain gauges, such as those to measure strains in bridges and plating of ship hulls, etc. De Boer mentions that he found this method too sensitive for his purpose. This method might be suitable for tele-measuring the strain on different parts of the gear in action and in that way study the forces involved in a complete gear.

It is always advisable to double-check results, and I believe that, when determining the resistance of the gear itself, one should study the performance of the boat by measuring the propeller thrust or the engine output. Having determined the ship's resistance, the total resistance of the gear is then obtained. When engine and gear data do not correspond, then something might be wrong. This double check may also serve as a basis for evaluating the influence of external factors, such as wind, current, wave action, etc.

Dependable and convenient depth metres are most important for the study of trawls. These can either be pressure instruments or echo sounders. The Germans long ago used pressure instruments hooked up to clockwork recorders to measure the opening height of trawl nets and the depth of floating trawls. Such instruments, however, can only be read after the gear is hauled, the results being more difficult to interpret than a direct recording on board, which can be read immediately. Echo sounders can be used for depth recordings either, as described by Schärfe, from a motor-driven boat operating over the fishing gear or, as described by Woodgate, by fixing a transducer to the appropriate part of the gear with a wire connection to the echo-sounder on board the vessel where the soundings are recorded.

Now comes the difficult problem of transferring instrument recorded data from the gear to the vessel. Clockwork recorders have the disadvantage of only supplying the data after the experiment; such instruments are mentioned or described in the contributions of de Boer, Dickson and Hamuro and Ishii. A continuous transmission of measured values during action could be obtained by a cable, as described by Woodgate, who states that a handwinch is sufficient for about 200 fm., and up to 500 m. cable length could probably be handled with a special winch. For wireless transmission, ultrasound waves have been applied by the Americans using frequency modulation, as described by Schaefers and Powell, and by the Germans using code signals.*

The main difficulty with this method lies in the propeller wake.

The most practical thing would be to have an electrical conductor inside the trawl wire. McNeely's paper is of highest practical value, and gives hope that it might be possible to produce such a wire for commercial trawlers. This would give the skipper the possibility of fixing small instruments to the trawl to see how it behaves. These electrical trawl wires permit the use of, for instance, strain gauges, echo sounders and television cameras on the trawl. It is important in the development of such trawl wires to try to have many conductors in each wire so as to hook up many instruments. In order to have the smallest possible diameter for these conductors, a change of the voltage for the passage should be considered.

The method using the angle of the trawl wire to the horizontal, to determine the depth of a midwater trawl, might work accurately enough in shallow depths, but it is considered insufficient for general use and should be replaced by the telemetering methods mentioned above. Determining the depth of gear by using the angle of the trawl wire in connection with its resistance coefficient to calculate its slope, has been proposed but when I tried to do this in 1949 my recording did not correspond to the theoretical formulae. The explanation probably was that we had vibrations in the trawl wire due to the vibrations of the engine and the propeller.

It is also important to measure the distance between the trawl boards. De Boer's paper contains a description of his interesting method of continuous recording. Another and simpler way, incidentally, used in shallow water, is to fix a planing float with line to each trawl board and determine the distance either by direct measurement, or by calculations using the angle between them and their distance from the towing vessel.

Carruther's jelly bottle method can be of help in the study of the geometry of the fishing gear. De Boer describes a clinometer and an angle of attack meter for the otter boards. Hamuro and Ishii describe a recording ground rope indicator. Such instruments are relatively inexpensive and, by using them intelligently, we could learn a lot about fishing gear.

The following instruments might also be of value although mainly intended for research purposes in connection with commercial fishing: a precise log preferably of the propeller type; an instrument to measure the towing resistance of the gear, preferably arranged in the slip hook so as not to interfere with the operation of the trawl; an instrument for predicting the output of the engine, such as a fuel meter calibrated in h.p., and depth measuring instruments. In addition, a trawl wire meter as described by Crecelius could be used.

An instrument indicating the presence of fish in the trawl would be of importance in commercial trawling. De Boer points out that the total resistance of the trawl decreases when the trawl is being filled. This is in contradiction to some American claims but, personally, I have never noticed additional resistance when fish are present. I have seen fish on an echosounder and I have seen how the dynamometer went up at the impact of the fish schools, but it then returned to its original point. How to determine the amount of catch would be a most interesting point to discuss. A television camera might be useful, or an electrical eye counting the fish. The electrical conductor equipped trawl wires might be of some help.

Schärfe has shown that the resistance of the trawl can be reduced by 30 per cent. by applying in the design engineering methods aided by underwater observations. Eddie has shown that a trawler used only 600 h.p. when the skipper believed that he was using 1,200. This confirms an observation of mine: that small trawlers only use a fraction of the horsepower the skippers believe them to be using. Takayama shows how to increase the headline heights from 2·5 to 5·4 m. with the help of model experiments. Hamuro determines the distance between pair-fishing trawlers. Sand describes how he developed an improved midwater trawl with the help of underwater observation and television. But many problems remain to be solved, such as the resistance of different trawls, and how this resistance changes at different depths.

With the exception of getting a fool-proof conducting trawl wire, there does not seem to be any real hindrance preventing development of the instruments that are needed. The problem really lies with governments, who should realize that gear technologists can help the fishermen, and that fisheries departments should have such technologists on their staff.

Mr. W. Dickson (Scotland): At the moment I think we must admit that the design of trawl gear is very much, as

* *Editor's note.* Recently successful trials using changes in the impulse rate for coding the measured values have been reported from the U.S.S.R.

we say in Britain, still by guess and by God, and we should work towards the day when we can say: such and such a ship will give a certain thrust and have such and such trawling speed, so that we can design a trawl which at that speed will consume that thrust and then also fish with gear of dimensions which are predetermined. When we can do that, then I think we can say we will have made some real progress with design. Those who design or build trawl boats can help us by giving the actual performance data. They should, when they build new vessels, give the towing pull of those boats at various speeds because only when we have that information will we be able to design nets to give us a predetermined performance.

Captain D. Roberts (U.K.): I am skipper of a Grimsby trawler.

Those of you who are not fishermen, who are not directly connected with operational fishing, may wonder why we fishermen do not take more advantage of these wonderful instruments that are described in many of the Congress papers. Well, I must point out that my job is not just to go out to sea to get fish. My job is to catch fish that will sell for more than it is costing my owner and I have not got the time to devote to such things, much as I would like to. Once on the fishing ground the fisherman is fully occupied with making successful day-to-day catches and assessing their value on the changing market. Experiments are for future trips and slow down the flow of the work under operation. Nevertheless, I do try things out in a small experimental way, whenever the circumstances allow it.

This Congress has shown me that we must pool our knowledge. I was not aware of the development of gear in Japan and many other places and am now aware that we fishermen should keep better track of what is achieved by our colleagues elsewhere. One thing should however be realized by technologists and biologists and that is that we fishermen cannot use new instruments and innovations unless they have reached the stage where they improve the catch. Our first job is to catch fish that will sell and sell for more than it costs us to catch them.

Mr. G. Albrechtson, Chairman: Thank you, Captain Roberts. I know you are the type of man who will cooperate with scientists, boat and gear designers and tell them when they are right and I assure you the fisheries workers not actually engaged in fishing do realize the difficulties of the fishermen conducting experiments. On the other hand all innovations must be tried out under actual fishing conditions and the logical way is that the fishermen should conduct suc trials themselves.

Dr. J. Schärfe (FAO): I would like to mention one non-technical reason why I prefer full scale, to model tests. The Institut für Netz- und Materialforschung in Hamburg (Institute for fishing methods and gear research) where I worked before I joined FAO, is concerned with applied research. We considered it necessary not only to obtain results of practical value for the commercial fishery but also to do all we can to make the fishermen accept what we have worked out for them. I think you will agree that model experiments, the results of which have to be interpreted mathematically, give most people the impression of being basic research rather than practical development, and are therefore not a very strong argument for convincing fishermen to give up their conventional methods or gear. This psychological factor comes on top of the problems of model testing of fishing gear as regards for instance suitable model scale and the proper method and the accuracy of extrapolation to full scale.

Mr. J. O. Traung (FAO): I do not consider model testing to be fundamental research. The formulation of friction formulae and model laws to permit extrapolation of results and development of suitable instruments might be —but not the evaluation of the results by the gear technological engineer. Model testing is to compare small scale models. If one is better than the other in model scale it predicts that that type would be better in the full scale too. One should of course not go with the model test results to fishermen and say, well with this and this formula you will get that and that net opening. One should look upon model tests as our way of testing new ideas. If the model test shows promising results, there is less risk that the full scale may turn out a failure.

Prof. S. Takayama (Japan): We use model experiments not only for qualitative comparison but for actual extrapolation to full scale fishing gear and find this method very useful. We are quite aware of the problems concerned with proper reduction of netting, but in spite of the limited accuracy we think the results are suitable for preparing full scale operations and particularly for cutting down experimental costs.

Dr. J. Schärfe (FAO): I agree with Mr. Traung that model experiments can be useful for testing certain completely new ideas for the consideration of which insufficient experience or knowledge is available. But, when trying to improve existing fishing gear as for instance trawls there usually exists quite a lot of experience which makes it possible to foresee, at least qualitatively, what the results will be. If such improvements are built up step by step, which in my opinion is a sensible way, there is not much risk that the experiments will turn out a complete failure. Furthermore, in such cases the experiments are usually started with gear types similar to the conventional ones, the value of which then is hardly affected by the experimental modifications because those can easily be reverted. So, even in the worst case, at the end you still have a conventional gear left. I, therefore, think that Prof. Takayama's remark on the comparatively lower costs of model experiments cannot be generalized. This might be true in certain cases when dealing with extremely big and expensive gear as for instance purse seines or the Japanese Setnets. But, because of their big size, the model scale then has to be very small which leads to the well known extrapolation difficulties. To my opinion all observations and experiments possible should be made in full scale. Quite a lot could be made with commercial gear during commercial operation, using specially designed measuring equipment which does not interfere with the fishermen's work. You then have the great advantage that you get the right picture directly and under practical fishing conditions and there is no question of making assumptions and figuring out the proper extrapolation factors. And such observations or experiments often don't cost more than the travel expenses.

Prof. T. Sasaki (Japan): I am representing the Science Council, Japan.

We are solving many problems by using underwater photography and television, for example, in connection with trawl fishing and other research on fishing gear. Another problem we are studying with this method is the significance of the colour of fishing gear. I would be interested to learn what types of underwater television equipment is used in other countries and to what extent.

Mr. H. S. Drost (Netherlands): I want to refer to the words of Captain Roberts. I quite agree with him that fishermen cannot work with all these things the scientists are using but, as we need a lot of data, I would like to ask Mr. Traung if it would not be possible to find a very simple dynamometer every trawler man could use to find out the resistance of the trawl net as measured by the tension in the warps.

Mr. J. O. Traung (FAO): In reply to Mr. Drost's question it must be mentioned that when dealing with the towing resistance and its significance the speed must be known too. I think that the resistance of trawls could most easily be recorded without much work, by using a strain gauge built into the slip hook, deck bollards, gallows or attached to the warps. With some simple wiring the values could be transmitted and recorded in the wheelhouse. The speed, however, is a much more complicated matter because we must decide which speed we want. The speed over the ground, or the speed through the surface waters. Many large trawlers have already LORAN or other such equipment with which the speed over the ground can easily be determined. The speed through the water could be determined with some type of log, but I am afraid gear research in general would not gain much by such data, collected by commercial trawlers under changing conditions. The Captain can, however, make use from even the comparative values to know whether he is for instance straining his net or his warps too much at, say 5,000 lbs. pull; or to use the exact speed measurements to ensure that he is not trawling too fast for some species of flat fish which he wants to catch.

Mr. M. Ben-Yami (Israel): I am a commercial fisherman from Israel, a skipper of a small trawler, and I have also done some research on trawl gear at the Sea Fishery Research Station, Haifa. I look on the question of gear research from the fisherman's point of view and I am always afraid that this research may become too concerned with problems of no immediate practical value. We can take an experimental net and we can measure the breadth, the width, the height, the length and the bias strength. We can measure until we know the strength of, and the strain taken by every mesh in this net, but unless we use the information gained to bring about practical improvements of fishing gear, there is a tendency to become engrossed in some scientific speculation of no practical value. The final goal of all such attempts must, of course, be the practical improvement of the fishing gear and I would like to stress that the actual result can only be proved by comparative fishing. The second and not less important task is then to make the fishermen accept the innovation. I think this cannot be done by Congress papers and also not by articles in various fishery journals. A fisherman will only believe what he sees with his own eyes and here the comparative fishing comes in again. If the new gear is operated commercially alongside other commercial fishing boats and the fishermen see that this gear continuously catches more fish, I am sure that this will immediately make them eager to adopt the new design.

I would now like to deal with one practical problem of trawl design. We think that the right way to raise the headline to increase the fishing height of a trawl net is to relieve the headline and the upper net of strain. But, with the Italian type nets we use and with other nets I have seen in the German harbours, all or at least part of the horizontal strain comes over the headline and the top part of the net. The achievement of the proper opening height is then effected by using floating or shearing devices against this strain. It may be right that the top of the net also acts as a kite when it meets the water flow at some angle of attack but this effect is very limited compared with the horizontal strain. Therefore this strain should be relieved.

To improve our conventional nets we have attached side lines to take over the strain from headline and upper net. These lines run along the net from the danleno to the codend. Furthermore, wings and belly were hung with some slack or coefficient of hanging to these side lines to give the upper part sufficient freedom. Now the headline is longer than the side lines and the webbing and free to be lifted by good floats. We found the trawl plane float superior to common spherical floats and use them almost exclusively. This modification resulted in doubling the opening height which usually is not more than about 1 m. with the Italian type trawl. Such modified nets are used in Israel commercially giving satisfactory results and they are slowly coming into production.

An additional modification of the upper belly was developed and successfully tested which is meant to give even more slack to the webbing. The trapezium shape of the upper belly can be obtained in two different ways. The usual method consists in shape cutting or braiding so that the creasings are at or at least near the side edges. In this case the edges are longer than the centre line which must result in some stress along the middle of the upper net. We tried the other way for which the trapezium shaped piece of webbing is cut along the centre line and the two pieces sewed together by joining the outer edges. Now the side edges are shorter than the centre line and the webbing of the upper belly has more slack. An experimental trawl has been made omitting side lines. The actual opening height achieved has not been measured yet but the practical results indicate that it gives better performance.

Captain A. Hodson (U.K.): The remarks our colleague from Israel made about how to increase the opening height of a trawl are particularly interesting for me because only last month I made some modifications of this kind. A comparison with the catches of other vessels fishing in the same area showed that this modified net caught more dogfish, which was possibly off the bottom.

In Grimsby we have the same length for headline leg and tow leg. The only thing I did was to increase the headline leg a bit. The effect of this simple measure was already very noticeable during shooting operation when steaming round to get the gear away from the side. The headline was at a higher arc and a greater angle between the legs than we were used to.

Mr. G. Albrechtson (Chairman): We have with us Mr. Larsson from Sweden. He is the inventor of the Phantom trawl and has carried out extensive research work in tanks with models of nets for both, pelagic and bottom trawling including special designs for opening the mouth of the trawl net.

Mr. K. H. Larsson (Sweden): I have read with special interest Dr. Schärfe's paper on experiments with trawl gear in full size because his results are almost exactly the same as I got 13 years ago with tank testing in Gothenburg. I then used a model trawl with 14 ft. headline made, incidentally, by our Chairman, Mr. Albrechtson. The trawl doors were 8+5 in. and we found that of the total resistance of the gear, about one third was due to the warps and the trawl doors and the rest came from the net. Dr. Schärfe found 37 per cent. for the doors and warps. As the model tests were done on a very smooth concrete bottom, the small difference could be explained by the bottom friction of the boards in the full scale tests.

I then tested some different types of trawl doors starting with some sort of a paravane which did not work at all. So I designed another type of door which I called the floating trawl door. I put some cork on the top of the door and lead on the lower part, so that, when floating in the water, it was kept upright. After experimenting with different shapes of doors of this basic type I finally achieved an increase of shearing power of about 32 per cent. compared with ordinary boards. As a result of this, I got an order from the Swedish Navy to test about 15 different types of trawl doors which might be suitable for mine sweeping. That was just after the Second World War when many mines had to be swept off the bottom of the big harbours. As a matter of fact, some mine trawls were made and used with good results. The Swedish Navy then made systematic trials with half scale gear in the open sea at the southern end of Sweden. It was a very good ground, 4 m. in depth, with hard sand bottom. There we made observations on speed, towing power and spread of trawls using the same method as Dr. Schärfe, i.e. measuring the distance between the warps one m. from gallows. We tested doors of different height to length ratio and also different cross-section curvatures, these doors all being hydrofoils. It was found that higher trawl doors gave better results. These tests finally led to a design which I call a wing door—a door like an aeroplane wing standing upright in the water. This was superior to all other designs giving more shear at much less resistance. Furthermore, it was found, by accident, that this trawl door could easily be made to go upwards or downwards in the water or travel steadily at will. Now it was possible to start work on the pelagic otter trawl. We started experiments with a small trawl net with these wing doors and very soon found that the floats on the headline and the weights on the footrope could not keep the net open against the strong outward pull of the trawl doors. So it became necessary to design better means for securing the vertical opening of the mouth. To be independent of the speed this had to be done by shearing devices. After testing different models which did not work, we finally arrived at a type which has been called the trawl toad. This is automatically balanced and is attached by one short strop to the headline or the footrope. There are two types of this kite—one lighter than water, which pulls the headline upwards, and the other, heavier than water which pulls the footrope downwards. Since the shear of these toads increases with the square of the speed exactly as is the case with the otter doors, the shape and size of the net opening is independent of the towing speed. This makes higher speed possible which I have found to be essential for getting good results with midwater trawls. As I believe that also for bottom trawling there is a trend to increase the towing speed, the combination of shearing devices for both horizontal and vertical opening can be taken as an example of designing for the future which, to my opinion, is a general demand for all gear research.

Mr. Y. Grouselle (France): I have myself done some research on mid-water trawling and I believe that the problem of adjusting the trawl to the depth wanted can easily be solved, provided that the actual depth of the gear during towing is recorded by some suitable measuring device. The new type of mid-water trawl I have developed and which is described in my paper apparently achieved the desired depth very quickly. But apart of the proper working depth the optional net opening has to be maintained. I have studied this problem in collaboration with the Institut Scientifique et Technique des Peches Maritimes. One of the results of these studies was the design of a special type of kite which I called *Exocet*. Contrary to normal floats this type of kite is rather independent of the trawling speed and, to my experience, is well suited to work satisfactorily under varying conditions.

In midwater trawling it is necessary to prevent the fish from passing below the footrope. In my new design, therefore, the footrope is in front of the headline similar to a normal trawl net with the square turned upside-down.

Dr. H. A. Thomas (U.K.): It seems that the question of whether a twine has the tendency to float or sink must play an important part in the design of certain nets. Not being a practical fisherman myself, I am putting this up as a point for discussion; is it really of value to the net manufacturer and the fishermen to have available fibres which will float on water? The fibre Courlene mentioned yesterday with regard to materials has a density of 0·95. Cotton has a density of 1·5 and will sink fairly quickly in either salt water or fresh water, while Courlene the polyethylene yarn will float quite readily. I think the fishermen present, and all who have experience in this very important business, should advise, both the designers and the fibre producers as to the value of yarns of this type. It might even be considered to make one part of the net of floating twine and another part of heavy twine. It might be of interest to show on the blackboard the densities of those fibres which are now finding use in the fishing trade, including cotton:

Courlene	0·95
Nylon or Perlon	1·12
Kuralon (the Japanese fibre)	1·26
Terylene	1·36
Cotton	1·5

We would very much like to have the opinions of experienced fishermen and designers, whether there are advantages to be derived from the density of the fibre and whether density plays an important part in the design.

Mr. G. Albrechtson, Chairman: The question of the different netting made out of synthetic fibres lighter than water has been raised. Trawl designers are always trying to get the trawl net to work lightly over rough bottoms by the use of bobbins or depressor "toads", so that the belly is pulled up from the bottom when sharp obstacles are met with which could damage the trawl. With the new polyethylene fibre it might be possible to design and make nets that would stay clear of such obstacles. I would be very interested to know if experiments on rough grounds have been carried out with nets made of such more or less buoyant material.

Mr. Z. Zebrowski (Poland): I belong to the Maritime Fishing Institute at Gdynia. We have in the past experienced much difficulty in interpreting the measurements of fishing gear, especially the trawl, due to the different methods of specification used. When studying the trawl gear used in the Baltic in 1950 we found that our fishermen were using 6 or 7 ways of determining the size of trawls. Almost every village or town had its own method. Furthermore, we counted mo:e than 100 different types of trawls, which big number seemed not to be justified in such a limited area as the Baltic Sea is. By introducing a definite and legal method of taking measurements we found that this number could be reduced to about 23 white fish trawls and about 18 herring trawls This standardization is in process of development and we aim to arrive at a more restricted number of trawl types for each of which there will be 5 sizes. This difference in size will only affect the front part of the trawls as the belly and codend for each type will remain the same. The material is being standardized too. From about 200 different types of netting, we are using about 40 for the cutter trawls in the Baltic. At present we specify the size of a trawl by the length of the headline where netting is attached and half of the stretched circumference of the front edge of the belly. These two numbers are sufficient for the experienced net maker and net designer to estimate the size of a trawl net. As a third number the mesh size of the codend could be added to give an idea of its selectivity.

Another matter I would like to mention is the necessity of a dictionary on fishing gear to facilitate the interpretation of gear descriptions from different parts of the world. Yet it seems, that before one can compile a dictionary we must first come to an internationally accepted classification of fishing gear.

Mr. G. Albrechtson, Chairman. The point made by Mr. Zebrowski on the need for a more accurate determination of the size of trawl nets appears to be quite acceptable. In Sweden the size of trawls is determined by the length of the headline alone, but this does not give full information as it does not give any indication of the size of the belly. Standardization of the method of designation would be a step forward.

Mr. J. W. Phillips (U.K.): My colleagues and I have made and tested many models of floats, some in swimming pools using a winch to tow the models, with weights attached to them, comparing the amount of lift that one can obtain from various shapes and designs of floating equipment. The most promising types were then very carefully tested hydrodymechanically in the tanks of Messrs. Saunders-Roe the aircraft manufacturers on the Isle of Wight, and we have learned how very much more there is to testing than we thought. For instance, I have always thought, that if you make a trawl plane float the right shape and attach it to the headline, the faster you tow it the higher the headline will come. Well, that is balderdash, absolute nonsense. The moment the speed is increased beyond a certain velocity, the drag overcomes the buoyancy, the angle of attack increases and disaster to the headline is imminent. Perhaps the technicians have known this, all along, but we had to use model testing to find it out. I do not think there is any real difficulty in designing and making lifting gear to raise the headline at any speed, provided you harness static buoyancy with dynamic lift. Furthermore, the gear must be very simple to attach to the headline and reliable under trawling conditions. The strength of the netting is, to my mind, vital because of the diverse forces at work and there is need for a good deal of research work in designing and making a net if these forces are not to fight one another. I feel that the future development of trawling gear depends to a great extent on model tests, both for the net and for the auxilliary gear.

Mr. I. Richardson (Lowestoft): I want to say a few words on integration in the technological approach, because I think we are a little at cross purposes. Obviously, tank testing can help in the assessment of fishing gear as far as hydrodynamics are concerned. But this probably, is as far as we can go with tank testing. Next comes the question: what material are we going to use in making the gear? In a trawl gear, we are mainly interested in breaking strength, so that we want a measurement of the strength of the gear as it is used. This is the strength of the mesh, not of the individual yarn and not of a knotted twine pulled straight. We want the mesh tested and we want it tested wet. Furthermore, we want comparison tables of all material, synthetic and natural, for proper choice or substitution. This selection of the optimal material with sufficient breaking strength cannot be solved by model tests.

Another vital problem which also can only be solved by observations under natural conditions is the reaction of the fish to the gear. I think that this point has not been stressed enough today. We have only heard about one or two instruments which can be used in observing fish behaviour to gear. I believe that this problem deserves far more attention in the future than has been paid to it in the past.

Dr. A. W. Needler (Canada): I would like to talk not only as a Biologist but also as a Senior Government Administrator. In general, fishing gear is extremely inefficient. In any test that I know of, gear has been shown to catch very small proportion of the fish which approach or which it approaches. In the case of scallop dredges in Canada, for instance, we have had good estimates of the density of population, checked with statistical methods and with photography of the bottom, and we have found that a simple dredge moving over fairly smooth bottom only takes 5 per cent. of the scallops. We had to study the reactions of the scallops to get some explanation of this, and found from frogmen observations that scallops escaped the dredge.

Now, to overcome such inefficiency, collaboration is needed. I am inclined to think that the least difficult person in this picture might turn out to be the Government Administrator, because if the others can bring their heads together and provide an apparently practical answer, government support will be forthcoming. Governments always yield to economic pressure, although sometimes they fail to yield to what you might call intellectual pressures. Sometimes, there are difficulties in establishing a working team due to lack of mutual understanding.

Dr. Rollefsen, who was one of the world's great fishery biologists, once said in an international conference: *we have to ask the fish a lot of questions, and we have to learn how to interpret his answers.* This has a great deal of bearing on the rational design of fishing gear. One of the big things to learn about fishing gear is what impulses it pushes ahead of it. Does it make a noise? what noise? what light? what pressure waves? what does it do? The biologists should join with the technologists to investigate the reactions of fish to gear, for which purpose tank testing techniques might also be useful.

There is another point which also bears on this need for a broad approach: and this is the economic side of fishing methods and gear development in general. When for instance harvesting fish stocks which cannot yield any more than they are yielding or very little more, the result to be expected will hardly be more fish but only reduction in production costs. This is only one example to show that economic considerations are also important for planning technical development.

200 tons of herring taken in one set with a two-boat purse seine off the west coast of Norway. Photo: FAO.

CLASSIFICATION OF FISHING GEAR

by

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Abstract

The author has divided fishing methods into thirteen categories beginning with fishing without gear. Each category is prefaced by a short description and is fully illustrated. The names of the several implements and methods are given in six languages.

Classification des engins de pêche

Résumé

L'auteur a divisé les méthodes de pêche en treize catégories, en commençant par la pêche sans engins. Chaque catégorie est précédée d'une courte description et abondamment illustrée. Les noms des divers instruments et méthodes sont donnés dans plusieurs langues.

Clasificación de los artes de pesca

Extracto

El autor ha dividido los métodos de pesca en trece categorias, empezando por la captura sin ningún equipo. Cada categoria empieza por una breve descripción acompañada de numerosas ilustraciones. Los nombres de los diversos artes y métodos de pesca se dan en varios idiomas.

THERE is at present no uniformity in the terms used to denote the fishing gear used in commercial fisheries in different countries and the name for the same gear may even change from one fishing area to another; furthermore, the name given to gear in one area may denote a different gear elsewhere. When translating the names of fishing gear from one language to another, these difficulties of nomenclature increase.

The aim of this paper is to present names which allow but one interpretation in different languages. But for some types of fishing gear, which are not generally known in other countries, new names have to be coined when translating into other languages.

I am indebted to Mr. A. R. Margetts, Lowestoft, for his helpful recommendations and for the collection of English names. The following scientists have also kindly given assistance:

Messrs. A. PERCIER and KURC, Paris, for French fishing gear names.
Mr. J. de VEEN, Den Haag, for Dutch fishing gear names.
Dr. B. RASMUSSEN, Bergen, for Norwegian names.
Dr. Aage J. C. JENSEN, Copenhagen, for Danish names.

In attempting to compile a classification of fishing gear and methods, founded on European methods, it was found necessary to establish 13 groups based on different principles of catching fish, and a short definition of each group is given. To prevent misunderstanding, some drawings illustrating fishing gear of different European countries are included.

Each group is divided into sub-groups, and varying aspects of fishing are taken into account for this division. It was not possible to prevent overlapping nor to separate the interconnections in every case. The principle of the fishing method and its historical development was first considered, while other subjects that seemed of importance were used for further classification. All gear classification will differ according to the different interests of the compilers, but it is to be hoped that this paper may form a basis for further discussions.

1. FISHING WITHOUT GEAR

This method belongs to the simplest forms of obtaining food and is practised on the European coasts during ebb-tide. Some of the tools used are knives to prise molluscs from rocks, picks and shovels to dig out shells, and hooks to pull crabs, cuttle-fish and other fish from their hiding places. Such tools should no more be called fishing gear than should be the little basket used in the French "pêche à pied", in which the fisherman carries home his harvest.

Fishing without gear is also carried out in freshwater, and in salt water when fishermen dive to catch fish by hand. There is also the method of using trained animals and birds, such as the cormorant, to catch fish.

2. WOUNDING GEAR

In his hunt for food, man has lengthened his arm by inventing such weapons as the lance, clamps, rakes and tongs. He has been able to extend his range again by the use of missiles thrown by hand or by equipment. Lances and harpoons and rifles are the wounding gears mostly used in Europe.

3. STUPEFYING METHODS

One method to prevent fish from escaping is to stupefy them. This can be done by concussion, for example, by hitting the ice under which a fish is lurking. The same effect can be obtained by an underwater explosion. Poisons can be used to paralyse fish, and suitable poisons can be made from both tropical and European plants. Electrical fishing is the most recent development in catching fish by stupefaction.

4. LINE FISHING

The principle used in line fishing is to offer the fish a real or artificial bait to entice it to bite. In principle, hooks are not essential; lines without hooks are well known, but as the fish tries to spit out the bait when it is lifted, gorges and hooks are added to prevent its escape although the former are no longer used. Various forms of hooks and gear are made for angling different kinds of fish.

Lines are fished in different ways. They can be anchored or left drifting, or they can be fixed in any position from the surface to the bottom. The line was originally a gear to catch single fish, but in the form of longlines it became a gear to catch large quantities of fish. Sometimes a fish becomes foul-hooked because the hook has caught in some part of its body. This has been developed as a catching method in the form of rip-hooks to catch certain kinds of fish. Rip-hooks are used either as single moving hooks or a close row of sharp hooks on a longline are placed across the path of the fish so that they hook themselves by their own movement. Gaffs are used to lift the fish out of the water and sometimes the gaffs themselves are used as gear to catch fish, thus they can be classed as big hooks or as a special form of fishing weapon (see "wounding gear").

5. FISH TRAPS

Barriers, corrals and true traps are known in hunting but in modern fisheries these traps have lost their importance, except, perhaps, the basket trap fykes, etc. Their catching principle is based on allowing the fish to enter the trap, using valve nets to prevent escape. Except for the entrance, small traps are completely closed like cages, only large traps are sometimes open above the water surface. Traps can be made of rigid material or network. Smaller fyke nets are held open by vertical hoops and braced horizontally by sticks or fixed between stakes driven in the sea-bed. In deep water or on hard ground, the traps are held in position by anchors.

6. TRAPS FOR JUMPING FISH

Some fish, when in danger or excited, jump out of the water, and they may act in the same way if they find themselves confronted by an obstacle. This is so typical of some species that a fishing method can be used to take advantage of such behaviour. Artificial obstacles, such as a fish-hedge or net wall, are built to make the fish jump. Sometimes the shadow of an object floating on the surface in the moonlight or sunshine is all that is needed. A horizontal floating net, a raft trap, or even a boat or box, can be used to catch the fish as they fall back.

7. BAGNETS WITH FIXED MOUTHS

A bagnet has a totally or partially framed mouth. The fixed form of bagnet is kept open by the force of the water flowing through it, the mobile type by being drawn through the water. The fish are actually filtered from the water.

Two groups of bagnets are known: the small scoop nets, of which there is a large variety, and the big gape nets. The gape nets are important in fishing in rivers and estuaries. They are fixed by stakes or anchors, or are used from anchored boats. The most developed bagnet is the otter board stow net, the mouth of which is kept open by otter boards.

8. DRAGGED GEAR

This group contains all nets and gear which are towed through the water, including dredges and all vertical nets, whether single or multi-walled, when dragged through the water. They are usually made of twine but sometimes of wire. The most important in this group is the trawl, the mouth of which is kept open either by a frame, a beam, floats, sinkers, otter boards or kites. Sometimes it is kept open by being towed by two vessels. Trawls are not always dragged along the sea-bed as there are also midwater or pelagic trawls.

9. SEINE NETS

In seining, one end of the net is shot from a fixed point, a certain area is surrounded and the other end of gear returned to the starting point, after which the gear is then hauled. The starting point can be on the shore of a lake or pond, the banks of a river or on the sea beach. In certain circumstances a boat can be used. The net has a pocket or bag in the middle to collect the fish. The seine is mostly worked on the sea-bed but it is also used in pelagic fisheries.

10. SURROUNDING NET

The task of surrounding nets is to encircle a detected fish school, which is sometimes scooped out with dip nets. The simplest example of this method is to close a creek with a barrier. Some forms of surrounding nets can be shot out in a spiral form, catching the fish as in a labyrinth. The best known forms of surrounding nets are the ring-nets and the purse seines. If the water is not too deep, the ring net sinks from the surface to the bottom. The most important use of this method is purse seining in the deep sea. In this case the lower end of the purse seine is closed and the encircled fish are unable to escape. Then the net is partially lifted and the fish are corralled and caught.

11. DIP OR LIFT NETS

This method is to submerge a hanging net, then pull it rapidly out of the water so as to capture any fish or crustaceans which happen to be over it. The smaller nets of this type are hand operated, but the bigger ones need a mechanism on land or on a boat. The netting is supported on a round or rectangular frame. The especially big sized lift nets used in the Norwegian sea fishery are held at the four corners by boats.

The same idea is used in the French water-wheels to pull the fish out of the water.

12. FALLING NETS

This method is to cover the fish with a cover pot or a cone-shaped net with a stiff opening. Cast nets, skilfully thrown out on the water surface, enclose the fish as they sink, and the fish are trapped in special pockets at the lower end of the net. Besides these hand-thrown nets, there are also much bigger cast nets that need gallows and boats.

13. GILLNETS AND TANGLE NETS

There are two main types: single wall nets and multi-walled or trammel nets. They are operated either as drift nets or anchored to the bottom. These nets are fished close to the bottom, in midwater or at the surface.

1.31 Fishing with cormorants in China.

	GERMAN	ENGLISH	FRENCH	DUTCH	NORWEGIAN	DANISH
1.	*Fischfang ohne Gerät*	*Fishing without gear*	*Pêche sans instrument*	*Visserij zonder vistuig*	*Fiske uten redskap*	*Fiskeri uden redskaber*
1.1	Handfang	by hand	A la main	Vangen met de hand	tumming	Fangst med hænderne
1.2	Taucher	diver	Par plongeur	Duiker	dykker	Dykker
1.3	Tiere	hunting animals	Animaux pêcheurs	Dieren	jaktdyr	Dyr
1.31	Kormorane	cormorant	Cormoran	Aalscholvers	skarv	Kormoran
1.32	Saugfische	sucker-fish	Remora	Zuigvissen	sugefisk	Sugefisk
1.33	Fischotter	otters	Loutre	Vistoters	fiskeoter	Fiskeodder
1.34	Hunde	dogs	Chien	Honden	hund	Hund
	GERMAN	ENGLISH	FRENCH	DUTCH	NORWEGIAN	DANISH
2.	*Verwundende Geräte*	*Wounding gear*	*Pêche par blessure*	*Verwondend vistuig*	*Redskap som sårer*	*Sårende Redskaber*
2.1	Stangengeräte	(hand instruments)	Instruments à manches	Handvistuig	stange (stöte-) redskaper	Redskaber til stangning
2.11	Speere ohne Widerhaken	lances	Lance sans barbelure	Speren zonder weerhaken	spyd uten mothaker	Spyd uden modhager
2.12	Speere mit Widerhaken	spears	Lance barbelée	Speren met weerhaken	spyd med mothaker	Spyd med modhager
2.13	Klemmen	clamps	Foene, trident	Klemmen	klyper	Klemme-redskabe
2.14	Harken	rakes	Rateau	Harken	raker	Harke
2.15	Zangen	tongs	Pinces à filet	Tangen	tenger	Fang-redskaber
2.2	Pfeile	bow and arrow	Arc	Pijlen	piler	Pil
2.3	Harpunen	harpoons	Harpon	Harpoenen	harpuner	Harpun
2.31	Handharpune	hand-harpoons	Harpon à main	Handharpoenen	håndharpun	Håndharpun
2.32	Gewehrharpune	rifle-harpoons	Harpon lancé au fusil	Geweerharpoenen	gjeværharpun	Harpungevær
2.33	Kanonenharpune	gun-harpoons	Harpon lancé au canon	Kanonharpoenen	kanonharpun	Harpunkanon
2.4	Gewehre	rifles	Fusil	Geweren	gjevær	Riffel
2.5	Blasrohre	blow-pipes	Sarbacane	Blaasroeren	blåserör	Blæserør med pil

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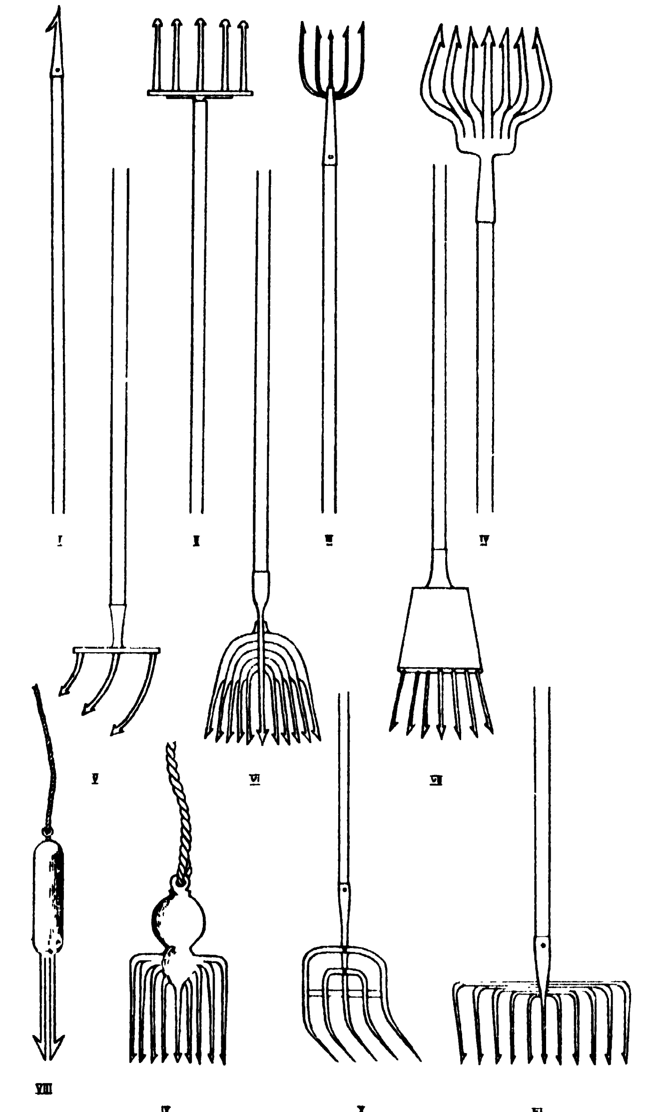

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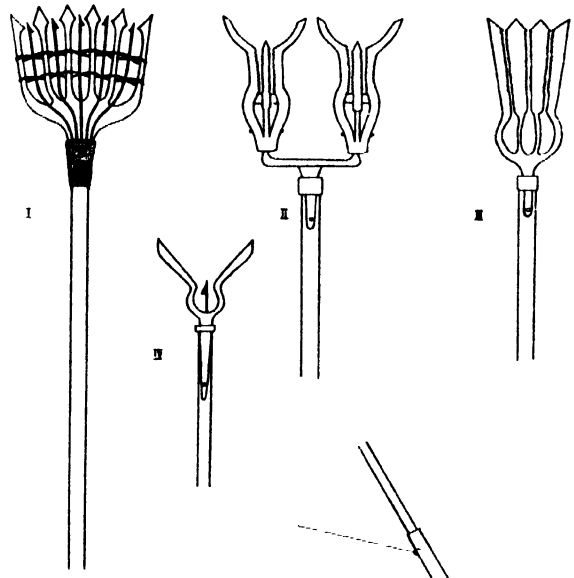

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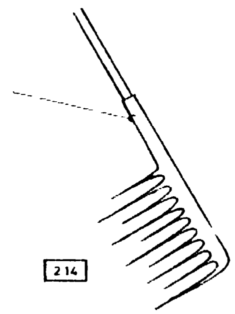

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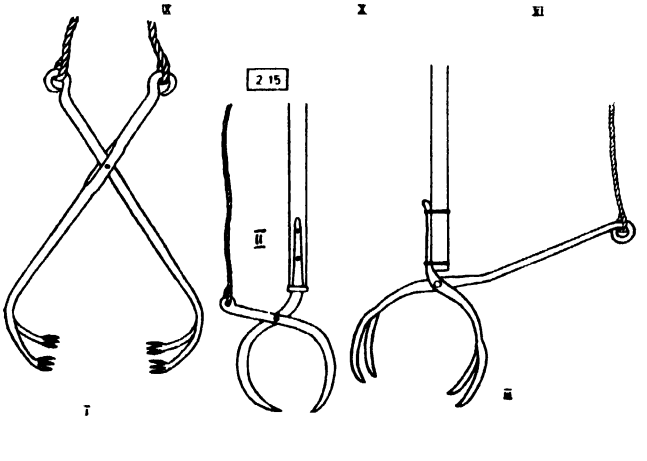

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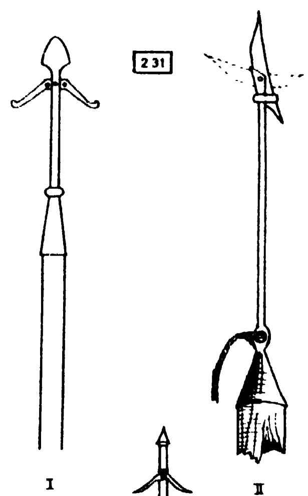

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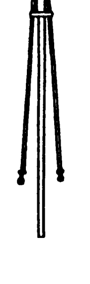

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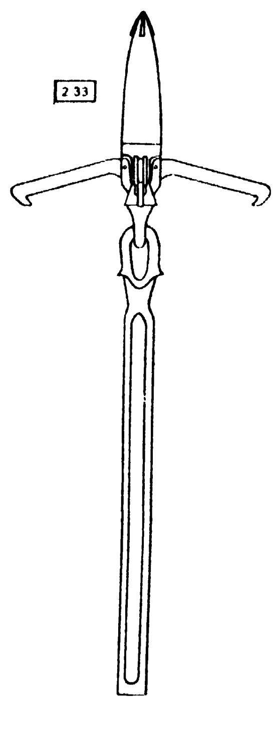
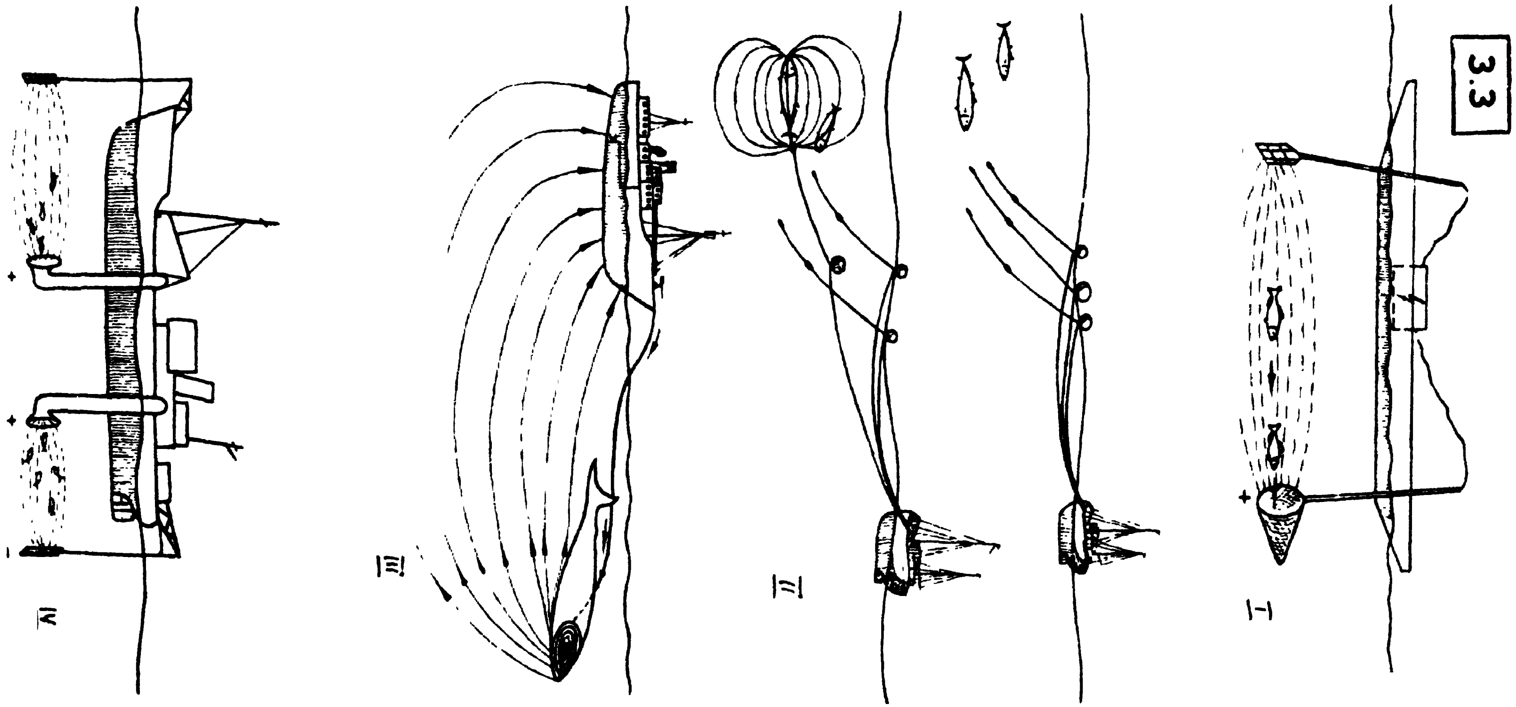
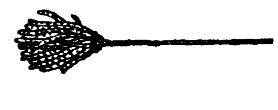




GERI	ENGLISH	FRENCH	DUTCH	NORWEGIAN	DANISH
Betäubende Metho	*Stupefying method:*	*Aéthodes de Pêche par ommotion et intoxication*	*Methoden waarbij ι bedwelmd wordt*	*Bedövende metoder*	*Bedøvende metoder*
Schlaggeräte	striking gears	Instrumentes contondan'	Slagvistuig	slagredskaper	Slagredskaber
Keulen	clubs	Gourdin	Knuppels	kölle	Kølle
Wurfhölzer	thrown missilι	Projectiles	Werphouten	kastetre	Kastetræ
Giftfischerei	poisons	Pêche par poisons intoxication	Giftvisserij	bruk av gift	Gift-fiskeri
Elektrofischerei	electrical fishiι	Pêche électrique	Electrische vissei	elektrisk fiske	Elektrofiskeri
Explosivstoffe	explosives	Explosifs	Explosieve stoffe	bruk av sprengstoff	Fiskeri med spræugstol
Fischschiessen	fish-shooting	Tir, déflagration	Visschieten	skyting	Skydning
Handgranaten	hand grenade	Grenade à main	Handgranate	håndgranater	Håndgranat
Dynamit	dynamite	Dynamite	Dynamiet	dynamitt	Dynamit

	German	English	French	Dutch	Norwegian	Danish
4.	*Angelfischerei*	*Fishing with line*	*Pêche a la ligne*	*Visserij met haken en beuglijnen*	*Fiske med snöre og line*	*Fiskeri med krog, snøre eller line*
4.1	ohne Haken	without hooks	Sans hameçon	Zonder haken	uten angel	uden krog
4.2	mit Haken	with hooks	A l'hameçon	Met haken	med angel	med krog
4.21	Knebel	gorge	Aiguille, hameçon droit	Knevelhaken	tverrtre	Tværpind
4.22	Bogenhaken	curved hooks	Hameçon courbe	Ronde haken	buet angel	Buet krog
4.221	bewachte	watched	au coup	Bewaakte	påpasset	under stadigt tilsyn
4.2211	Handangel	hand-angling	Ligne à main	Hengel	snörefiske	Håndsnøre, håndline
4.22111	Leinen	handline	Ligne	Lijnen	handsnöre, juksa	Håndline med agn
4.22112	Ruten	rod	Canne	Roeden	stang	Håndsnøre
4.22113	Schleppangel	troll line	Ligne trainante	Trapen	dorg	Slæbeline, Dørg
4.222	unbewachte	unwatched	Dormante	Onbewaakte	uten tilsyn	uden tilsyn
4.2221	Treibangel	floated line, drift longline	Ligne flottante	Drijflijn	flöytline	Flydekroge uden forankring
4.2222	verankert	anchored	Ancrée	Verankerd	forankret line	Forankrede kroge
4.22221	Stellangel	standing line	Ligne dormante	Stellijnen	snikline	Forankrede flydekroge
4.22222	Reihenangel	longline, set longline	Palangre, corde	Beuglijnen	line, bakke	Langliner, Bakker
4.3	Reissangeln	rip hooks	Turlutte à la faux	Rukhaken	krökeredskaper	Pilk
4.4	Gaffs	gaffs	Croc	Knoeken	klepper	Hugkrog



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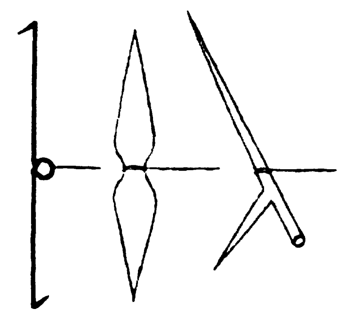

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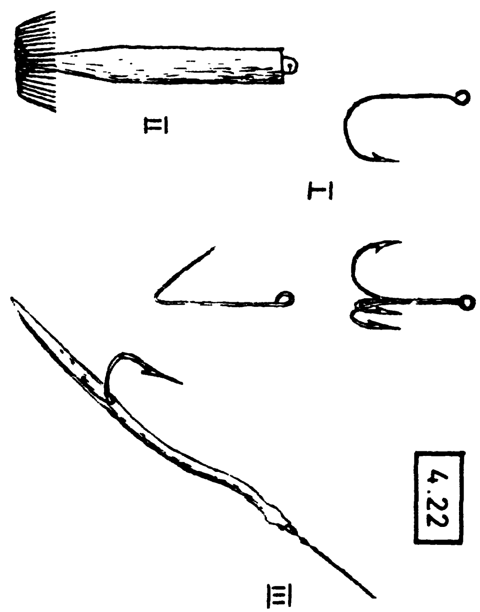

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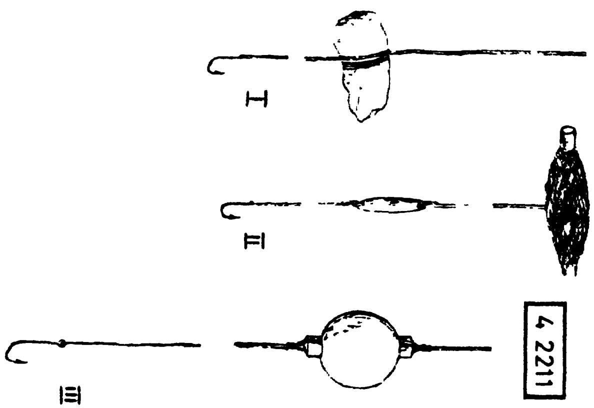

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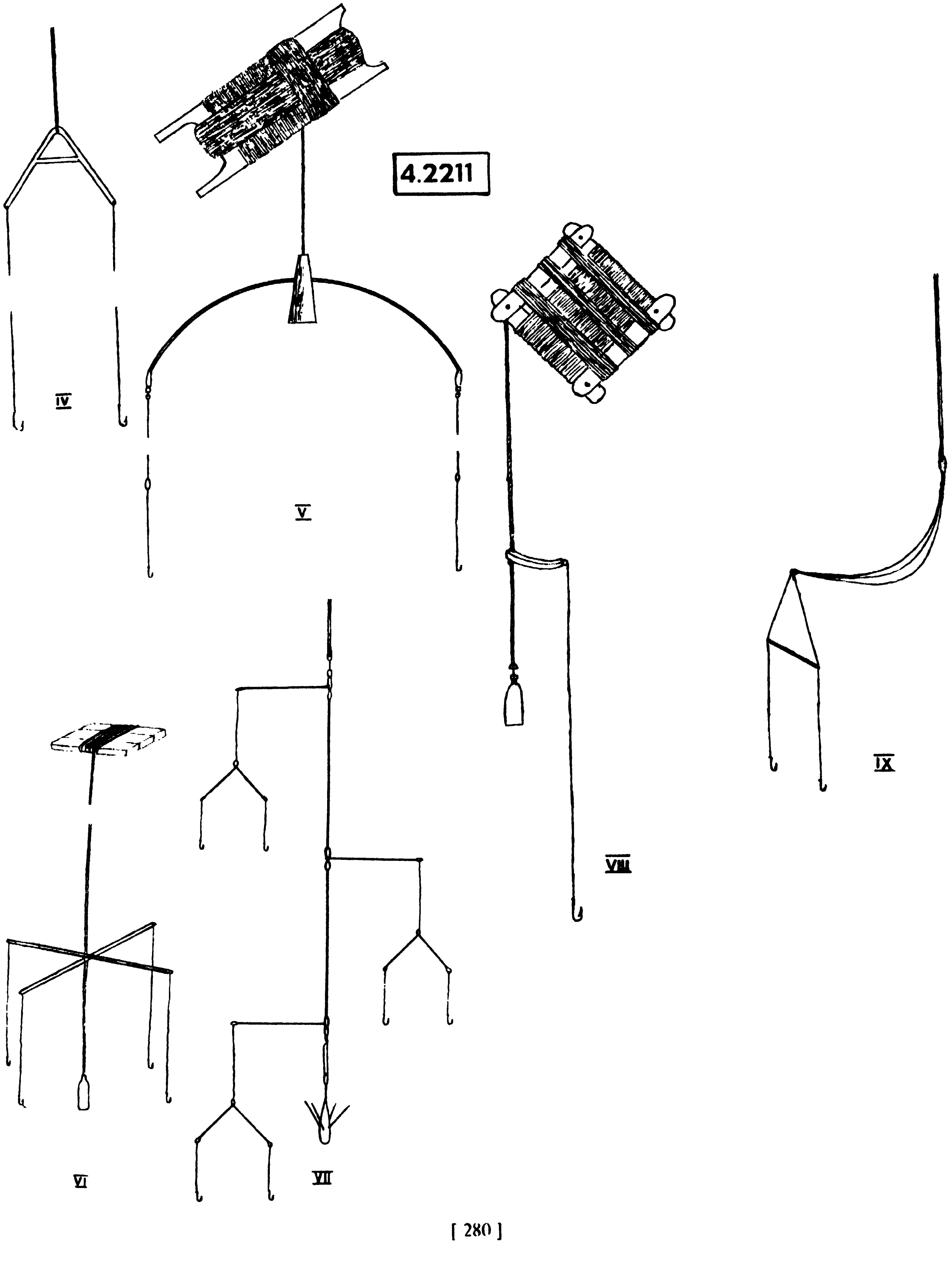
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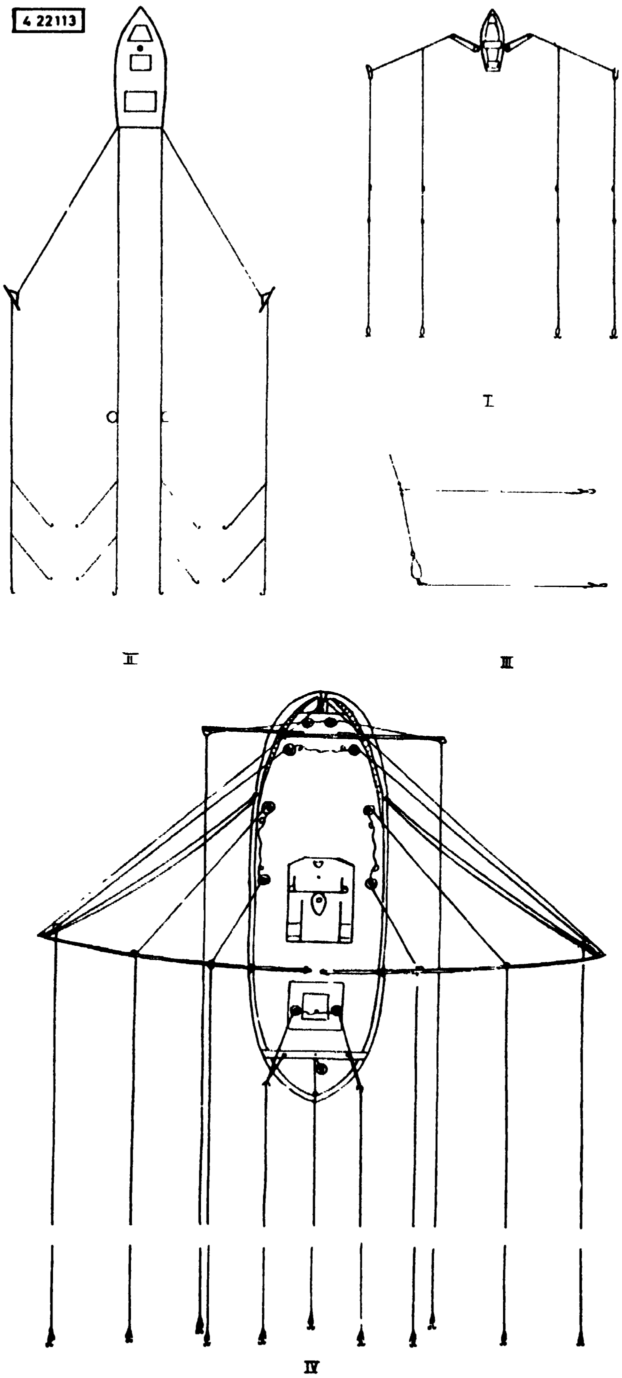
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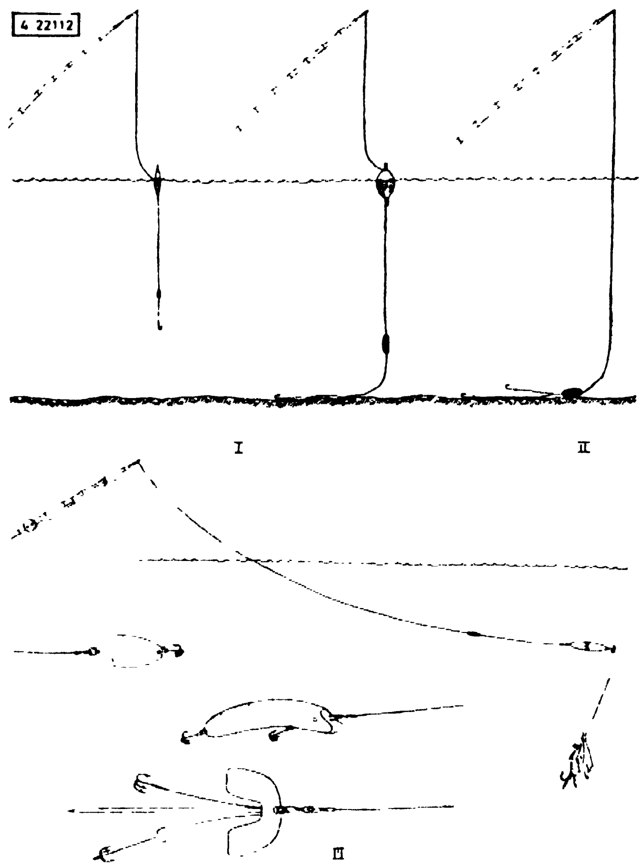
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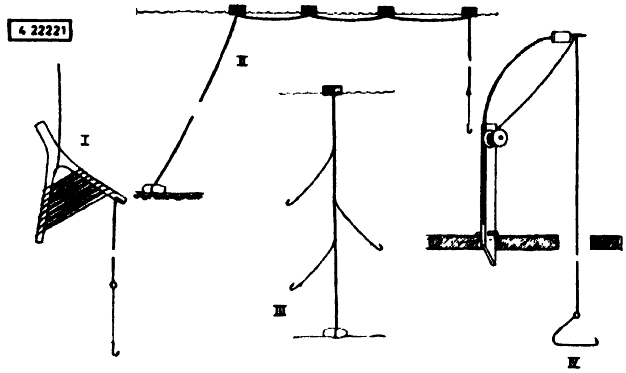
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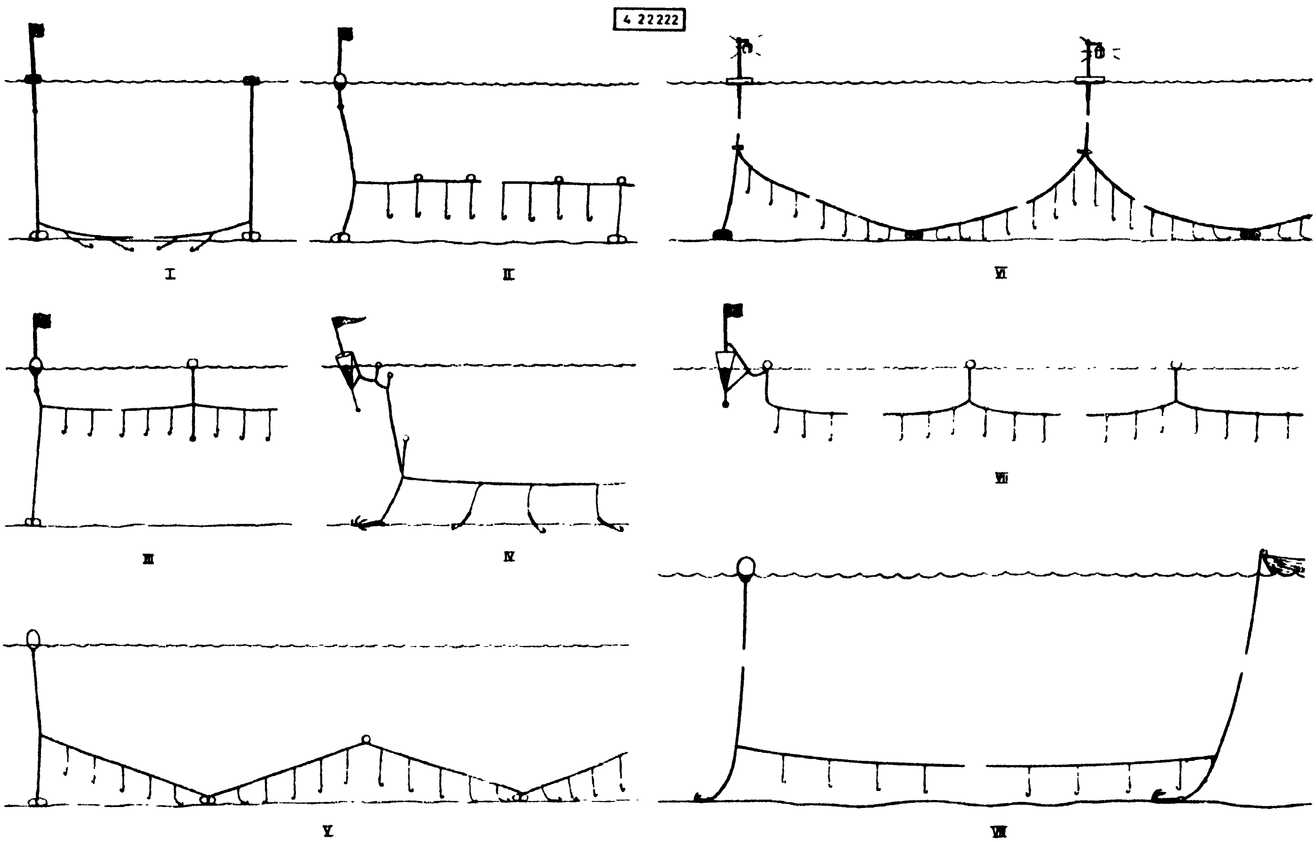
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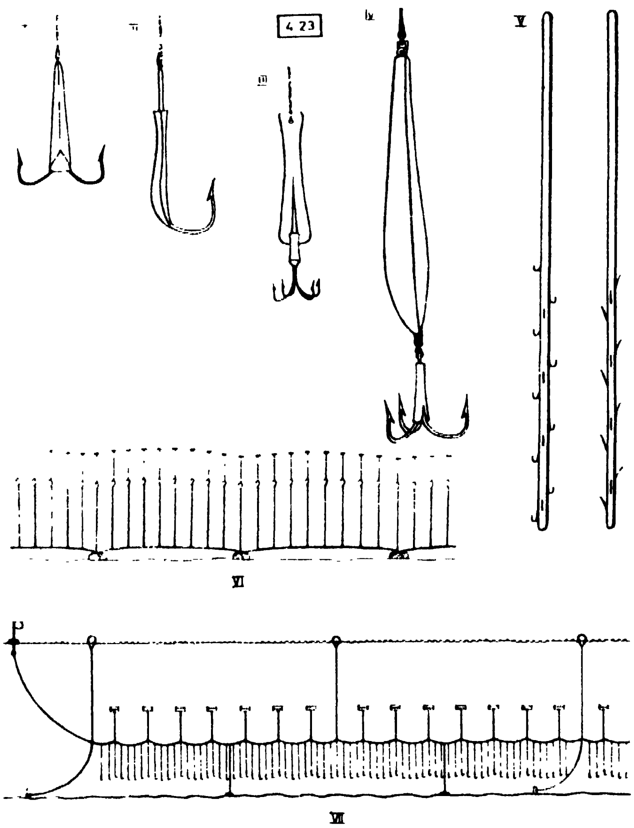
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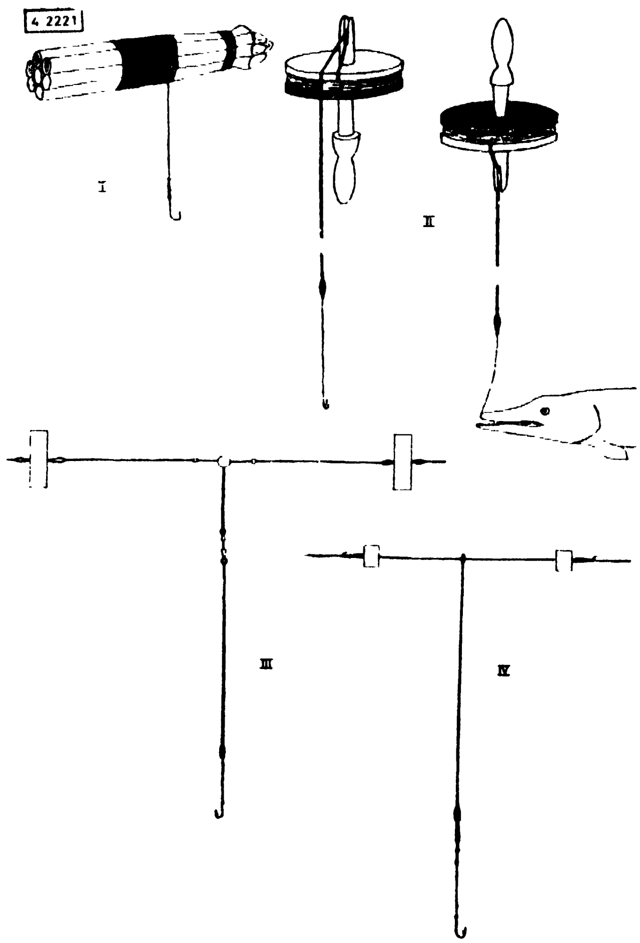
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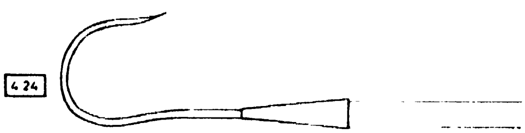
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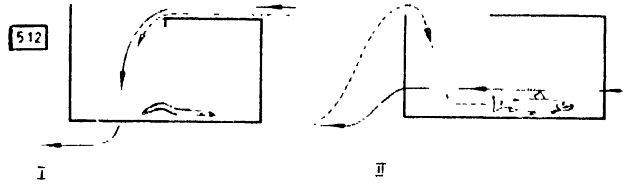
	German	English	French	Dutch	Norwegian	Danish
5.	*Fischfallen*	*Fish traps*	*Pièges à poisson*	*Visvallen*	*Fiskefeller*	*Fiskefælder*
5.1	Fangbauten	barriers	Barrages	Barrieren, Vangstkeerschutten	sperringer	Spærringer
5.11	Fischzäune	fish-hedges	Claies	Schutwand	fiskekjerr, stöd	Fiskegårde
5.12	Selbstfänge	box traps	Pêcheries fixes	Kamers	fangkasser	Fangstkasser
5.2	Labyrinthbauten	fish corral, fish weir	Bordigues	Doolhoven, weren	bunngarn	Labyrint-redskaber
5.3	Fallen im eigentlichen Sinn	true traps	Pièges proprement dits	Echte vallen	egentlige feller	Egentlige Fælder
5.31	Schwerkraftfallen	gravity traps	Trappe à contrepoids	Zwaartekracht vallen	loddfeller	Fælder, der lukker med fjeder eller tyngdekraft
5.32	Schlingen	snares	Collets, noeuds coulants	Lussen	snarer	Snarer
5.321	Drahtschlingen	wire-snares	Collet en fil métallique	Draadlussen	av ståltråd	af ståltråd
5.322	Tauschlingen	rope-snares	Collet en corde	Touwlussen	av tau	af Snører
5.323	Stockschlingen	stock-snares	Collet sur perche	Stoklussen	av kjepper	af Træ
5.33	Schwippgalgenfallen	whippy bough trap	Piège á tension	Zwiepgalgvallen	vippegrenfeller	Vippegalge-fælder
5.34	Torsionsfallen	torsion shutter trap	Piège á torsion		torsjonsfeller	
5.4	Reusen	baskets	Casiers	Fuiken en Kubben	Teiner og ruser	Ruser, bundgarn etc.
5.41	Bodenreusen	ground baskets	Casiers de fond	Grondkubben	kasseteiner	Bundsatte ruser
5.411	Korbreusen	fish pots	Nasses	Kubben van tenen	kurvteiner	Kurve
5.412	Drahtreusen	wire baskets	Casiers métallique	Kreeftenkorfjes, IJzeren	teiner av ståltråd-netting	Ståltrådsruser, tejner
5.413	Garnreusen	fyke net	Verveux	Fuiken	ruser	Garnruser, ruser
5.4131	Spannsäcke	braced bag	Verveux rigide	Spanzakken	böyleruser	Ålekube eller ålemine
5.4132	Bügelreusen	fyke net with rings	Casiers en filet	Hangers,Glooiing fuikjes	tonnebåndruser	små Bøjleruser
5.414	Käfigreusen	creels	Hotte à poisson	Kooifuiken	Stånnde teiner	Garntejner
5.415	Grossreusen	trap net, pound traps	Pêcheries fixes	Grote fuiken, zeefuiken	stor-ruser	Store ruser
5.4151	Bügelreusen	trap nets with rings	Verveux à aile	Beugelfuiken	böyleruser	Bøyljeruser
5.4152	Kastenreusen	box nets	Parcs à poisson	Kastfuiken	kasseruser	Kasseformede ruseredskaber bundgarn etc.
5.41521	Pfahlreusen	stake nets	Hauts-parcs et bas-parcs	Paalfuiken, bothargen	peleruser	Fæstet til pæle
5.41522	Ankerreusen	fixed nets	Madrague	Verankerde fuiken	forankrete ruser	Forankrede
5.42	Schwimmreusen	buoyed trap	Parcs flottante	Drijffuiken	flöy truser	Flydende ruseredskaber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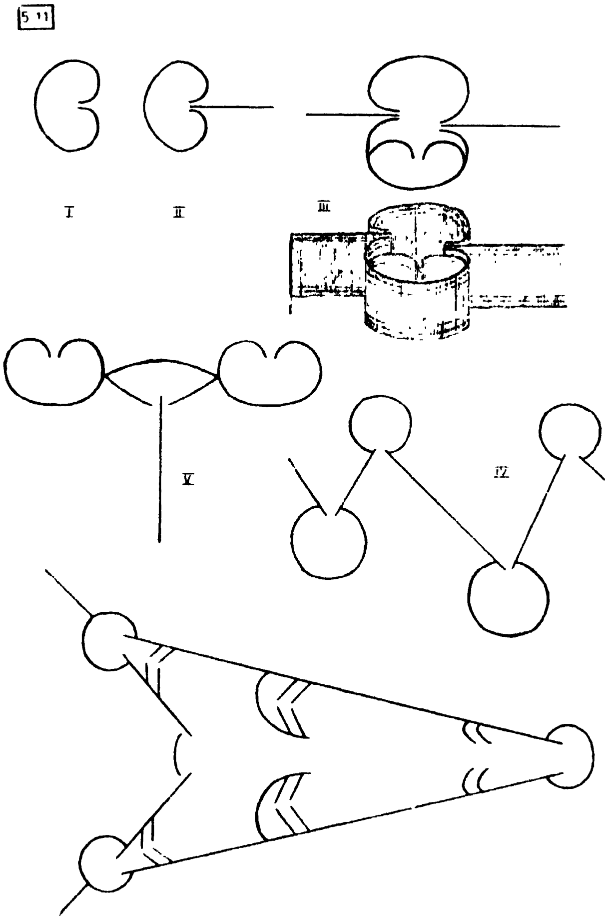
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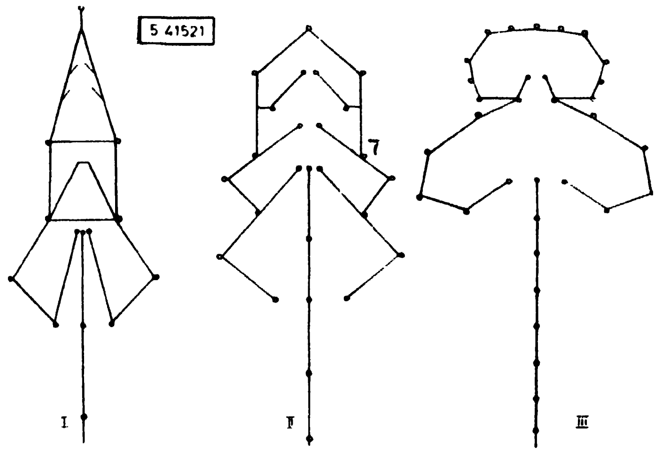
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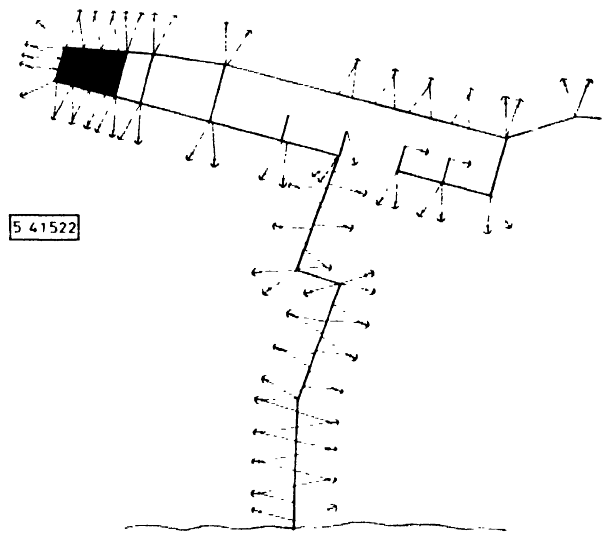
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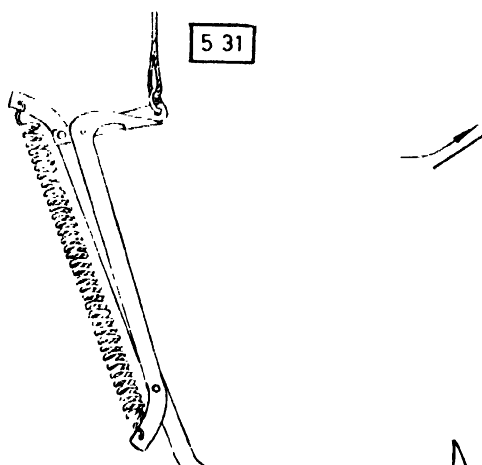
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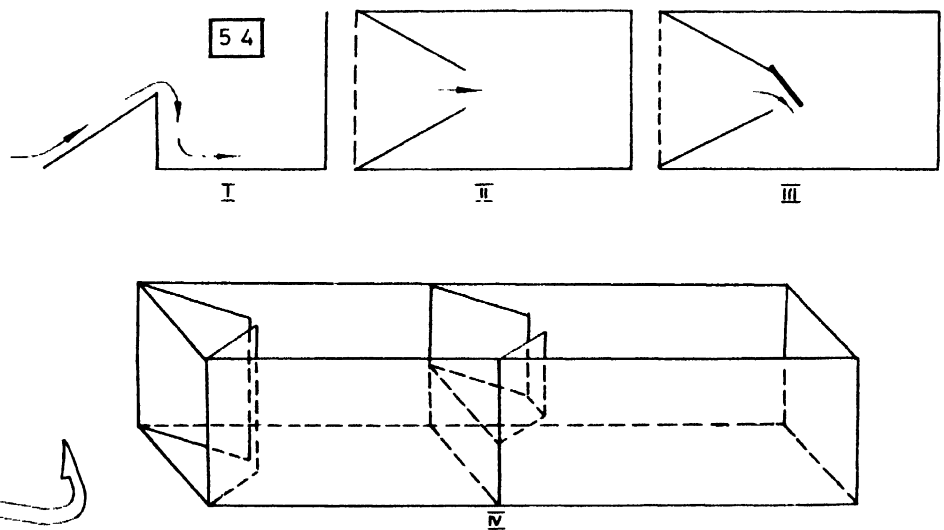
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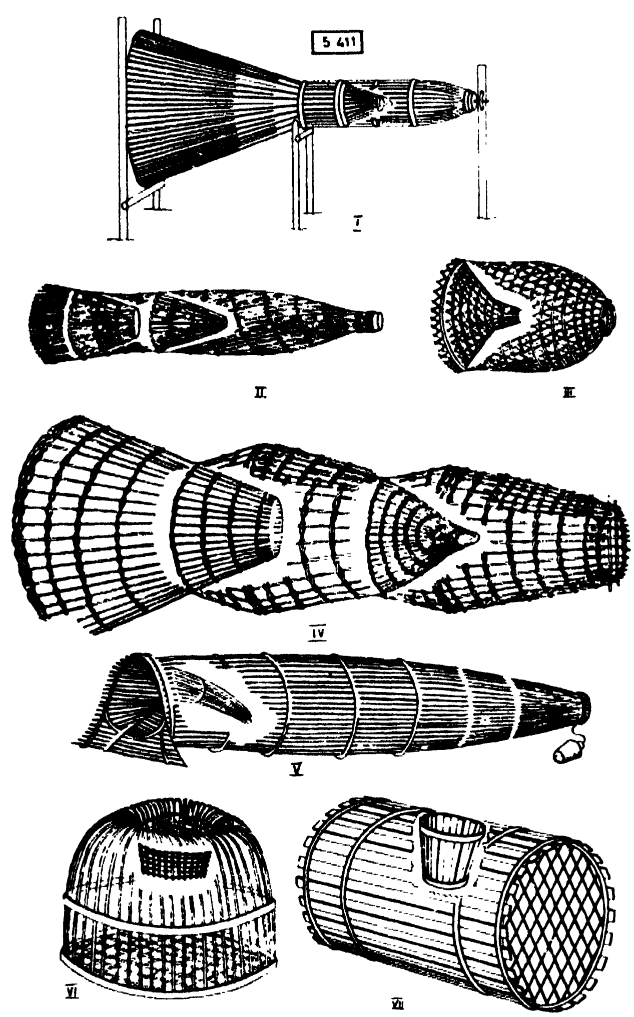
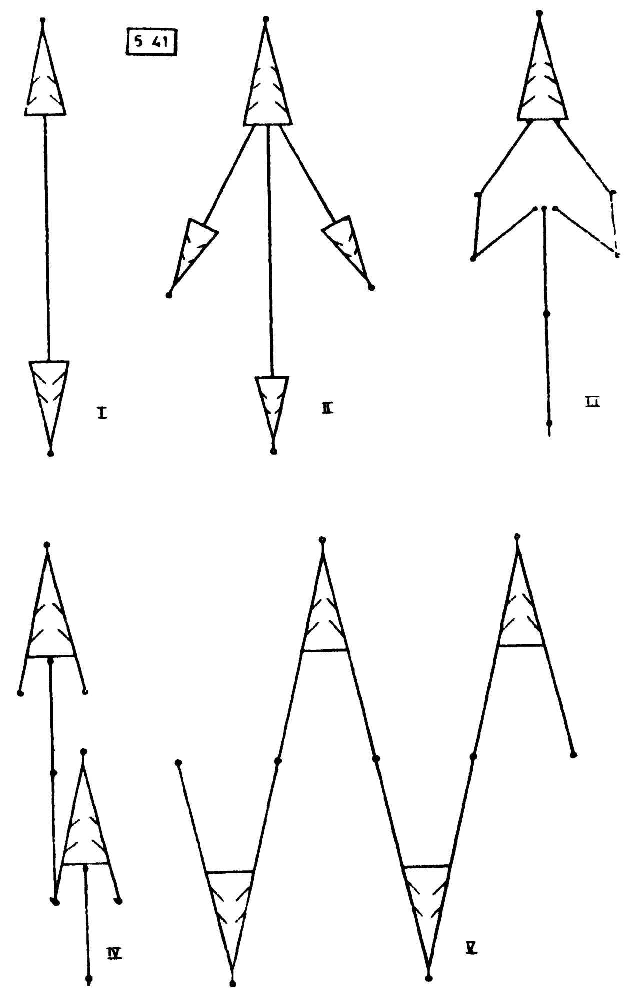
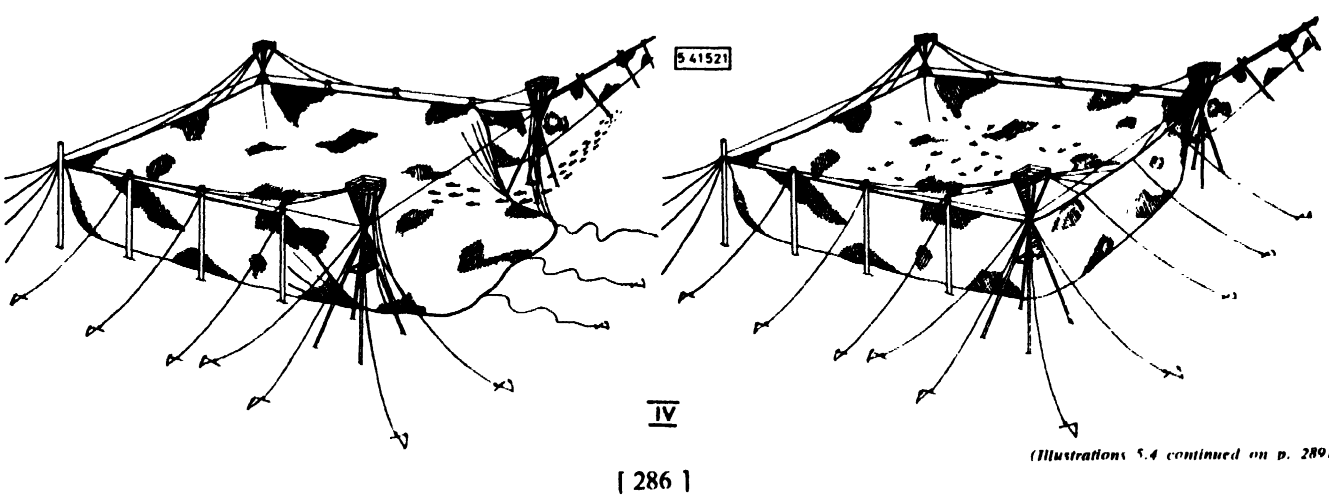
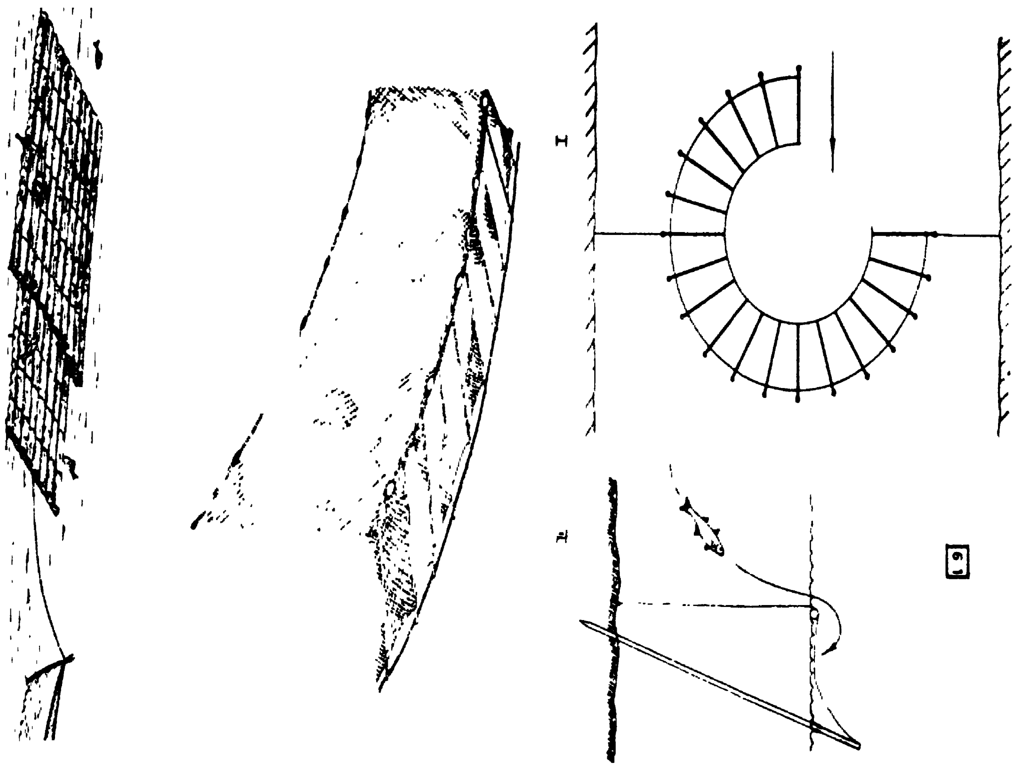




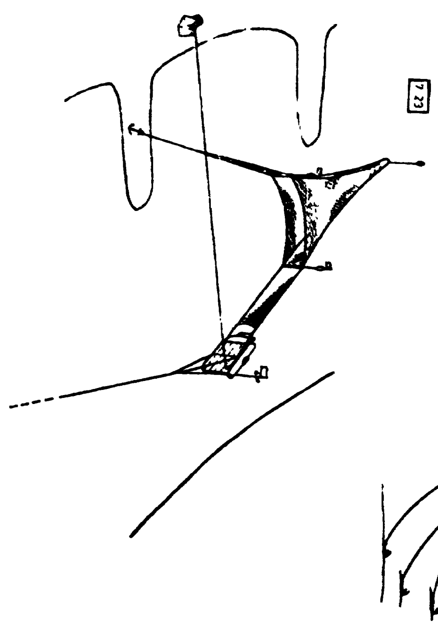


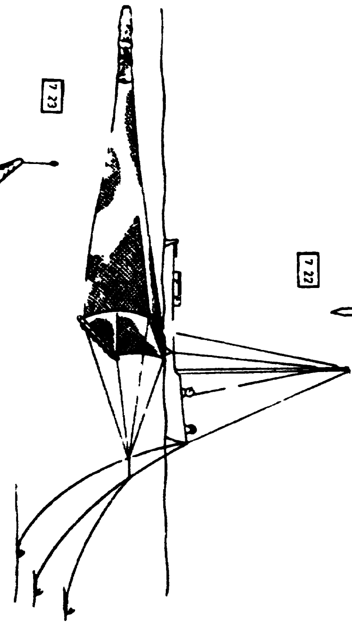
IV

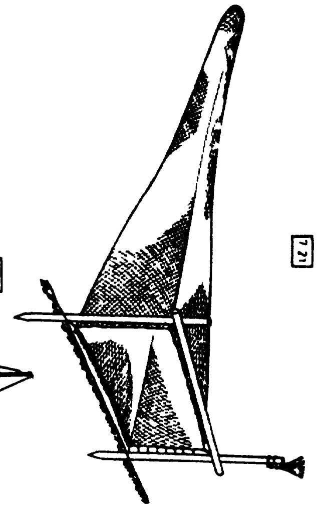
(Illustrations 5.4 continued on p. 289)

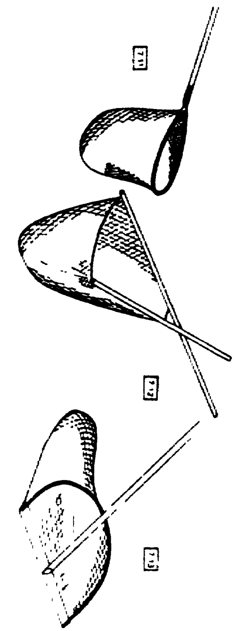


	GERMAN	ENGLISH	FRENCH	DUTCH	ORWEGIAN	DANISH
	Sprungfischfischerei	*Aerial traps, jumpi traps*	*Installations pour capturer le poisson sautant hors de l'eau*	*Visserij op springende vis*	*· hoppende fi:*	*Redskaber til fangst af springende fisk*
6.1	Verandanetze	verandah net	Sautade	Veranda netten	verandane	Veranda-net
6.2	Mattenfischere	raft trap	Pêche à la natte—canna	Visserij met matten	flåtefeller	Flåde-flæder
6.3	Bootsfallen	boat trap	Capture au saut dans le bateau	Bootsvallen	båtfeller	Bådformede fælder
6.4	Fangkästen	box traps	Caisse (ou vivier) de capture	Kasners	fangkasser	Fangstkasser



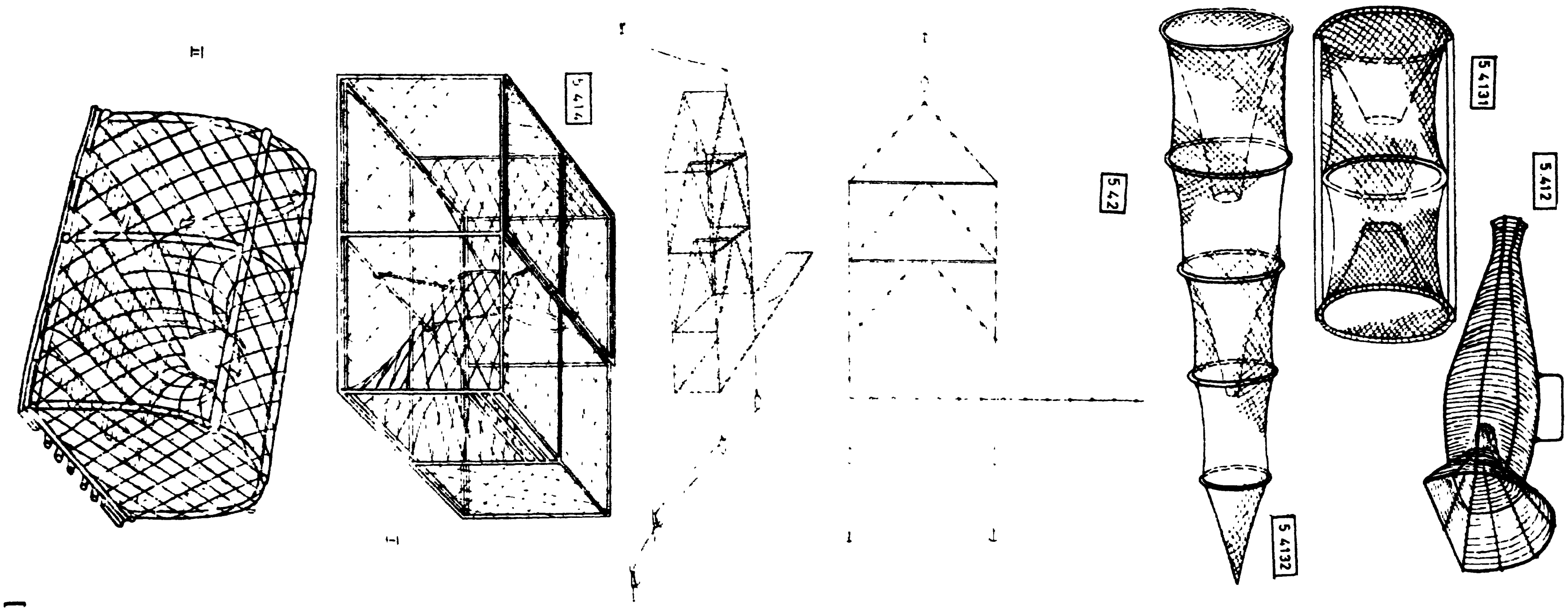






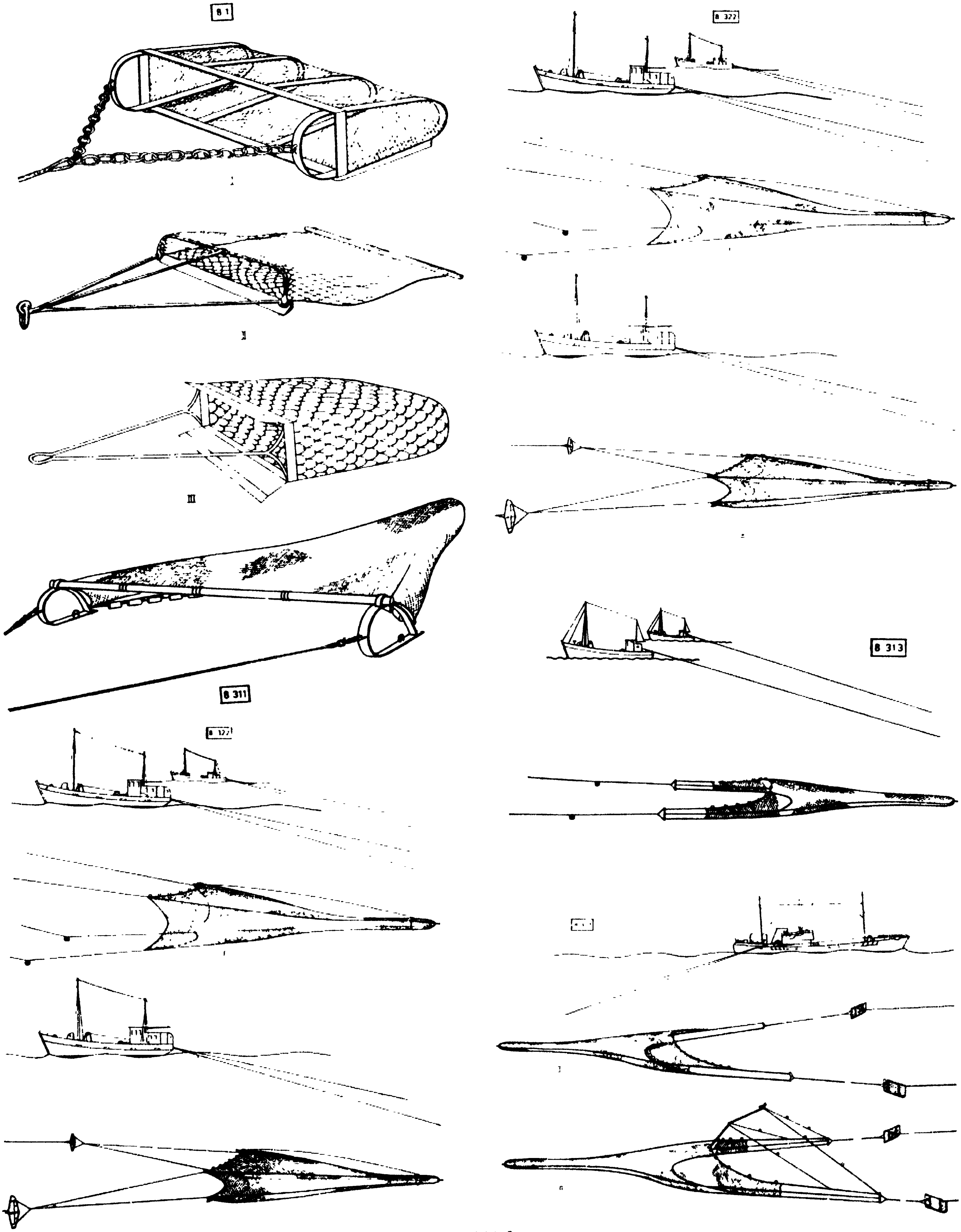
	German	English	French	Dutch	Norwegian	Danish
7.	*Hamen*	*Bag nets with fixed mouth*	*Filets à armature*	*Kuilen*	*Håver*	*Hamen, Ketsjere*
7.1 . .	Kleinhamen	scoop, dip net	Haveneaux	Kuiltjes	småhåver	Ketsjere
7.11 . .	Bügelhamen	landing net	Epuisette	Beugelkuilen	skafthåver	Bøjle-ketsjere
7.12 . .	Scherenhamen	skimming net	Bout de quièvre ou grand haveneau	Scheersaaiings-korren	saksehåver	Sakse-ketsjere
7.13 . .	Schiebehamen	push net	Trouble, haveneau	Schuifhamen	skyvehåver	Glib
7.14 . .	Schlepphamen	dragged bag nets with fixed mouth	Haveneau remorqué	Sleepsaaiings-korren	slepehåver	Slæbe-ketsjere
7.2 . .	Grosshamen	gape nets	Diables	Grote kuilen.	storhåver	Hamen
7.21 . .	Pfahlhamen	swing nets (stow nets) on stakes	Diable	Staande kuilen	fortöyde håver	Fortøjet til pæle
7.22 . .	Ankerhamen	swing nets (stow nets) on anchors	Chalut á l'étalage	Ankerkuilen	forankrete håver	Forankrede
7.23 . .	Scherbretthamen	otter-board stow net	Diable á un panneau divergent	Bordenkuilen	flöythåv med oterbord	med Skovle

CLASSIFICATION OF FISHING GEAR



	German	English	French	Dutch	Norwegian	Danish
8.	*Schleppgeräte*	*Dragged gear*	*Arts trainants*	*leepvistuig*	*Sleperedkaper*	*Netredskaber, der slæbes*
8.1	Dredgen	dredge	Dragues	Dreggen	skraper	Skrabere
8.2	geschleppte Netzwände	sweep nets	Dreige ou drège	Sleepnetten	sleping av åpen not	Slæbte not redskaber
8.21	einwandig	single walled	A une seule nappe	eenwandig	med en notvegg	med 1 væg
8.22	dreiwandig	triple walled	A trois nappes	driewandig	med tre notvegger	med 3 vægge
8.3	geschleppte Netzsäcke	trawl	Chaluts	Gesleepte kuilen-korren	slept notpose	Slæbte, poseformede redskaber
8.31	Grundschleppnetze	bottom trawl	Chalut de fonds	Bodemtrawl	bunnslepenot, trål	Bundtrawl og bund-vod
8.311	Baumkurre	beam trawl	Chalut à perche	Boomkor	bomtrål	Bomtrawl
8.312	Scherbrettnetz	otter trawl	Chalut à panneaux	Ottertrawl	otertrål	Skovlrod og trawl slæbt fra et fartoj
8.313	Gespann-Netz	pareja	Chalut boeuf, gangui	Wonderkuil, haringkuil	partrål	Dobbeltspand eller parfiskeri
8.32	pelagische Schleppnetze	floating trawl	Chalut pélagique	Pelagische trawl	flytetråler	Pelagisketrawlredskaber
8.321	an der Oberfläche	surface floating trawl	Chalut de surface	aan de oppervlakte	overflatetråler	ved overfladen
8.322	in beliebiger Tiefe	mid-water floating trawl	Chalut à évolution variable	op willekeurige diepte	midtvannstråler	i vilkårlig dybde egentlig flydretrawl

(See illustrations next page)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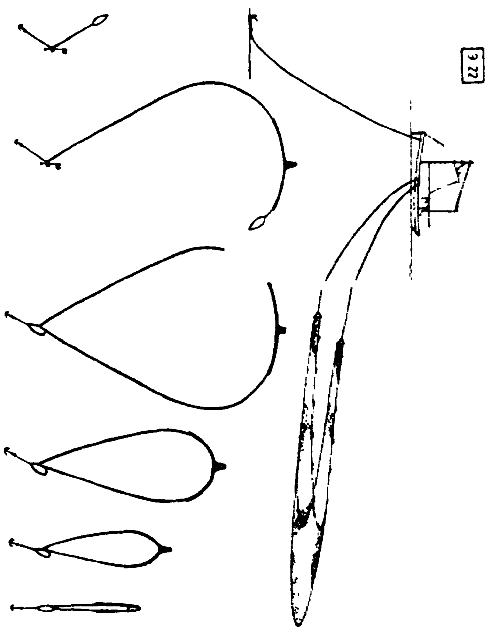
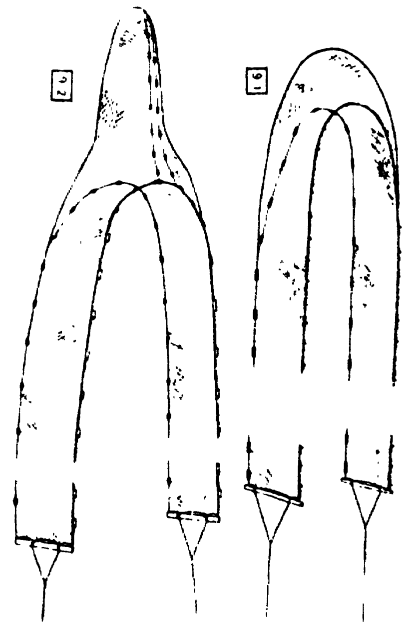
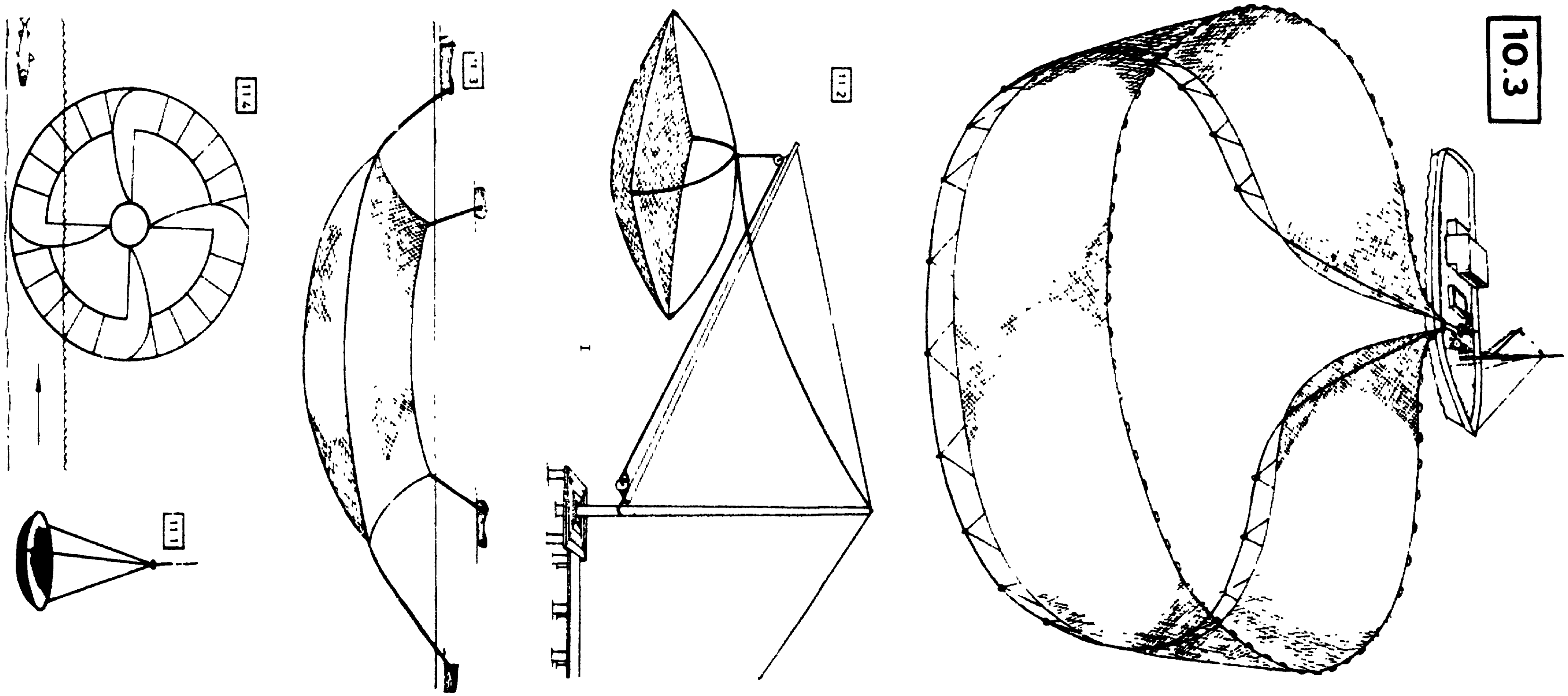
	German	English	French	Dutch	Norwegian	Danish
9.	*Zugnetze*	*Seine*	*Sennes*	*Zegens*	*Vad. dragnöter*	*Vodredskaber*
9.1 . .	sacklose Zugnetze	without bag	Senne sans poche	Zegens zonder zak	uten fiskepose	Vod uden pose
9.2 . .	Zugsäcke	with bag	Senne avec poche (eissauge)	Zakzegens	med fiskepose	Vod med pose
9.21 . .	Strandwaden	beach seine	Senne halée à terre	Strandzegens	strandnot, landnot	Landvod
9.22 . .	Bootswaden	boat seine	Senne halée à bord	Bootzegens, galzegens	vad	Vod, brugt fra fartoj



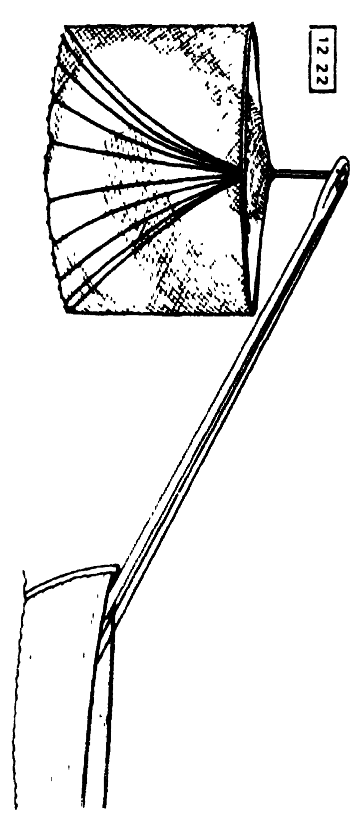


	GERMAN	ENGLISH	FRENCH	DUTCH	NORWEGIAN	DANISH
	'mschliessungsne	*Su· 'ounding nets, e· nets*	*Filets tourn· ·*	*Omsluitingsnet·*	*nnesperringsnöter*	*ndespærringsnoter*
0.1	Sperrnetze	barrier nets	Filets tournants non coulissant (cerco)	Schutwand	sperrenöter	Spærrenot
0.2	Spiralnetze	spiral nets	Filets spirales (thonaire)	Haringhorten	slyegarn, jagegarn	Noter, sat i spiral
0.3	Ringwaden	ring nets, purse	Filets coulissants	Ringzegens	snurpenöter	Ringnot, snurpeno



	GERMA·	ENGLISH	FRENCH	DUTCH	NORWEGIAN	DANISH
	Senk- oder Heb	*Dip nets, lift nets*	*'arrelets, échiquiers*	*'ink- of optilnetten*	*·nke- og lof'enöter*	*Synke- eller løftenet*
1	Handsenknet	hand lift nets	Balance	Totebellen	gliper	Håndløftenet, (hummerkranie
2	Standsenknet	stationed lift net	Carrelet sédentaire	Slaande zinknetten	verp	Faststående dyppene
3	Senktücher	boat lift nets	Carrelet sur bateau	Zinknetten	synkenoter	Synkenot
·	Wasserräder	water-wheels	Tourniquet	Waterraderen	vannhjul	Vandhjut

12 22



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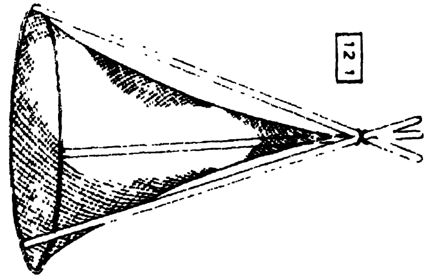
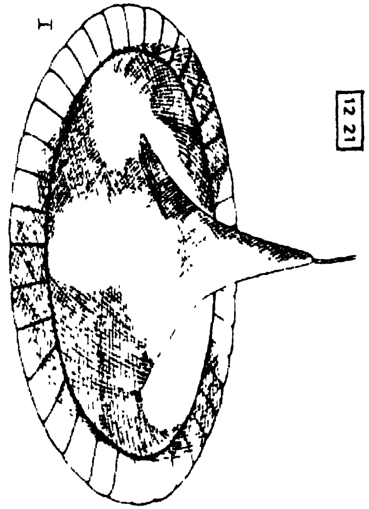


12 21



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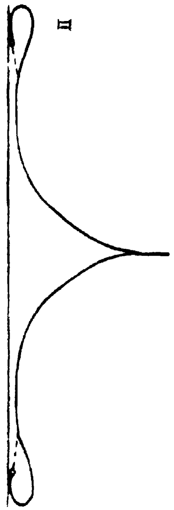

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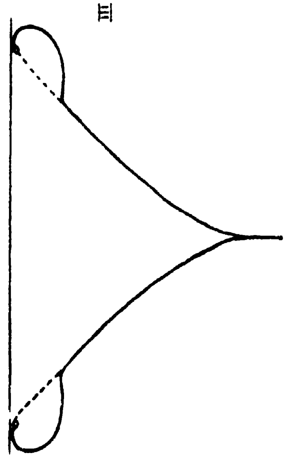

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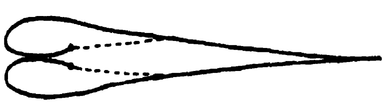
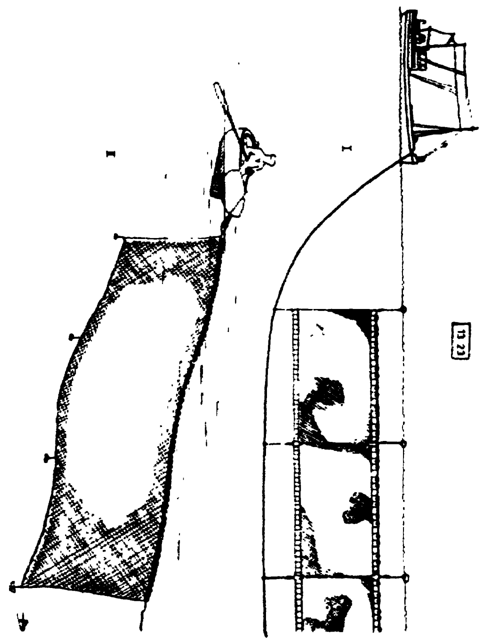
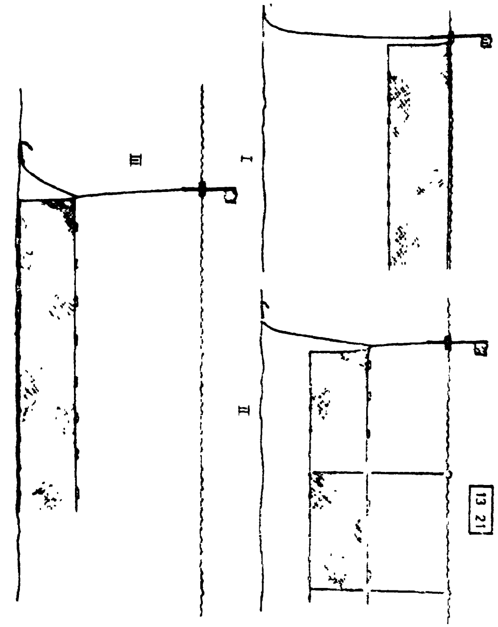
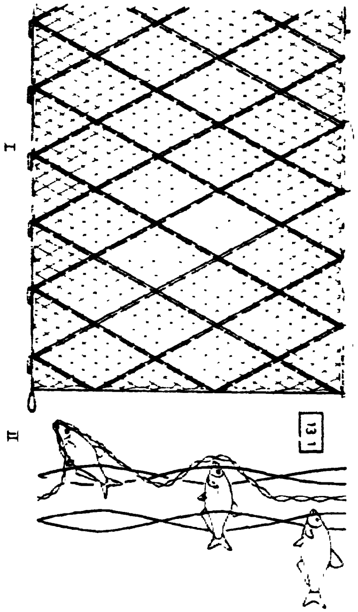


IV

	GERMAN	ENGLISH	FRENCH	DUI	NORWEGIAN	DANISH
2.	*Greifnetze*	*Falling nets*	*Filets lancés*	*Vallende n*	*Dekknöter, Fallnøt*	*Faldnet, Kastenet*
2.1	Stülpgeräte	lantern nets, cover pots	Nasse à main	Stolpnetten	klokketeine	Faldnet med fast ramme
2.2	Wurfnetze	cast nets	Epervier	Werpnetten	hivenett	Kastenet
2.21	Handwurfnet	hand cast nets	Epervier à main	Handwerpnet	kastet med hand	Kastet med hånden
2.22	Standwurfnet	cast nets from gallows or sheerlegs	Epervier dormant	Grote werpn en	kastet med spill	Faststående faldnet, hvis bund snurpes
2.23	Schleifgarne	cast nets from boats	Grand épervi	Gebbe	kastet fra bat	







	German	English	French	Dutch	Norwegian	Danish
13.	*Setznetze*	*Gillnets, Tangle nets*	*Filets calés*	*Staande netten*	*Garn*	*Hildingsgarn*
13.1 . .	Dreiwandnetze	trammel nets	Tramail	Ladderingnetten vlouwen	trollgarn	Trevæggede eller tovæggede togger- eller grim
13.2 . .	einwandige Netze	gillnets	Filets maillants	eenwandige netten	garn	
13.21 . .	Stellnetze	set gillnets	Folle	Stelnetten	settegarn	Forankrede envæggede hildingsgarn, bundsatt
13.22 . .	Schwebnetze	floating gillnets	Filet droit	Zweefnetten	flöytgarn	Forankrede mellem bund og overflade
13.23 . .	Treibnetze	drift nets	Filet dérivant	Drijfnetten	drivgarn	Driogarn
13.3 . .	Verwickelnde Netze	Tangle nets	Ret, filet embrouillant	Vlouwen, ladderingnetten	Viklegaren	Indfiltringsnet

ORIGIN OF THE DRAWINGS

No.		*Origin*	*Sources*
2.12	I.	England	Davis, F. M.: An Account of the Fishing Gear of England and Wales. London 1937, p. 123
	II.	Austria	Original
	III.	Sweden	Original
	IV.	Sweden	Original
	V.	England	Davis, F. M.: An account of the Fishing Gear of England and Wales, p. 123.
	VI.	Italy	Original
	VII.	Malta	Burdon, T. W.: A Report of the Fishing Industrie Malta, Singapore, 1956, p. 30.
	VIII.	Norway	Brobak, L.: Fartøy og Redskap. Fabritius and Sønners Verlag, Oslo 1952, p. 108.
	IX.	Malta	Burdon, T. W.: A Report of the Fishing Industry of Malta, p. 30.
	X.	France	Boudarel, N.: Les richesses de la mer. Paris 1948, p. 409.
	XI.	France (Cannes)	Photographic
2.13	I.	Germany (Schlutup)	Original.
	II.	Denmark (Viborg)	Photographie.
	III.	Denmark (Esbierg)	Original.
	IV.	Germany (Schlutup)	Original.
2.14		Germany	Benecke, B.: Fische, Fischere und Fischzucht in Ost und Westpreussen. Königsberg 1881.
2.15	I.	Malta	Burdon, T. W.: A Report of the Fishing Industrie of Malta, p. 30.
	II.	—	Original.
	III.	France	Naintré, L., Oddenino, C. u.M. Laurens: La pêche en mer. Paris 1948.
2.31	I.	Italy	Bertùcciolo, U.: Il primo libro del pescatore. Venedig 1955, p.46.
	II.	France	Chenard, M., P. Desbrosses and J. Le Gall: Revue des Travaux de l'Office des Pêches XVI, 1951, p. 105.
2.32		Norway	Original.
2.33		Norway	Schubert, K.: Der Walfang der Gegenwart. Handbuch d. Seefischerei Nordeuropas XI, 6, Stuttgart 1955, p. 96.
3.3	I.	Germany	Original.
	II.	Germany	Meyer, P. F.: Elektrizität und Fischfang. Orion 3, 1953, p. 96.
	III.	Norway	Schubert, K.: Der Walfang der Gegenwart. Handbuch d. Seefischerei Nordeuropas XI, 6, Stuttgart 1955, p. 98.
	IV.	U.S.S.R.	Skosziewicz: Die neuesten Fischfangmethoden in der UdSSR. Leipzig. 1954, p. 57.
4.1		Germany	Original.
4.21		France	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik. Heft 9, 1953, p. 19.
4.22	I.		Original.
	II.	Spain (San Sebastian)	Original.
	III.	Iceland	Original.
4.22111	I.	Ireland	Original.
	II.	Ireland	Original.
	III.	Germany	Original.
	IV.	Germany	Peters, N.: Angeln. Handbuch d. Seefischerei Nordeuropas IV, 1942.
	V.	Faroe Isles	Original.
	VI.	Spain	Rubio, M.: Artes y Embarcaciones de Pesca en Cataluna. Barcelona 1955, p. 72.
	VII.	England (Lowestoft)	Original.
	VIII.	France	Boudarel, N.: Les richesses de la mer. Paris 1948, p. 410
	IX.	France	Boudarel, N.: Les richesses de la mer. Paris 1948, p. 411.
4.22112	I.		Original.
	II.		Original.
	III.		Original.
4.22113	I.	Switzerland	Hager, E.: Der Fang der Seeforelle. Schweizerische Fischerei-Ztg. 65, 1957, p. 7.
	II.	Germany	Meschkat, A.: Neues über die Schleppangel. Fischereiwelt 2, 1950, p. 153.
	III.	Norway	Brobak, K.: Fartøy og Redskap. Oslo 1952, p. 105.
	IV.	France	de La Tourasse, G.: Revue des Travaux de l'Office des Pêches XVII, 1951, p. 6.
4.2221	I.	Germany	Original.
	II.	France	Original.
	III.	Germany	Original.
	IV.	Denmark	Original.
4.22221	I.	Germany	Original.
	II.	Germany	Henking, H. : Die Ostseefischerei. Handbuch d. Seefischerei Nordeuropas V, 1929, p. 87.
	III.	Germany	v. Brandt, A.: Fischfanggertäe und Fangmethoden. Prot. z. Fischereitechnik. Heft 9, 1953, p. 24.
	IV.	Sweden	Original.
4.22222	I.		Original.
	II.-V.	Norway	Brobak, K.: Fartøy og Redskap, Oslo 1952, p. 102-103.
	VI.	Spain	Rubio, M.: Artes y Embarcaciones de Pesca en Cataluna. Barcelona 1955, p. 79.
	VII.	Norway	Brobak, K.: Fartøy og Redskap. Oslo 1952, p. 101.
	VIII.	Portugal	Original.
4.23	I.	Sweden	Original.
	II.	Iceland	Original.
	III.	Germany (Kiel)	Original.
	IV.	Iceland (Reykjavik)	Original.
	V.	France	Le Manuel des Pêches Maritimes. Memoires de l'Office des Pêches Maritimes No. 10, fasc. 2, 1935, p. 90.
	VI.	Russia	Soljan, T.: Classification of fishing boats, gear and methods. 1956. Illustrations p. 19.
	VII.	Russia	N.N.: Fishing gear of the Caspian Sea. Moscow 1951, p. 197.
4.24		France	Naintré, L., C. Oddenino and M. Laurens: La pêche en mer, Paris 1948, after p. 112.
5.11	I.-III.	Rumania	Antipa, Gr.: Pescaria si Pescuitul. Bukarest 1916, p. 541 ff.

No.		*Origin*	*Sources*
	IV.	Yugoslavia	Soljan, T.: Classification of fishing boats, gear and methods. 1956. Illustrations p. 21.
	V.	Sweden	Seligo, A.: Strandgewässer Mitteleuropas V, 1925, p. 74.
	VI.	France	Boudarel, N.: Les richesses de la mer, Paris 1948, p. 426.
5.12	I.	Germany	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 31.
	II.	Germany	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 31.
5.31		Sweden	Original.
5.4	I.-III.		v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 36.
	IV.	Germany	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 36.
5.41	I.-V		v. Brandt, A.: Fischfanggeräte und Fangmethoden, Prot. z. Fischereitechnik, Heft 9, 1953, p. 41.
5.411	I.	Germany (Varel)	Original.
	II.	Germany (Hamburg)	Original.
	III.	Italy	Original.
	IV.	Germany (Emsmündung)	Original.
	V.	England	Fisheries notice No. 9, Capture of Eels. 1954, p. 12.
	VI.	France (Tregunc)	Photographie
	VII.	France (Malinbay)	Photographie.
5.412		France	Original.
5.4131		Germany	Original.
5.4132		Germany	Original.
5.414	I.	Germany (Heligoland)	Original.
	II.	Ireland	Photographie.
5.41521	I.	Germany	Breitenstein, W. and K. Jäger: Die Geräte der Seen- u. Flussfischerei in Wundsch, H.H.: Fischereikunde.Radebeul and Berlin, 1953, p. 179.
	II.	Germany (Rügen)	Meyer, P. F. and L. Rübenberg: Die Ankerreuse. Zeitschrift f. Fischerei 40, 1942, p. 303.
	III.	Denmark	Klust, G.: Bundgarne. Fischereiwelt 5, 1953, p. 78.
	IV.	Russia	N.N.: Fishing Gear of the Asow- and Black Sea. Moscow 1952, p. 41.
5.41522	I.	France	Bouderal, N.: Les richesses de la mer. Paris 1948, p. 430.
5.42		Norway	Brobak, K.: Fartøy og Redskap, Oslo 1952, p. 92.
6.1	I.-II.	Italy (Adria)	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 70.
	III.	France	Boudarel, N.: Les richesses de la mer, Paris 1948, p. 449.

No.		*Origin*	*Sources*
6.2		Portugal	Baldaque da Silva, A.A.: Estado actual das Pescas em Portugal. Imprensa Nacional, Lisbon 1892.
7.11			Original.
7.12			Original.
7.13			Original.
7.21		Germany (Norddeich)	Original.
7.22		Germany (Rhein)	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 47.
7.23		Germany (Elbe)	Original
8.1	I.	Germany (Husum)	Photographie.
	II.	France	Le Manuel des Pêches Maritimes. Memoires de l'Office des Pêches Maritimes, 1935.
	III.	Russia	N.N.: Fishing Gear of the Asow- and Black Sea, Moscow 1952, p.145.
8.311		Germany (Carolinensiel)	Original.
8.312	I.	Germany	Original.
	II.	Germany	Original.
8.313		Germany	Original.
8.322	I.	Denmark	Original.
	II.	Sweden	Original.
9.1		Germany	Seligo, A.: Die Fanggeräte der deutschen Binnenfischerei, Berlin 1914, p. 97.
9.2		Germany	Seligo, A.: Die Fanggeräte der deutschen Binnenfischerei, Berlin 1914, p. 180.
9.22		Denmark	Mortensen, F. V. u. A. C. Strubberg: Die dänische Seefischerei. Handbuch d. Seefischerei Nordeuropas VIII, 1931, p. 66-67.
10.3		Norway	Brobak, K.: Fartøy og Redskap, Oslo 1952, p. 61.
11.1		Germany	v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 62.
11.2	I.	Germany (Oberrhein)	Photographie.
	II.	Russia	N.N.: Fishing Gear of the Caspian Sea. Moscow, 1951, p. 189.
11.3		Norway	Brobak, K.: Fartøy og Redskap, Oslo 1952, p. 85.
11.4			v. Brandt, A.: Fischfanggeräte und Fangmethoden. Prot. z. Fischereitechnik, Heft 9, 1953, p. 62.
12.1		Germany (Ammersee)	Photographie.
12.21	I.-IV.	Switzerland	Steinmann, P.: Schweizerische Fischkunde, Aarau 1948, p. 111
12.22		Germany (Hamburg)	Photographie.
13.1	I.	Germany	Breitenstein W. and K. Jäger: Die Geräte der Seen- und Flussfischerei in H.H. Wundsch Fischereikunde, Radebeul und Berlin, 1953, p. 181.
	II.	—	Original.
13.21	I.-III.	Germany	Original.
13.23	I.	Germany	Original.
	II.	France	Original by A. Percier.

TRAWLING GEAR

by

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Abstract

Otter trawls vary from country to country and from port to port and, says the author, who shall decide what is right and what is wrong? The general principle of the assembly of the trawl is universally accepted and in these days of high towing speeds the question of the distribution of the strain on the net is very important. There is always a weakest spot and that is where the trawl tears and, the netmaker's problem is to find these spots and strengthen them. A general account of the rigging of the common otter trawl is given and, in addition, herring trawls and the midwater trawls are discussed. The value of synthetic fibres is otter trawl construction has yet to be proved and the high initial cost is against their general use, for, while a synthetic fibre codend may last for months, the possibility of the total loss of the trawl is always present. The author lists seven important factors which are involved in spreading or setting the modern trawl gear, and he suggests that the successful "skipper" is the man who is able to bring all these factors under proper control so as to produce the most effective fishing instrument which in turn matches his own skill and intelligence.

Chaluts

Résumé

Les chaluts à plateaux diffèrent suivant les pays et même les ports, et, se demande l'auteur, qui peut dire lequel est bon et lequel est mauvais? Le principe général de montage du chalut est universellement adopté et, á notre époque où les vitesses de chalutage sont élevées, le problème de la répartition de l'effort sur le filet est très important. Il existe toujours des points faibles où le chalut se déchire, et le problème du fabricant de filets consiste à localiser ces points et à les renforcer. L'auteur fait un exposé d'ensemble du gréement du chalut ordinaire à plateaux et étudie en outre le chalut à harengs et le chalut flottant. La valeur des fibres synthétiques pour la fabrication des chaluts à plateaux reste à démontrer, et leur coût initial élevé s'oppose à la généralisation de leur emploi, car si un cul-de-chalut de fibres synthetiqués peut durer des mois, la possibilité de la perte totale du chalut est toujours présente. L'auteur énumère sept facteurs importants qui conditionnent la diffusion ou l'adoption des chaluts modernes et il suggère que le "patron de pêche qui réussit" est celui qui est en mesure de contrôler tous ces facteurs de façon à produire l'engin de pêche le plus efficace qui à son tour s'harmonise avec son habileté et son intelligence.

La red de arrastre

Extracto

Las redes de arrastre varían de país a país, de puerto a puerto y, según el autor, nadie puede asegurar cual es mejor. En general se acepta el principio que rige para la armadura de las redes de arrastre pero, actualmente, con el empleo de grandes velocidades de arrastre, el problema de la distribución de los esfuerzos sobre el arte son muy importantes. Como siempre existen puntos débiles por donde la red se rasga, la dificultad del fabricante estriba en encontarlos y reforzarlos. En el trabajo también se describe, en general, la manera de armar una red de arrastre, y analiza un arte de este tipo para la pesca de arenque, además de otro que trabaja a profundidades intermedias. Todavía no se ha probado el valor de las fibras sintéticas en las redes de arrastre y su alto costo inicial va contra de la generalización de su uso, dado que, si bien un copo de este material puede durar meses, siempre existe la posibilidad de la pérdida total de una red de arrastre. El autor da una lista de varios factores de importancia en el calamento de una red de arrastre moderna y sugiere que un "patrón capaz" es el hombre que puede regular todos estos factores para obtener el instrumento de pesca màs efectivo, posible de comparer con su propia abilidad e inteligencia.

THIS paper deals with the otter trawl and its variations, together with the ropes and fittings which go to make the whole into a fishing instrument. No two countries use this gear in just the same form and even neighbouring ports have their own ideas as to detail. Underwater photography does show something of what happens when the gear is spread, but we still lack certain knowledge as to what happens when heavy gear is being towed in deep water.

SETTING OF OTTER TRAWL GEAR

There are several factors involved in spreading or setting modern otter trawl gear. Unless they are all in proportion to one another, maximum efficiency is not attained. These factors are:

1. Speed of tow.
2. Length of warp used in relation to depth of water.
3. Angle of attack of otter boards, determined largely by the placing of the brackets.
4. Length of sweepline.
5. Weight of footrope.
6. Floats on headline.
7. Proportions and mounting of the trawl itself.

There are cases where two similar trawlers fish side by side and one consistently out-fishes the other. I suggest that the man who is successful is the one who manages to bring all the features listed above into such proportion as to produce the most successful fishing instrument.

THE OTTER TRAWL NET

Broadly speaking, most of the vessels carrying out bulk fishing in Arctic waters use trawl nets with headlines ranging from 78 to 105 ft. In Britain, the most popular type is still the Granton Trawl in its two versions, i.e., the smaller type with 78 ft. headline and 116 ft. footrope, and the larger one with 10 ft. longer wings and hence 98 ft. headline and 136 ft. footrope. It appears that some French vessels have shortened their upper and lower wings so much that there is only 60 ft. of headline with net on it. Legs extend beyond the headline and footrope so that there is a normal length to the danlenos. The sideline is also continued to the danleno. It is a common practice now, when fishing on rough ground, to detach the lower wing from the footrope in its forward parts, or to eliminate the forward end of the wing altogether.

Although there are variations, the general principle of the assembly of an otter trawl net is internationally accepted. Measuring on the side-seam of the wings, the lower wing is 10 per cent. longer than the square and upper wing. This allows the sideline to lift, following the upward pull of the headline, and thus the lower wing is more or less vertical in the water. The footrope from the wing end to the quarter point is again some 10 per cent. shorter than the sideline, thus throwing the main towing strain where it should be, namely, from the footrope legs down the footrope wing pieces and the bobbin bunts to the quarter points, then down the belly lines to the sidelines and so down to the codend.

In these days of powerful modern vessels towing their gear at speeds up to five knots, the question of distribution of strains is of great importance. However carefully one adjusts the net on its supporting lines, there are bound to be weak points causing tears, with loss of fish and fishing time. The problem of the net-maker is to strengthen these parts as much as possible. Something can be done by increasing the area of double netting around the upper and lower bosoms, by using double twine for several meshes inside the leading edges of the wings and by running a width of double twine down the bellies just inside the side-seam. Some skippers use nylon or similar synthetic fibres in the place of manila around the quarter meshes. This is the point where most damage occurs, which seems inevitable. We know that the headline and footrope will tend to form an arc, and to this arc we attach sections of netting which have distinct angles at the quarter points. It might be a worthwhile experiment to make a net in such a manner that the upper and lower mouth is rounded instead of having sharp corners as at present.

OPENING WIDTH

It would seem that during operation, a trawl with an 80 ft. headline has a distance of approximately 50 ft. between wing ends but this is pure conjecture arrived at by experimenting with models. If the trawl opening is too wide, it would clearly be more difficult for the floats to lift the headline. I think we have less opening with legs and sweeplines than we had years ago when the otter boards were on the wing ends. The "pony boards", which some vessels use instead of danlenos, seem to give a wider mouth opening with a corresponding reduction of headline height.

OPENING HEIGHT

The question of headline lift will have been discussed elsewhere. Briefly, the lateral pull of the otter boards tries to bring the headline down; some of the resistance of the codend falls on the square and thus tries to pull the headline back. The thrust of the water as the trawl advances also tries to push the headline and its floats back towards the codend. In spite of these various stresses, there is no doubt that modern floats and kites do lift the headline to a considerable height.

OTHER GEAR COMPONENTS

There are many variations in otter trawl gear to be found in different parts of the world. North Europeans like the steel bobbins; in America and Canada these are little used. The British prefer the steel danleno, but in Germany the pony boards are popular, while in the Americas no danlenos are used at all. Sweeplines vary in length from 15 fathoms to 125 fathoms, according to individual opinion and circumstances.

HERRING TRAWLS

Before discussing the midwater trawls, it is necessary to review the developments which have taken place in the conventional otter trawl in order to adapt it for catching herring and mackerel. Originally a very large net with small mesh throughout was used. In the late twenties it became the practice to use large meshes in the front parts of the trawl net, together with a kite so rigged as to give maximum lift to the headline. Today the main practice is to use two kites, which can be rigged in different ways, and travel at a considerable height from the bottom, i.e. the lower kite pulls up the headline, and the higher one breaks up the shoal of fish and sends part, at least, downwards into the path of the net. Some countries use a 35 m. headline trawl, others one of 20 m. but with very deep wings. Both fish very successfully.

MIDWATER TRAWLS

For a generation fishermen have been trying to tow a trawl in midwater. This can now be done both by a net towed from a single ship and by one towed between two vessels. It seems, however, that the results have not been as good as predicted after the first experiments. The Larsen gear is used successfully every winter in the herring fishing off Skagen. At that time and at that place the water is somewhat cloudy and the herring very plentiful. This success has not been repeated in the clear, deeper waters of the North Sea. Herring are often caught in quantity with the two-boat gear and sometimes with one-boat gear in the English Channel, where again the water is cloudy.

A similar net towed by one vessel has been tested very extensively by the British Ministry of Fisheries in the North Sea, and by the Canadian Fisheries Department in the Vancouver district. The experiments were carried out by the drifter or small trawler type of vessel. Icelandic fishermen have for some years used a box-shaped midwater net towed by a large single trawler on a ground near the Westman Islands, usually called "the Stones", which is far too rough to be fished by the usual bottom trawl. In the spring, cod arrive in great numbers and the shoals are so large that the trawl, if well opened, can hardly fail to sweep up large quantities of fish.

One is tempted to conclude that midwater gear has only been used with success where ideal conditions exist. This means either shoals so extensive that a net dragged through the area is almost certain to catch them, or turbid water in which the fish do not see the net approaching. Experiments continue, and it seems likely that midwater trawls will come more and more into the picture. The difficulties are obvious. Except where fish are abundant, the shoal has to be located and the depth of the gear quickly adjusted. Sonic instruments are now available which show the skipper the depth at which his trawl is fishing. It would seem that the bulk of our white fishing operations will continue to be carried out with conventional bottom trawls but that with time fishing grounds will be found where the conditions exist which make midwater trawling a commercial possibility.

SYNTHETIC NET MATERIAL

Without questioning the virtues of nylon and other synthetics, it can be stated that, for the trawl net, these fibres do not have the same advantages over vegetable fibres which they have for the gillnet. Size for size, they have approximately twice the breaking strength of manila and are virtually impervious to rotting. A big disadvantage in trawling is their high cost, and the possible loss of all or part of the net is always present. However well designed a trawl may be it must, in parts and at times, chafe along the bottom. A codend made of synthetic twine and well protected with hides may last for six months and pay for itself several times over. Only time can show whether the material will be widely adopted for trawling.

A deckload of cod.

GERMAN CUTTER TRAWLING GEAR

by

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Abstract

This paper concerns exclusively bottom trawling gear omitting midwater trawling, which, to a certain extent, has been adopted by the German cutters, particularly in recent years. After a short description of vessels, crew and auxiliary equipment, characteristic examples of the following types of gear are described in detail: flatfish and roundfish trawl, herring otter trawl, and herring pair trawl. The main emphasis is laid on design and construction of the nets, including a short paragraph on the use of machine braided webbing.

Les chaluts du coutre allemand

Résumé

Cet article concerne exclusivement les chaluts de fond, les chaluts flottants étant exclus, qui ont été adoptés récement jusqu'à un certain point par les coutres allemands. Après une courte description des bateaux, des équipages et de l'équipement auxiliaire, l'auteur décrit en détail des exemples caractéristiques des types d'engins suivants: chalut à poissons plats et autres poissons, chalut à plateaux à hareng et chalut-boeuf à hareng. L'auteur insiste sur le dessin et la construction des filets, un court paragraphe est consacré à l'utilisation de filet fabriqué mécaniquement.

Los artes de los cúteres alemanes

Extracto

Esta ponencia trata exclusivamente de los artes de arrastre de fondo, omitiendo los artes flotantes que han sido adoptados recientemente, hasta cierto punto, por los cúteres alemanes. Despues de reseñar brevemente las embarcaciones, las tripulaciones y el equipo auxiliar, el autor describe con pormenores ejemplos característicos de las siguientes clases de material: artes de arrastre para la pesca de peces planos y otros, artes de arrastre de puertas para la pesca del aranque y artes de arrastre remolcados por parejas para la pesca del arenque. El autor hace hincapié en el proyecto y construcción de los artes y dedica un párrafo al empleo de redes fabricadas mecánicamente.

GENERAL

TRAWLING is the most important fishing method used in the German sea fishery. Except for the shrimp fishery, which is carried out in coastal waters by small cutters (10 to 15 m. long) using the beam trawl, fishing is done by otter trawling and pair trawling. There are three classes of ships engaged in otter trawling: big trawlers, trawling luggers (which are also equipped for drift net fishing) and big cutters, the operating range of these vessels being in relation to their size. The gear of these vessels differs not only in size, but also in material, construction, and rigging.

The big trawlers fish exclusively for round fish and herring and use two basic types of gear specially developed for these fisheries. The luggers, which fish exclusively for herring, use the same type of herring gear but of smaller size when trawling. The big cutters, which operate for flatfish, roundfish and herring, also use two types of gear, one for roundfish and flatfish and another for herring. These vessels are used for otter trawling as well as pair fishing.

The big cutters have recently started midwater trawling for herring and sprat in the south-eastern North Sea during the winter, generally using the two-boat type of gear. This paper deals exclusively with this class of vessels.

The Vessels

The size of the big cutter trawlers lies between 14 and 26 m. overall (fig. 1).

Propulsion is exclusively by diesel engines of 90 to 200 h.p. giving a cruising speed of about 9 knots and a towing speed of 2·5 to 3·5 knots. Fishing is done exclusively over the side, preferably to starboard. The main fishing areas are the south-eastern North Sea and the Baltic Sea. Many of the boats are fitted with radio telephone, radio direction finders and echo sounders for navigation and fish location. The crew ranges from 3 to 5 men, depending on the size of the vessel; all hands are fully qualified fishermen. Fishing trips rarely exceed one week. The winches of the smaller boats are often constructed from the rear axle of a truck and are driven from the main engine by means of a driving belt (fig. 2).

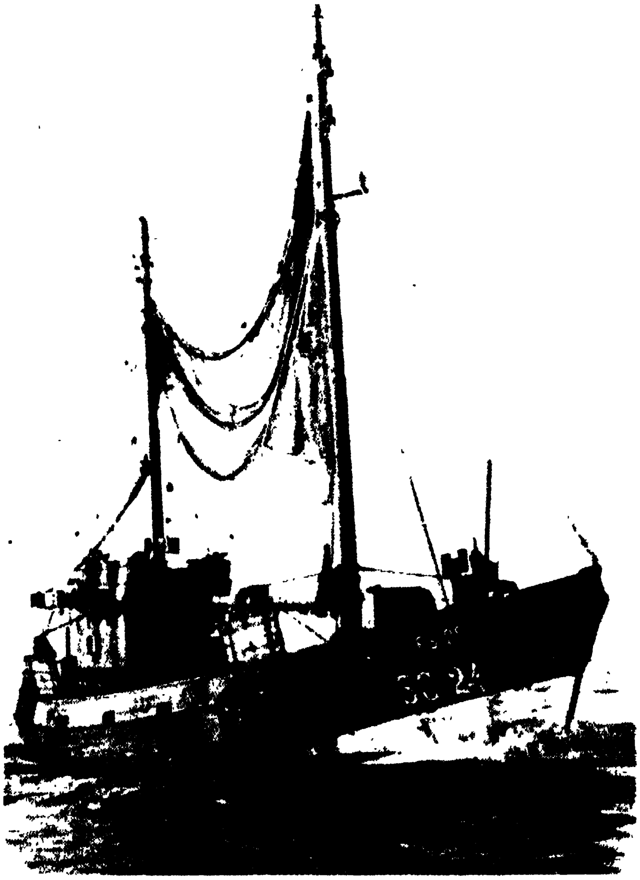

Fig. 1. Modern German cutter (Type KFK).

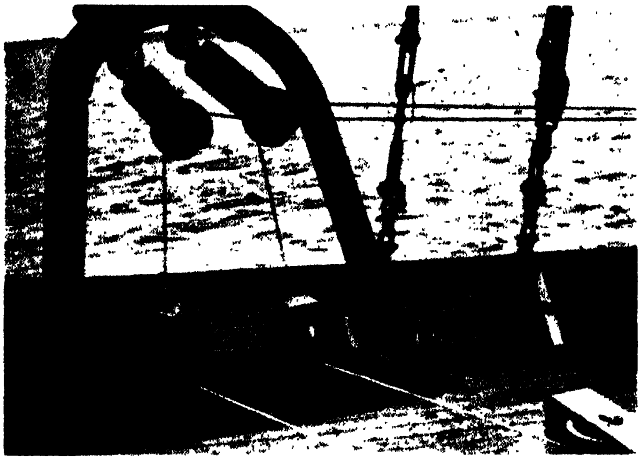

Fig. 3. Fore gallows with two blocks for both warps.

The two drums usually have a capacity of about 400 fm. of warp (wire cable of about 9 to 14 mm. ø) but are not big enough to take up the bridles as well.

The two gallows are arranged at the side in the same manner as on the bigger trawlers. For pair-fishing, however, the aft gallows are inconvenient and fore gallows have been constructed, carrying two blocks to accommodate both warps (fig. 3).

This leaves the deck and rail free for better handling of net and lines, but, on the other hand, requires additional care when shooting and hauling to prevent the gear being fouled.

The bridles are hauled in on the winch barrels, and to facilitate hauling and prevent chafing of the bridles, special rail-rollers and fairleads are used, to give the rope the right direction to the barrels (figs. 4 to 6).

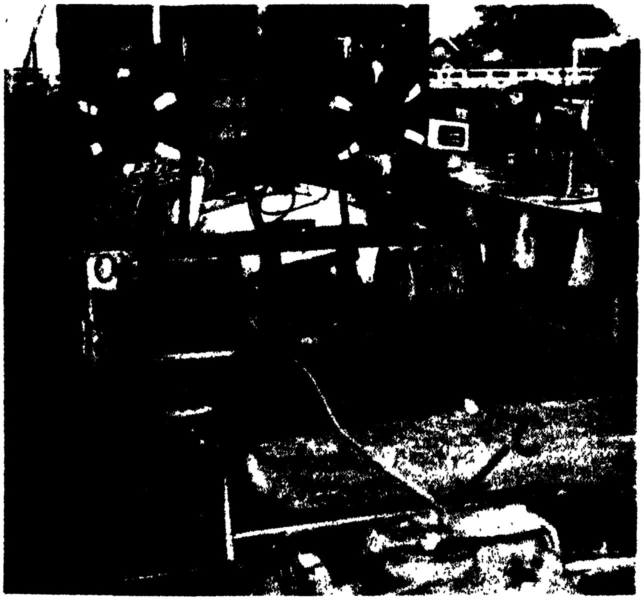

Fig. 2. Cutter winch made out of a rear axle of a truck. C= centre-bollard; L=leading-bollard to give the bridle the right direction to the barrel of the winch.

Fig. 4. Example of the arrangement of centre-bollards (C) and leading-bollards (L).

Very simple devices keep the warps together near the stern when towing. Sometimes the warps are only belayed round a common bollard or put into a lip. Some vessels use a special type of clamp fixed to the gunwale, which facilitates the release of the warps before hauling (figs. 7 and 8).

The Trawling Gear

The warps are about 9 to 14 mm. ø.

The otter boards are made of wood, with iron reinforcement. The size is from 0·85 to 1·0 m. in height and 1·8 to 2·0 m. in length, and the weight lies between 50 and 100 kg. each. They are relatively higher than the boards used by the bigger trawlers. To obtain the required angle of attack, iron brackets are used, but chain strops or a combined chain bracket arrangement can also be found (fig. 9).

The "chain boards" are more difficult to operate because they foul more easily. The most modern form has rigid iron brackets instead of the folding pair type (fig. 10). This construction, which originated in Denmark, is now well introduced in Germany. Very often such boards have glass or aluminium floats attached near the upper edge to keep the board upright on the ground when towing is interrupted (fig. 11).

The boards are often fitted with shoe-plates (8 to 10 cm. wide), made out of iron sheet about 3 mm. thick, to prevent them ploughing too deep in the muddy bottom.

In pair-fishing, the width of the net opening is controlled by the distance of the two boats and no otter

Figs. 5 and 6. Two different types of rail-rollers for leading the bridles when heaved over the rail. 5 = removable roller. 6 = fixed roller.

Fig. 7. Special clamp serving as towing-block.

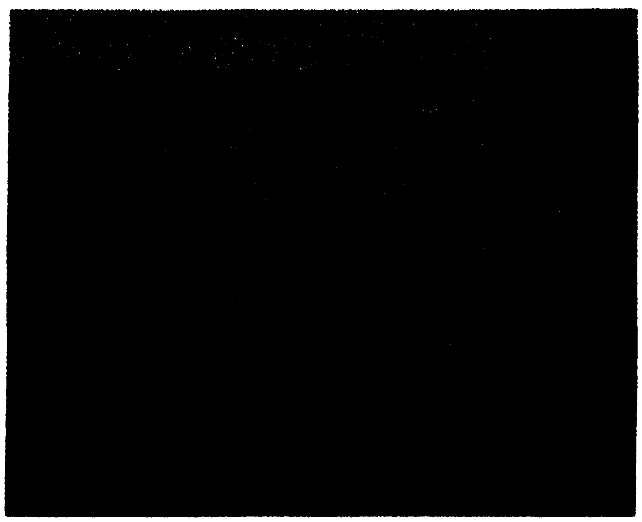

Fig. 8. Rail-roller used to keep the warps together (Pair-fishing).

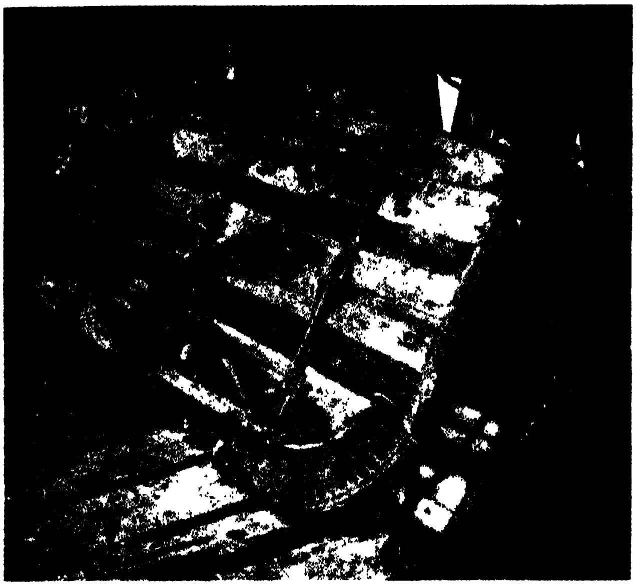

Fig. 9. Otter board with combined chain-bracket arrangement.

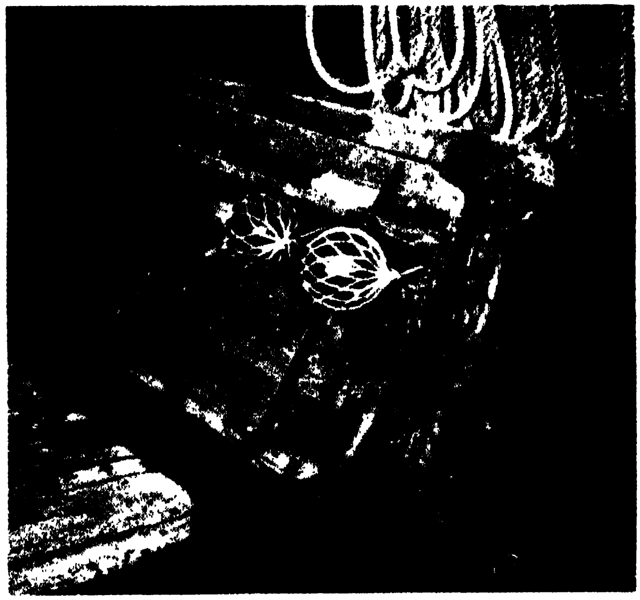

Fig. 11. Otter board with glass floats to prevent the board from falling flat when towing has to be interrupted.

boards are required. Instead heavy sinkers are used to weight the gear down (fig. 12).

A main sinker (M) of about 60 to 120 kg replaces the otter board and is attached at the connection between warp and bridle. A second sinker (D) of about 15 to 20 kg. is fixed at the lower edge of the danleno, whilst a third weight (W) of about 8 to 10 kg. may be attached at the connection of the ground rope leg to the wing end. These weights are often made out of bunched chains instead of solid iron because chain bundles are less likely to cause damage to the ship's side when hauling in bad weather.

THE FLATFISH AND ROUNDFISH GEAR

There are great differences in the fishing gear of the cutters due to differences in fishing conditions, size of the boats, historical origin, etc. In the following, some characteristic examples are given for each of the main types used.

Although quite similar gear can be used for flatfish and roundfish, specific types of gear are usually in use too. For the cod fishery in the Baltic Sea, several types of nets with different mesh sizes and twine strengths

Fig. 10. Modern otter board with rigid iron bracket (Danish Type). A = Point of attachment for the warp.

Fig. 12. Weights for bottom pair-fishing.

have been specially developed for different fishing conditions. The most common method is otter trawling, although pair-fishing is sometimes practised for cod. When operating for flatfish, the ground rope must have good contact with the bottom, whereas the opening height is of less importance. For catching roundfish, however, the headline must have a certain opening height, and the ground rope may travel lighter over the bottom. These conditions can be realised to a certain extent with the same gear by choosing an adequate rigging of the legs, the right type of ground rope, and by suitable lifting devices for the headline. The ground rope has to be lengthened in relation to the headline to gain good contact with the bottom.

The bridles are usually of hard-laid manila rope of 16 to 24 mm. ø. They are often made up of two to three parts of equal length, being thicker in the section nearer the net. Sometimes, combined rope of 16 to 20 mm. ø is used. The length depends to a certain extent on the depth of the water and lies between 60 and 80 fm., longer bridles being used in deeper water. The connections of the bridle with the otter board at one end and the danleno at the other, are made by means of shackles with swivels; (V. D. Kelly eyes and links are not used).

The danlenos are made of hardwood with iron fittings and the lower end is weighted. The length varies between 0·6 and 0·7 m. They are equipped with a strop for fixing the bridle and, with loops for the attachment of the legs or the net respectively.

As a rule, the net is fastened directly to the danleno, but legs are occasionally used. If necessary, short pieces of wire are inserted for regulating the length of the ground rope. Chain is used for the ground rope when fishing for flatfish, and a wire of about 10 mm. ø, served with yarn and rope, with eyesplices at both ends, is used for roundfish. Additional chains may be wrapped round to increase the weight. A bolshline is laid on to attach the net in the usual way.

The headline is also wire of about 10 mm. ø and served with yarn. Sometimes combination rope of comparable strength is used. Kites are rarely used, and buoyancy is assured by a varying number of 8 in. floats (from 10 to 35), made of glass or synthetic material. The connection of the webbing to the headline is usually direct, without a bolshline.

Cutters of 120 to 180 h.p. fish with 90 ft. nets of this type. This value of the ground rope length is nothing but a name. Flatfish nets are handbraided from manila twine, while roundfish nets for the Baltic Sea usually are assembled from sections of machine-made cotton netting. The following twine strengths are suitable:

Part of the net	*Breaking strength (wet)*
Upper wing	45 kg. (99·2 lbs.)
Lower wing	45 kg. (99·2 lbs.)
Square	45 kg. (99·2 lbs.)
Belly	48-50 kg. (105·8-110·3 lbs.)
Codend	90 kg. (198·5 lbs.)

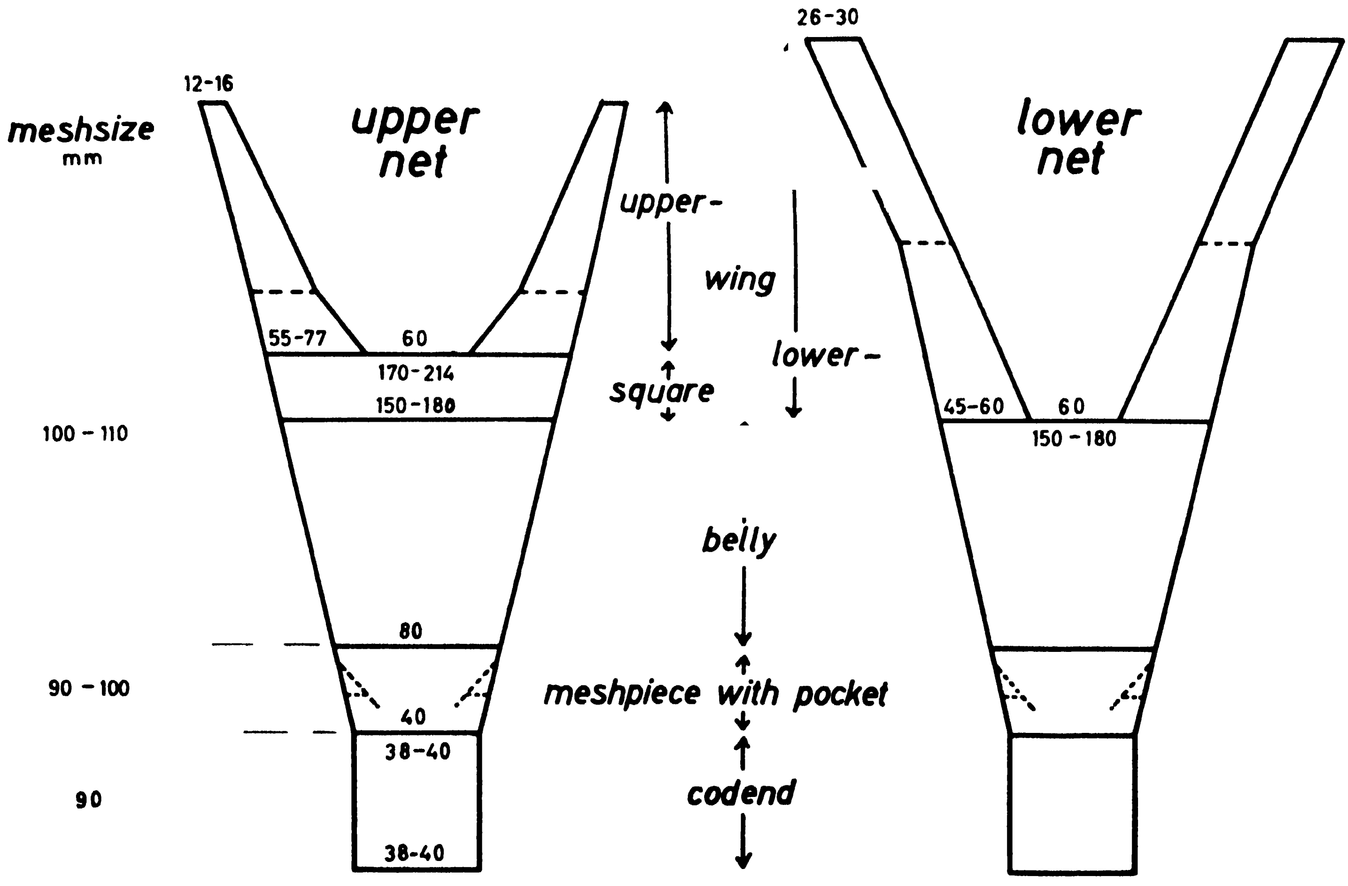

Fig. 13. Construction plan of 90 ft. flatfish trawl.

The nets consist of an upper and a lower part, which are made up of similar sections. An example of this type of net is given in fig. 13.

The first part of the headline side of the upper wing, starting from the bosom, may be baited, every row instead of every other row. This results in a quickly diminishing width. Further towards the wing tip, it may be continued with fly-meshes until the end. The lastrich side, consequently, cannot be straight but must have a number of creasings inserted, to compensate this quick loss of meshes on the headline side in order to obtain the desired length of about 8 to 11 m. The mesh size is generally 100 to 110 mm.

The square has the same mesh size as the upper wings. The width may vary between about 170 and 214 meshes at the top and about 150 and 180 meshes at the bottom. Depending on the baiting rate, the depth may differ and the total length can vary between about 1·7 and 3·7 m. Usually, a longer square is combined with a shorter wing and vice versa.

To obtain the necessary slack, the lower wing is made about 1/6 to 1/5 longer than the upper wing, plus square. The ground rope side is fly-meshed, and to obtain the required length, the lastrich side has a compensating number of creasings.

As almost no reduction of the mesh size is needed, the belly is usually an undivided piece of equal mesh size (about 100 to 110 mm.). It is about 150 to 180 meshes wide at the start and about 80 meshes wide at the end. According to the width at the top and the baiting rate, the total length lies between about 6·0 and 10·0 m.

The throat is usually about 80 meshes wide at the start and about 40 meshes wide at the end. The mesh size may be slightly smaller than in the belly and lie between 90 and 100 mm. The total length may vary between about 3·0 and 4·0 m.

The floppa, or the so-called "pocket" are arranged in the throat. The floppa is usually a trapezium-shaped piece of netting attached along its upper edge to the upper net, and at the sides to the lower net along a halfer. But there are also rectangular floppas in use, the front edge of which is attached to the upper net in the usual way, while the side edges are laced in the lastrichs leaving about 0·5 m. of the end free. To form the "pockets" upper and lower net, starting from the lastrichs, are laced together on the halfer leaving an opening of only about 20 meshes in width free. To prevent the fish from being pressed into the corners formed by the seams and the lastrich, the tip of the pocket is closed by lacing upper and lower net together on the full mesh. Such pockets are only used for the flatfish fishery, and the floppa is preferred for roundfish.

Usually, the codend has no baitings. The width may be about 38 to 40 meshes of about 90 mm. mesh size, so that the length is about 4·5 to 5·5 m.

Halving becket and bull ropes are not customary. The net is hauled in by hand, the codend stropped and hove on deck by means of a gilson.

THE HERRING OTTER TRAWLING GEAR

For herring and sprat fishing, the cutters use a very light gear adapted to their limited engine power. This gear has a high net opening, 5 to 8 m. with the ground rope travelling lightly over the bottom.

The same otter boards are used as for the flatfish fishery. The bridles are handled without pennants and are made of combination rope of about 18 to 20 m. ø. The length varies between about 30 and 60 fm. and varies with the depth of water. The bridles are fixed in the same manner as already described.

The danlenos are similar to those used for flatfish gear except for their size, and may be between 1·2 and 1·3 m. long.

The legs are made of wire rope of 12 to 14 mm. ø. There are usually three legs, i.e. one each for the headline, the lastrich, and the ground rope. Their length varies from about 12 to 15 m. Usually the headline and the lastrich leg are fixed at the upper, and the ground rope leg at the lower, loop of the danleno. The usual length relation of these legs is maintained. A lengthening of the ground rope or its legs results in sharper travelling over the bottom.

The headline is usually made of combined rope of about 12 mm. ø. It has eyesplices at both ends for connection with the legs by means of shackles. Bolshlines are unusual with this type of net, which is attached directly to the headline. A varying number of floats (about 15 to 25) are attached to give buoyancy and, if a kite should be used, which is very seldom, it is attached directly to the headline.

The ground rope is also usually made of combined rope but of about 14 mm. ø. Like the headline, it also has eyesplices at both ends for connection with the legs. In contrast to that used in the flatfish gear, this ground rope is not served with ropes or anything else. The net is attached directly without bolshlines. To give weight, iron rings of about 20 cm. ø, and weighing about 1 kg. each, are fixed by means of short strops; the distance of the ground rope from the bottom can be regulated by the length of these strops. The advantage of such rings is that they cannot hook into or fall through the meshes, so that fouling is avoided. About five rings may be distributed over the bosom, while in the wing sections they are distributed at a distance of about 1 fm.

The lastrich is strengthened by combined rope of 10 to 12 mm. ø down to the codend; manila rope is preferred on the lastrichs of the codend. The wingends of these strengthening ropes connect with the legs.

Differences between the length of the netting at the headline, lastrich, and ground rope in the wingends, are compensated by the length of headline, lastrich rope and ground rope respectively. As a rule, these ropes extend the netting accordingly.

A common size of net used with this type of gear is 90 to 100 ft. (fig. 14).

In contrast to the flatfish net described above, these nets or, at least, the smaller meshed parts, are always made from machine-made netting. The material is cotton or man-made fibre, such as Perlon or nylon. The following twine strengths are suitable for the different net sections.

Part of the net	*Breaking strength (wet twine)*
Upper wing	14 kg. (30·9 lbs.)
Lower wing	14 kg. (30·9 lbs.)
Square	14 kg. (30·9 lbs.)
Belly	6·5 to 11 kg. (14·3 to 24·3 lbs)
Tunnel	8·5 kg. (18·7 lbs.)
Codend	11 kg. (24·3 lbs.)

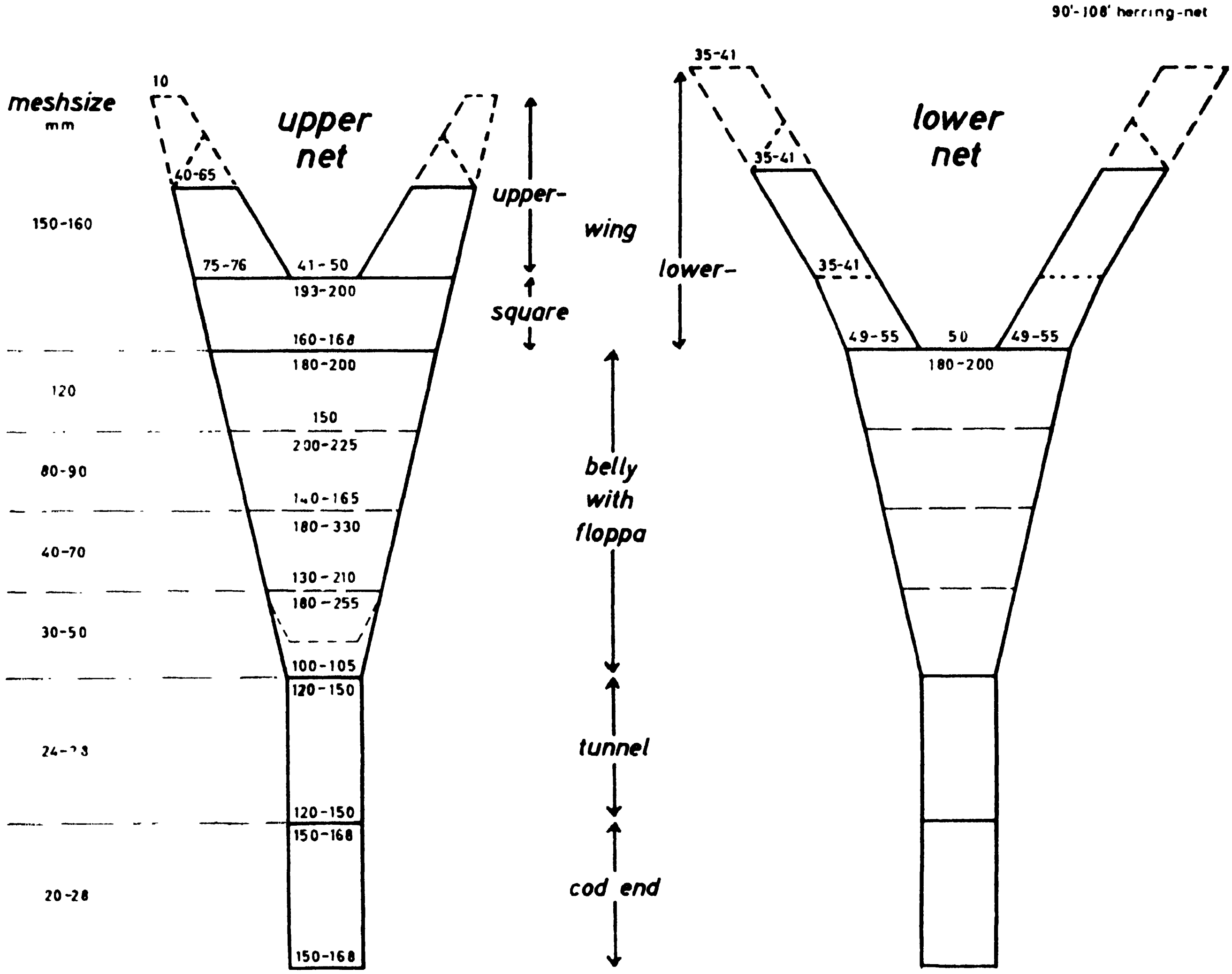

Fig. 14. Construction Plan of 90 to 108 ft. herring trawls.

The twine used in this type of net is of relatively low breaking strength and such light nets need careful handling, particularly in bad weather. On the other hand, this net construction shows that the twine strength used is often higher than necessary. Thinner twines mean lower towing resistance and a further saving of material. The latter is particularly important when the more expensive synthetic materials are used.

The headline side of the upper wing is usually fly-meshed or cut on the halfer. The lastrich side is not straight but usually runs out at the same baiting rate as the side edges of the square. Some nets have long wings and others short wings, so that the length may vary considerably, i.e., between about 4 to 10 m. The base of the upper wings are rather wide compared with the width of the bosom. The end of the shorter type of wings may be wide (about 40 to 65 meshes). Often such short wings end with an additional triangular-shaped piece of netting. This piece, which is fly-meshed or cut on the halfer at both edges, is attached mesh to mesh at the normal end of the wing. While the headline edge is fixed at the headline, the opposite side is not laced into the lastrich but attached to the fishline (combination rope of about 8 to 10 mm. ø) which leads from the groundrope over the lastrich to the headline. In this case, an additional lengthening of the shorter lastrich is needed for compensation with headline and ground rope.

The length of the square is about 4·0 to 4·5 m. The mesh size is usually the same as in the upper wings, i.e. 150 to 160 mm.

The lower wings have the same mesh size as the upper wings and square. The total length may exceed the length of the upper wing plus square by the usual 1/6, but more often the lengths of upper and lower net are equal. As the ground rope side is fly-meshed, the lastrich side has a compensating number of creasings to obtain the necessary length. If the upper wing ends have a triangular shaped piece of netting, the lower wings are constructed in the same way.

The mesh size diminishes considerably in the belly which consequently is divided into several sections. The example given in fig. 14 shows that great variations

Fig. 15. Heaving codend.

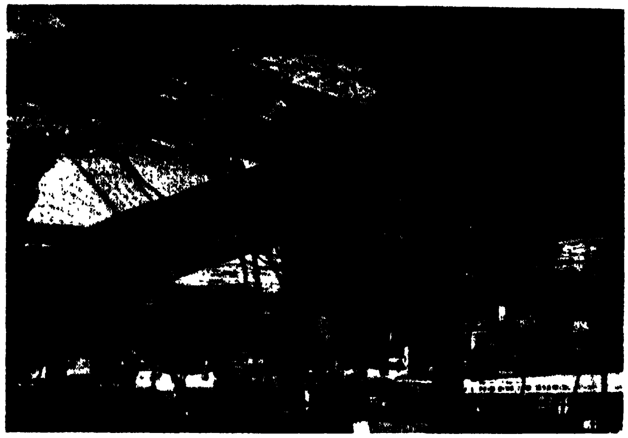

Fig. 17. Example of closing the codend by means of a special lock (Danish type). For closing, lock has to be pulled.

in the construction exist. The belly usually ends with 100 to 105 meshes, including the throat. The throat forms the last section and usually contains the floppa. The total length of the belly may vary between 18 and 21 m.

The floppa is a trapezium or a rectangular piece of netting about 2 m. long, and is inserted in the way already described. No floppa is needed in water depths of less than about 20 m., because the length of tunnel and codend prevents the fish from escaping.

The tunnel is rectangular and has a width of 120 to 150 meshes. Its length can be from about 7 to 9 m. The mesh size of this piece is usually somewhat smaller than in the last section of the belly.

The mesh size and number of meshes in the width of the codend depend on the species of fish to be caught. For herring a mesh size of about 28 mm. is suitable. In this case, the codend would have the same number of meshes in width as the tunnel. For catching sprat, however, a smaller mesh size (about 20 mm.) is needed,

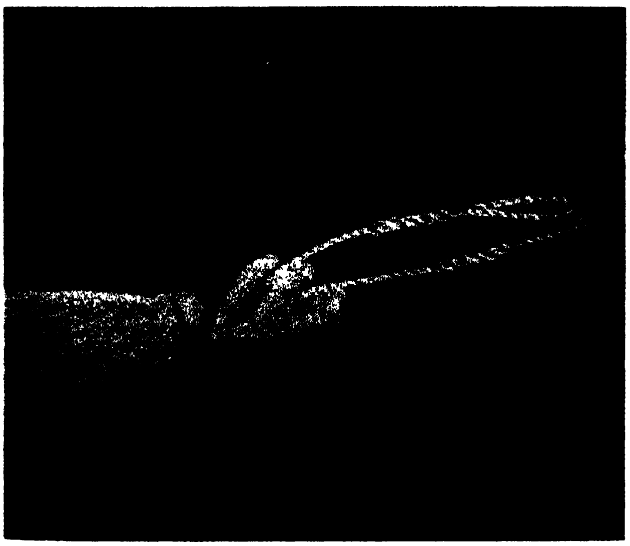

Fig. 16. Example of closing the codend by means of a cod line with a simple knot.

and the number of meshes in the width must be correspondingly increased. The length of the codend may vary between about 3·5 and 9·5 m., depending on the preference of the skipper and the size of catches expected.

An additional codend, made of manila or Perlon twine (breaking strength about 65 kg.), with a mesh size of about 120 mm., is used for heaving the bag aboard. This "heaving codend" covers the last part of the real codend and is about 2·5 m. long (fig. 15).

Its front part may be made of single twine, but the heaving part is often double braided. The codend protrudes through the opening in the heaving codend and, by closing this, the real codend is also secured. This can be done by means of a codline and use of a simple knot (fig. 16) or by a special design.

The apparatus shown in fig. 17, developed in Denmark, allows for quicker opening and closing when big catches have to be divided into several bags. The lastrich strengthening ropes of the codend may end in eyesplices which can be used for fixing a line to a buoy or an auxiliary rope. The latter are often attached to prevent loss of the aft part of the net in case of damage.

A halving becket with bullrope is provided for heaving the bag. In contrast to the gear of big trawlers, this halving becket—in addition to the loops at the lastrichs—is rove through a number of iron rings which are fixed at intervals around the codend.

To obtain a high opening, this net is rigged so that the main pull lies on the lastriches. The netting stretches in use and this loosening of the rigging results in a higher towing resistance. As a tight rigging is preferred nowadays, the net has to be cut off about every month and rigged up tightly again.

Fig. 18 shows the way in which the different pieces of such a net can be cut out of machine-made netting with as little loss as possible. Of course, different pieces or bales of machine-made netting have to be used for the parts with different mesh sizes and twine strengths. The netmakers order such bales from the factories in the necessary width, according to the length of the respective part of the net.

The square and wings, which usually have the same mesh size and twine strength, are often constructed

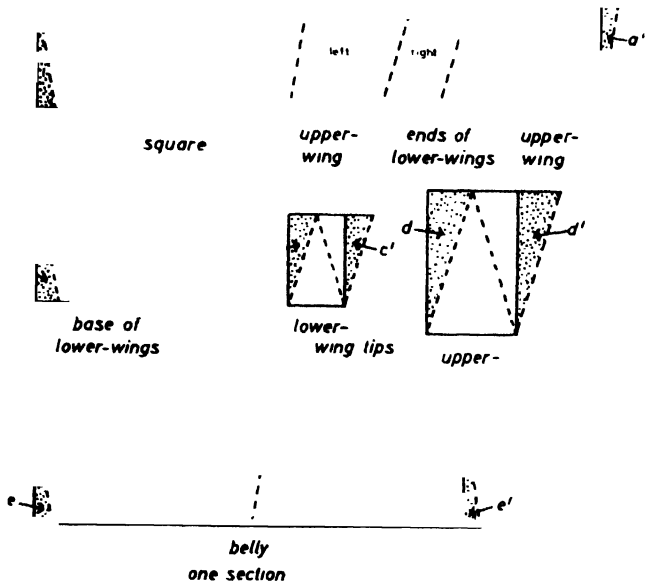

Fig. 18. Method of cutting 90 to 108 ft. herring trawls out of machine-made netting.

in such dimensions that they can be cut out of one and the same bale. A certain difficulty may arise if the lastrich side of the base part of the lower wings is baited in another way to those of square and upper wings. (fig. 14). This means that all sections cannot be cut out of one piece of machine-made netting continuously, and two bales are needed to avoid loss. Fig. 18 shows how this can be done by putting the triangular shaped pieces cut from the front edge (a, b) to the back edge (a′, b′). As the attachment of these pieces means additional work, it is more economic to cut the parts of more than one net out of one machine-made piece of netting, as the operation has then only to be done once. Netmakers, therefore, usually use two bales, one for the square, upper wings, and the fore parts of the lower wings, and one for the base parts of the lower wings, from which the respective pieces are cut when needed. The piece cut away at the beginning then may be added to the back edge when the end of the bale is reached.

If triangular shaped wing tips are needed, a loss of netting can be avoided only if separate rectangular pieces of machine-made netting are available. As already mentioned, both side edges of these end pieces are cut on the halfer. As the bases of those for upper and lower wing are different, the lengths are different too. If netting of the proper width is available, loss can be avoided by using the triangular shaped pieces cut off at the beginning, in the way described above.

The different sections of the belly have different mesh sizes, twine strengths, and lengths and, therefore, have to be made out of separate bales. The upper and lower part of each section are cut as shown in fig. 18, i.e., the two parts appear inverse. The triangular shaped piece cut off in the beginning is handled as usual.

No explanation is necessary for cutting tunnel and codend, which are rectangular.

All nets can be made from machine-made netting, but variations are possible. For instance, missing triangular edge pieces can be added by handbraiding. The selection of the actual method is determined mainly by economic considerations.

To repair destroyed parts, fishermen take a collection of different pieces of netting with them so that whole sections can be replaced.

THE HERRING PAIR-FISHING GEAR

The length of the ground rope in this type of gear, which is towed by two cutters, is similar to that found in the gear of big trawlers, but the length of the net is greater. The large size, in relation to the limited engine power (about 240 to 360 h.p. both boats together) is made possible because the nets are light, made out of cotton or synthetic twine. In the North Sea, slightly smaller nets are used than in the Baltic Sea.

Weights of 60 to 120 kg. are fixed at the connection of warp and bridle.

The bridles are made of combined rope of 18 to 20 mm. ø, and may be 40 to 65 fm. long. For deeper water longer bridles are preferred. They are connected by shackles with swivels to the warps and the strops of the danlenos or the legs, respectively.

If danlenos are used, they are of the usual wood/iron construction and about 1·3 m. long. The charging weight at the lower end is 15 to 20 kg. A strop of 2 to 3 fm. length is provided for the attachment of the bridle, whilst the legs are fixed to two iron loops near each end. The danlenos may often be omitted. In this case, two additional legs, 5 to 6 fm. long, lead from headline and lastrich (or its legs) on the one hand, and from the ground rope (or its leg) on the other hand, to the point of connection with the bridle. These additional legs must have good swivels to avoid fouling.

The legs are made of combined rope of 12 to 14 mm. ø. The length may vary considerably, i.e., between 4 and 16 fm. Sometimes the legs may be omitted. Headline,

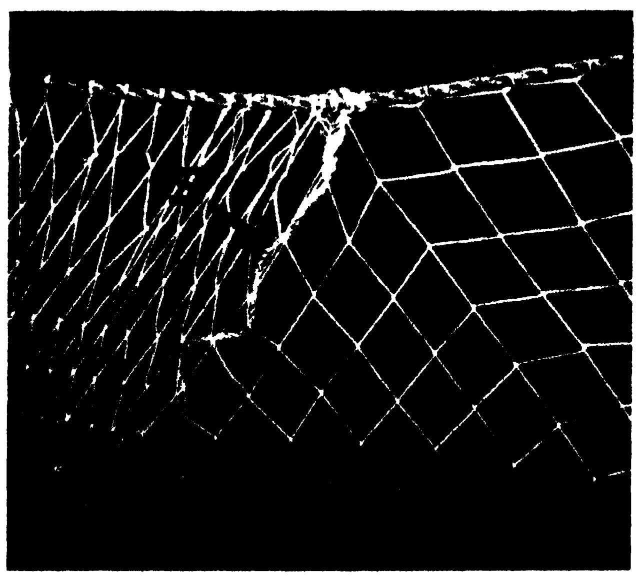

Fig. 19. Direct attachment of the net to the headline. S Strengthening rope, fixed on the halfer.

lastrich, and ground rope are then fixed to the danlenos directly. As with the herring otter trawling gear, headline and lastrich are then attached to the upper loop, and the ground rope to the lower loop of the danleno.

The headline, usually is made of combined rope of about 12 mm. ø, and has eyesplices at both ends for connection to the legs or the danleno. As bolshlines are not used, the net is attached to the headline directly (fig. 19). For lifting, a varying number (25 to 35) of floats (aluminium, plastic, or glass, 8 in. ø) are distributed over the whole length. Kites or false headlines are not normally used.

The ground rope, also, of combined rope is of 14 to 16 mm. ø. Like the headline, it has eyesplices at both ends. It is not served with ropes and the net is fixed on directly. For charging, iron rings are used in practically the same way as described for the otter trawling gear. If legs are used, an additional weight of 8 to 10 kg. is usually attached to each wing end at the point of connection with the legs.

The lastrichs are strengthened down to the codend by combined rope of 10 to 12 mm. ø. For the lastrichs of the codend itself, manila rope of about 14 mm. ø is preferred. If triangular shaped wing tips are used, the wing ends of these strengthening ropes must extend the netting sufficiently to compensate the greater lengths of the headline and the ground rope. The ends have eyesplices for connection with the legs or the danleno.

Usually, 140 to 160 ft. nets are used with this type of gear. A scheme for the construction of such nets is given in fig. 20. It must be mentioned that the measurements as given are only examples and do not cover all the variations which are in use. These nets are constructed of machine-made netting. The material is

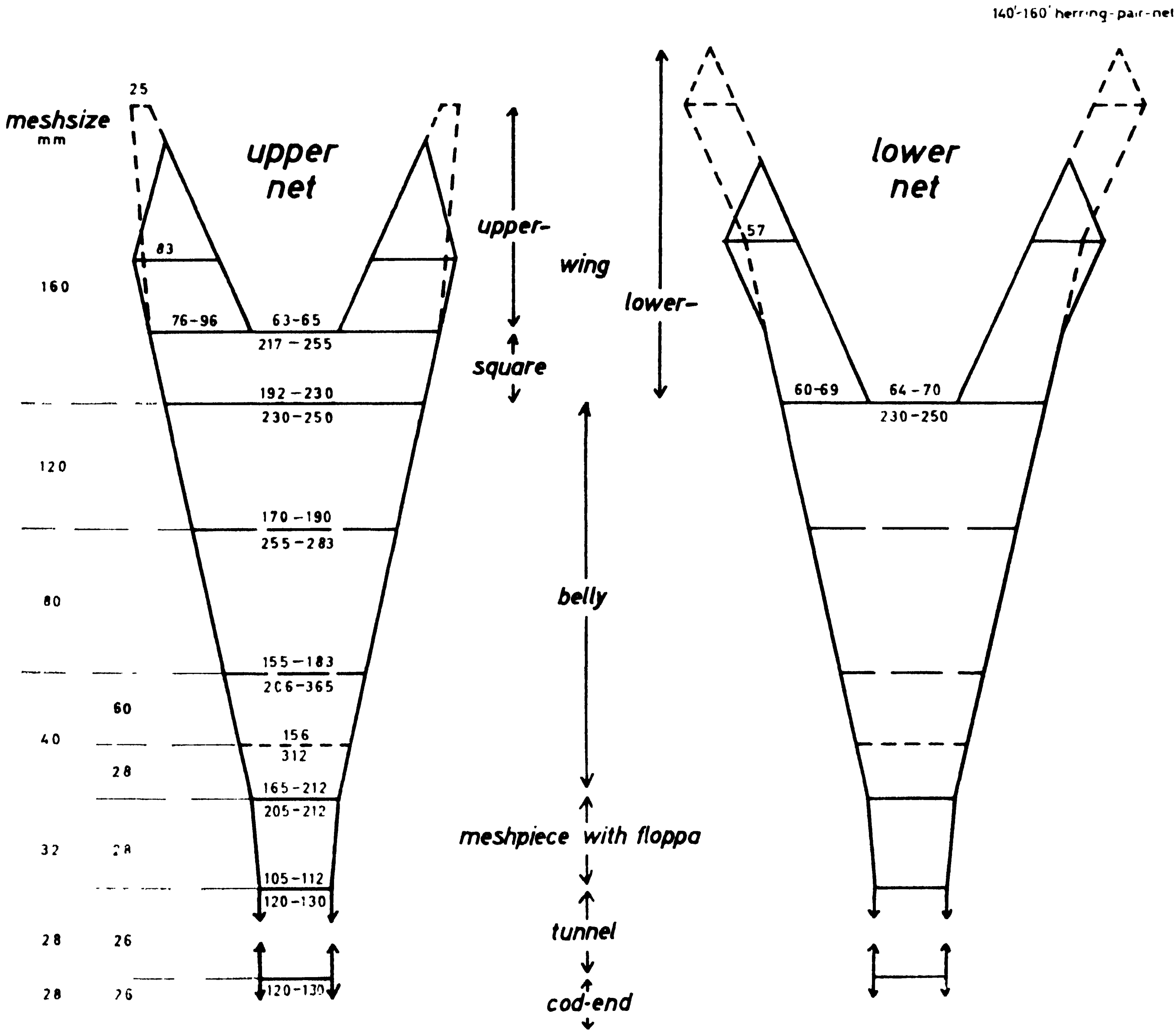

Fig. 20. Construction plan of 140 to 160 ft herring pair-trawls

cotton or synthetic fibres. The following twine strengths are suitable for the different parts:

Part of the net	*Breaking strength (wet)*
Upper wing	14 kg. (30·9 lbs.)
Lower wing	14 kg. (30·9 lbs.)
Square	14 kg. (30·9 lbs.)
Belly	6·6 to 11·0 kg. (14 to 24·3 lbs.)
Tunnel	8·5 to 12·5 kg. (18·7 to 27·6 lbs)
Codend	14·0 to 17·5 kg. (30·9 to 38·6 lbs.)

These values are almost the same as for the otter trawl gear except that the tunnel and codend are usually more strongly made to cope with the bigger catches obtained by pair fishing with such big nets. However, the twine strength is much lower, although the nets are as large as those used in big trawlers. This results in lower towing resistance, saving of material, and better catching ability.

As is customary, the headline side of the upper wings is fly-meshed or cut on the halfer. The lastrich side is usually not straight, but either runs in the same slant as the side edges of the square or at least has some creasings. The length may vary between about 11·0 and 12·5 m. There are types with straight terminal edges of about 25 meshes in width, and others terminating in one mesh. The latter are constructed in the same way as already described for the triangular shaped tips of some herring otter trawl nets. The mesh size is about 160 mm.

The square has the usual trapezium form. The mesh size is the same as in the upper wings. The length may be about 4 m.

The ground rope side of the lower wings is fly-meshed or cut on the halfer. The lastrich side may run partly the same way as the side edge of the square. More creasings have then to be inserted in the remaining part to gain the necessary length. The lower wings usually end with a triangular-shaped part which terminates in one mesh. The real lastrich, in which upper and lower net are connected, does not extend further than the point where these triangular pieces begin. The side edges opposite the ground rope, which are fly-meshed or cut on the halfer, are then attached to the fishline. This fishline, usually, is made of combined manila wire rope of 10 to 12 mm. ø.

In the belly the mesh size has to be diminished considerably. It usually consists of 4 to 5 sections not only with different mesh size, but with different twine strength and also a different baiting rate. The total length of the belly amounts to about 26 to 28 m. This means that it is longer and the net is more slender than the herring net of big trawlers. The end of the belly may be 105 to 112 meshes wide including the mesh piece. The floppa is inserted in the last section of the belly. It may be trapezium or rectangular and is inserted in the same way as already described for the other types of cutter nets.

The tunnel, as usual, is rectangular. As its mesh size usually is a bit smaller than in the last section of the belly, the number of meshes in the width must be correspondingly higher. The total length may be 5 to 6 fm. If the rest of the net is made of cotton, for the tunnel and codend synthetic fibres are preferred.

The codend usually has the same mesh size, and also the same number of meshes in width, as the tunnel. A smaller mesh size has to be used for catching smaller fish than herring, i.e. sprat. In this case, the number of meshes in width must be correspondingly higher. The total length may be 5 to 6 fm. The same type of heaving codend is used as described for the herring otter trawling gear.

The method of cutting such nets out of machine-made netting is almost the same as described for the herring otter trawling gear. The only difference arises with the long-winged type. But the length of such wings is a multiple of the square length so that they can be easily cut with the square and the lower wings from the same cale of webbing.

This last type of cutter gear can be considered as the most progressive and effective. Pair fishing seems to be an economical method, particularly for boats with lower engine power. The catch, usually, is more than twice that which each cutter could obtain by otter trawling.

SHRIMP TRAWLING GEAR AS USED IN THE GULF OF MEXICO

by

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Abstract

In place of the usual 80 to 100 ft. single trawl, typical trawlers (about 67 ft.) have started to operate two trawls, each about 45 ft. headline, from outriggers on each side. These two otter trawls may be of the *flat* or the *balloon* type. A three-drum winch is used, with one drum for each trawl, and one for the try-net. The boats operate to a depth of 30 fm. A typical *Campeche* shrimp trawler makes 6 to 7 trips per year and obtains an average catch of about 90,000 lb./year of 21 to 25 lb. shrimp, heads off basis. The complete gear is described in detail.

Le Dispositif pour la pêche des cervettes au chalut dans le golfe du Mexique

Résumé

Au lieu du simple chalut habituel de 80 à 100 pi. (24,38 à 30,48 m.), les chalutiers typiques (d'environ 67 pi., soit 20,43 m.) ont commencé à trainer deux chaluts ayant chacun une corde de dos de 45 pi. (13,72 m.) environ, à l'aide de tangons montés de chaque côté. Ces deux chaluts à plateaux peuvent être du type *plat* ou *ballon*. On utilise un treuil à trois tambours, un tambour chaque chalut et un pour le chalut d'essai. Les bateaux pêchent à une profondeur de 30 br. (54 m.). Un chalutier à crevettes, typique de Campêche, accomplit jusqu'à 6 ou 7 sorties par an et fait une pêche moyenne d'environ 90.000 lb./an (40.820 kg./an), de crevettes de moule 21 à 25/lb. (47 à 55/kg.), crevettes étêtées. Tout le dispositif est décrit en détail.

Redes de arrastre para la pesca de cameron utilizadas en el golfo de Mexico

Extracto

En lugar de la red única de 80 a 100 pies de longitud utilizada correintemente, los arrastreros tipicos (alrededor de 67 pies) han empezado a trabajar con dos redes de arrastre, cuya relinga superior tiene 45 pies, operadas desde batangas situadas a los costados. Estas redes de puertas pueden ser del tipo *plano* o de *globo*. Se utiliza una maquinilla con tres tambores, usando dos de estos para las redes de arrastre y otro para la red de sacar muestras. Los barcos actúan a una profundidad de 30 brazas. Un barco tipico de tipo Campeche dedicado a la pesca de camarón hace de 6 a 7 salidas al año y obtiene una captura media de unas 90.000 libras de camarones por año siendo el tamaño de éstos equivalente a 21 a 25 ejemplares sin cabeza por libra. Se describe con detalle el arte completo.

THERE have been broad and significant changes during 1957 in the gear of the Gulf of Mexico shrimp trawler. Briefly, the typical 67 ft. trawler, working in waters to a depth of 30 fm. for pink and brown shrimp, has abandoned the usual single trawl towed off the starboard outrigger and has switched to towing two smaller trawls, one port and one starboard.

In place of the usual 80 to 100 ft. single trawl the typical trawler now tows two 40 to 45 ft. trawls and finds that:

(a) the gear is easier to tow and handle;
(b) the gear is safer for the crew;
(c) the two trawls produce more shrimp per unit of effort than a single large trawl;
(d) gear losses from wrecks and *hangs* are lower as only one trawl is usually involved and cost of repair or replacement is lower.

Handling two trawls simultaneously is done by using longer out-rigger booms, usually about 24 ft. long, constructed of heavy duty steel pipe with ½ in. wall thickness, braced by external welded struts.

The typical shrimp trawler has always fished from out-riggers rather than from a gallows frame and so the change merely involves longer and stouter out-riggers. Instead of using two $\frac{7}{16}$ in. trawl warps running to the single trawl, the vessel now fishes each pair of doors on a long bridle, with a single trawl cable spliced into each bridle.

The typical trawler is equipped with a three-drum winch. The top drum handles the port side warp, the bottom drum handles the starboard side warp, and the centre drum is reserved for the try-net, the 8 ft. trawl with miniature doors which is used to locate the shrimp. Both nets are set and lifted simultaneously, generally on a straight automatic pilot course. The port trawl is fished about 25 fm. behind the starboard trawl to avoid the possibility of fouling. The winch man engages both winch drums to take up his gear and commences hauling. The starboard trawl is taken in first, using a long boat hook to reach out for the *lazy line* attached to the codend. The codend is then lifted over the rail by means of the winch barrel and dumped on deck. By this time, the port trawl is ready for the same procedure.

The two smaller trawls actually catch more shrimp

Fig. 1. A typical mass-produced 67 ft. American shrimp trawler, showing the trawling outriggers in the raised position. Note external bracing of outrigger booms. This vessel's main propulsion engine develops 150 h.p.

than an equal size single trawl. Since towing speed is generally higher with the smaller trawls, it is possible that the increased production is merely the result of covering more ground. This is not believed to be the whole story and the answer may well lie in the reaction of the shrimp to the trawl itself.

The two trawl rig has not been generally adopted for catching white shrimp, which have a tendency to assemble in small schools, so that much manoeuvring is required to stay in the shrimp. Many white shrimp vessels on the Atlantic coast are still using a single trawl rig.

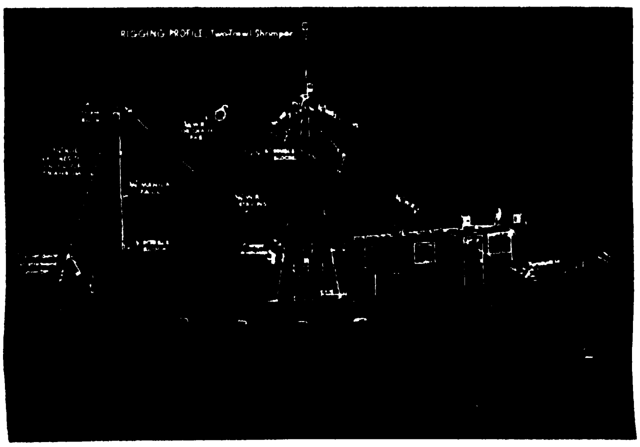

Fig. 2. Rigging profile of a typical two-trawl shrimper. On a 67 ft. vessel, the outrigger booms average 24 ft. in length.

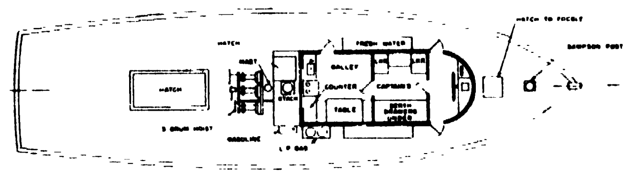

Fig. 3. Deck plan of a 67 ft. American shrimp trawler showing location of 3-drum trawl winch in relation to deckhouse.

TRY-NET

The feature which distinguishes the American shrimp trawler from almost any other trawler in the world is the try-net, the small trawl equipped with miniature doors which is used to sample the bottom for shrimp before the main trawl or trawls are put overboard.

The try-net is fished from a small davit on the stern of the vessel.

As it is light and easily handled, it can be set, towed for 2 to 5 min., and lifted, all by one man. A competent captain keeps his try-net fishing, even while his regular gear is set, to ensure staying in the shrimp. This is particularly important in the white shrimp fishery. An experienced captain soon learns how to interpret his try-net catch, which may consist only of two or three shrimp, in terms of what it will produce in his large trawl and is also able to evaluate the presence of trash fish on the shrimp grounds.

As power is required to handle this small trawl with ease, the try-net accounts for the fact that virtually all shrimp trawlers are equipped with three-drum winches. In the case of a two-trawl vessel, the centre drum on the winch is usually reserved for the try-net.

DOORS AND WARPS

A typical 150 h.p. two-trawl vessel is equipped with 125 to 150 fm. of $\frac{7}{16}$ in. steel galvanised wire rope on two

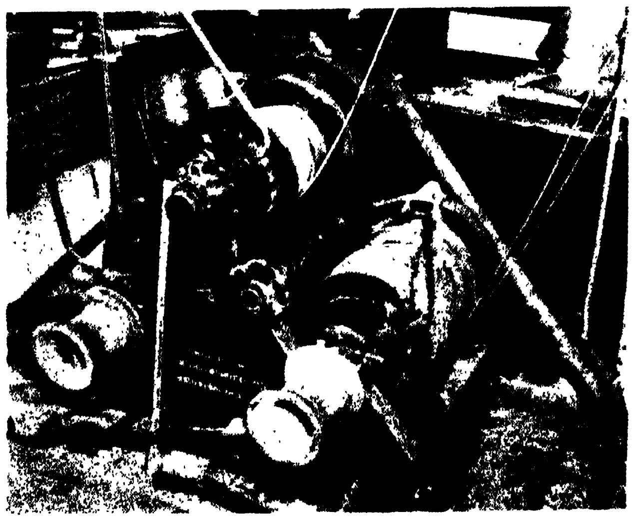

Fig. 4. A new 3-drum winch especially developed for two-trawl operation, which is more compact and efficient than the common units. The top drum handles the try net and the other two drums one trawl each. The bridles are wound up on the winch drum.

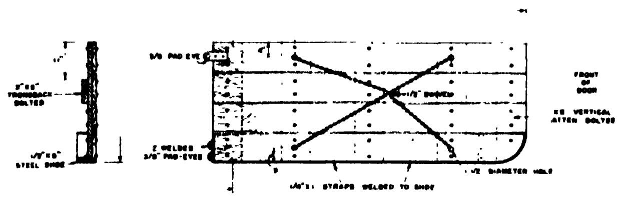

Fig. 5. Construction details of standard 84 in. by 32 in. trawl door used on two-trawl shrimpers.

drums of the winch and a shorter length, generally the same type, on the centre drum for the try-net.

Two light trawl doors, approximately 84 in. long by 32 in. high, rigged with chains and 15 to 20 fm. wire rope bridles, spread the 42 ft. trawls, which may be the conventional flat net or the balloon trawl. The doors used by the United States shrimp fleet are much lighter in construction than doors used in other fisheries. Their relative lightness makes them easy to handle by small crews and they have been successfully used for many years.

Fig. 5 shows the construction of a typical shrimp door 84 in. long by 32 in. high, normally supplied to the Gulf of Mexico shrimpers using the two trawl system. The door is constructed of 1¼ in. pine timber, planed on both sides to a thickness of 1 in. Other size trawls require larger or smaller doors; for example, a 100 ft. flat net will require a door approximately 144 in. long by 45 in. high.

The American fisherman normally buys his doors by the pair, completely rigged and ready to fish. However, by studying the illustration, the construction on the door can be readily deduced. The formula generally used for spacing the chain bridles is as follows:

L is the total length of the door, in inches.

$\frac{L}{4} - 1$ is the distance in inches from the front of the door to the centre of front chains.

$\frac{L}{4} \cdot 2$ is the distance in inches between the front and rear chains.

$\frac{L}{4} + 1$ is the distance in inches from the rear of the door to the rear chains.

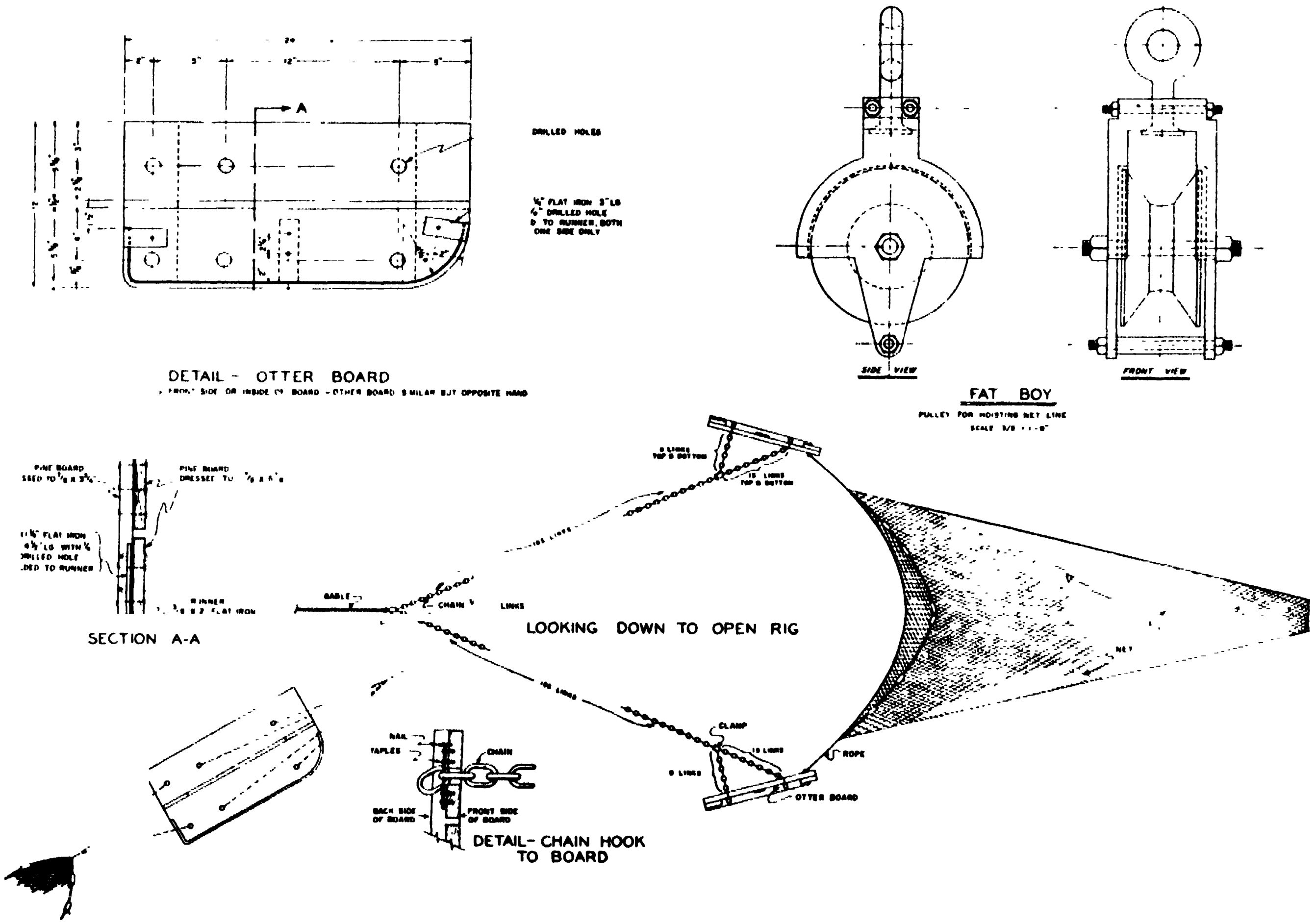

Fig. 6. Constructional details of the try-net gear.

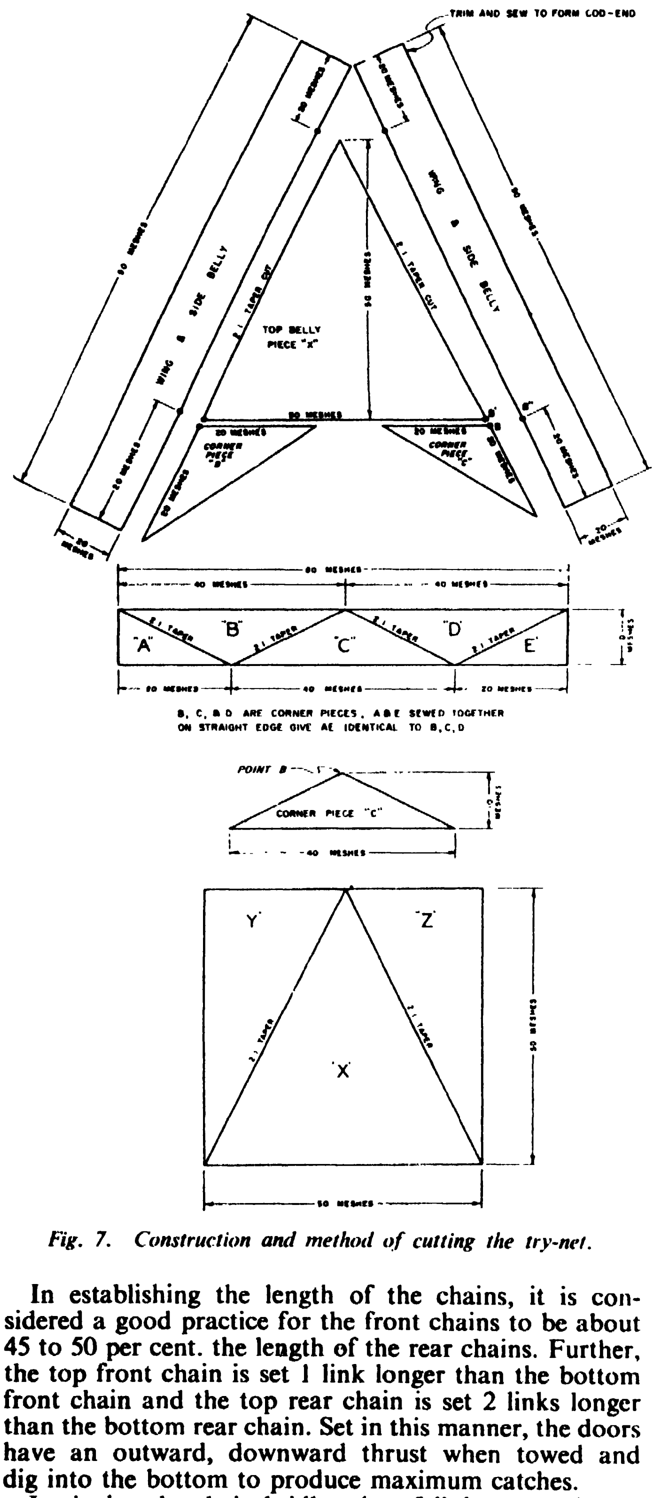

Fig. 7. Construction and method of cutting the try-net.

In establishing the length of the chains, it is considered a good practice for the front chains to be about 45 to 50 per cent. the length of the rear chains. Further, the top front chain is set 1 link longer than the bottom front chain and the top rear chain is set 2 links longer than the bottom rear chain. Set in this manner, the doors have an outward, downward thrust when towed and dig into the bottom to produce maximum catches.

In rigging the chain bridles, 4 or 5 links are added to each length of chain so as to provide for adjustment as needed. The chain settings shown in fig. 7 are counted from the inner face of the door to the $\frac{3}{8}$ in. shackle attached to each length of chain. The 4 end shackles are all hooked into a $\frac{1}{2}$ in. swivel on each door. The towing bridle is attached to the swivel.

The usual criterion for efficient performance is the polishing of the steel shoe plates; if these develop rusty or dirty spots it can be assumed that the doors are not fishing properly and should be adjusted. Adjustment is quickly made by lengthening or shortening the chains by means of slotted steel plates or locks on the outer face of the door. The $\frac{3}{8}$ in. proof coil welded chain used today is galvanized and weighs 168 lb./100 ft. It has an outer length of $2\frac{1}{32}$ in. per link and averages 9·75 links/ft.

BLOCKS AND BOOMS

The trawl blocks for handling the warps are of particular importance. They must have a broad, gently V-shaped cross section so that splices, bridles, etc., will pass over them freely, permitting the leading edge of the trawl door to come up to the block. The blocks should be galvanised and the sheave flame-hardened and mounted on heavy roller bearings.

In rigging the out-rigger boom topping lifts, care must be taken to insure that the trawl block, in fishing position, is at least 12 ft. off the water under calm conditions, otherwise the out-riggers will dip into the water when the vessel rolls. As, in the raised position, the heavy out-riggers affect the stability of the vessel, they are generally lowered into fishing position when running from one fishing ground to another. Many vessels also mount their out-riggers on the mast by means of a revolving pin so that the out-rigger forestays can be slacked in rough weather and the booms lowered to the after deck for safety.

The trawler's main topping boom must be securely stayed to withstand the extra stresses involved and it is customary to install a welded steel ladder from the tip of the topping boom to the centre of the transom caprail. This ladder is also useful in clearing a fouled block or doing repairs on the boom itself.

NETS

Three common shrimp trawls are shown in figs. 8, 9 and 10. There are innumerable variations in size and construction, depending upon the area, size of vessel and type of shrimp. As this discussion is concerned with the typical two-trawl Gulf of Mexico trawler, emphasis will be placed on the 40 ft. flat trawl. Individual variations of this size will be found from 43 to 45 ft. in width.

Fig. 10 shows a 40 ft. no-overhang trawl, i.e., the headline of the trawl rides directly over the footrope. Many fishermen prefer to make their nets with 12 to 18 meshes of overhang so that the headline precedes the footrope, the theory being that the shrimp will leap upward when disturbed by the footrope and strike against the forward-projecting top of the trawl.

In hanging this net, which is one of the simplest to construct, $\frac{5}{16}$ in. manila rope is used for both headline and footrope. Three meshes are caught per hanging, with ties spaced about $4\frac{1}{2}$ in. About 4 in. between the headline and the webbing and about 6 in. between the footrope and the webbing are considered standard measurements. Three-inch corks are spaced across the headline, 1 every 10 ties; 4 oz. leads are added to the

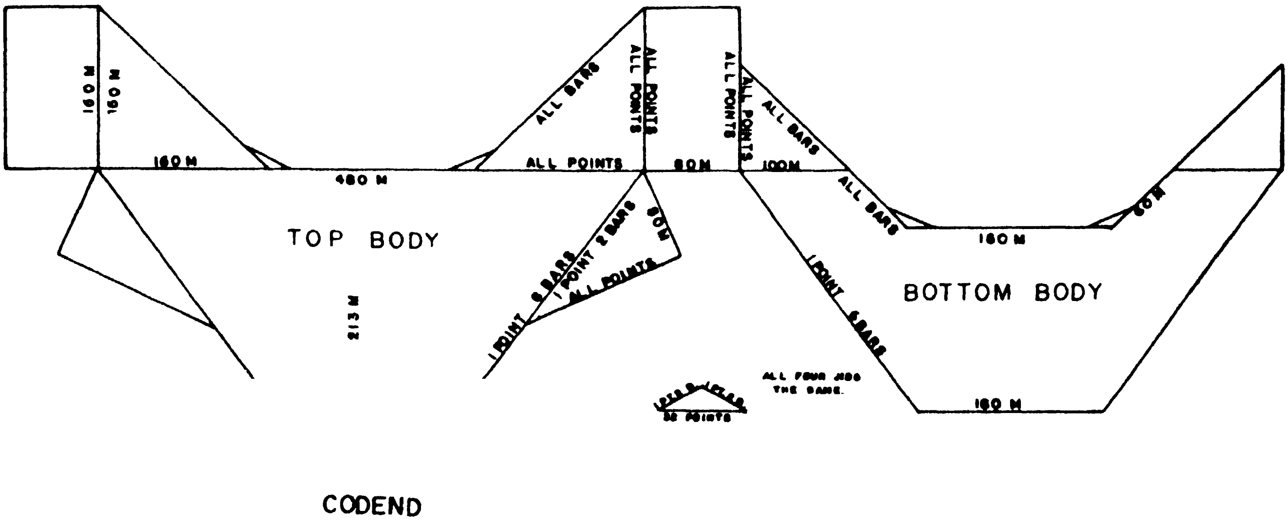

Fig. 8. Construction diagram of typical 74 ft. Balloon trawl for single trawl operation. Wings, body, dogears and jibs are 18-thread, 2½ in. stretched mesh cotton webbing. The codend is 42-thread, 2 in. stretched mesh cotton webbing.

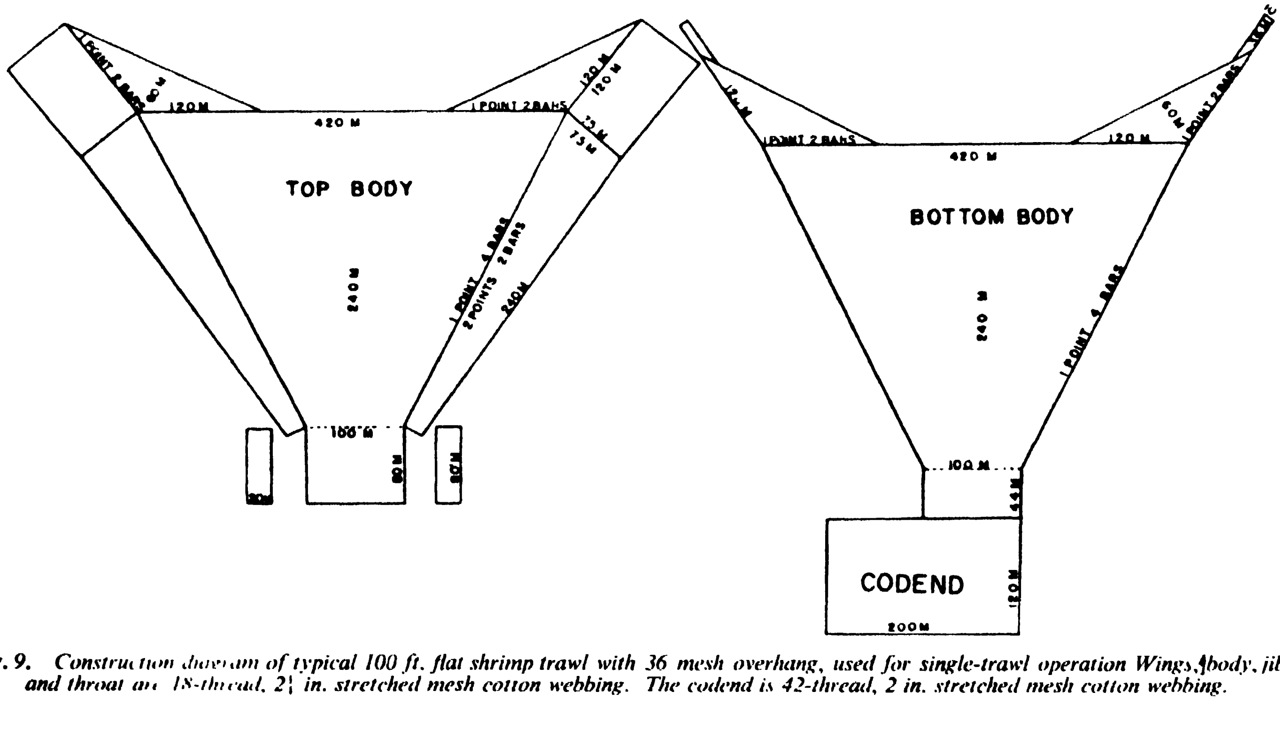

Fig. 9. Construction diagram of typical 100 ft. flat shrimp trawl with 36 mesh overhang, used for single-trawl operation Wings, body, jibs and throat are 18-thread, 2½ in. stretched mesh cotton webbing. The codend is 42-thread, 2 in. stretched mesh cotton webbing.

ground rope as required, generally 1 every 5 ties in the body and 1 every 3 ties in the jibs.

PRODUCTION

The typical 67 ft. Campeche shrimp trawler averages 6 to 7 trips per year from the coast of the United States to the fishing grounds off the coast of Yucatan Peninsula, Mexico. An average catch for a well-equipped vessel with a capable crew is about 90,000 lb./year of 21 to 25 per lb. shrimp, heads off basis, but many vessels fall short of this production. With the advent of the two-trawl system, many owners are examining the possibility of using larger vessels with greater horse-power, capable of handling larger nets, i.e. two 70 ft. balloon or flat trawls instead of the conventional 45 ft. size.

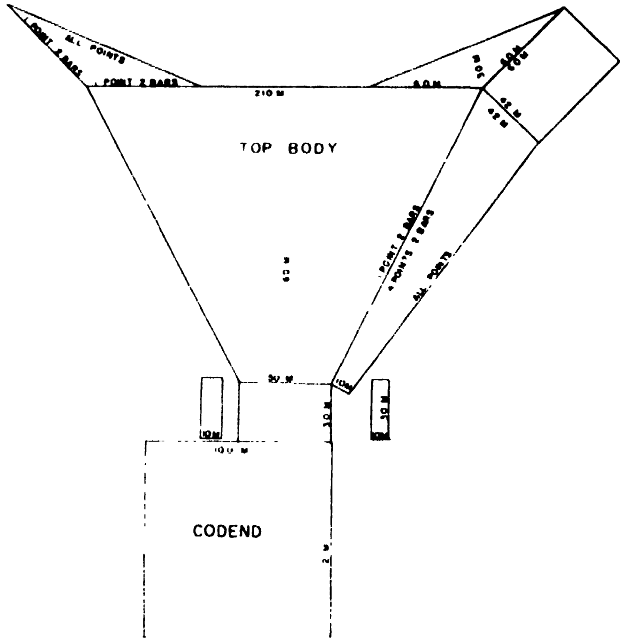

Fig. 10. Construction diagram of a 40 ft. no-overhang flat trawl. Wings, body, jibs and throat are 15-thread, 2¼ in. stretched mesh cotton-webbing. Codend is 42-thread, 2 in. stretched mesh cotton.

A small shrimp trawler on the U.S.A. Gulf Coast.

TRENDS IN TRAWLING METHODS AND GEAR ON THE WEST COAST OF THE UNITED STATES

by

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Abstract

Most of the changes that have taken place in the otter trawling fleet since the introduction of the V.D.-method have occurred since the last war, the most spectacular ones being the assimilation of electronic devices such as depth finders, Loran, radar, and fishfinders.

The high cost of radar slowed down the installation of this device but about 25 per cent. of the off-shore trawlers are now equipped with instruments using 3 or 10 cm. wave-lengths. The value of C.R.T. fishfinders has not yet been properly assessed because there seems to be some difference of opinion as to their ability to locate and increase catches and it is felt that too much interpretation is left to the fisherman. One important result of the use of electronic devices has been the expansion of the fishing grounds, and the average maximum fishing depth has increased from 144 fm. in 1952 to 280 fm. in 1956. In addition to these post-war innovations two other mechanical devices, the Trawl Cable Meter and the Drum Trawl technique have been developed, but, notwithstanding all these, the skill and intelligence of the skipper and crew are still the key factors governing the efficiency of the fleet.

Evolution des méthodes et engins de chalutage sur la côte occidentale des Etats-Unis

Résumé

La plupart des changements intervenus dans la flotte des chalutiers depuis l'introduction de la méthode V.D ont eu lieu depuis la dernière guerre; les plus importants ont consisté dans l'utilisation d'appareils électroniques tels que les sondeurs, le Loran, le radar, et les appareils à repérer le poisson.

Le prix élevé du Radar a freiné l'emploi de ce dispositif mais à l'heure actuelle 25 pour cent environ des chalutiers de haute mer sont équipés d'appareils fonctionnant sur des longueurs d'onde de 3 ou 10 cm. La valeur des détecteurs de poisson équipés de lampe à rayons cathodiques n'a pas encore été établie avec précision car les avis sont partagés sur leur aptitude à localiser le poisson et à augmenter le volume des pêches et l'on considère qu'une trop grande marge d'interprétation est laissée aux pêcheurs. Un des résultats importants obtenus à l'aide des appareils électroniques a été l'extension des lieux de pêche, et la profondeur maximum moyenne de pêche est passée de 144 brasses en 1952 à 280 brasses en 1956. Outre ces innovations d'après-guerre, on a mis au point deux autres dispositifs mécaniques, l'appareil de mesure du câble de chalut et le tambour de chalut; mais en dépit de tous ces perfectionnements, c'est l'habileté et l'intelligence du patron de pêche et de son équipage qui sont encore les facteurs essentiels du rendement de la pêche.

Tendencias sobre métodos y uso de redes de arrastre observadas en la costa occidental de los E.U.A.

Extracto

La mayoría de los cambios experimentados por la flota de arrastreros desde la introducción del metodo V-D, turvo lugar después de la guerra, siendo el más espectacular el uso de dispositivos electrónicos como: ecosondas o localizadores de peces, lorán y radar.

El alto costo del radar demoró la instalación de este equipo, pero un 25 pour cent de los arrastreros de altura cuenta ahora con instrumentos que usan ondas de 3 o 10 cm. de longitud. El valor de los localizadores de pèces con tubos de rayos catódicos no ha podido evaluarse en forma adecuada porque, al parecer, existen ciertas diferencias de opinión en cuando a sus posibilidades para localizer y aumentar la pesca, creyéndose que se deja demasiada interpretación al pescador. Resultados importantes del uso de disposibtivos electrónicos han sido el aumento de la superficie de explotación de los bancos de pesca y de la profundidad máxima de captura desde 144 brazas en 1952 a 280 brazas en 1956. Además de estas innovaciones de posguerra se han ideado otros dos dispositivos mecánicos: el medidor de la longitud del cable de arrastre y la de técnica recoger la red de arrastre mediante un carretel. No obstante esto, la habilidad e inteligencia del patrón y de la tripulación son todavia los factores principales que regulan la eficacia de la flota pesquera.

OTTER trawlers from ports along the Pacific Coast operate in the offshore waters from Santa Barbara, California (U.S.A.) northward to Hecate Strait, British Columbia (Canada), a distance of nearly 1,500 miles. The vessels are mostly converted seiners and halibut schooners from 45 to 100 ft. in length (figs. 1 and 2), the average being about 60 ft. The fish capacity of these trawlers is about 33 short tons. Three or four-man crews are used although five and six-man crews were common during the war years. Almost all West Coast trawlers use gallows placed, one on each side, near the stern. Normally the net is shot directly over the stern and hauled in over the starboard side.

The use of the seine or schooner-type trawler has allowed operators to convert and rig quickly for salmon, halibut or albacore whenever these fisheries may be more lucrative. Because of the seasonal nature of the fisheries, trawling has been a part-time "off season" operation for many vessels.

ELECTRONIC AIDS

The more important changes in fishing gear and methods influencing the efficiency of trawling, following the adoption of the Vignoron-Dahl fishing method, have evolved during the last 10 to 15 years. The most spectacular trend – one which has occurred in major fisheries throughout the world – has been the assimilation of various electronic devices developed and/or modernized during World War II. An important consequence of this trend has been the increasing dependence of trawl fishermen on this equipment. Depth recorders, Loran, radar, and fishfinders, which represent post war refinements in ultrasonic techniques, are all carried aboard the better equipped vessels.

DEPTH RECORDERS

The use of echo sounders aboard West Coast trawlers preceded World War II and Scofield (1948) reported 25 per cent. of the California trawl fleet was equipped with them by 1947. Practically all offshore trawlers were using them by the end of 1948 and reliance on the device had become so complete that the failure of the echo sounder meant a return to port for most trawlers.

LORAN

Interest in war surplus Loran sets increased in 1949, especially in the Pacific Northwest (U.S.) where adverse weather conditions made accurate offshore navigation difficult. The advantages of precise fixes for trawl fishing were quickly recognized and by 1954 Loran was being used by most trawlers fishing between Eureka, California, and the Canadian border.

The adoption of Loran resulted in a new era and methodology for the West Coast trawl fishermen. Precise navigation increased the effectiveness of trawling and it was especially important in making deep-water fishing a profitable operation. The rugged submarine topography of the offshore grounds had previously made their exploitation difficult and at times unprofitable. Loran, coupled with echo sounders, gave trawlers the accuracy needed to define and maintain their position while fishing.

Since 1954, Loran has so completely dominated the navigation and fishing of trawlers that reference to trawl grounds is seldom related to prominent headlands or banks but more often as a "Loran microsecond" reading. Loran readings have in many instances replaced other methods of recording position in trawlers' log books and the practice of towing by time intervals has been discarded by some skippers in favour of towing actual distances as measured by microsecond intervals.

RADAR

Incorporation of radar progressed somewhat slower and the first sets were not installed until 1954.

The trawl fishermen were well aware of the safety

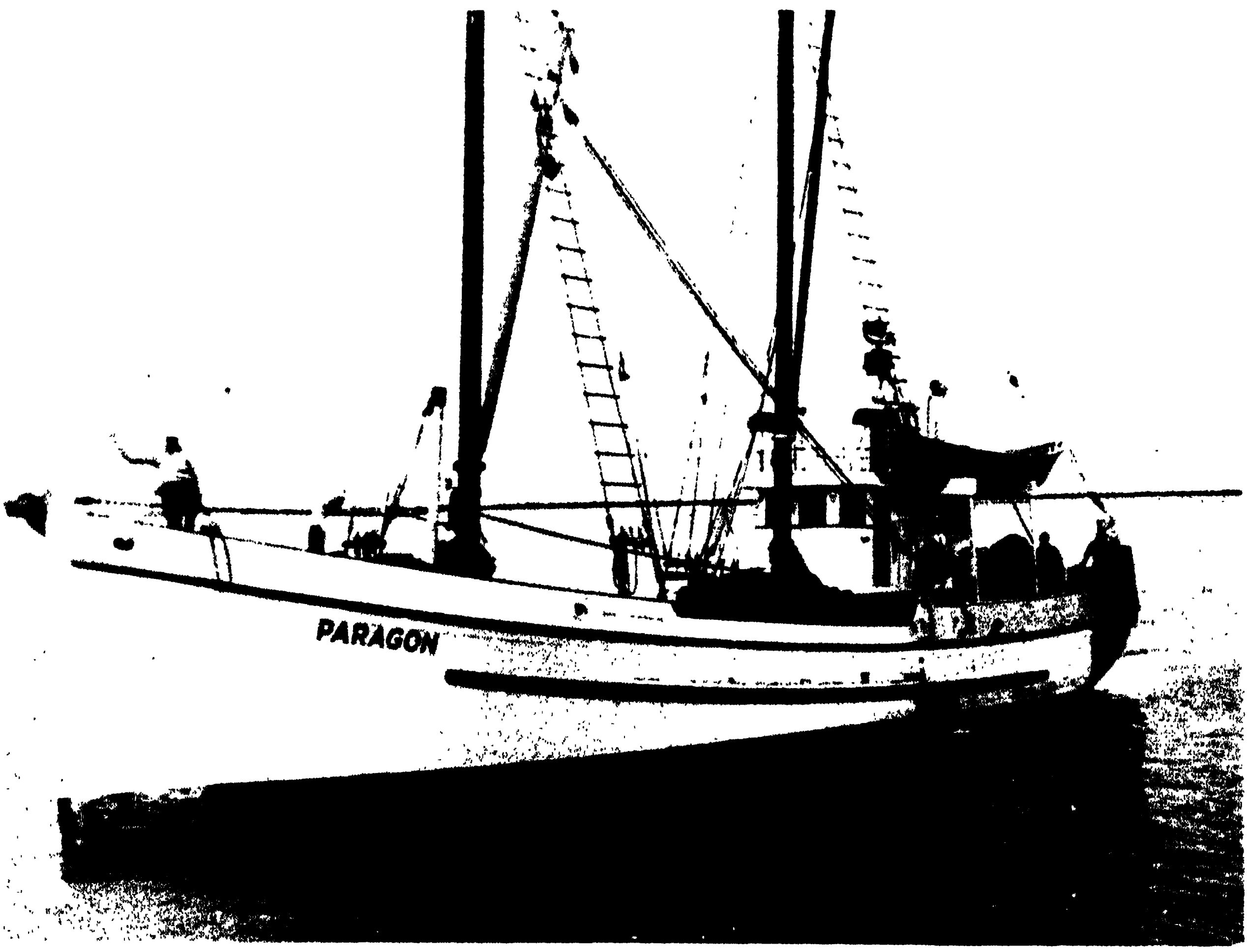

Fig. 1. Schooner type trawler (Neah Bay, Washington).

advantages of this device and the possibilities of "around the clock" fishing. Apparently, the basic cost has been the major reason why radar has not been installed aboard a larger number of vessels. In the Pacific Northwest area about 25 per cent. of the offshore trawlers are now equipped with radar, using wave-lengths of 3 or 10 cm.

FISHFINDERS

The cathode ray tube presentations, which allow the operators to select and expand the echo trace for a particular depth interval, have been adopted by only a small portion of the fleet. The ability of these devices to locate fish and increase catches is not as yet definite and mixed opinions exist between trawl fishermen who have used them. Interpreting echo traces requires considerable experience, and increased yields which might result from the ability of these devices to detect ground fish is dependent on the operator's proficiency, as they leave considerably more for the fishermen to evaluate than either Loran or radar. In spite of this handicap, some skippers who have used fishfinders are convinced of their ability to locate schools of cod or rockfish.

DEEP WATER TRAWLING

It is difficult to asses the individual or cumulative effect that various electronic devices have had on the trawl fisheries. It is obvious, however, that accurate offshore navigation, the ability to survey quickly the bottom contours, and to maintain desired depths and position, have increased the fishermen's knowledge of fishing grounds and subsequently the ability to harvest ground fish. These aids have undoubtedly played an important rôle in the recent expansion of trawling to deeper waters along the continental slope. Active deepwater trawling started off the Northern Californian coast shortly after World War II and, by 1950, trawlers were prospecting deeper banks off the states of Oregon and Washington. Increased deep-water fishing is demonstrated by records maintained by the State of Washington Department of Fisheries. Prior to 1950, less than 5 per cent. of the annual catch was estimated to have been caught at depths greater than 100 fm. By 1954, close to 25 per cent. of the total catch was being harvested at depths ranging between 100 and 200 fm., and during 1956 trawlers often reported catches at depths exceeding 250 fm. Off

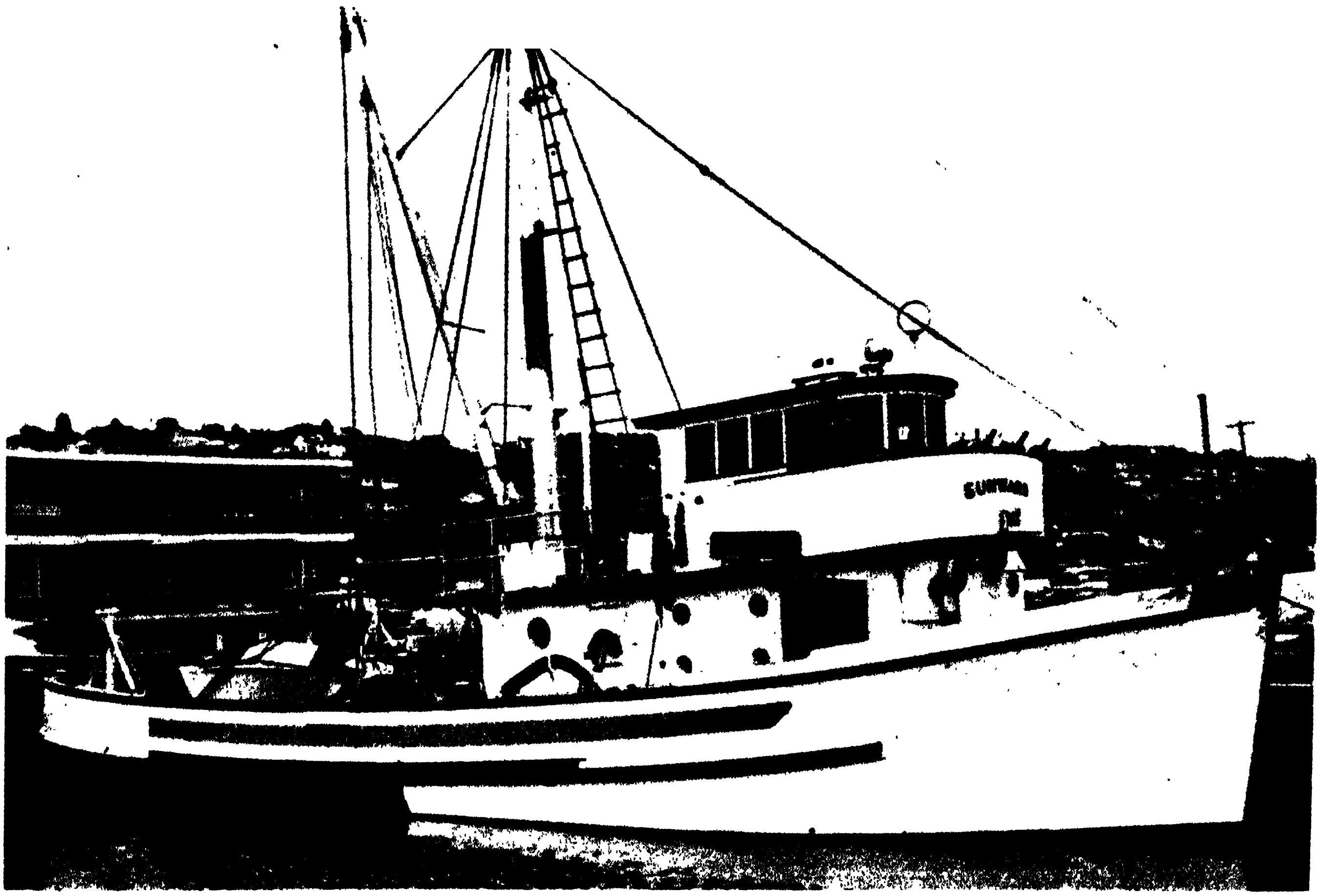

Fig. 2. Seiner type trawler (Seattle, Washington).

Eureka, Californian vessels have prospected at depths exceeding 300 fm. This expansion to offshore grounds was made feasible and practical by electronic aids.

NETS

Trawl nets in use along the Pacific Coast vary considerably in size and design according to the geographic areas and racial background of the fishermen. Both the eastern two-piece net and the western four-piece trawls are common and, in Central California, fishermen of Italian descent use a modification of the paranzella net for otter trawling. Nets vary in cut, twine size, width and length according to fisherman preference but are essentially similar to nets used in all the world's major trawl fisheries. Cotton nets have been in use since the inception of the fishery, but the use of imported manila and hemp nets has increased during the past five years. Between 1950 and 1953, nylon codends were tried on board several northwest trawlers, but the gravel and hard bottom, which are typical of many trawl grounds in this area, caused serious abrasion and wear of the nylon and most fishermen returned to the use of cotton.

The only notable change in net usage has been the adoption of larger meshed nets or codends in conformance with mesh regulations promulgated by Pacific Coast fisheries agencies. A minimum of 4½ in. stretched mesh (with minor variations between States) is now adopted as a regulation along the Pacific Coast.

MECHANICAL AIDS

Two innovations of trawl gear developed since 1950, and unique to the Pacific Coast States, are the trawl cable meter and drum trawlers. Both were pioneered and developed in the Puget Sound area of Washington State.

CABLE METER

The first trawl cable meter was designed around the specific needs of Puget Sound trawlers by the Olympic Instrument Laboratories, Vashon, Washington. The meter, which has become increasingly popular among local fishermen, replaces the use of cable markers to determine the amount of warp spooled off winch drums.

Fig. 3. *"Drum Trawler"* Sunbeam. *Stern view (Seattle. Washington).*

DRUM TRAWLERS

During 1954 several Puget Sound trawlers changed over to this method. Drum trawlers use a power driven drum similar to that used with the "drum seine", but with a somewhat smaller spool. In operation, the otter boards are brought to the gallows, the wings of the net shackled to the reel core, and spooled on the drum. The codend is picked up in the conventional manner, with slight variations. The drums are powered by hydraulic drive and are designed with four speeds forward and reverse. Operators of drum trawl vessels report that they can fish in heavier weather and can haul the net more quickly than the conventional trawlers. Drum trawling has eliminated restacking the net and no lifts of the net are necessary prior to bringing the catch aboard. The drum trawl method of fishing has been patented and its use up to the present time has been restricted to vessels owned by the designers.

SUMMARY

Progressive changes which have occurred in a group of Puget Sound trawlers from 1952 to 1956 are summarized below.

The addition of better fishing gear, new net designs, electronic aids, increased mechanization, better vessel design and increased power have all combined to increase trawl efficiency. Theoretically, boat efficiency might be expressed (mathematically) as the cumulative total of the efficiency contributed by each item to the fishing effort. The most important variable in such an equation, which influences the efficiency of any item or the total efficiency of the gear and vessel, is the *experience of the crew and skipper*. Fishing knowledge, experience, and intelligence, therefore, remain the *key factors*.

TABLE I

Gear changes for 20 trawlers fishing during 1952 to 1956 (Puget Sound area)

Equipped with	*Number and percentage of vessels equipped with indicated electronic devices* 1952		1955		1956	
	Number	*Per cent.*	*Number*	*Per cent.*	*Number*	*Per cent.*
Echo sounder	20	100	20	100	20	100
Radio D/F	17	85	19	95	19	95
Loran	6	30	20	100	20	100
Radar	0	00	5	25	5	25
Fishfinder	0	00	4	20	5	25
Cable meters	0	00	2	10	6	30
Drum trawlers	0	00	2	10	3	15

	1952	*1955*	*1956*
Average maximum fishable depth	144	240	280
Average maximum h.p.	144	152	158
*Average number of meshes in circumference of net (at throat)	406	370	370

*Smaller number of meshes resulted from increase in mesh size.

STERN TRAWLING VERSUS SIDE TRAWLING

by

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Abstract

This paper concerns the problems connected with stern trawling and also gives account of the reasons which have led to the development of this type of operation. Design of the vessel and arrangement of the deck-gear are inseparable from the operations of shooting and hauling of the gear. The author describes the deck arrangement of auxiliary gear, together with the mode of operation on board different types of stern trawlers: the *Fairtry* and the *Fairfree*, built in Britain, and the *Puschkin* class, the *Heinrich Meins* and the *Carl Kämpf* built in Germany. The advantages of the transverse gantry with roving pulleys, over the usual gallows are especially pointed out.

Comparaison du chalutage par l'arrière et du chalutage sur le côté

Résumé

L'auteur examine les problèmes que pose le chalutage par l'arrière et expose les raisons qui ont conduit à la mise au point de ce type de pêche. Les plans du bateau et la disposition des engins de pont sont conditionnés par les opérations de mise à l'eau et de relevage du chalut. L'auteur décrit la disposition des appareils auxiliaires sur le pont ainsi que la manoeuvre à bord de quatre types différents de navires équipés pour le chalutage par l'arrière: le *Fairtry* et le *Fairfree*, construits en Grande Bretagne, les bateaux de la classe *Puschkin*, le *Heinrich Meins* et le *Carl Kämpf* construits en Allemagne. Il souligne tout particulièrement les avantages du portique transversal à poulies coulissantes, sur les potences conventionnelles.

El arrastre de la red por la popa y por el costado de la embarcación

Extracto

Este trabajo trata de los problemas relacionados con el arrastre de la red por la popa y describe las razones que han inducido a perfeccionar este tipo de operación. El proyecto del barco y la distribución del equipo de cubierta son inseparables de las maniobras que requiere el calamento y recogida de la red. Por este motivo, el autor describe la distribución y funcionamiento del equipo auxiliar montado en la cubierta de cuatro tipos de arrastreros que remolcan la red por la popa: el *Fairtry* y el *Fairfree*, construidos en Gran Bretaña, el *Puschkin*, el *Heinrich Meins* y el *Carl Kampf* en Alemania, haciendo notar las ventajas de un puente transversal con poleas de vaivén sobre los pescantes de arrastre comunes.

THE design of trawlers is undergoing a fundamental change at present. Instead of the single-deck trawler arranged for handling the gear over the side, recent developments point towards the use of shelter-deck vessels arranged for handling the trawlgear over a ramp at the stern. This rather radical deviation from a fishing method which had become standard practice throughout most of the world, was caused by the desire to convert trawlers, designed exclusively for catching and transporting the fish, into factory-trawlers. Processing of the catch, the increased number of men required and the placing of additional machinery, raised space problems, the solution of which required either sacrificing fish hold capacity or gaining space by adding a shelterdeck, or a "semi-shelterdeck", i.e. on one side only or a trunk deck.

All these proposals, however, when combined with the usual method of handling the net over one side of the ship, meant difficulties in placing the trawl-winch and leading the warps and, moreover, seriously curtailed the space on the working deck for handling the catch in a continuous flow.

The "side trawler" must heave the gear on the windward side to avoid drifting over the net. In this position she is parallel to the waves, which, of course, in bad weather causes heavy rolling of the ship. These "intended" movements are of material assistance to the crew when pulling in the belly of the net but are, at the same time, a serious disturbance when the trawler is fitted out with conveyor belts and processing machinery.

Such considerations caused the British designers of factory ships to search for ways and means of handling the trawl gear over the stern. It took quite a while to overcome the scepticism of the conservative fishermen towards this new idea but, due to the successful trials on the British factory trawler *Fairtry* and the numerous Russian factory trawlers of the *Pushkin* class, developed by the Howaldtswerke, Kiel, the way is now paved for a more general application of the stern handling method. The fear that the fish would be squashed when pulling the codend up over the stern-ramp proved unfounded. The normal round-fish required neither roller conveyors (as proposed by the Stülckenwerft, Hamburg), nor a lifting platform at the stern (proposed by Dr. Lehmann) nor an inclined conveyor belt (proposed by the writer for sardines), nor a large diameter roller at the upper end of the ramp as used on the *Fairfree* and the *Fairtry* (proposed by Sir Dennis Burney). Instead, a simple ramp, without any moving parts, proved absolutely sufficient when having a parabolic cross section at the lower end and a large-radius rounding at the deck end.

The method of handling the intricate trawl gear over the stern has, however, caused many difficulties. All yards and owners have tried various ways and have, when possible, put them under patent protection. The most difficult problem to solve was a method of shifting the pull of the warps from the gallows to the stern ramp and vice versa.

On the *Fairfree* and *Fairtry*, auxiliary wires (sweepline gilsons) were used to haul the sweepline from the trawl-doors to the ramp while, at the same time, the warps were slackened (see fig. 1a).

The complete manoeuvre of hauling is carried out as follows: The warps, leading from the gallows at the side of the stern and over two fairlead bollards to the winch drums, pull the boards up to their lifted position. The boards are then hung up and disconnected from the warps and sweeplines, which are connected by the pennants. On each side of the slip-deck and the ramp, auxiliary wires (sweepline-gilsons) are carried around the corresponding sides of the stern, connected to the forward end of the sweepline and heaved in by means of warping heads on the ends of the trawl winch. At the same time the warps are slackened to the necessary extent. This manoeuvre heaves the net on to the main deck until the danlenos reach the winch. The free length of deck is about 20 to 25 m. (70 to 80 ft.) which is not sufficient to heave the entire net aboard in a single operation as the net is about double this length. The sweeplines are therefore clamped to the deck to free the warping drums for a second pull - again by means of gilsons - until the codend has been hauled on deck.

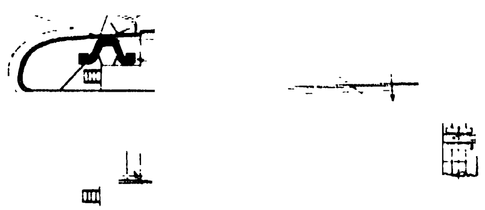


Fig. 1a. Arrangement of using sweepline-gilsons on the Fairtry *(patented).*

On the *Fairfree*, which is a converted corvette of the British Navy, the deck runs continuously, with small sheer right through from stem to stern. The deck is rounded off on the sides of the ramp and underneath the gallows, which are placed to both sides of the stern and inclined over the sides. An observation bridge for directing the manoeuvres is arranged right over the ramp (fig. 2). To reduce the friction of the net, the top end of the ramp was fitted with a long roller of large diameter. Vertical fairlead rollers flank the sides of the gap between the low end of the ramp and the observation bridge to guide the warps when fishing along "steep edges" where much turning is required. These rollers, proposed by Sir Dennis Burney, are useful also for leading the various wires between the gallows and the ramp.

The experience of the *Fairfree* formed the basis for the design of the *Fairtry* which has since become the prototype of subsequent factory trawlers. *Fairtry* has a shelterdeck extending almost her entire length, which ends in a step down to the main deck shortly forward of the gallows. The gallows are placed at both sides near the stern but somewhat further forward than on the *Fairfree*. The fishing observation bridge is placed forward of the upper end of the ramp, and the vertical fairlead rollers at the low end of the ramp are omitted (see fig. 1b). The 24 factory trawlers of the *Pushkin*-class followed in 1954/55.

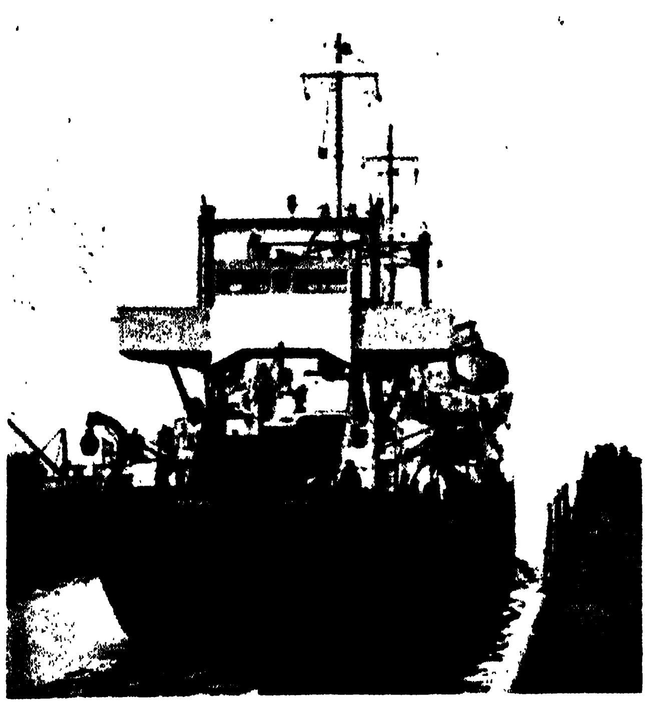


Fig. 1b. Stern view of the prototype factory trawler Fairtry.

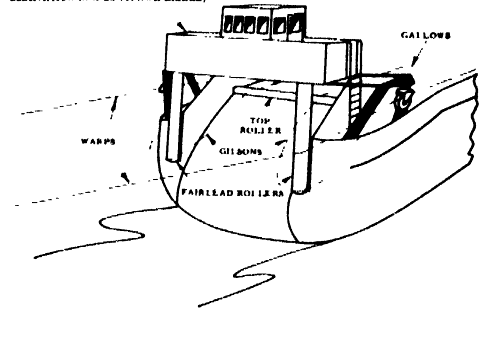


Fig. 2 Safety rollers for stern-ramp on Fairfree, *acc. to* Burney *(patented).*

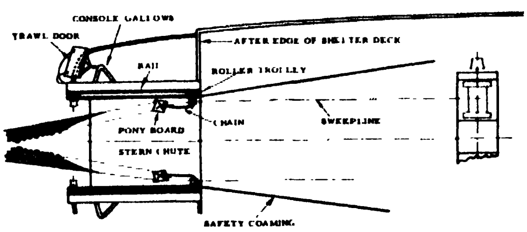


Fig. 3. Leading warps with roller-trollies acc. to method of "Kieler Howaldtswerke AG." (patented).

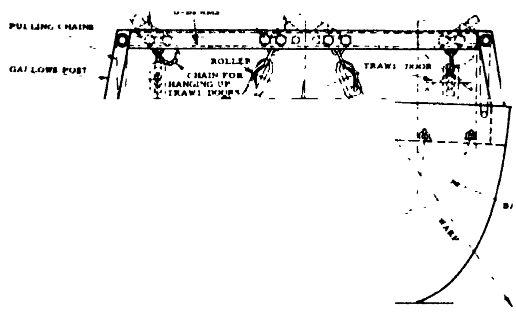


Fig. 4. Transversely movable gallows rollers on "Portal-Gallows" acc. to method patented by "GHG", Bremerhaven.

Here again we find the shelterdeck ending shortly forward of the stern with a step down to the main deck. The ramp rises from the water surface to the height of the shelterdeck. Instead of leading the warps over gallows rollers, they are supported by rollers attached to trollies which run on horizontal rails fitted to either side of the ramp and extending to the rear end of the vessel (fig. 3). This arrangement keeps the deck and the ramp clear when the warps are fastened or unshackled from the boards and allows shooting the trawl gear from the ultimate rear end of the vessel, which is considered a desirable convenience.

After the net has dropped down the ramp by its own weight, it is drawn away from the ship by the wake of the vessel and pulls the trollies, to which the danlenos are fastened by a chain and slip-hook, to the rear end of the rails where they are blocked. Then the chains from the danlenos are released, the sweeplines are run out, and the warps are connected to the boards which are hung ready for fishing. By running out the warps further the boards spread the net while sinking down to the bottom.

The tension on the warps, their downward and forward pressure on the rollers, allows the trollies to move automatically forward to their initial position as soon as they are unblocked. The whole manoeuvre of shooting takes place without the least deviation from the fishing course and much time is saved.

The trawl observation bridge on the *Pushkin* trawlers was combined with the bridge deck, forming its rear end. The manoeuvres of the gear on the slip deck can be easily observed and the captain can move quickly from the navigation bridge to the trawl observation bridge.

In reviewing the above arrangement, the costs cannot be overlooked which makes desirable a simpler design for smaller stern trawlers. On two such trawlers built in 1956-57 by the Rickmerswerft in Bremerhaven, the shelter-deck was carried continuously, i.e. without step to the vessel's stern. On both vessels the portal-gallows rollers design was again used, the ramp is the same and the trawl boards are hung up against the flat sections of the stern on either side of the ramp. The face of these flat sections is inclined torward from the water to the deck and fitted with guide bars for the boards.

The first of these two boats, the *Heinrich Meins*, built for the GHG in Bremerhaven, shows a gantry-shaped gallows (fig. 4) extending from one side of the ship to the other. The gallows rollers are hung on trollies which traverse between two horizontal U-beams. The trollies can be blocked in side position when the trawl boards are hung up and also in a position near the centre line of the ship. They are moved between these two positions by a system of pulling chains and sheaves. When shooting the trawl gear, and during the trawling operation, the gallows sheaves are in their central position and support the warps. This leaves the deck and the ramp free for the net. Before hauling the net, the sweeplines can be thrown down from the open gallows blocks to the ramp by an eccentric movement of the sheaves and conical slip irons. Towing-up gilsons are used for lifting the warps into the gallows sheaves. The trollies for the gallows sheaves are moved into their position near the ship's side when lifting and hanging up the trawl boards after hauling, and when fastening the warps and sweeplines to the boards before shooting.

Two Voith-Schneider propellers drive the *Heinrich Meins* from under the fore-ship. This feature allowed the super structure, with the navigating bridge, to be placed so far forward that a free upper deck of about 50 m. (160 ft.) length came behind the superstructure. The net can be hauled up on this deck in a single heave, thus saving the time of a second heave by means of a gilson.

The transverse gallows rollers were considered too expensive and too complicated for rough service on the still smaller trawler, *Carl Kämpf*. Though the overhead gantry is used, the gallows sheaves have a fixed position over the places for the trawl doors, which permits a relatively simple handling of the gear, as compared to the handling aboard side trawlers.

Hauling of the sweepline gilsons could be done as on *Fairfree* and *Fairtry* by using the side barrels, but—in order to save time—two special sweepline gilson drums have been fitted between the warp drums. The danlenos can be hauled on deck up to the trawl winch by these drums. Then it is possible to heave in the rest of the net with gilsons worked over the barrels on the ends of the winch (see fig. 5a).

The latest improvement is a special hauling block, installed high enough so that the codend can be hauled in line with the slope of the ramp.

On the rather small *Carl Kämpf*, the superstructure for the navigating bridge is so short that the trawl observation bridge is arranged immediately behind the chart-room (see fig. 5b).

At present opinions differ concerning the various alternative methods of handling the trawl gear over the stern. It must be left to practical experience in the future to find a standard solution to this problem, combining simple, rugged construction, simple handling and easy control.

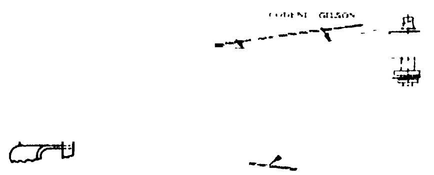
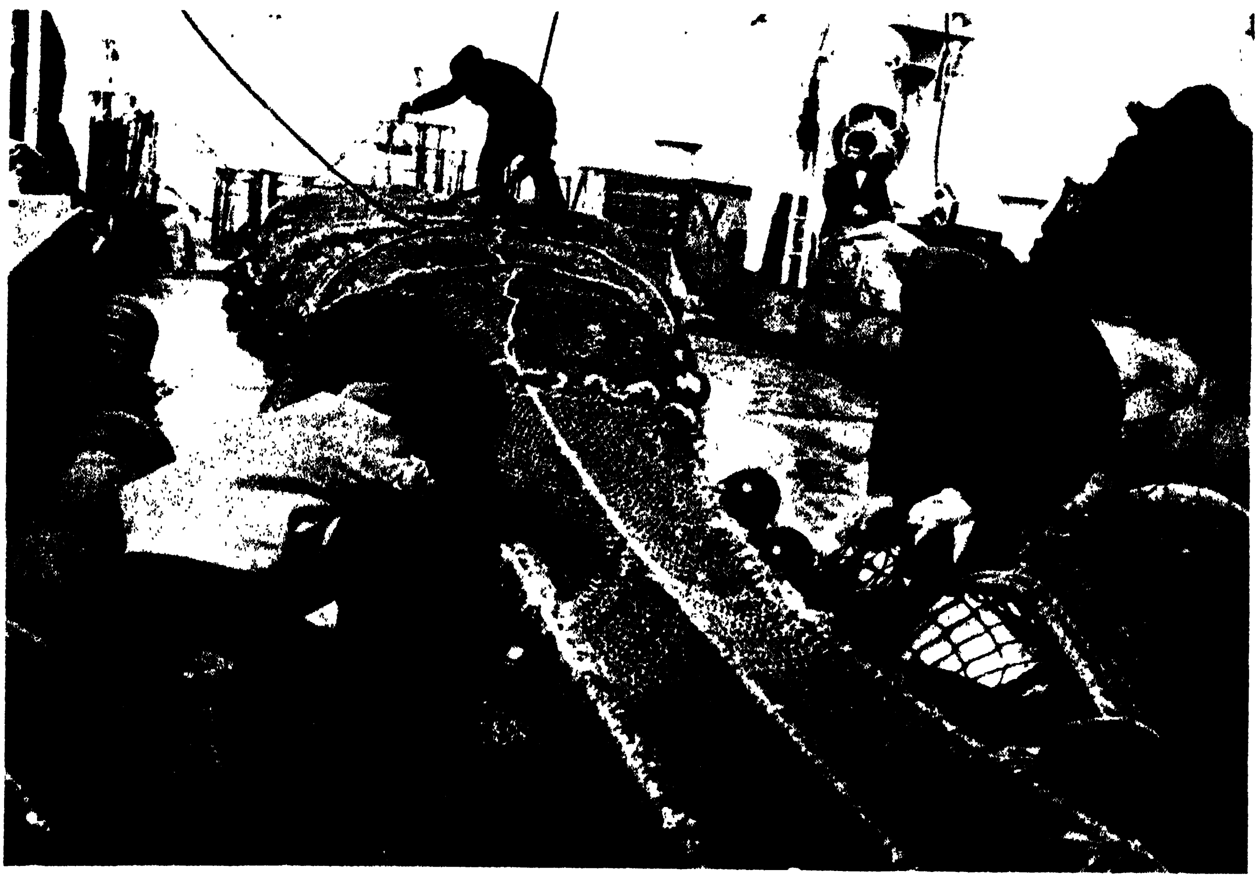


Fig. 5a. Leading warps with "Portal-Gallows" and sweepline-gilsons acc. to method of "Rickmers Werft", Bremerhaven (patented).

Fig. 5b. The stern-trawler Carl Kämpf *on trials.*



Hauling the codend over the stern chute of a large Russian factory trawler.

POWER REQUIREMENTS FOR DEEP SEA TRAWLING

by

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Abstract

With the present methods of preservation of the fish and the present rates of capture, the point has almost been reached beyond which increases in speed of long distance trawlers will be uneconomic, but if improved preservation methods were available, the optimum speed might change.

In order to get the maximum economic advantage from up-to-date freezing methods, it may be necessary to design ships with machinery which has a power output only slightly in excess of that needed for trawling, since the need for very fast runs to market would be reduced. Observations of the h.p. developed under various fishing conditions were made on three different trawlers and the tentative conclusion is that about 600 s.h.p. are required for a deep sea trawler towing the trawl, and a maximum of 750 or 800 s.h.p. are needed for running free. This paper should provoke discussion on the economics of deep sea trawling.

La puissance nécessaire pour le chalutage hauturier

Résumé

En raison des progrès réalisés dans la préservation des poissons et l'efficacité des engins de pêche, on a presque atteint la limite au-delà de laquelle l'accroissement de la vitesse des chalutiers hauturiers n'est pas rentable; mais si l'on pouvait améliorer les méthodes de préservation, la vitesse optima pourrait s'en trouver modifiée.

Pour tirer le maximum d'avantages économiques des systèmes modernes de congélation, il peut être nécessaire de dessiner des navires dont la machinerie n'a qu'une puissance légèrement supérieure à celle qu'exigent les opérations de chalutage, car la nécessité des retours à très grande vitesse au port de débarquement serait moins impérieuse. Des observations de la puissance en c.v. absorbée dans différentes conditions de pêche ont été effectuées sur trois chalutiers et l'on a conclu provisoirement qu'un chalutier hauturier avait besoin d'une puissance de 600 C.V. environ pour tirer le chalut, et un maximum de 750 à 800 C.V. pour naviguer. Cette étude pourrait servir de document de base à des débats sur l'économie du chalutage hauturier.

Potencia requerida para la pesca de arrastre en aguas profundas

Extracto

Con los métodos actuales de preservación del pescado y el volumen de las capturas casi se ha alcanzado un punto sobre del cua seria anti-económico aumentar la marcha de los arrastreros de altura; no obstante al disponer de métodos de conservación adecuados podría cambiarse la velocidad óptima.

A fin de obtener al máximo beneficio económico de los modernos sistemas de congelación, seria necesario proyectar barcos con maquinaria de una potencia ligeramente superior a la requerida para las faenas de arrastre, por reducir la necesidad de viajes de regreso rápidos a las bases de operaciones.

A bordo de tres arrastreros de altura diferentes se hicieron observaciones para determinar la potencia desarrollada en las diversas condiciones de pesca, llegándose a la conclusión provisional de que un barco de este tipo requiere 600 C.V. al freno en el lance y un máximo de 750 a 800 C.V. durante la navegación normal. Se estima que este trabajo debe provocar una discusión sobre los aspectos económicos de a pesca de arrastre.

THE efficiency of exploitation of a fishery can be measured by such criteria as the weight of fish landed per man-day of effort, per ton of fuel consumed, per unit of capital employed and per unit cost of maintenance of ship and fishing gear. By converting each of these into monetary terms it is possible to establish both a basis for economic analysis of the fishing operations and a criterion of overall efficiency.

The design of the fishing gear and its method of use affect the rate of catch; in addition, such factors as distance of the fishing grounds and method of preservation of the fish can affect the number of crew, the fuel consumption and the size of the ship.

The interaction of catching rate, distance and method of preservation is well known. The ships of the British distant-water fleet return on average with about a half load of fish because of the limitations of crushed ice as a means of preserving the catch. The size of the ships is determined partly by considerations of weather; the real advantage of the larger ships is the ability to maintain speed in bad weather. Speed can reduce the time to and from the fishing grounds during which men and capital are idle, but causes increased capital outlay, maintenance costs and increased fuel consumption, the latter being the biggest single item in the costs of a distant-water trawler.

EFFECT OF PRESERVATION METHODS ON THE SPEED

Improvements to methods of preservation are usually directed towards the quality of the fish, but the economic benefits of improved quality are not easily forecast whereas additional costs of the new methods are often obvious. Freezing at sea, for instance, is more costly than the present method of icing. However, freezing at sea can give direct economic advantages, for instance, by increasing edible weight landed per unit of fishing effort e.g. by avoiding weight losses in stowage, condemnations, and the necessity to send surplus fish to the fish meal factory. Yet another possibility is that the use of a freezing plant would tend to reduce the need for high speed, and it was the examination of this point which led to the observations recorded below.

With the present size and quality of catches, the point has almost been reached beyond which increases in speed in long distance trawlers will be uneconomic, since the extra length and power required would make costs excessive in relation to the value of the landings. With an improved method of preservation the optimum speed might change. For instance, if the use of antibiotics in association with crushed ice were found to be feasible it would extend the keeping time or "shelf life" of the fish by some days, and the period of fishing might be extended. Speeds could then remain as high as at present, or they might even increase very slightly, since the extra catch might justify higher costs. If fishing were extended by a shorter period than the extension of "shelf life", as seems more reasonable, then some, or all, of the time gained might be used for only slightly slower but much more economical running from the fishing grounds to the home port.

Freezing renders the fish virtually imperishable and in this extreme case it would be necessary to consider Arctic trawler designs with the whole range of possible powers down to a lower limit set by the requirements of trawling. The optimum power for a given size of freezing trawler might be quite near the minimum; freezing plant uses up space and capital but this might be saved by adoption of smaller main engines and fuel tanks. It may be economically attractive to fit a freezing plant into a hull of 185 ft. b.p. or very little more. The adoption of freezing need not then bring the problem of physical size of ship and length of voyages associated with factory trawlers. Gradual development in size of ship can take place as and when this seems worth while.

The immediate problem is to determine what shaft horse power and thrust are really necessary in the trawling condition. Opinions seem to vary; a figure of 800 s.h.p. is often quoted as necessary for a long-distance trawler and often figures as high as 1,200 h.p. are mentioned. Knowledge based on actual records seems to be scarce.

Such knowledge would also be useful to the designer of multi-engined trawlers. It is desirable to trawl on fewer than the maximum number of engines available, and it would obviously be more satisfactory if the choice of engines could be such that those actually in use during fishing were running either at maximum efficiency or near maximum economic power.

TRAWLING POWER

Some efforts were made by the staff of the Torry Research Station to determine trawling powers. There was no attempt made at a systematic study of the effects of different gear, or varying depths, weather and catch, or of the design of propellers, since these subjects are not within the terms of reference, but some of the observations may be of interest to the appropriate research organizations.

Vessel A is the Sir William Hardy, a steel trawler of 130 ft. b.p. This is far smaller than a typical distant-water trawler, but the trawling gear itself is of the same size, perhaps slightly heavier. Special facilities were available for making accurate measurements of power and speed, so that the power developed by a larger trawler could be deduced from powers measured on this vessel when trawling and running free.

The readings were taken during a series of special trials conducted jointly by the British Shipbuilding Research Association, the Ship Division of the National Physical Laboratory and the Torry Research Station. The propulsion machinery is diesel-electric and power readings were taken by sub-standard electrical instruments specially fitted for the trials. Speeds were taken by the ship's Pitometer log, calibration curves for this instrument being available from the comprehensive measured mile trials which formed the greater part of the whole series. Wind speeds were measured by cup anemometer.

The trawling tests were carried out in fine weather in a depth of 30 fathoms on a smooth and level bottom of estuarine mud. The method was to tow at constant engine settings into, across and down the wind, the ship being kept on each course for a sufficient time to get a series of steady readings. On the fourth side of the square, the engine settings were altered to give increased trawling speed. In this way figures were obtained at three different speeds, using a trawl with a rope bosom. The highest speed runs were repeated, using the same trawl with 15 inch diameter spherical steel bobbins.

Fig. 1 shows the results which are recorded in Table I. The effects of tide have not been eliminated and this might explain why there is little difference in the performances across-wind and down-wind. The placing of the points relating to the run with bobbins is not compatible with those for the rope bosom, the down-

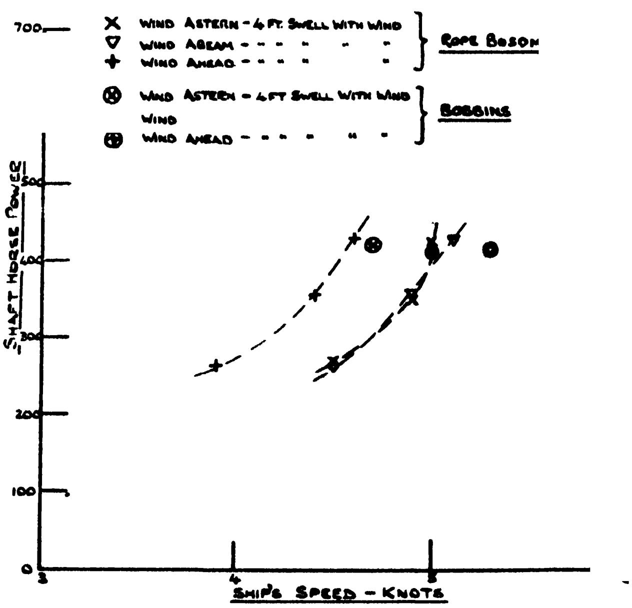

Fig. 1. Relation between power requirements and towing speed.

Table I

Series A

Ship's Speed Knots	*Shaft h.p.*	*r.p.m.*	*Depth fm.*	*Wind Speed and Direction off Bow*	*Sea*
	Trawl with Rope Bosom				
4·5	274	133·9	29	17·4K—180°	
4·5	266	131·7	29	22·4K -80°S	
3·9	264	131·9	32	23·2K—10°P	Moderate swell
4·9	352	146·5	29	15·5K 165°S	from about
4·9	356	145·3	30	23·1K—70°S	221° (true)
4·4	356	145·7	31	24·5K—10°P	wave height
5·0	426	154·9	29	11·0K -160°S	about 4 ft.
5·1	427	154·2	30	22·3K—70°S	
4·6	427	154·5	30	23·2K- 10°P	
	Trawl with Bobbins				
4·7	422	153·1	31	15·5K—165°S	Also choppy surface
5·3	419	152·9	30	21·8K-- 70°S	
5·0	418	154·3	32	21·5K—5°P	

wind being the slowest instead of the run into the wind. It was found that the bobbins had been digging into the mud so possible explanations are that the net gradually filled with mud during the runs, or that the bobbins dug in more at some times than at others.

The power required to drive the ship running free at speeds from three to five knots was measured in the speed trials and found to be 15 s.h.p. at 3 knots, 25 at 4 knots and 40 at 5 knots in a flat calm and at the condition of the trawling tests. Allowing for reduced efficiency, slight seas and change of trim, the power required to drive the ship alone (when trawling at 4 knots) would not be more than, say, 40 s.h.p.

It is proposed that these observations be supplemented by readings taken during normal voyages, this task being facilitated by the calibrated electrical horse power meters, logs and r.p.m. indicators. Some idea of the effects of depth and wind would then be obtained. As far as can be deduced from readings taken up to the time of writing, the extra torque required to trawl into a force 8 wind would result in an increase in power of less than 100 s.h.p.

In the meantime it has been possible to take readings during normal voyages in two commercial trawlers of about 180 ft. b.p. One trip was made in each vessel primarily for the study of fish spoilage, and readings of trawling powers and speeds were taken only when convenient.

Table II

Series B

Ship's Speed Knots	*Shaft h.p.*	*r.p.m.*	*Depth fm.*	*Wind Force and Direction off Bow.*
Approx. 3—4	475	100	—	2 to 3 — 45°S
	525	100	90-150	6 t o7 — 45°S
	320	90	—	6 — 145°P
	500	100	—	4 — 70°S
	560	100	—	6 to 7 — 0°
	390	92	90	3 — 70°S
	480	99	100	4 — 70°S
	500	95	60-80	5 100°S
	450	90	100	—
	500	95	—	6 —
	550	95	—	7 to 8 —
	500	95	—	2 to 3 —

Table II gives the readings taken on a trip to Iceland and Faroe in Vessel B, a diesel-electric trawler of 190 ft. b.p. The figures for ship's speed are very approximate and no great reliance should be placed upon them. The propulsion system had a variable-torque characteristic.

The level of power developed is not very different from that of the small ship in shallow water. A power of 560 s.h.p. was observed when towing into a force 7 wind.

Vessel C was a steam trawler of 181 ft. b.p. with triple-expansion engines and a Bouer-Wach exhaust turbine. The readings taken during a trip to Bear Island are given in Table III. Power was measured by a Siemens torsion meter and ship's speed both by SAL log and by timing the passage of a floating object.

Again, the general level of powers developed is similar to that in Ship A. Again, the torque probably varies from one reading to the next, since the normal engine setting when towing is well below maximum torque and the settings were varied to give constant r.p.m. as near as possible.

The last two tests in Table III were an experiment in which maximum torque was applied. It is interesting to note that nearly normal maximum power (which is 1,300 s.h.p.) could be developed under these conditions. In spite of the threefold increase in power, the speed of trawling rose by only 20 per cent. in relation to the most strictly comparable runs at normal settings. Judging by the other observations from ships A, B and C (fig. 2), the increase in power absorption is to be attributed to the propeller working at a point of low efficiency rather than to a sudden increase in the drag of the gear between 4·2 and 5·0 knots, but this is not conclusive; it is possible that a sharp increase in the drag of the gear used in ship C occurs at a lower speed than for the gear used by ship A.

The result would explain the opinions that 800 to 1200 horse-power is developed by a big trawler when fishing.

Table III

Series C

Ship's Speed Knots		*Shaft h.p.*	*r.p.m.*	*Depth fm.*	*Wind Force and Direction off Bow*	
Sal. Log	*Floating Object*					
3·5	—	435	78	—	0	0
3·4	—	406	76	170	0	0
3·5	—	462	79	230	0	0
4·2	—	417	78	80	0	0
3·4	—	405	78	- -		- -
3·8	4·0	380-425	78	160-180	0	0
3·2	3·27	480	80	76	4 —	45°P
4·3	4·2	430	78	76	4 -	45°P
4·0	—	412	77	76	4 —	180°
3·7	3·6	430	78	76	4 ·	180°
4·8	—	1230	110	100	0	0
5·2	—	1270	110	100	0	0

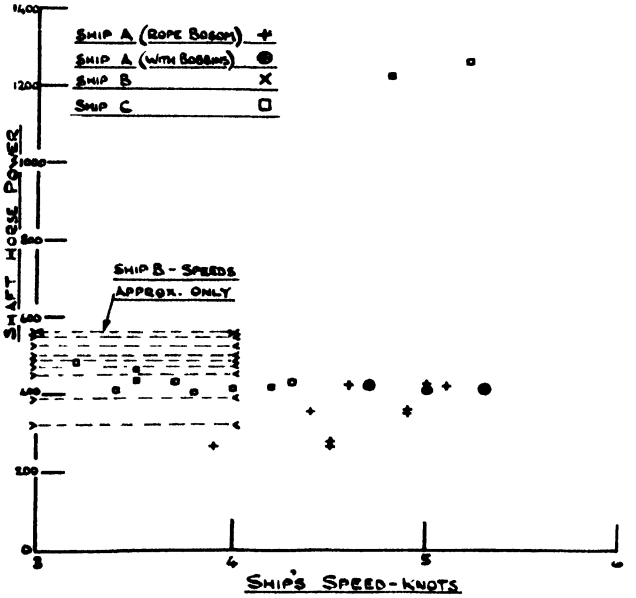

Fig. 2. Relation between power requirements and towing speed.

It had been assumed earlier by the author that these figures were rational deductions from the propeller r.p.m. known to be employed when trawling, on the assumption that maximum torque was used. It may be that in some cases high torques are used.

If some large trawlers do indeed have to develop 800 to 1,200 s.h.p. to trawl effectively, it indicates either great variation in the quality of propeller design, which is hardly likely, or in the rigging of the trawls. The experiment recorded above shows however that a vessel with a propeller of high enough efficiency in the trawling condition to allow of powers being kept as low as 400 h.p. can be operated so inefficiently that the power absorption rises to 1,250 h.p.

Since there is more than adequate torque for fishing available on a big trawler, the choice of engine settings is to a large extent at the mercy of arbitrary decisions. In British trawlers the skipper chooses the r.p.m. Many years ago the largest trawlers were steam vessels of the size and power (600 s.h.p. maximum) of the vessel A. Such a vessel had to develop maximum torque in order to produce the thrust required to trawl at acceptable speeds; the r.p.m. were then about two thirds to three quarters of the maximum r.p.m. when running free. As the ships have increased in size and power, the skippers have continued to trawl at the same r.p.m., and by many skippers r.p.m. is still regarded as a direct measure of power. It is possible that a slight improvement in efficiency in either the running free condition, or in the trawling condition, or in both, might be achieved if the designer of the propeller were allowed a free choice of r.p.m. for trawling. Ship's speed and the thrust required to pull the trawl at that speed would have to be known.

Guidance on the best speed for towing a trawl would be very welcome. Given favourable conditions, sufficient torque and a suitable propeller trawls could be towed at much higher speeds than usually achieved by large British commercial distant-water trawlers. It has been suggested that by towing too fast the configuration of the gear is upset or that the gear is lifted off the seabed. The skipper of ship C was unwilling to make the maximum torque tests as he expected the gear to be damaged.

CONCLUSIONS

The tentative conclusions to be drawn from the observations recorded in this paper are that a deep sea trawler towing a trawl of conventional design and with a suitably designed propeller needs to be able to develop 500 s.h.p., or 600 s.h.p. at most. Given constant-power characteristics a total power of 600 s.h.p. would be ample. Given constant-torque characteristics perhaps 750 or 800 s.h.p. maximum when running free would be required. Any power installed in excess of this figure should be economically justified by the extra speed it produces in service. The size of the ship has relatively little effect on the power requirements. It is quite easy to increase fuel consumption of a big trawler by a large amount with relatively little effect on the speed of the trawl. It is not known if this effect is due entirely to the propeller working at a point of low efficiency or to a sudden increase in the drag of the trawl, the increase occurring at lower speeds for some trawls than others. Information would be welcomed on the optimum speed of trawling and on the thrust required to tow the gear at that speed. Improvements in propeller design might follow as well as more accurate knowledge on the power requirements for deep sea trawling.

FLEET OPERATION OF TRAWLERS WITH A MOTHERSHIP

by

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Abstract

Two future possibilities in distant water fishing are the self-producing factory trawler and the big mothership with accompanying trawlers. The main drawback of the latter has been the difficulty of transferring the catch from the trawler to the mothership especially in rough seas. This paper shows how this difficulty can be overcome, by using detachable codends which can be left floating in the sea attached to a buoy and a radar float, later to be picked up by the mothership. The handling of the fish would be done entirely on the parent vessel, which would allow the trawlers, equipped with numerous spare codends, to devote more time to fishing, and the adoption of such a method might lead to changes in the design of trawlers, for the large fish holds would no longer be necessary.

Les opérations d'une flottille de chalutiers avec un bateau-mère

Résumé

Il y a deux possibilités futures pour la pêche dans les eaux éloignées: le chalutier navire-usine pêchant lui-même et le gros bateau-mère accompagné de chalutiers. Le principal inconvénient de ce dernier a été la difficulté de transférer la pêche du chalutier au bateau-mère, particulièrement par mer forte. Le présent article montre comment cette difficulté peut être surmontée en utilisant des culs-de-chalut amovibles que l'on peut laisser flotter dans la mer, attachés à une bouée et à un flotteur-radar pour être ramassés plus tard par le bateau-mère. Le traitement du poisson serait effectué entièrement sur le bateau-mère, ce qui permettrait aux chalutiers munis de nombreux culs-de-chalut de rechange de consacrer plus de temps à la pêche. L'adoption d'une telle méthode pourrait conduire à changer le dessin des chalutiers étant donné que les grandes cales à poisson ne seraient plus nécessaires.

Explotación de arrastreros que trabajan con un buque fábrica

Extracto

Las posibilidades futuras de la pesca de altura son el arrastrero-fábrica y el gran buque madre de varios arrastreros. El principal inconveniente de este último reside en la dificultad de transferir la pesca de la embarcación que la captura al buque madre, especialmente con mar gruesa. En el presente trabajo se demuestra la manera de evitar esta dificultad usando copos separables que peuden dejarse flotando en el mar atados a una valiza o boya de radar a fin de ser posteriormente recobrados por el buque madre. Al manipular la pesca en esta embarcación, los arrastreros provistos de numerosos copos tienen tiempo de efectuar más lances. La adopción de dicho método puede inducir a modificar el proyecto de estos últimos barcos, en atención a que no sería necesario disponer de grandes bodegas para el almacenamiento del pescado.

WHEN comparing the possibilities of self-producing factory trawlers and big factory motherships with accompanying trawlers, the decisive argument against the latter has been hitherto the unsolved problem of handing over the catch in rough sea, especially in the Atlantic regions. Because of this difficulty, and despite economic considerations, the use of the factory trawler has been given preference. But there are increasing indications that experts realize that the development of fishing techniques would be considerably influenced if the problem of handing over the catch from the trawler to the main vessel could be solved. So far, little success has attended efforts to solve this problem. Some of the methods which have been used are as follows:

TRANSFER BY MEANS OF DERRICKS

For this method shelter is needed as offered by islands or nearby coasts, so it is restricted to certain areas. Furthermore, this method presents a problem when hauling up a well filled codend as there is a big risk that the net might split. At present this technique is used by the Japanese, Americans and Russians.

TRANSFER BY MEANS OF TACKLE RUNNERS

Poland and the USSR some time ago adopted the method of using tackle runners with containers. The vessels lie alongside, protected by means of several big triple-tyre-fenders. This method underlies the same restrictions as those just mentioned.

TRANSFER BY MEANS OF ELEVATORS

Also this method can be practised in calm sea only. The substantial loss in quality, moreover, restricts the use of this method to ships producing fish meal, as, for instance, the Norwegian factory ship *Clupea.*

TRANSFER BY MEANS OF PIPELINES

One of the earliest experiments with flexible pipes and a transfer pump, the "Yeoman Pump", took place in

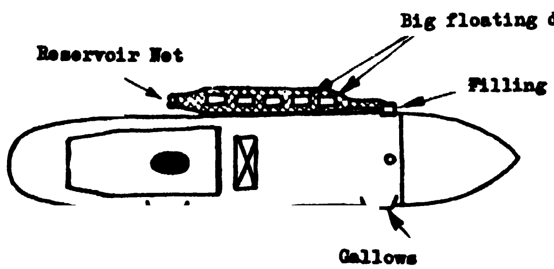

Fig. 1. Common Trawler with "Roscher Bünn".

the USA, but this method cannot be maintained in rough seas because of constant leakages at the pipe connections.

It is evident that all these methods are useless for our fishing regions because of the generally unfavourable weather conditions.

TRANSFER BY MEANS OF SPECIAL NET BAGS

An interesting proposal, made by Roscher, is based on the provision of a stern chute. According to this plan, the fish should be gutted aboard the trawler and then put into a reservoir net equipped with a lightbuoy and directional transmitter (fig. 1). These operations demand the same number of crew on the trawlers as before and, as a factory mothership is used, there is no saving of labour.

Unfortunately, this proposal has not been put to a practical test as yet so no judgement can be made with regard to its performance. Nevertheless, the proposal certainly presents a possible practical method for disposing of additional catches of older trawlers which are not equipped with a fish meal plant.

TRANSFER BY MEANS OF DETACHABLE CODENDS

If hauling up the codend and gutting the fish were done by the factory ship, the crew of the trawlers could be reduced. Such a development could lead to specially constructed trawlers having no fish holds. This could be effected if it were possible to transfer the ungutted catch to the factory ship in the codend itself, which, furthermore, would be much less bulky than the heavy reservoir proposed by Roscher.

For this purpose, the net is divided transversely across the lengthening piece (fig. 2) and thimbles are attached to the two sets of joining meshes. A rope passing through these thimbles joins the two parts together and, in a matter of a few seconds, the codend can be released.

The trawler hauls the net only as far as necessary to get hold of the connection so as to detach the codend which, before releasing, is then securely closed and to which a buoy, equipped with radar reflector and a lamp is attached (fig. 3). As the first codend floats away, waiting to be picked up, another codend is laced to the lengthening piece and fishing begins again.

Practical experiments on the German research vessel, *Anton Dohrn*, have proved the possibility of trawling with such a detachable codend as well as the practical handling of the catch by this method. A thorough examination of the quality of the fish after varying periods of drifting has indicated no loss in quality if the fish are processed immediately after they are taken aboard the ship, which is what we are aiming at.

Thus the method seems to be suitable for transferring the catch even under the unfavourable sea conditions prevailing, for instance, in the North Atlantic, and we are now in a position to start fundamental studies with regard to new types of fishing vessels.

OPERATION OF TRAWLER FLEETS

The Russian trawler fleet, like the first English fleets, uses the flotilla system, with a "buoy boat" searching for a good fishing ground. As soon as a new ground has been found, the trawlers gather there, but one vessel remains on the old ground until the new one is found to produce good catches.

THE PACIFIC EXPLORER

The flotillas of the American and Japanese factory motherships work in a similar manner, and there are reports that the *Pacific Explorer* - a freighter which, at the instigation of the American Government during

The "NEKRASOV", one of the new refrigerator trawlers of the Murmansk trawler fleet.

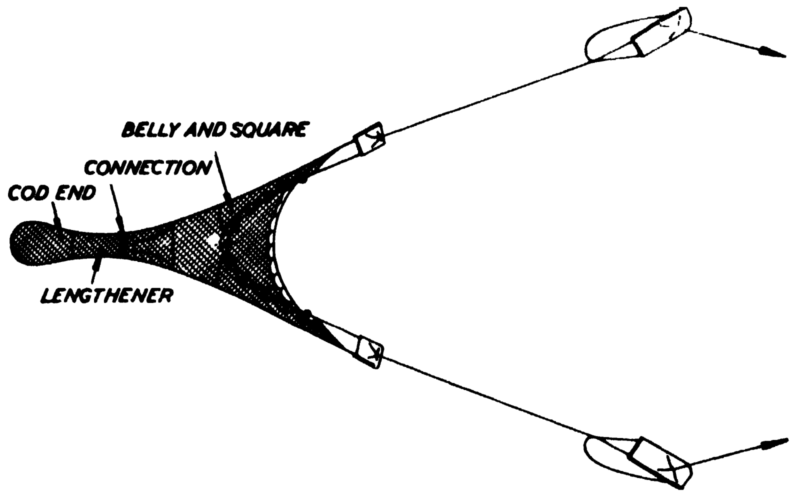

Fig. 2. Shows the construction of the trawl with a detachable codend.

the last war, was converted to a factory ship - has been employed as mothership for 10 smaller vessels catching halibut and king-crab in Alaska for periods of 90 sea-days. The fishing vessels are often chartered at ports near to the fishing grounds. These search prospective fishing grounds, which were marked by buoys until the flotilla could concentrate in one spot. During certain radio service hours there was a routine exchange of information between the units of the flotilla.

Because of the rather small size of the fishing vessels and the bad weather, the fishing had to be interrupted for about 20 per cent. of the time. The catch was transferred by means of derricks, the operation was carried out under the lee of nearby islands. The main problem for the factory vessel was the varying amount of daily catches. The plant, therefore, had to work intermittently and the crew had to be given a catch premium to compensate for this differing volume of work. While the watch on board was, as usual, four hours twice a day, the plant watch was seven hours twice a day when the hauls were successful. The premium system provided for an increase of 25 per cent. of the hourly rates if the work lasted for at least two hours uninterruptedly. This led to the situation that the crew refused to take over a smaller haul because they would not take two hours to deal with the catch.

American Labour Unions have laid down a clear division of work in these factory ships and have forbidden the deck crew to work in the plant, even when the plant was short-handed.

The long periods of employment of the vessels-- subject to the season--called for extended time in port when the crews constantly leave for other jobs. On every trip new men had to be trained. The whole undertaking in the USA was suffering because the crews could not be tied to the ship and, furthermore, the Labour Unions did not grant special regulations.

THE *MORSKA WOLA*

Another report concerns the Polish flotilla experiment in herring fishing with the *Morska Wola*--a former German motorship of 3350 GRT and 10 knots speed—which took place after the initial Russian trials in 1953. The long distance from the Polish ports to the herring fishing grounds in the North Sea, for example, the Fladen Ground, led to the idea of releasing the trawlers from transport tasks. The catches of herring were salted in barrels for supply to the canning industry. Special mention is given to the fact that there was absolutely no indication that the fishermen refused to cooperate with the factory ship.

The experience gained at the Fladen Ground suggested that the cutters did not work satisfactorily as they were constantly in need of technical repair. The factory mothership was supplied from 20 to 30 fishing vessels, and the transfer of the catches by means of tackle runners was very much subject to weather conditions. At wind force 2 to 3 Beaufort, an average of one barrel per minute could be handed over. Consequently, the transfer of the full load of a fishing vessel of trawler or lugger size took about five hours.

Radio-telephone communication was established between the *Morska Wola* and the fishing vessels. The fishermen received weather reports by radio and, in cases of sickness, medical instructions were given from the mothership. Furthermore, appointments for the transfer of catches were made by radio, and repairs to the fishing vessels were executed by expert workers from the mothership ferried over by launches.

THE RUSSIAN FLOTILLAS

The reports of the Russian flotillas show that a start was made in 1951 from Lithuanian ports with two trawlers operating in the North Atlantic. Today there are 100 trawlers and six big factory ships operating from these ports and other factory ships operating from the port of Murmansk. Factory vessels with landing space for helicopters are now being built at Memel and in Poland while other fish transport vessels for Russia are being built in Sweden and Eastern Germany, all of which indicates the long-sighted planning devoted to building up the flotilla system in the USSR.

The Russian reports again and again refer to the fact that the tremendous increase in their herring production depends on the use of these factory motherships as a "base". The average time these ships spend in port for landing the catches, repairs, and taking in provisions amounts to a third of a year.

The short-term conversion of freighters for seasonal employment in the fishery, however, is being violently criticized in Russia, while it also seems that the rather sudden and extensive employment of flotillas has shown organizational discrepancies. The use of several factory motherships without having fishing vessels definitely allotted to them has made it difficult to control their work, with the result that the pressure of work on the factory ships was irregular, and at times, because the supply of barrels was insufficient, fishing had to be stopped. The great difficulties in transferring the catches or barrels are repeatedly mentioned in the reports. It is also revealed that the ships, operating outside the three-mile zone, in the lee of the Faroe Islands, had constantly to change position with every shift of the wind. When this was not done, there were so many accidents, that the ships' hospitals became overcrowded and patients had to be sent to the Thorshavn hospital. One cannot dismiss the project, however, because of these "growing pains" and, indeed, the new Russian plans are expected to lead to much better organization.

RECENT AND FUTURE DEVELOPMENTS

This flotilla system has been practised by the Japanese for a long time with success, because the transfer of the catch holds no difficulties thanks to numerous islands within the catching region. The Russians now intend to have the factory motherships enlarged into a "catching base" equipped as a shore station with accommodation, such as hotel, post office, theatre, movie theatre, etc. Poland, having rented a pier of the Cuxhaven fishing port, prefers the advantage of this shore station for transferring the herring catch to transport vessels, while other countries endeavour to establish such shore stations near to the fishing grounds for white and red fish as, for instance, in Greenland or Spitzbergen. There is even talk about constructing artificial islands for use as ports and air bases.

For West Europe, where the herring grounds are fairly near, flotilla operations would mainly be needed for white and red fish. The main hindrance to such flotilla operation has been overcome now that the problem of handing over the catch has been solved by using detachable codends. Each trawler in the flotilla group should work with hauls of equal duration but the timing of the hauls should be staggered, so that the factory ship can steadily pick up the floating codends and maintain continuous processing.

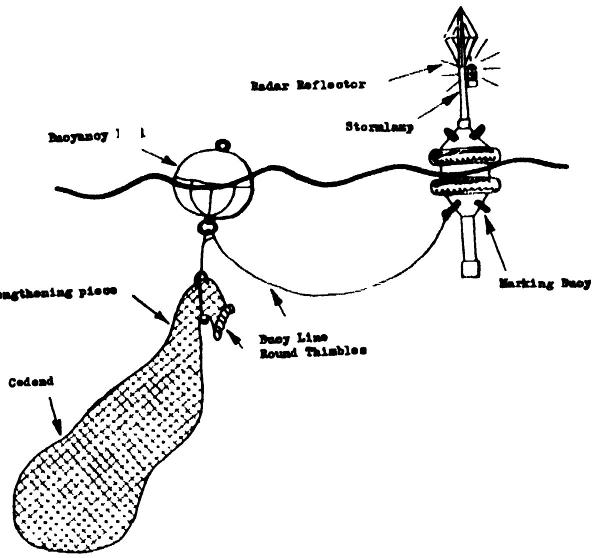

Fig. 3. Detachable codend prepared for drifting.

Mothership loading up catches from the fishing vessels on the high seas at Sakhalin Island.

MIDWATER TRAWLS AND THEIR OPERATION

by

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Abstract

These trawls are a comparatively recent development and although certain types are being used successfully in many different fisheries, their design can still be said to be in a state of evolution. The general pattern and use of the trawls are dependent, to a much greater extent than in most other gears, on the behaviour and biology of the species for which they are intended. This paper deals fully with the main biological factors which are necessary for the successful use of the mid-water trawls and also with the general principle of their design. The two types of trawl, those operated by single vessels and those towed between two vessels, are fully described and the author concludes with the suggestion that perhaps the most profitable future development is towards the dual-purpose bottom and midwater trawl that can be used alternatively on or off the seabed. In this way, fish like the herring, cod and mackerel which inhabit various water levels, can be exploited to the full.

Les chaluts flottants et leur manoeuvre

Résumé

Ces chaluts sont de création relativement récente et bien que certains types soient utilisés avec succès dans un grand nombre de pêches différentes, on peut dire qu'ils sont encore en pleine évolution. La conception générale et l'emploi des chaluts dépendent, dans une mesure beaucoup plus grande que pour la plupart des autres engins, du comportement et de la biologie de l'espèce de poisson à la pêche de laquelle ils sont destinés. L'auteur examine les principaux facteurs biologiques qu'il est nécessaire de connaitre pour obtenir de bons résultats avec les chaluts flottants, ainsi que les principes généraux de leur conception. Il décrit en détail les deux types de chaluts (les uns manoeuvrés par un seul bateau, et les autres remorqués entre deux navires) et il conclut en suggérant que le chalut de l'avenir qui donnerait les meilleurs résultats serait probablement celui qui pourrait être utilisé à volonté au fond ou entre deux eaux. On pourrait ainsi exploiter complètement les espèces de poissons telles que le hareng, la morue et le maquereau qui vivent à des niveaux différents.

Las redes de arrastre para profundidades intermedias y sus usos

Extracto

Puede decirse que algunos tipos de estas redes de arrastre, ideadas comparativamente hace poco tiempo y usados con éxito en diversas pesquerias, están todavia evolucionando.

Las caracteristicas generales y el uso de estos artes dependen de la reacción y biologia de las especies a que se destinan. Por estos motivos, en el trabajo materia de este extracto se estudian, en detalle, los principales factores biológicos que son necesarios para usar con éxito las redes de arrastre destinadas a las pesca en profundidades intermedias, y el principio general que rige la construcción de dos tipos de redes de arrastre, a saber: remolcados por una y por dos embarcaciones. El autor ha llegado a la conclusión de que tal vez en el futuro el modelo màs adecuado sea uno que permita tanto la pesca de fondo como a profundidades intermedias, y pueda usarse junto al lech mar o inmediatamente sobre éste. Asi se podrian pescar especies como arenque, caballa y bacalao que viven a diverso nivel.

INTRODUCTION

SINCE the Second World War midwater trawls (also known as floating or pelagic trawls) have been introduced in the commercial fisheries of some countries to exploit concentrations of fish in the water layers away from the seabed. Midwater trawling is still untried or unproven in many parts of the world, and is still restricted to the exploitation of only a few species of fish, principally herring, sprat and cod. Although intensive experimentation is being carried out, the designs, detailed rigs and methods of operation of mid-water trawls are still less well defined than in the ground trawls, which have evolved over a much longer period of time to suit specific conditions. The design and operation of these two types of trawl differs in important aspects. The pattern is governed by the behaviour characteristics of the fish and the milieu in which these trawls operate.

FACTORS GOVERNING DESIGN, OPERATION AND EFFICIENCY OF MIDWATER TRAWLS

Regulation of Fishing Depth

A fundamental feature of midwater trawling is that the zone of operation extends over the whole water column; the gear must work at different depth zones according to the particular depth distribution of the fish. This varies widely in space and time. For some species the depth range is very narrow, and constitutes a very small fraction of the total depth column. These features dictate the fundamental first essentials for success in midwater trawling. These are:

(i) knowledge of, or the means for detecting, the depth of the fish concentrations;

(ii) the means for ensuring that the trawl operates at the required depth.

Thus, whereas most ground trawling is still conducted without the use of specific fish detection devices, their use in midwater trawling is of fundamental importance and midwater trawling has developed in close association with fish detection devices, especially the echo sounder. However, the provision of fish detection devices alone is not sufficient to ensure success. The second fundamental requirement is of equal importance.

Sometimes the depth range within which the fish are concentrated is no greater, or very little greater, than the vertical opening of the trawl itself, in these instances very small errors in depth regulation of the gear will reduce seriously the size of catch.

Pelagic fish concentrations (e.g. herring) also often exhibit marked changes in depth distribution from time to time and from one locality to another, and even in the course of a single haul. Therefore, not only must the operator be able to set the midwater trawl at the required depth, but he may also change its fishing depth during the course of a haul. Information on such changes in depth distribution of the fish can also be gauged from echo-sounding recordings taken during the tow. Therefore the use of these devices should be an integral part of each trawling operation.

The most direct way of gauging the depth of the trawl is to attach to the trawl a suitable depth measuring device which records continuously on board the towing vessel. Only in this way can the fisherman *know* at what depth the trawl is fishing. Many such instruments have been produced and tested in recent years. They are of two main types:—

(1) Ultrasonic oscillators or transducers as used in normal echo-sounding, which are linked with recorders on the towing vessels by an electric cable and which are fixed to a part of the trawl and shot with it during trawling operations. The operation of these instruments is essentially the same as in echo-sounding; records of the depth of the trawl from the seabed, the height of opening of the mouth of the net, and the fish in the vicinity of the mouth of the net, are conveyed from the transducer through the cable to the recorder on board the towing vessel. This type of instrument has been developed and marketed in the United Kingdom by Pye Marine Co. Ltd.

(2) Battery-operated "telemeters" which are fixed to the trawl and transmit coded signals. These are picked up on board the towing vessel by a receiving apparatus. Two different transmitting systems have been employed in instruments developed, or being developed, in the United States, Germany and the United Kingdom. In the American Depth Telemeter, developed at the Marine Laboratory of the University of Miami[17], a directional, variable frequency transmitter produces beamed acoustic signals between 21 and 35 kcs. the frequency changing with depth. These signals are picked up by the directional hydrophone at the ship and passed to a radio receiver. The same general system is used in the German instrument, but instead of frequency modulation to indicate the depth of the net, the transmitter works on a fixed frequency of 15 kc., and emits groups of intermittent acoustic signals, the numbers of which vary according to depth.

These instruments have proved efficient in experimental trials, and both types have advantages and disadvantages. The first type gives the most information since it records the height of the mouth opening of the net and the behaviour of fish in its vicinity, as well as the depth of the net in the water. However, it has the disadvantage of requiring a cable link with the recorder on board ship.

Instruments of the second type need no cable, but use a transmitting system. For effective use, the transmitters must, however, be directed towards the towing vessel which places restrictions on the positions in which they can be fixed to the gear, and the presence of "noise" from other sources may reduce the efficiency.

An obvious operational modification of the first type is already receiving attention, i.e. to tow the transducer free from and above the trawl. This reduces many of the inherent handling difficulties, since the oscillator can be launched after the trawl has been shot. It also gives information about the distribution of fish above as well as below the headline of the net[4]

These instruments have not yet become an everyday part of commercial midwater trawling gear, and the marketing of a relatively cheap, reliable, easily handled and robust instrument for commercial use is an urgent requirement. Meanwhile, the regulation of the fishing depth of midwater trawls must be effected by less direct and often less accurate methods. The most common is to regulate the speed of towing and/or the length of the towing warp, based on experience.

Experiments with different trawls have been made, using varying warp lengths and different towing speeds. The depth of fishing has been measured by recording depth gauges attached to the net or by echo sounding from vessels following the towing vessel [14, 15, 18]. These experiments have provided measures of the towing depth and the angle of the towing warps at the ship for a range of warp lengths and towing speeds. Tables, showing the relation between these variables, and protractors for measuring the angle of the towing warp, are issued by the manufacturers of midwater trawls from which the fishermen can gauge the length and angle of warp to use at a given towing speed. The protractor can be used at intervals during each haul to provide a rough check on the depth of the trawl.

Experimental trials have shown that this method is only useful for providing an approximate guide to the depth of fishing. Factors other than towing speed and warp length also affect the depth of the net, i.e. the size of the warps, the detailed rig of the gear, the material from which the net is constructed, the strength and direction of the water currents, wind strength, and possibly also the size of the catch. It is inevitable that sole adherence to the data supplied by the trawl manufacturers may sometimes result in substantial errors in fishing depth. It is advisable for each operator to conduct his own depth determinations for different warp lengths and towing speeds (most commonly measured in numbers of engine r.p.m.), using the complete rig where fishing is to be done. This can be achieved with relatively simple and cheap depth recorders, obtainable in most countries today, or in cooperation with other vessels equipped with echo sounders. While such trials will tend to increase the accuracy of depth regulation, the need for the direct recording depth indicators must be stressed, because of variations from haul to haul and from one set of operational circumstances to another.

IMPORTANCE OF BIOLOGICAL FACTORS

Factors related to the behaviour and general biology of pelagic fish concentrations, and the differences between them and bottom living fish are responsible for many of the departures in design and operation of midwater trawls from the basic ground trawl pattern.

The biological features of greatest importance are given below:

(i) Most pelagic fish are active and/or fast swimmers and probably react quickly and more violently to stimuli, i.e. the approaching trawl, than do species inhabiting the seabed. Information on the flight reactions of pelagic fish is still very scanty, but echo sounder recordings[2, 3] indicate that most of them are downwards into deeper water, an avenue of escape which is available to pelagic but not to the bottom living species.

(ii) Many of the fish exploited by midwater trawls are in compact schools, especially during daylight, and respond as a body to disturbance stimuli. The shoaling habit is much less marked amongst bottom living fish, which tend to have a small depth distribution and a relatively extensive area distribution, and probably react more individually to disturbance stimuli.

(iii) Pelagic species have well developed organs of of sight and hearing (including those for the perception of low frequency vibrations). These may also facilitate their avoidance of the gear, particularly in daylight when the warps, otter boards and the net will be seen more easily. In bottom trawling, the low visibility may be made worse by the disturbance of the seabed caused by the otter boards, sweeplines and footrope. Accurate information on the part played by vision and sound perception in avoidance is very scanty, but they are believed to be of a major importance and have been taken into serious consideration in the rigging of midwater trawls. They are held responsible for the failures encountered in midwater trawling in some areas and with some designs of trawl. It is significant that midwater trawling has generally proved more effective at night, especially in regions of clear water of low phosphorescence level, and has been most successful with "pair" trawls, towed by two vessels, which have no otter boards to cause low frequency vibrations. The noise and propeller wakes from the towing vessels are also removed further from the path of the trawl than with the one-boat trawls.

(iv) The temperatures of the upper water layers are usually higher than those near the seabed. This tends to increase the activity of pelagic fish relative to bottom fish inhabiting the same region and hence stimulate their avoidance ability. Information on the effect of temperature on activity and avoidance is also scanty, but it is significant that most of the midwater trawl fishing in Europe takes place in winter when water temperatures are low.

Thus, the behaviour and habits of the fish probably govern the effectiveness of midwater trawls to a critical degree and also influence the design and rigging and operation of the gear. Success or failure can usually be traced to differences in behaviour and habits of the species between areas and seasons. The European herring constitutes a good example. This species is successfully caught by midwater trawl in a number of localities, mostly during the winter months, but results are poor or only moderate in the summer when the herring are probably more active and are relatively widely distributed in small compact schools. The most favourable conditions for midwater trawling are probably those in which (a) the fish concentrations (schools or aggregations) are fairly large and remain approximately stationary; (b) the fish are relatively "inactive" either by virtue of low water temperatures or their physiological state (in general, "spawning" and "spent" fish are probably less "active" than the feeders); (c) the fish do not undergo rapid diurnal depth migrations, and their depth distribution is fairly constant over the fishing locality; (d) the water is shallow and turbid or, if clear, contains low concentrations of phosphorescent organisms; (e) the light intensity is low.

While success in midwater trawling may, of course, be achieved when some of these conditions are not satisfied, particularly when the fish concentrations are very large and dense and when large midwater trawls are towed at high speeds by powerful vessels, they do define the generally most favourable conditions and they may serve as a guide to the potentialities in new, untried situations, and to the trawl manufacturer in the design and construction of the gear.

GENERAL FEATURES OF MIDWATER TRAWL DESIGN AND OPERATION

The general features outlined above define the general requirements in design and operation of the gear. These requirements can be categorized as follows:

(1) A net with a large vertical as well as horizontal mouth opening.

This feature is necessary in view of the vertical as well as the horizontal distribution of the fish concentrations, and to increase stability of the gear in midwater. In consequence, most midwater trawls have a square or rectangular mouth opening in which the depth is equal to or little smaller than the width. This is achieved at the expense of wings, which are relatively small or absent, and by the insertion of large side panels between the top and bottom net surfaces. The headline and footrope are usually of the same thickness, but to achieve a large vertical opening, floats or shearing devices are attached to the headline and weights and/or depressing devices to the footrope.

These features mark the most striking lines of departure in general design from the ground trawl pattern.

(2) The lower surface of the net extending as far forward as the upper surface (and possibly beyond it).

This is necessary to counter the suspected downward escape reaction of the fish. In most pelagic trawls in use at present the upper and lower net surfaces, and the headline and footrope, are made of equal length, but some designers have advocated the extension of the lower surfaces of the trawl in front of the upper surface[16].

This feature is again in striking contrast to the ground trawl design. The differences in general shape between the mouth regions of ground and midwater trawls are shown in fig. 1.

(3) Smooth water flow characteristics.

These are important in both midwater and ground trawls, but their importance is particularly great in midwater trawling, in which turbulence near the front of the net may result in violent flight responses by the fish. To meet this requirement, and to minimise the escape of fish through the larger meshes at the front of the net, midwater trawls are relatively long, finely tapered, funnel-shaped bags, with long extension pieces and codends which have no "flappers". The shape and absence of flappers reduces the likelihood of fish becoming "meshed" in front of the codend. The long codend also reduces the escape of fish from the net during hauling and facilitates the handling of large catches.

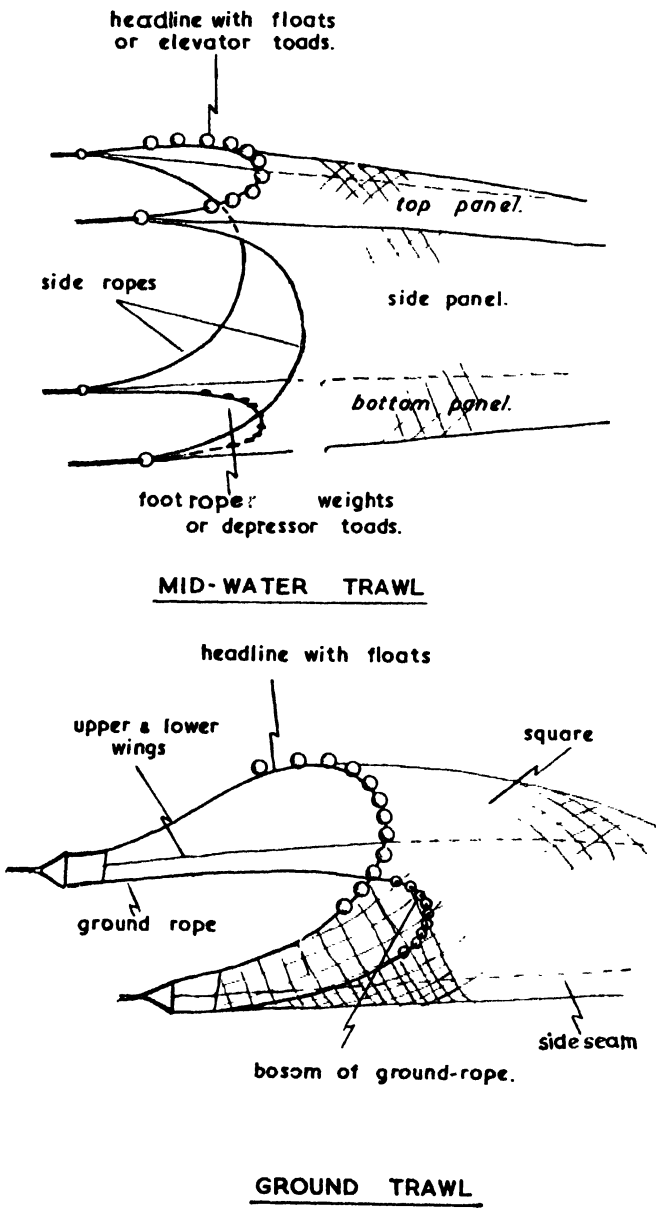


Fig. 1. Mouth regions of midwater and bottom trawls.

(4) Fast towing speed.

This is especially important because pelagic fish are fast swimmers. Since midwater trawling is at present carried out mainly by relatively small, low powered vessels, it is important that the overall drag of the gear should be reduced to a minimum to permit the fastest possible towing speed. In consequence, midwater trawls are usually made of the lightest materials, compatible with the required strength and durability; the sizes of ropes and warps are usually reduced to a workable minimum, and shearing devices (otter boards, etc.) are reduced in size and weight and/or designed to provide a better lift/drag ratio. The smooth water flow characteristics and absence of net attachments, such as flappers and "cowhides" or "false bellies", also contribute to the overall minimizing of drag. Most midwater trawls used hitherto have been made of different grades and sizes of cotton twine, variously treated to reduce water absorption, increase the smoothness of water flow and arrest deterioration, but the superior qualities of synthetic fibres has led to their increasing use.

(5) Minimum visibility, noise and vibration of gear units.

These requirements, which are very difficult to achieve with complete satisfaction, minimize the flight responses of the fish. Various rigs have been adopted, chiefly concerned with keeping the warps and/or the otter boards as far from the mouth of the net as possible when towing, and with improving the overall stability and hydrodynamic flow characteristics of the net and other gear components. Measures taken have been:

(i) the use of special shearing-boards, having low turbulent flow characteristics;
(ii) mounting the otter boards, on side cables attached to the main towing warp;
(iii) the adoption of the "pair" fishing method without otter boards.

TYPES OF MIDWATER TRAWLS

Present midwater trawls can be divided into two operational categories: (a) trawls towed by two vessels; (b) trawls towed by a single vessel.

The former was the first to be introduced on a commercial scale with the invention in 1948 of the Larsen "Atom" trawl by Mr. Robert Larsen of Skagen, Denmark. This trawl, or closely similar trawls, has proved successful commercially in Europe for catching clupeoid species, mainly herring and sprat, and its use has increased greatly in recent years in some European fisheries.

The one-boat pelagic trawls have appeared on the scene since the introduction of the "Atom" trawl. While no one type has yet proved successful commercially on as wide a scale as the two-boat trawl, several types have been developed in different parts of the world and have received extensive publicity following operational trials and/or limited adoption commercially. Amongst the most prominent are: the Larsson "Phantom" trawl, the Icelandic "Breidfjord" trawl, and the British-Columbian trawl, developed recently in western Canada. These types also illustrate the more important variations in the design and rigging of one-boat midwater trawls. The feature of other types of midwater trawls, not dealt with here, can be found in trade journals of most countries and a number of them have been patented.

THE LARSEN TWO-BOAT TRAWL

This trawl was originally developed for use in the herring fishery off the coasts of Denmark. The dimensions, design details and method of operation were planned for the type and size of vessels operating in that fishery, and with a view to the minimum of change in boat lay-out and equipment. The use of this gear successfully initiated was then extended to fisheries in other countries, having different types, sizes and powers of vessels working under different conditions. In consequence, trawls of different dimensions have been constructed and differences in the detailed rig and method of operation have arisen to suit local conditions, vessel characteristics and fishermen's preferences. One such trawl is the "Jet Fighter", designed for fishing for herring and sprats in the Baltic[11].

The trawls produced by Mr. Larsen, or manufactured under licence, have been designed for vessels ranging from about 40 to 100 ft. (13 to 30 m.) in length and from 40 to 250 h.p. They are available therefore for almost all classes of vessels other than the large deep-sea trawlers. In practice, the upper limit of vessel size for this type of gear is set by economic considerations rather than by inherent technical limitations.

The Net

The Larsen trawl net conforms with the general form of midwater trawls already outlined. It has a square mouth opening; it is of square cross section throughout its length; it constitutes a long finely tapering bag terminating in a long codend; and it is made throughout of light material.

The nets at present in use in commercial operations are made of varying grades of cotton or synthetic twine and range in size from about 28 by 28 ft. to 60 by 60 ft. mouth opening and 96 to 180 ft. total length. The smallest of the sizes mentioned above are suitable for use on boats of 30 to 50 h.p., while the largest are used on vessels of over 200 h.p. Most of the nets used commercially lie between these extremes. The commonest sizes are: (a) nets with a mouth aperture of about 48 by 48 ft. for use on vessels from 30 to 150 tons, with engines from 100 to 250 h.p.; (b) nets with a mouth aperture of about 36 by 36 ft. for use on boats from 20 to 50 tons, with engines from 50 to 120 h.p.

The nets are of simple design, consisting of four sections, the top, bottom and two sides, of equal size and shape, which are attached, on assembly, to sidelines 2 to 2½ in. in circumference running down the length of the net. The shape, with the approximate dimensions of a single net section for a 48 by 48 ft. trawl is shown in fig. 2, and the whole net is shown diagrammatically in fig. 3.

The net sections (fig. 2), are shaped to provide an even taper throughout their length down to the codend and are provided with short wing sections, so that when in action the top, bottom and side leading edges of the net are swept back from the four corner towing points. This feature minimises differential strains on the netting near the mouth, and improves the water flow in this region. The leading edges of the four sections are attached to 2 to 2½ in. ropes, that are attached to the top section forming the headline and that to the bottom section the footrope.

The mesh sizes vary according to the size of the net and the kind of fish which is being caught, ranging from 5 to 6 in. (120 to 150 mm.) stretched in the wing sections to ½ to ¾ in. (12 to 20 mm.) stretched in the codend. The codend is also usually covered by a larger meshed nylon bag for protection and to facilitate handling, especially when hoisting. For this purpose also, the codend is supplied with a "splitting strap", 5 to 10 ft. from its end, which consists of a wire or rope strop, about 12 ft. long, encircling the outer nylon covering of the codend and passing through galvanised rings attached to the webbing. The two ends of the splitting strap are shackled to a rope

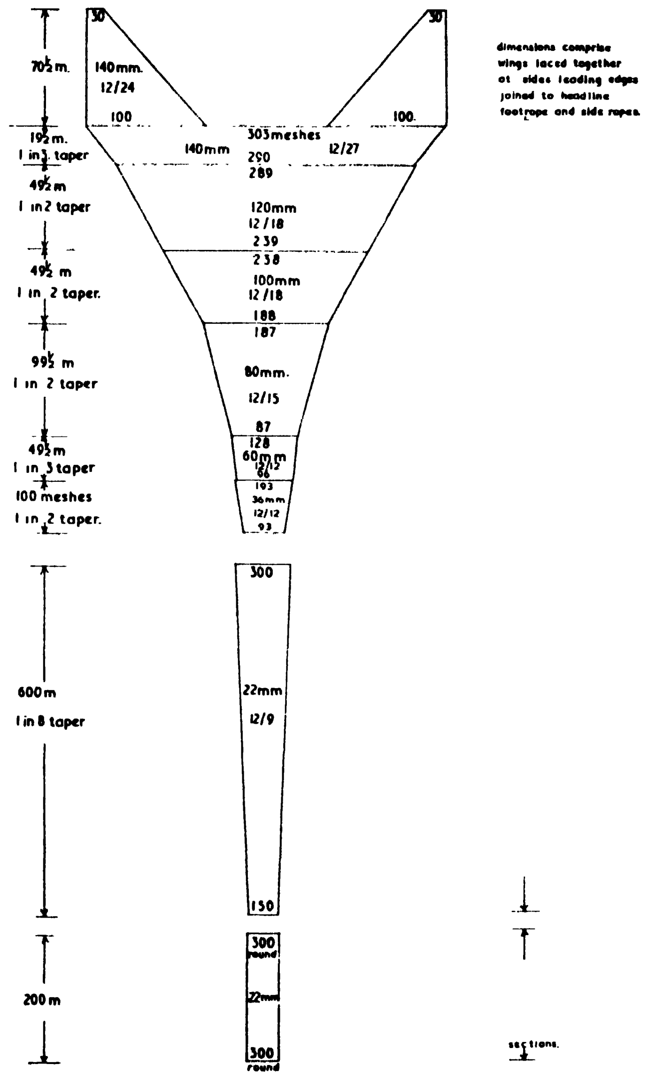


Fig. 2. Dimensions of single panel of 48 ft. by 48 ft. Larsen "Atom" trawl. Lengths and widths of net sections given in number of meshes. Mesh sizes in millimetres.

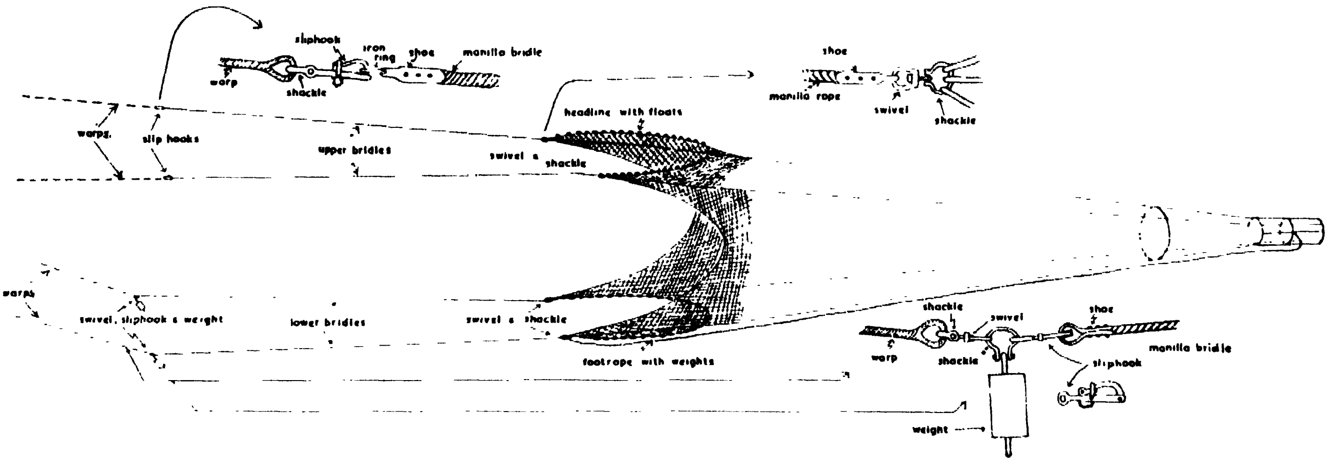


Fig. 3. Larsen net and bridle attachments shown diagrammatically.

("lazy line", "pork line"), longer than the total length of the net, which hangs free from the net and is attached to one of the lower towing corners. When the net comes alongside the ship during hauling, this rope can be used to haul up the codend, and the catch of fish if large can be split into a number of bags. A "pursing rope" running between the bottom and top corners on one side of the net is also used by some fishermen.

Floats and weights are attached along the headline and footrope respectively to produce the necessary vertical opening of the mouth of the net. Some 20 to 30 evenly spaced 8 in. metal or plastic floats along the headline and 17 to 18 lb. (approximately 8 kg.) of weights distributed along the footrope, are probably adequate for the medium sized 48 ft. net. Additional heavier weights are sometimes attached to the lower towing corners and along the towing bridles close to the net, and other larger floats or "buffs" are also sometimes attached to the upper towing corners to provide extra lift.

The Bridles

Each of the four corners is attached to a rope or combination wire bridle. The bridles from the upper and lower corners of one side of the trawl are attached to the warps from one of the towing vessels and those from the other side of the net to the other vessel (see fig. 4).

The lengths of the bridles vary according to the size of the trawl, the lower bridles being usually about 2 fm. longer, and lighter than the upper ones. For the smaller sizes of trawl, the upper bridles are usually made of 2¼ in. circumference combination wire and are 16 fm. long, while the lower bridles are of 2 in. combination wire and 18 fm. long. For the larger trawls, the corresponding dimensions are:

Upper bridles: 26 fm., 2½ in. combination wire; or 4 in. manila rope;
Lower bridles: 28 to 29 fm., 2½ in. combination wire, or 3½ in. manila rope.

Eyes are sometimes spliced at intervals along the lower bridles for the attachment of weights.

One end of each bridle is attached to a corner of the net by a swivel which is connected to a thimble at the end of the headline or footrope extensions with harp-shaped shackle (fig. 3). At its other end, the bridle is attached to the towing warp with a special sliphook (fig. 3). Between sliphook and swivel of the lower bridles is a shackle for the attachment of a further weight, usually a cylindrical block of iron or a bundle of heavy chain. The weights vary between 130 to 350 lb. (60 to 160 kg.) according to the size of the net, the power of the towing vessel and the depth at which it is required to fish.

Operation

The method of operating the Larsen gear has been described in detail by Glanville [6, 7], so that attention will be paid here only to the more important features of the operation, which since it is conducted by two vessels working together, is more complex than with the one-boat trawls and demands a high degree of skill and co-operation by the crews of the vessels. The operation also makes specific demands on the towing vessels, both of which should be of the same, or nearly the same size and power, and of high manoeuvrability. This last feature is one of the most important in setting the upper limit of vessel size for the effective operation of this gear. No special demands are made on deck layout, but sufficient deck space aft is required for the exchange of towing bridles between the two vessels. The basic deck equipment required on each ship for operating the gear is the same as for normal bottom trawling; this comprises a winch, with a capacity of 500 to 600 fm. of 1¼ to 1½ in. steel towing warp, gallows, the after one fitted with an extra sheave, and the normal gilson or hauling derrick for landing the catch. In addition, two bollards, one just forward of the after gallows and the other aft of the forward gallows, are desirable accessories for use in shooting the gear.

The vessel holding the net lies broadside on to the wind and the net is paid out over the side as in normal trawling operations. Three to four fathoms of both sets of bridles are then paid out, and held on the bollards. The second vessel approaches from astern, passes under the lee quarter and stops. A heaving line for taking the ends of the after bridles is thrown between the vessels and the bridles are hauled aboard the second vessel and made fast to the sliphooks on the warps, the aft warp being already in position over the after gallows with the weight attached, and the forward warp brought aft to the gallows for attaching its bridle. At the same time, the pair of bridles remaining on the vessel shooting the net are attached to its warps in the same way. The bridles are then thrown off from the rail bollards and the boats move slowly ahead and away from one another. At the same time the forward warps on the shooting vessel are slackened out until they are level with the after gallows, when they are picked up and put into the extra gallows sheave. Both vessels now steam on course and increase speed and continue to bear slightly away from one another, paying out warp as they go. Communication is maintained during this operation either by radio telephony or by shouting.

Warp is run off until long enough to set the net at the required depth. At present, this is gauged indirectly from tabulations of the depth of towing for different warp lengths, towing speeds and warp angles, the latter being measured with a simple pendulum protractor supplied with the gear. Then the two vessels steam on parallel courses for the duration of the tow.

The distance between the vessels is an important feature of the operation, the optimum distance being largely a matter of experience gained from repeated operations. A distance of about one half the warp length, excluding the bridles, is commonly adopted. Station keeping is difficult and requires practice, and in the early stages of operation a measured rope is sometimes used between the vessels. Practised fishermen, however, usually keep station solely by eye.

At the end of the tow, the two vessels head down wind and move in towards each other until they are about a boat's length apart and the gear is lying astern. They then move slowly ahead and heave in the warps until the weights and bridles have been brought up to the after gallows, when they stop and one set of bridles is passed back, with a heaving line, to the original shooting vessel. These are passed round the stern to the windward side of the vessel and the lower one fixed to a warping head of the winch, slack being obtained by moving the vessel astern. The four bridles are then hauled in together and are neatly coiled in preparation for shooting, the lower by the winch and the upper pair by hand. The net is then hauled as in normal trawling practice and the catch brought aboard in one or more "bags".

This type of fishing operation is beset with a number of formidable inherent difficulties and drawbacks which are not present with one-boat trawling. Operational costs are higher for vessels of the same size; and more manpower as well as a higher level of operational skill and seamanship are required. Weather is also a more serious limiting factor. Such factors undoubtedly prompted the development of the one-boat midwater trawls. However, the two-boat method has a number of important advantages which tend to offset these drawbacks. In most regions where the one-boat and two-boat trawls have been used together, the latter have so far proved the most effective: this is particularly evident in the European herring fisheries. The factors which contribute to this greater efficiency probably relate to a number of technical features of the gear and method of operation which affect the behaviour of fish near the trawl mouth. The features which are possibly of special importance are:

(i) the absence of otter boards. This avoids the "noise" and other disturbances in the vicinity of the mouth of the trawl.

(ii) the absence of propeller noise in the direct path of the trawl.

(iii) the generally marked divergence of the warps from the mouth of the net.

The specific design of the trawl itself may also play a part.

ONE-BOAT MIDWATER TRAWLS

Developments in the one-boat trawl have taken place independently in different parts of the world and these have led to differences mostly in the structure and rigging of the gear components (spreading and lifting devices, ropes, bridles, etc.) rather than in the specific design of the nets, which have, in the main, conformed with the general pattern and basic characteristics as exemplified by the Larsen trawl. These differences reflect the attempts by designers to satisfy one or more of the requirements of high stability, large mouth aperture, low turbulence and disturbance near the mouth of the net and low overall drag. The differences are well illustrated by the Larsson "Phantom" trawl, the Icelandic "Breidfjord" trawl and the British Columbian trawl. These possess features of design and rig differing markedly from one another and together they mostly cover the range of the gear make-up of present day one-boat midwater trawls.

The Nets

The nets conform with the main characteristics of midwater trawls in being approximately square, or rectangular in shape down to the codend. Nets of different

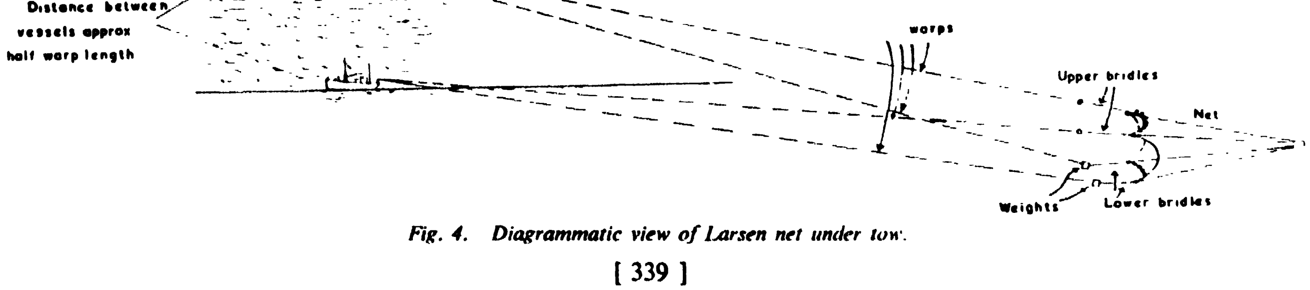


Fig. 4. Diagrammatic view of Larsen net under tow.

dimensions have been designed for use on different classes and sizes of vessels and for different species or fish. The Larsson "Phantom" trawl was developed principally for use in the European herring fisheries by vessels of the same range of size and power as for the Larsen trawl. The "Breidfjord" trawl was designed for use by larger vessels in the Icelandic cod fishery. The British Columbian trawl was intended for use in the local herring fishery by stern trawling vessels of 150 to 175 h.p.

The general make-up of the nets is illustrated in fig. 5. The data for the Larsson trawl were obtained from Messrs. Albrechtson and Company of Gothenburg, Sweden, and those for the British Columbian trawl were taken from information published by Barraclough and Johnson[1].

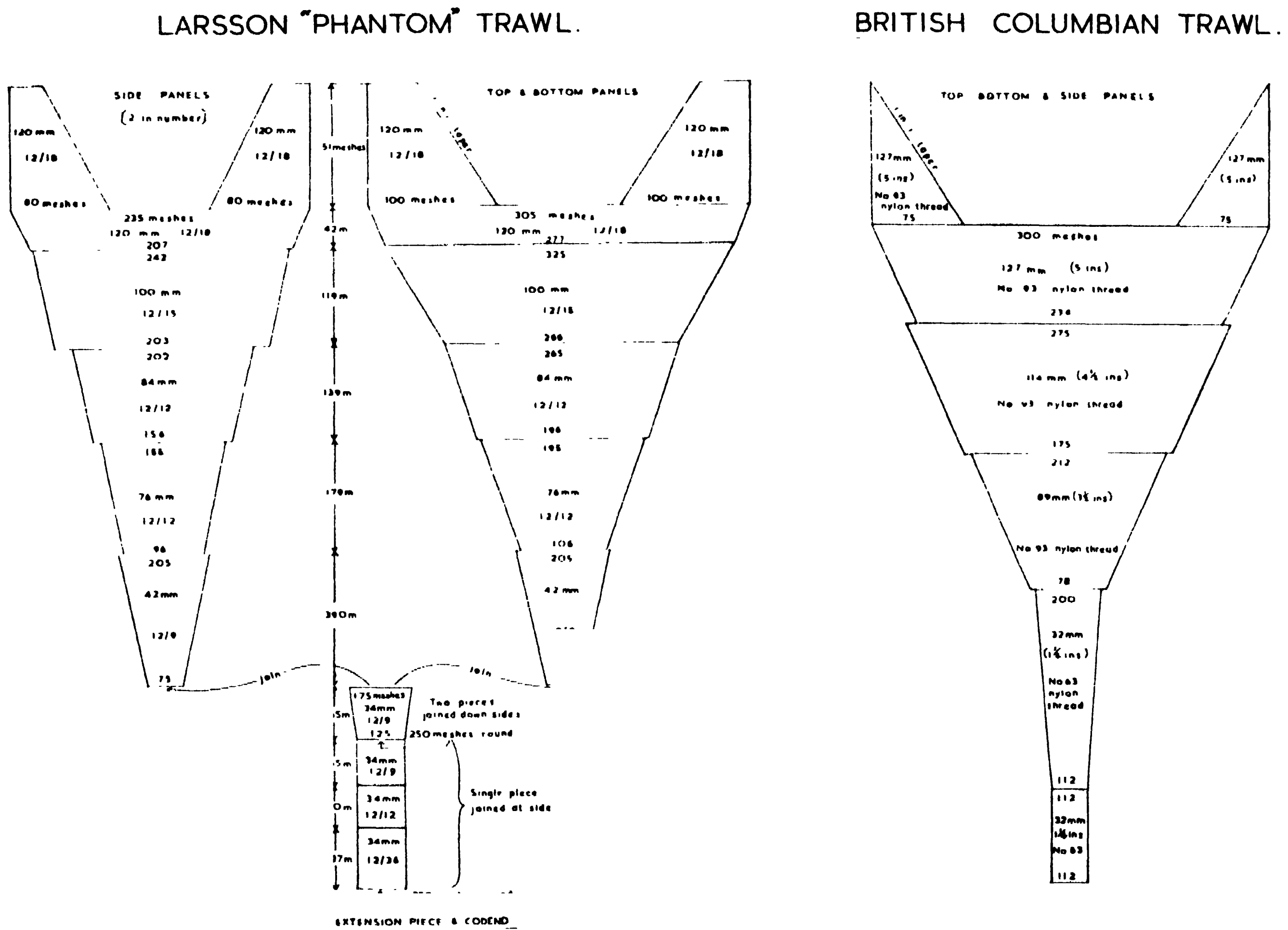
The nets differ in some important dimensional details.

(i) In the Larsson trawl, the side panels are narrower than the upper and lower panels whereas in the British Columbian trawl they are of the same size. The Larsson trawl is therefore of rectangular cross section and the British Columbian trawl of square section.

(ii) The British Columbian trawl is much larger overall, the result principally of differences in the sizes and power of vessels for which the trawls were intended.

(iii) The mesh sizes in the British Columbian trawl are larger overall. This is undoubtedly due in part to differences in the size composition of the fish schools in the regions fished, but the provision of a larger mesh in the forward parts of the net is held by many experts to improve water flow and reduce drag and turbulence in the net.

In each of these trawls the net sections are laced together and fixed to sidelines running down their lengths to the codend for strengthening purposes, and the leading edges are fixed to ropes to provide headline, footrope and sidelines respectively. Larsson trawls have mainly been made of cotton twine for the webbing and manila for the ropes while in the British Columbian trawl nylon has generally been used for the net, sidelines and footrope, and combination rope (manila and six-strand wire) for the headline. The British Columbian trawl has, in addition, a "zipper" device for opening the codend along its length, so that the catch can be brailed from the net without hauling the codend aboard. This probably saves time with large catches and also permits the catch



Dimensions of upper, lower and side panels of Larsson and British Columbian trawls. In the British Columbian trawl all panels have the same dimensions, but in the Larsson trawl the side panels have different dimensions from the upper and lower panels.

to be taken aboard in good condition. In the Larsson trawl, the codend is tied in the usual way with a codline and the catch is hauled aboard as in normal trawling operations. A splitting strap is usually attached to the codend for dividing the catch into "bags".

Arrangement of ropes, bridles and otter boards

The differences in the construction and rigging of the ropes, bridles and otter boards are the result of attempts to achieve operational efficiency and, in particular, to minimise disturbance by bridles and otter boards near the mouth of the net, and to ensure a large vertical mouth opening. The general arrangement of these components, with the dimensions of each, for the three trawl types are shown in fig. 6.

The simplest arrangement is displayed by the Larsson trawl, in which no special provision is made to offset the otter boards from the path of the net, and the most elaborate by the British Columbian trawl, in which the otter boards were initially fixed to side cables, attached to the main towing warp. In later models this side cable or "pennant" arrangement has been abandoned.

Otter Boards

Special otter boards have been constructed for use with both the Larsson and the British Columbian trawls (fig. 7).

The "wing door" developed by Mr. K. H. Larsson has greater spreading power, less drag and higher stability than plane boards of the same surface area. It is constructed of wood, capped with metal; it is elongated with tapered ends, the bottom one of which is weighted. It is of aerofoil cross section with a smooth leading edge and a more pointed, V-shaped trailing edge. The warp is fixed to the board by two lengths of chain attached to the board mid-way along its length, and one of the points of attachment is adjustable in order that the angle of attack of the door can be changed. The bridle from the danleno is attached to the board via a special ring which is attached to the trailing edge of the board by wire or chain cables of equal length. The ring has a series of holes round its circumference by which the positions of attachment of the bridle and door cables can be changed and so alter the angle of incidence of the board to the vertical and hence its depth seeking properties. The ring is dispensed with by some operators, who prefer to use a pair of simple chain backstrops attached to the two ends of the board and joined to the bridle by a shackle. With this arrangement, of course, the provision for quickly changing the angle of incidence of the board is lost. Holes are also provided at the upper and lower ends of the doors for fitting floats and weights respectively, if required during operations.

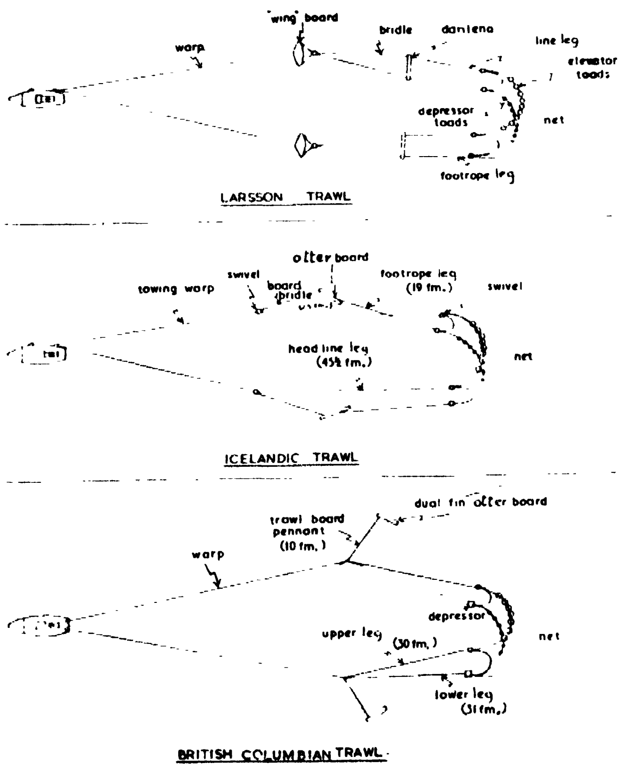


Fig. 6. Arrangements of nets, bridles, trawl-boards and towing warps of Larsson, Icelandic and British Columbian trawls.

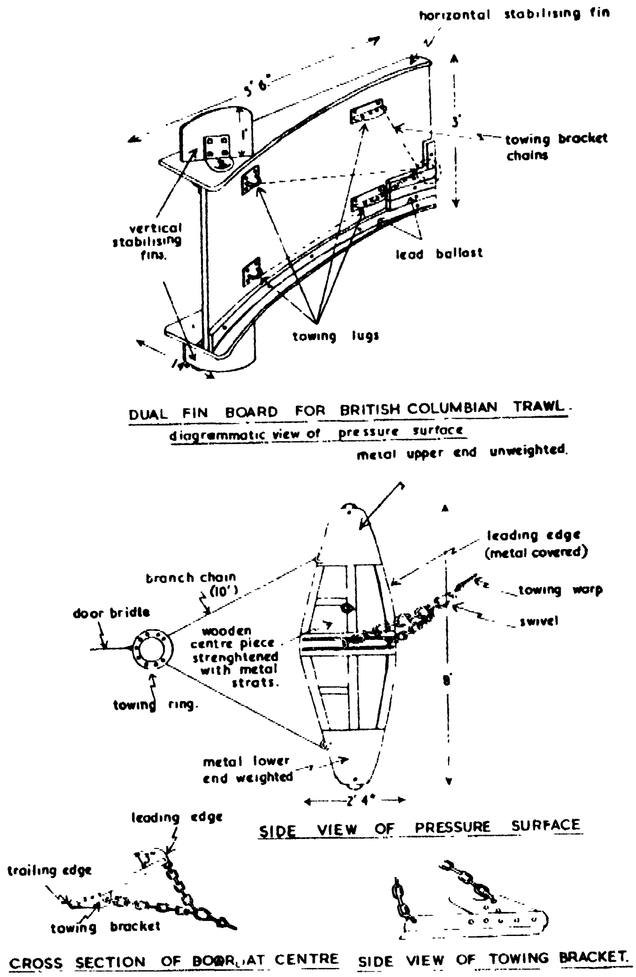


Fig. 7. Diagrammatic representation of British Columbian "dual-fin" otter board (after), and of Larsson "wing" board

The "dual-fin" otter board, designed for the British Columbian trawl[1], is constructed of curved ⅝ in. laminated plywood, measuring 5½ ft., having upper and lower horizontal stabilizing fins, also made of laminated plywood (⅜ in.), attached to the main surface by angle iron strips on the upper and lower edges. Two adjustable vertical fins, of ⅜ in. plywood, are also bolted to the upper and lower horizontal fins. Four towing lugs are attached to the concave surface of the door, on two of which a series of alternative holes are provided for attaching the towing bracket chains (⅝ in.) the free ends of which are shackled to a steel towing ring. The towing penant is also attached. The upper chains have 16 links in the fore-section and 26 in the after section while the lower chains have 17 and 27 links respectively. (These dimensions can, of course, be changed according to the operator's wishes.) The board is weighted with lead bars, totalling 135 lb. to provide a satisfactory balance to the boards during operation.

There appears to be no specially designed otter board for use with the Icelandic trawl, which has been worked with standard plain, wooden otter boards. However, it can be used equally well with boards of the Larsson or other types.

Danlenos

In the beginning, danlenos were used with the Larsson trawl but not with the Icelandic or British Columbian trawls. They were of the "stick" type, about 9 ft. long 6 in. wide and 3 in. thick, made of wood, capped with metal, and shaped so as to provide a shearing effect when towed through the water. The inner (pressure) surface was plain and the outer surface curved.

Fastening rings were attached at each end of the danleno to which the bridles to the net and the boards were attached. The bottom end of the danleno was weighted.

Floats, Elevators and Depressors

A large vertical mouth opening is a well-known requirement for midwater trawls, and for both the Larsson and the British Columbian trawls, special devices have been developed to achieve this.

The devices developed by Mr. Larsson comprise "elevator toads", which take the place of the customary floats along the headline, and of "depressor toads", which take the place of weights for the footrope (fig. 8).

The elevator and depressor toads are constructed alike, except that while the bodies of the elevator toads are lighter than sea water, giving them a positive buoyancy, the heads of the depressor toads are weighted with lead or other metal to make them heavier than water and to make the head heavier than the tail. The body of each toad has a pressure surface, which is roughly V-shaped in cross section, and a suction surface, which is convexly rounded in front and channel-shaped at the rear. The thickness of the body decreases at both ends from maximum near the front end. A metal stabilizing fin is attached to the pressure surface of the body at the rear end, and a pin for fixing the line for attaching the toad to the headline or footrope of the net, is inserted a short distance in front of the pressure centre on the pressure surface.

The elevator and depressor toads provide stable lifting and depressing forces increasing with the towing speed. The toads commonly used with the Larsson trawl have a body length of about 14 in. (excluding the tail fin) and maximum width of 9 in. and these develop a lift of about 15 lb. at 3 knots.

The number of elevator and depressor toads required for effective operation of the trawl varies with the size and material of the trawl and the angle of attack of the otter boards. Furthermore, this is subject to wide differences of opinion by operators. However, an arrangement recommended by the suppliers of the gear is 5 elevator and 7 depressor toads attached in the central parts of the headline and footrope respectively, with ordinary spherical floats attached to the wing sections of the headline, on either side of the elevator toads. An elevator and depressor toad at each of the upper and lower wing tips respectively is also often recommended.

The only special devices designed for use with the British Columbian trawl are two depressors which are shackled to the lower bridles (figs. 6, 8) just in front of the wing tips of the net. They are attached so that they can slide freely on the bridles and facilitate handling.

In the Canadian experiments with the British Columbian trawl[1] headline flotation was effected with eleven 8 in. Phillips trawl plane floats, attached about 2 ft. apart along the bosom of the headline. The type and number of floats to use with this gear is again subject to the operator's personal choice and experience. Weights are attached at intervals along the length of the footrope.

It seems that no special elevator or depressor devices have been developed for use with the Icelandic trawl,

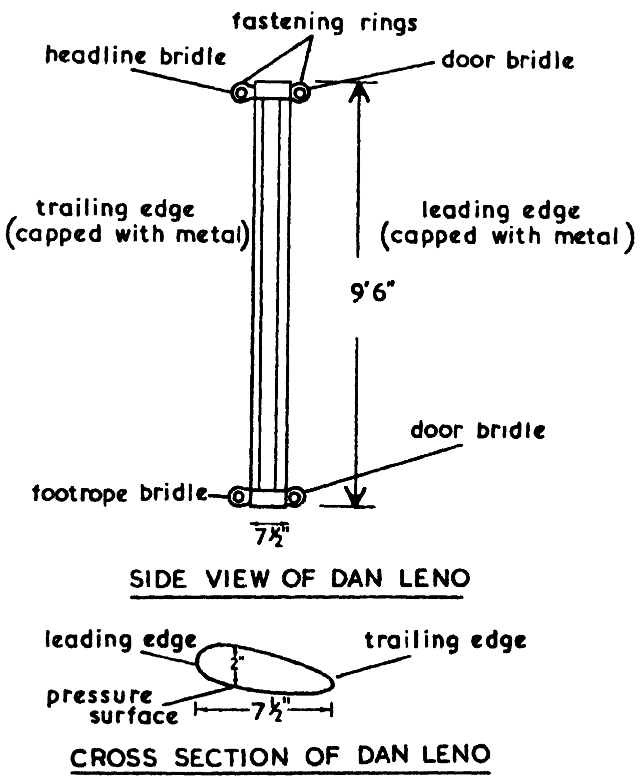


Fig. 8. Diagrammatic representation of Larsson danleno.

except that small wooden kites are attached to the upper corners of the mouth of the net to provide extra lift. Standard floats and weights have been used for the headline and footrope.

Operational Features

Both the Larsson and Icelandic trawls were designed for use on standard European trawlers equipped for shooting and hauling from the side, and they can be readily handled in the manner customary for bottom trawls. The British Columbian trawl, on the other hand, was designed for shooting and hauling over the stern and the rigging of the trawlboards on side pennants presents no operational difficulties, but it might present difficulties on vessels equipped for side handling.

Since no comparable data on the relative efficiency of these trawls are available, it is difficult to itemise their relative merits. Observations indicate that each is stable under tow and each provides a satisfactory vertical mouth opening when towed at speeds between 3 to 5 knots. Heights of from 4 to 7 fm. have been recorded for the Larsson trawl, of 7 to 8 fm. for the British Columbian trawl[1], and of 4 to 5 fm. for the Icelandic trawl (unpublished information held at the Scottish Home Department Marine Laboratory, Aberdeen).

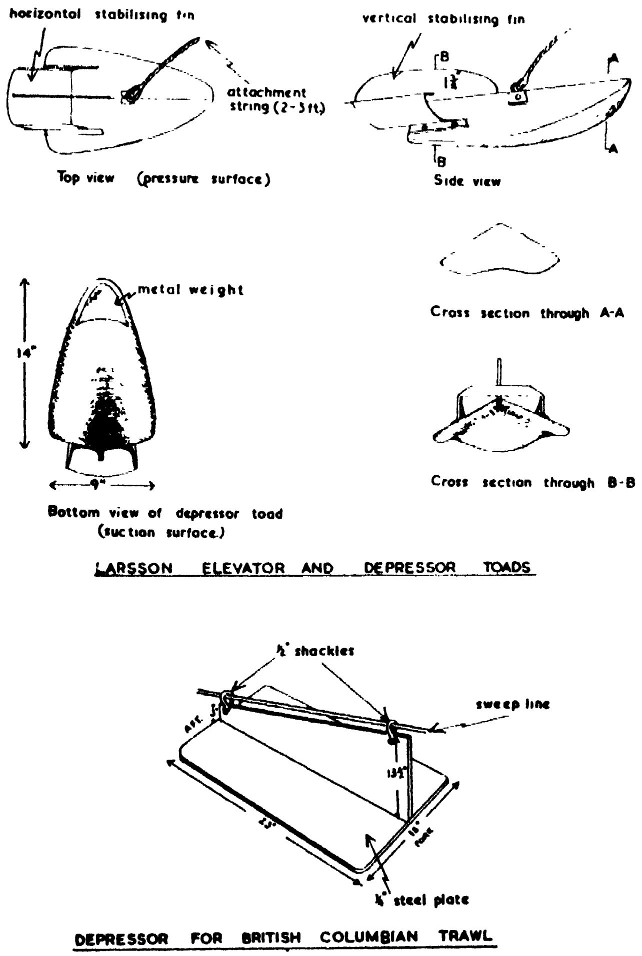


Fig. 9. Larsson elevator and depressor toads and British Columbia depressor.

At this stage in midwater trawling development, which is still largely exploratory and experimental, the criteria by which to gauge the potentialities of a particular design or rig of trawl are difficult to specify, and the factors which govern the efficiency of the gear are not accurately known. Extensive comparative trials with a variety of net designs and gear rigs are required to obtain the necessary knowledge. In particular, more information is required of the reactions of pelagic fish to the gear in different regions, seasons and depths. Such information is now accumulating in different parts of the world and new designs and rigs of gear are being developed. It is likely therefore that new designs and rigs of midwater trawl will be developed to supersede those described here.

Perhaps the most profitable line of future development is towards dual-purpose bottom and midwater trawls which can be worked alternatively on or off the seabed. Many of the species of fish inhabiting the continental shelf and which are exploitable in midwater, also spend part of their lives close to the bottom. Herring, cod and mackerel are notable examples. This alteration between the demersal and the pelagic habit is often sporadic and unpredictable, although the herring exhibits a generally regular diurnal movement. The development of a dual-purpose-gear, or one in which the demersal gear could be quickly modified at sea, would permit greater flexibility in commercial operations and would reduce the cost of fishing for species which habitually move between the bottom and midwater.

REFERENCES

[1] Barraclough, W. E. and Johnson, W. W. "A new mid-water trawl for herring". Bull, Fish. Res. Bd. Can., no. 104, pp.25. 1956.

[2] Brandt, A. von. "Schwedisches Einschiff-Schwimmtrawl Fantom." Fischwirtschaft, 5, 25. 1953.

[3] "Erprobung des schwedischen Einschiff-Schwimmtrawls von Larsson." Protokolle Fischereitech., 3, 3-13. 1954.

[4] Craig, R. E., "Echosounding and fish detection." Paper presented to this Congress. 1957.

[5] Delpierre H J-B. "Le chalut flottant islandais." Le Marin, nos. 313-4, 1953.

[6] Glanville, A., "The Larsen midwater trawl." Fish Bull. F.A.O., 9, 113-29, 1956.

[7] "Design and operation of the Larsen trawl." World Fishing, 5(12), 38-42, and 6 (1) 34-7. 1956-57.

[8] Larsen, R. "Floating trawl." British Patent Specification, no. 695, 361, 1953.

[9] Larsson, K. H. "Improvements in trawl nets." British Patent Specification, no. 670, 222, 1952.

[10] "Improvements in shearing boards". British Patent Specification, no. 674, 911. 1952.

[11] Meschkat, A. "Der 'Düsenjäger', ein neuer Schleppnetztyp." Fischereiwelt, 2, 177-9, 1950.

[12] Richardson, I. D. "Some problems in midwater trawling". World Fishing, 6 (2), 28-31. 1957.

[13] "Midwater trawling. Pair fishing experiment on herring 1955-56." Fish. Lab. Leafl., Lowestoft, no. 12, pp. 26, 1957.

[14] Scharfe, J. "Messung der Oefnungshöe von Schleppnetzen mit Echolot." Fischwirtschaft, 5, 282-4, 1953.

[15] "Uber Messungen an Schleppnetzen." Arch. Fisch. Wiss., 6, 64-83, 1955.

[16] Sigurdsson, J. "Improvements in or relating to trawl-fishing nets." British Patent Specification, no. 699, 206, 1953.

[17] Stephen, F. H. and Shea, F. J. "Underwater telemeter for depth and temperature." Spec. sci. Rep. Fish. U.S. Fish Wildl. Serv., no. 181, pp. 23, 1956.

[18] Wood, H. and Parrish, B. B. "Echo-sounding experiments on fishing gear in action." J. Cons. Int. Explor. Mer. 17, 25-26, 1950

SCANDINAVIAN EXPERIENCE WITH MIDWATER TRAWLING

by

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Abstract

Although the pelagic trawl has only been in use in Scandinavia for nine years, the idea of using these trawls is an old one, and patents were granted for these special nets at the beginning of the century. In this paper, two-boat trawls and one-boat trawls are described and the advantages and disadvantages of each are mentioned. For example, the author states that the two-boat trawl must be limited to the use of small fishing craft and that one-boat nets are best used by the more powerful trawlers. The technique of lifting the headline and depressing the footrope in order to obtain the maximum amount of opening for the mouth of the net is fully described, and the use of "trawl-toads" with the Phantom Trawl, designed by the author is also discussed. The Sterner Persson one-boat trawl, with three towing lines on each side is used for catching "ströming" (Baltic herring) in the Baltic and a catch of 10 tons in ½ hr. has been reported. The author feels that there is a good future for pelagic trawls.

Expérience acquise en Scandinavie avec le chalut flottant

Résumé

Bien que le chalut pélagique ne soit utilisé en Scandinavie que depuis neuf ans, l'idée en est anciene et des brevets relatifs à ces types spéciaux de filets ont été pris au début de siècle. L'auteur décrit les chaluts à deux bateaux et les chaluts à un bateau, et expose les avantages et inconvénients de ces deux types d'engin. C'est ainsi que selon l'auteur, l'emploi du chalut à deux bateaux doit être limité aux petits bateaux de pêche, tandis que le chalut à un bateau est utilisé dans les meilleures conditions par des chalutiers à vapeur plus puissants. L'auteur fait un exposé détaillé de la technique employée pour soulever la ralingue supérieure et abaisser la ralingue inférieure afin d'obtenir le maximum d'ouverture de la gueule de chalut; il étudie également l'emploi des "crapauds de chalut" avec le chalut "Phantom" dont il est l'inventeur. On se sert du chalut Sterner Persson à un bateau, avec trois funes de chaque côté pour pêcher les "strömming" dans la Baltique; on a capturé de la sorte 10 tonnes de poisson en une demi-heure. L'auteur estime que les chaluts pélagiques ont un bel avenir.

Ensayos hechos en Escandinavia con una red de arrastre para pescar a profundidades intermedias

Extracto

Aunque sólo durante los últimos años han comenzado a usar en Escandinavia la red de arrastre pelágica, la idea de utilizar este tipo de arte es muy antigua, habiéndose otorgado patentes de invención a principios de siglo. En este trabajo se describen las redes remolcadas por una y dos embarcaciones, así como las ventajas e inconvenientes de ambas. Por ejemplo, según el autor, la primera es utilizada por arrastreros de vapor potentes, mientras que el uso de la segunda se limita a embarcaciones pesqueras pequeñas.

Se describe, en detalle, la técnica de hacer subir la relinga de boyas y de bajar la de plomos para que la boca se abra,al máximo y el uso de "trawltoads" en la red de arrastre "Phantom" proyectada por el autor. La red de arrastre "Sterner Persson" remolcada por una embarcación, mediante 3 cables unidos a cada costado, se usa para pescar "strömming" en el mar Báltico, habiéndose logrado lances de 10 toneladas en media hora. El autor cree en el porvenir de las redes de arrastre pelágicas.

THE idea of catching fish shoals between the surface and bottom by means of trawls seems to be of about the same age as the ordinary bottom trawling. Patents have been granted for several pelagic trawl constructions since the beginning of this century, but none has become popular among fishermen.

The main reason might be that methods for locating fish in the water were rather poor and unsatisfactory. This was changed by the development of echo sounding and asdic during World War II, and its later application to fish location. Once depth and thickness of fish shoals can be ascertained, pelagic trawling is given a *raison d'etre*.

Much research has been done in several countries to develop reliable midwater trawls. In Scandinavia, this work started during the war and pelagic trawling has been practised there for about nine years.

Two different systems exist: the one-boat and the two-boat method.

The first reaction of the fishermen was in favour of the two-boat trawl, which is towed by two vessels side by side at a certain distance from each other, with the warps spreading outwards from the net to the boats. There is nothing in front of the net to frighten the fish. A special advantage of the two-boat trawl is that no otter boards are needed. Otter boards cause a certain resistance, so their absence means saving fuel or increased trawling speed, which in many cases can give better catches.

Many objections have been made against the one-boat system. Some fishermen considered it impossible to catch any kind of fish with it. The noise of the propeller, otter boards and warps was supposed to frighten the fish away from the net mouth. Theoretically, this sounds reasonable, but the many good catches made with one-boat trawls have demonstrated it must not always be true.

The two-boat system, has disadvantages too. It is very important that the two boats move at the same speed and keep a constant distance from each other. It is difficult to comply with these requirements in bad weather. Currents might bring the net to one side, and this causes an increased pull for one of the boats. It is often said that one should have two boats of the same size and engine power to get good results. It seems, however, more important that there should be two skippers on the boats who co-operate and who, in the long run, have the same idea of fishing places and other conditions which influence the fishing result. There is a saying that "brother skippers do not know each other" after having fished with a two-boat gear for some time.

It seems impossible for two big trawlers to fish together, and the one-boat floating trawl therefore has come more and more into use.

Designing a one-boat midwater trawl is a more difficult technical problem than making a two-boat gear. Otter boards are needed to ascertain a satisfactory horizontal opening. The ordinary flat otter board, which is used in bottom trawling, does not quite meet the requirements of midwater trawling. Its angle of attack is 30 to 35 degrees, and when it loses contact with the bottom, it often starts swinging in the water. Its sheering ability is not very good. Another problem is to obtain a sufficient opening height without using heavy weights, which are normal on the two-boat trawls. Floats on bottom trawls generally are balls made of glass, steel, light metal alloy, or plastic. The lifting capacity of a ball is affected by the towing resistance which increases as the square of the speed. This means that with ball floats the trawling speed is limited, and the towing power required is rather high.

For a midwater trawl it is essential that the height and width of the mouth are independent of the speed. There should be, however, a balance between vertical and horizontal powers affecting the mouth of the nĕt. While the lifting capacity of ball floats decreases with increased speed, the sheering power of the otter doors increases as the square of the speed. This problem can be solved by sheering devices, working upwards and downwards on headline and footrope. Different kinds of such devices are on the market.

The midwater trawl nets in Scandinavia generally are constructed with identical upper and lower parts and identical side parts. Sometimes all four parts have the same dimensions. While cotton is normally used, in recent years good results have also been obtained with nylon and Perlon. The higher breaking strength of these new materials allows for thinner twines and thus for greater towing speed.

It has been found difficult to tow the net in the right depth and many different methods have been tried. One way is to observe the angle of the warps to the horizontal. Knowing the length of the warps, the depth of the net can be calculated, under the assumption that the warps run in a straight line. A correction of 15 to 20 per cent. has to be subtracted from the calculated result to compensate the actual slope of the warps. This method is simple but not quite reliable, because currents may have an influence on the depth of the net without changing the warp angle. Simple instruments have been developed which can be lowered along the warp and pulled up again during towing. After years of pelagic fishing many skippers know from experience how to bring the trawl to the right depth. But there is still a demand for a reliable instrument which, in a simple way, i.e. preferably without wire connections between net and ship, informs the skipper continuously about the depth of the net.

Midwater trawls have been used by Scandinavian fishermen mainly for catching herring in the Skagerack and Kattegat during the winter season. From about the end of November to the beginning of March a big herring fishery goes on there. Previously, purse seines were used, but midwater trawling was started on a commercial scale for the first time in the 1948-1949 season. Today most of the herring is caught by midwater trawls.

In the beginning, midwater trawling was carried out during the night when the herring is found at 10 to 30 fm. depth, depending upon weather conditions and darkness. Later, it was also found that the method can be used in daytime. Now, more and more fishing takes place in

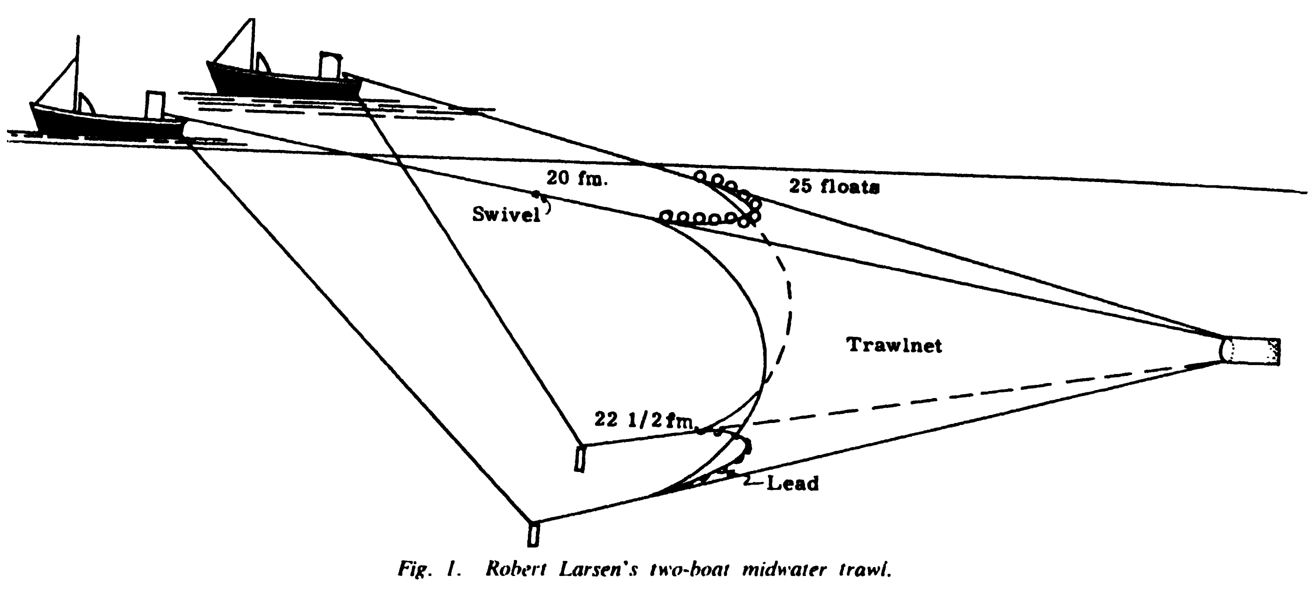

Fig. 1. Robert Larsen's two-boat midwater trawl.

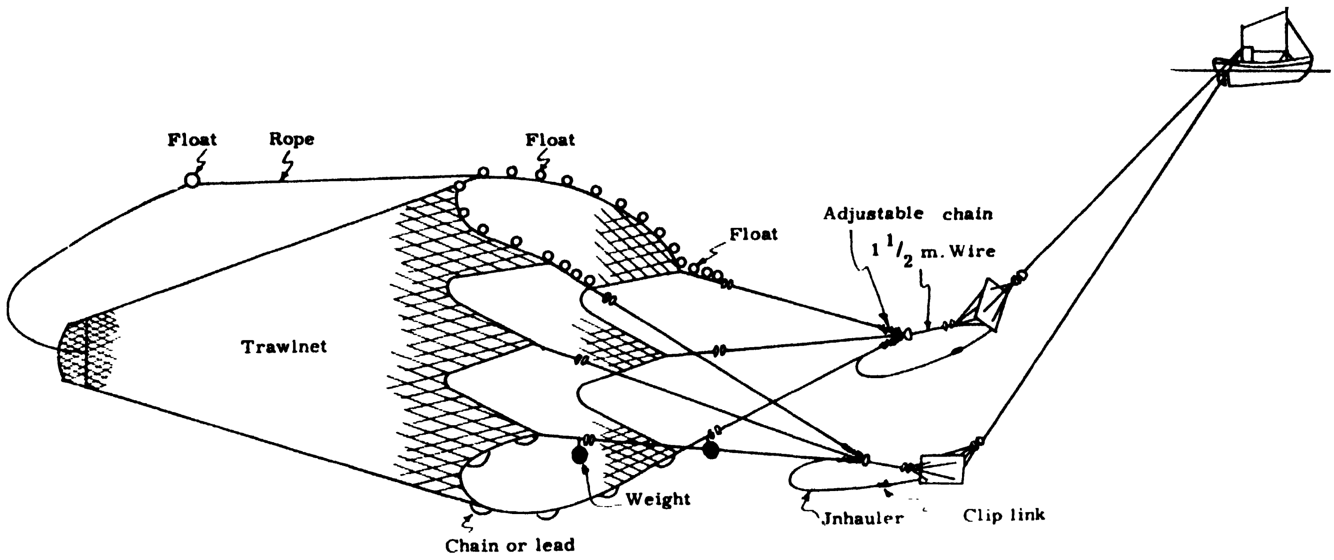

Fig. 2. Sterner Persson midwater trawl or one or two boats. When towing with two boats weights are used instead of otter boards.

daylight when the herring usually are found in 50 to 80 fm. depth.

The echo sounder tells the skipper the depth of the shoals and their size so that he can regulate the length of the haul, which might vary between 10 min. and 2 hours.

Some fishermen believe that echo sounding disturbs the fish and frightens them away, but the results of experiments do not support this theory. Some observations made during night fishing with a one boat trawl in the Skagerack are worth mentioning. During towing, the echo sounder recorded shoals of fish of regular character but when it was time for hauling and the deck lights were switched on, the shoals immediately disappeared. After dimming the lights, the shoals very soon appeared again. This observation was repeated several times with the same result. As the engine and propeller were running the whole time, it seems as if the sound from the propeller and/or the engine does not disturb the fish but the deck-lights do.

Up to now, midwater trawling has been done relatively near the surface, but it is likely that in the future midwater trawls will also be used near the bottom. When large fish shoals are on the bottom, extending to several fathoms in height, a normal bottom trawl can only catch a certain part of them because its mouth is often too low. A midwater trawl has a higher opening and consequently may catch more. For proper regulation of the depth of the net, it seems the best to have the trawl travel at a certain distance above the seabed. This could be arranged by using trawl-toads.

MIDWATER TRAWL TYPES IN USE

The best known types used in Scandinavian waters are Robert Larsen's two-boat trawl, Sterner Persson's one-boat trawl and the Phantom trawl, a one-boat trawl designed by the author of this paper.

The functioning of the Larsen two-boat trawl is shown in fig. 1.

The net is made of four identical pieces. No otter boards are needed. Each boat has an upper and a lower warp. Big weights attached to the lower warps at a certain distance in front of the net together with weights on the footrope and floats on the headline, give the net its

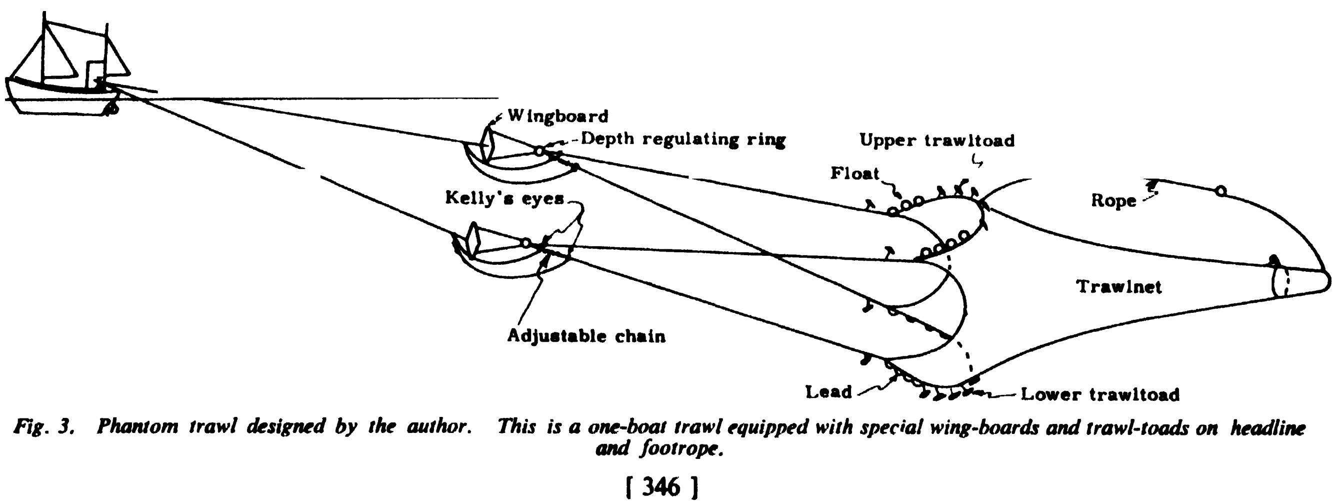

Fig. 3. Phantom trawl designed by the author. This is a one-boat trawl equipped with special wing-boards and trawl-toads on headline and footrope.

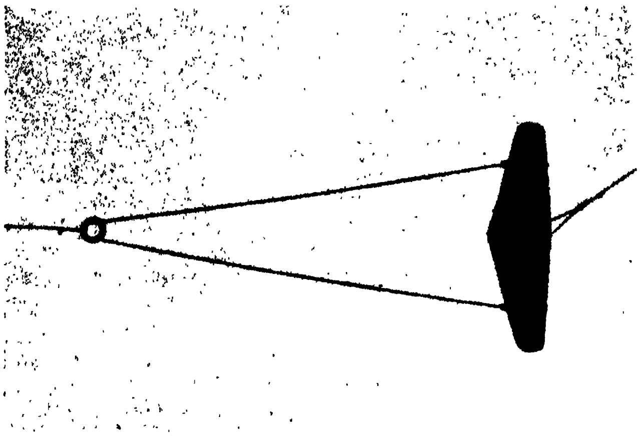

Fig. 4. Wing-board of the Phantom trawl with depth regulating ring.

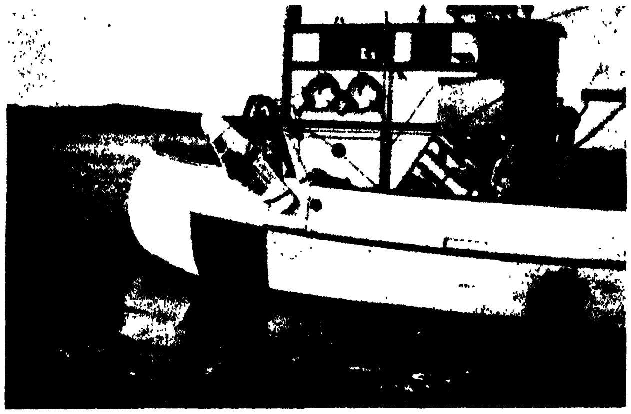

Fig. 5. A Larsson wing-board hanging in the gallows of a Swedish cutter.

vertical opening. The depth of the trawl is usually regulated by the length of the warps and can also be influenced by the distance between the two towing boats. Normal trawling speed is said to be 3 to 4 knots.

The Sterner Persson trawl (fig. 2) has a six-wing net with three legs on each side between the otter boards and net. Short chains in upper end lower legs and close behind the otter boards serve for easy regulation of the amount of pull on the middle legs. The Persson trawl has ordinary otter boards, with four-chain brackets for the warps and the legs for a better control of the working performance. The vertical opening is ascertained by floats on the headline and weights on the footrope. The depth of the trawl is also regulated by the length of warps. A number of these trawls are said to be in use in the Baltic, where good catches of the Baltic herring ("strömling") have been recorded. A catch of 10 tons of herring in a haul of ½ hour and a total catch of 36,000 kg. in one week of fishing have been reported.

The Phantom trawl (fig. 3) has been designed on results of tank tests at Statens Skeppsprovningsanstalt in Göteborg. By testing 15 different types of sheering boards for the Swedish Navy, the author found that the wing-board (figs. 4 and 5) has twice the sheering ability of an ordinary board of the same area. As it works with an angle of attack of 13 to 14 degrees, it moves steadily and smoothly through the water. By a very simple arrangement—the depth regulating ring—an upward or downward sheering component can be created. Instead of common floats, trawl-toads are fixed to headline and footrope to open the net mouth vertically. The balance between the vertical and horizontal forces is secured as the sheering power of both wing-boards and toads increases equally at the square of the speed. Thus a rather high towing speed of 4 to 5 knots is made possible. At a speed of 4 knots the lifting power of one trawl-toad of normal size (length about 40 cm.) is about 16 kg. compared with little more than 2 kg. for a spherical float of 8 in. diam. At the same speed, the resistance of the spherical float is about 6 kg. and of the trawl-toad about 8 kg. That means that the lifting force of a trawl-toad is 7 to 8 times that of a spherical float at only slightly higher resistance. With increasing speed the difference between the trawl-toad and the spherical float changes more and more in favour of the trawl-toad. Measurements made under fishing conditions have demonstrated that by using 5 to 7 toads on the headline of an ordinary bottom trawl, the opening height can be doubled. By attaching heavy trawl-toads to the footrope of a trawl it becomes possible to keep it just off the bottom. The author is of the opinion that this will help to save small fish and spawn and thus might be a way to prevent overfishing which now seems to affect the North Sea stocks. It is, therefore, suggested that it would be worthwhile to arrange for comparative fishing tests with a trawl with wing-boards and trawl-toads on headline and footrope and an ordinary trawl of equal size.

Thorough tests of the Phantom trawl gear, including towing speed, towing power, depth of the trawl, opening height, etc., under different conditions have been made by experts from the Institut für Netzforschung in Hamburg, in the presence of British, Danish and Swedish observers and the results have been reported in the fishing Press.

THE THAMES FLOATING SPRAT TRAWL

by

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Abstract

The author, a former Whitstable (U.K.) inshore fisherman, reports that after the last war two Essex fishermen, Messrs. Alf and George Leggatt, decided to depart from the traditional stow net method of catching sprats in the Thames Estuary because they wanted something more mobile and more positive. Accordingly, they devised a two-boat net which they use from their two 39 ft. shallow draught diesel trawlers of almost revolutionary design. After many trials, the net was perfected and then, with the use of the echo sounder, it proved to be a first-class producer of good quality sprats. This paper deals intimately with the design and operation of the net, the hauling and shooting, and the author points out that while this method of fishing has many advantages over the drift net and stow net, it has the one failing that it is unselective and may at times produce quantities of small fish. This is perhaps unavoidable, because to increase the size of the mesh would increase the number of fish meshed in the mouth and funnel and the net could quite easily become unmanageable.

Le chalut flottant de la Tamise pour la pêche des sprats

Résumé

L'auteur, ancien pêcheur côtier de Whitstable (Royaume-Uni) raconte comment deux pêcheurs de l'Essex, MM. Alf et George Leggatt, décidèrent après la guerre de rompre avec la méthode traditionnelle de la pêche des sprats dans l'estuaire de la Tamise à bord de bateuax ancrés, car ils voulaient un système plus mobile et plus positif. Ils construisirent donc un filet manoeuvré par leurs deux chalutiers Diesel à faible tirant d'eau et de 39 pieds de long, d'un type presque révolutionnaire. Le filet fut perfectionné après de nombreux essais, puis, à l'aide de l'écho-sondeur, il s'avèra être un engin de première classe donnant des sprats de bonne qualité. L'auteur expose en détail la conception et la manoeuvre du filet, la façon de le mettre à l'eau et de le relever, et fait observer que tout en possédant de nombreux avantages sur le filet dérivant et le filet fixe, ce système a l'inconvénient de ne pas être sélectif et d'être parfois susceptible de capturer d'importantes quantités de petits poissons. Il semble que ce défaut soit inévitable, car si l'on augmentait la dimension des mailles, les poissons capturés dans la gueule et le corps seraient plus nombreux et il deviendrait rapidement impossible de manier le filet.

Le red de arrastre flottante para espadín usada en el río Támesis

Extracto

El autor, un ex-pescador de bajura de Whitstable, en el Reino Unido, informa que después de la última guerra los Srs. Alf y George Leggatt, de Essex, decidieron apartarse del método tradicional-que usaba una red de copo fija a una embarcación al ancla—empleado en el estuario del Támesis para capturar espadín, a causa de necesitar un procedimiento más movible y positivo. Para esto idearon una red de arrastre que remolcaron con sus dos arrastreros de poco calado, 39 pies (11,9 m.) de eslora y construcción casi revolucionaria, provistos de motores Diesel. Después de muchos ensayos lograron perfeccionar una red que, mediante el uso de la ecosonda, demostró tener muy buenas condiciones para capturar espadín de buena calidad.

Este trabajo también se refiere, en detalle, a su construcción y manipulación—calamento y recogida—señalando el autor que si bien ofrece muchas ventajas sobre los artes de deriva y la red de copo fija a una embarcación anclada ("stow net"), tiene el inconveniente de no seleccionar la pesca y de capturar a veces peces pequeños. Esto es talvez inevitable a causa del aumento del tamaño de la malla, que incrementaría el número de peces enmallados en la boca y el engullidor dificultando considerablemente la manipulación de la red.

ALTHOUGH the practice of two-boat trawling for sprats is only in its seventh year, a thriving sprat fishery existed in the Thames Estuary prior to the Second World War. Fishermen used the stow net, drift netting being precluded by heavy steamer traffic and shallow water. This net, held open by baulks of timber, was streamed in the tideway from an anchored smack. Catches, though often heavy, were unpredictable owing to the immobility of the net, and landings often far from fresh, several tides sometimes being needed to produce a full load.

The introduction of the Larsen trawl in 1948 prompted two Essex fishermen, Alf and George Leggatt, who had for some time believed that this lack of mobility could be overcome by the use of two boats to spread and position the net under power, to initiate experiments. They already possessed two 39 ft. shallow draught diesel trawlers of modern—almost revolutionary—design, equipped with small trawl winches made from back axles of cars and capable of holding 70 fm. of wire. A net was therefore ordered, to their own design, from the Great Grimsby Coal Salt and Tanning Co., and trial hauls were made in March 1950 as the sprat season was closing. Results were disappointing, and it was apparent that the presence of gulls was no reliable indication of the presence and depth of fish.

A Kelvin Hughes MS24 echo sounder was therefore installed and in the following summer they steamed west to Cornwall to assess the new technique's usefulness in catching pilchard. The experiment was not a success, but with the assistance of a frogman, the late J. H. Hodges, it was found that the net was seldom at the depth estimated, and that the vertical opening was far less than the intended 24 ft. A new net was then ordered, having a theoretical opening of 36 ft. by 36 ft., which proved to give a vertical opening of 24 ft. in the water.

Armed with this knowledge, an echo sounder, and a good deal more experience, the brothers returned to Whitstable, and in the autumn were able to locate good schools of sprats in the Estuary and to land heavy catches regularly.

This regularity of landings and the fresh, undamaged quality of the fish, found a ready market with the canners, and a third boat was engaged to carry fish. Detachable codend sleeves, when full, were passed to this boat so that fishing could be resumed by the main pair. This codend sleeve was drawn over the end of the main net, and held by four lashings.

The Leggatt's example was soon followed by other local fishermen, and although Mr. Larsen himself introduced his trawl at Tollesbury and Harwich, the net used by this now thriving fishery is of the Leggatt pattern. It is to this gear and its operation that the following description applies.

Broadly speaking, the net is a tapering funnel of square section with wings tapering to the four towing points formed by the roping. Mesh in the entry is of 2 in., reducing to 1 in. in the codend of the main net, to which are attached three 20 ft. lengthening pieces of proofed cotton net of $\frac{7}{8}$ in. mesh, 180 meshes wide, giving an overall length of 186 ft. For the main net, nylon twine and nylon roping have proved to be far superior to natural fibre for strength, water resistance (and fuel economy), and for its ability to withstand rot. Up to the present, cotton has proved satisfactory for the lengthening pieces as these are soon weakened by loading operations and are renewed before rot begins. The headline is supported by six or eight spherical floats 6 in. in diameter, while the lower wings are sunk by a 67 lb. weight on either wing end, shackled on to a foot of light chain.

The boats should have engines of not less than 30 b.h.p.—more if possible. It is a great advantage if a "pair" are matched, or have at least the same draught, dimensions and engines, with revolution counters, so that towing effort, drift, and leeway are identical on each side of the net. If fish are to remain in good condition, a spacious fish hold is essential, so that the depth of fish is never such as to crush those underneath. The boats in question have a load capacity of 7 tons without crushing, while the wheelhouse siting gives ample room for net handling and loading, allowing great scope for the warps when manoeuvring.

The winch must be of the twin drum type, and should carry sufficient wire, of at least $\frac{5}{16}$ in. diameter, to get the net into whatever depth is to be worked. A roller fairlead of the seine type is fitted on each quarter.

To prepare the gear for fishing, the net is flaked down aft on the leader boat and the wings, marked to identify upper and lower, laid out ready to pass to the other vessel. The codend is tied about 6 ft. back, to provide slack net for loading, using a codend float rope of ample length. On locating a satisfactory school, the leader boat steams down tide to overrun it, then turns into the tide, streaming the net as quickly as possible. When the net is streamed as far as the entry, speed is dropped to steerage way and the net checked, while the other vessel comes alongside to receive his wings from the third hand, with instructions as to warp length, speed and so on. To avoid delay, the second boat must always stay close behind the leader, and it is advisable to shackle heavy clip hanks to the warps, so that the wings can be attached without delay. As the boats part, the lower warps are released, followed by the upper warps, until the required marks are reached on the wire. Due to its greater angle, extra length is required on the lower warp, according to the depth fished.

No hard and fast rule can be laid down for the length of the warp needed to fish any given depth, as this depends on the varying factors of speed, type of net, and distance between boats. While accurate electronic aids are being developed, a guide can be obtained by the measurement of warp angle, and the calculation, with the aid of tables, of net depth. Station keeping and speed affect net depth considerably, and while the former comes with practice, the revolution counter is the answer to the latter. Close station will raise the net, wide station lower it, due to the loss of way: the distance between boats should be such as to extend the angle formed by the net itself.

An echo sounder on each boat is an advantage, to ensure that both are over the fish, while R/T communication is a valuable adjunct to hand signals and enables wider searching. The sounders should be compared for depth and sensitivity at frequent intervals.

It is often necessary to turn, in order to pass through a school for a second time, the outer boat turning fast round the inner, which must keep a pull on the warps to avoid fouling the net or allowing it to drop. Towing against the tide need not produce headway, it being sufficient to stem the tide, or even make sternway against it when very fast-running.

Length of haul is determined by the density of the school, and it is possible, under ideal conditions, to catch the net's capacity of 200 bushels (approximately 5·1 tons) in as little as 15 minutes, when an indication is given by the codend float pulling under and by loss of way. A really full net is a liability, as the time taken to get 5 tons of tightly packed fish alongside safely is often more than that taken for another haul.

To haul the gear, the boats are sheered alongside and made fast with prepared breast ropes of 4 in. coir, and, in bad weather also by springs. One cannot have too many fenders, preferably doubled tyres on chain or wire. Properly made fast, two matched boats, well fendered, should lay together without damage in a gale, but if damage seems likely, the wings can be passed to the leader, and the other vessel, with one man on board, taken out of danger. Hauling is generally carried out stern to wind, keeping the warps even, until the wings are reached, when the slack net is hand hauled over the transom or quarter, engine power being used to keep the boats square, and to tow up the sleeve should it begin to sink. Should the haul be good, the sleeve is taken forward, overhauled, and supported every 8 ft. by chain weighted "girtles" 12 ft. long, which are passed round and down the sleeve, until it is made fast in bights to the bow. Should this not be done, the fish will sink the sleeve vertically when they die and lose buoyancy, making the sleeve difficult to recover. In this event the codend float and line are used to help bring it to the surface.

A "cutting-off ring" of $\frac{7}{16}$ in. iron, 3 ft. in diameter, mounted on a stout staff, is used to cut off manageable quantities of fish which are run down to the slack net gained after removing the float rope, when they can be lifted inboard manually or by derrick.

This form of fishing has considerable advantages over drift netting, being more positive in action, and producing fish that are unmarked by the gillnet. On the adverse side, it cannot be said to be so selective, for the catch frequently contains a proportion of smaller fish. Without the use of a mechanical grader, this tends to preclude the fresh market, leaving only the canning industry and the fishmeal plant, with consequent lower prices. An increase in mesh size has been suggested, but in the writer's experience this is not practical, as with the existing mesh the gear becomes at times almost unmanageable owing to the number of fish gilled in the entry and funnel. Should the mesh of the lengthening pieces be increased, the same would occur over another 60 ft. preventing free water flow, damaging fish and obstructing the escape of "whitebait", a mixture of immature herring and sprats which abounds in the Estuary.

It seems possible, with reservations, that this form of fishing could be used for other types of pelagic fish. The scaring effect of the net, negligible in the muddy Thames, may, however, count against it in clear water. The poor hauls experienced by single boats towing a modified trawl of this type on shallow settings would seem to indicate that the sprat is able to evade the net when startled by propeller noise above it, and that the sight of the net in clear conditions might have the same effect. Further information on this point may soon be available after trials on Cornish pilchards.

Underwater photo of a midwater trawl model, scale 1 : 10, with a hydrofoil kite. Photo: J. Schärfe

THE DEVELOPMENT OF A NEW HERRING TRAWL FOR USE IN MIDWATER OR ON THE BOTTOM

by

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Abstract

With the assistance of experienced fishermen and the testing of models, the trawl described in Fisheries Research Board of Canada Bulletin No. 104 was developed and demonstrated. It is a one-boat (175 h.p.) trawl of light nylon construction with specially designed curved dual-fin otter boards attached on pennants to keep the boards and towing cables away from the front of the net. A special feature is a provision for opening the codend while still in the water to remove herrings by brailing. Early in 1955 catches of up to 35 tons of winter herrings were taken in 20 min. tows in depths as great as 50 fm.

Later, improvements were made by which the trawl was used commercially with success both in midwater, and with the otter boards on the bottom and the net just off it, but even with a still stronger version of the original net and towing speeds up to 4½ knots, it has failed to catch commercial quantities of the faster-moving *summer* herring. Attempts are now being made to overcome this.

Mise au point d'un nouveau chalut flottant ou de fond pour la pêche au hareng

Résumé

Le chalut décrit dans le Bulletin No 104 du Fisheries Research Board of Canada a été mis au point et essayé avec l'aide de pêcheurs expérimentés et à la suite d'essais sur maquettes. C'est un chalut en nylon fin destiné à être remorqué par un seul navire de 175 CV et équipé de plateaux à deux ailerons d'une courbe spéciale, fixés a deux cables frappés sur les funes destinés a maintenir les plateaux et les funes écartés de la gueule de chalut. Cet engin comporte un dispositif spécial d'ouverture du cul-de-chalut lorsque ce dernier est encore dans l'eau de façon à décharger les harengs à l'épuisette. Au début de 1955, on a pêché avec ce chalut jusqu'à 35 tonnes de harengs d'hiver en 20 minutes à des profondeurs atteignant 50 brasses.

Par la suite, des perfectionnements apportés a ce chalut ont permis de l'utiliser avec de bons résultats aussi bien entre deux eaux qu'avec les plateaux sur le fond et le filet legèrement au dessus; mais on n'a pas réussi à pêcher avec cet engin des quantités importantes de harengs d'été, plus vifs, même en renforçant encore le chalut et en augmentant la vitesse de chalutage jusqu'a 4,5 noeuds. Des essais sont en cours pour résoudre ce probleme.

Evolucion de una nueva red de arrastre para pescar arenque en profundidades intermedias o sobre el fondo del mar

Extracto

Con ayuda de pescadores experimentados y pruebas de modelos se demostró y perfeccionó el funcionamiento de la red de arrastre descrita en el boletin No. 104 del Fisheries Research Board of Canada.

Este arte se proyectó para trabajar con un solo barco (175 C.V.) ; es de nylon delgado y tiene puertas curvas con dos aletas, unidas mediante cabos a los cables de arrastre para desviarlos del frente de la red. Entre sus caracteristicas especiales figura el hecho de permitir la abertura del copo cuando está aún en el agua para sacar el arenque de invierno mediante un salabardo.

A principios de 1955, en 20 minutos se obtuvieron con este arte hasta 35 toneladas de arenque a 50 brazas. Posteriormente se perfeccionó y usó con exito comercial en profundidades intermedias. Al utilizar puertas de arrastre se pudo pescar con la red muy cerca del fondo, pero aun con modelos más pesados que el original y velocidades hasta de 4 1/2 nudos, fué imposible capturar gran cantidad de arenque de verano que nada mas rápidamente. En la actualidad se están haciendo nuevas pruebas para evitar este inconveniente.

THE introduction of midwater trawling for herring in European waters, and, more particularly, the success of the two-boat trawl developed by Robert Larsen in Denmark, led to experiments by British Columbia fishermen. These met with only moderate success and a demand arose for the Government to develop a trawl suited to conditions in the British Columbia herring fishery.

In 1954 work was started by the Fisheries Research Board's biological station at Nanaimo, B.C., using funds provided by the Industrial Development Service of the Department of Fisheries, to develop a suitable trawl for use by moderate-sized trawlers or multi-purpose vessels. Such a trawl has been developed and demonstrated, and is now in commercial use in the autumn and winter herring fishery.

The broader purpose of the work was to develop a single-boat mid-water trawl effective in exploratory or commercial fishing for faster-swimming fish than the winter herring. In this, success has been limited and work is still proceeding.

DESIGN AND TESTING OF A MIDWATER TRAWL, 1954-55

The first stage was the design and testing of the midwater trawl described in *Bulletin* No. 104 of the Fisheries Research Board of Canada. A trawl was needed which could be towed from a single boat of about 150 to 175 h.p. The fishermen felt that the conventional mounting of otter boards near the mouth of the net tended to scare fish away and should be avoided. The trawl should be

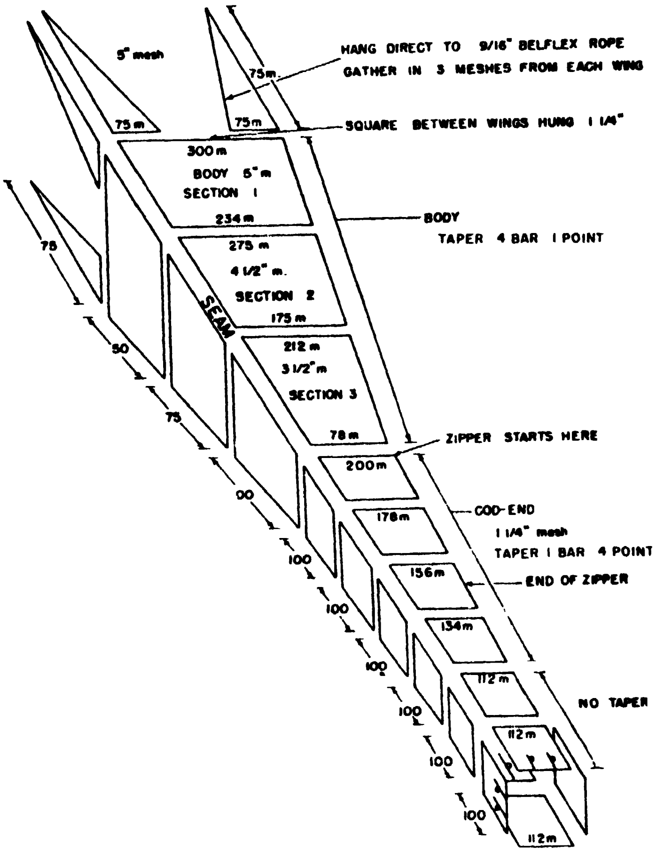


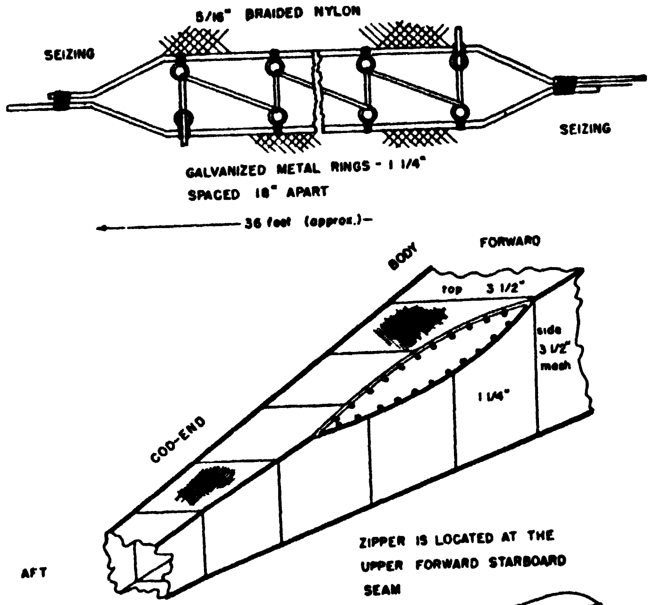
Fig. 1. Sectional view of the first net

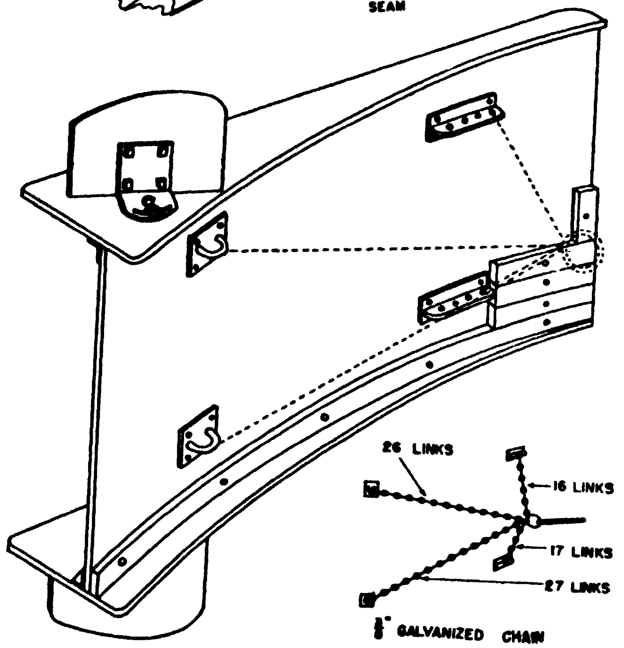
large enough to make paying catches; in particular, it should have a large vertical opening for fishing layered schools of herring, but be light enough to handle easily on small vessels. It was considered important to be able to tow the trawl at a higher speed than in the past.

Nylon was selected for less weight and towing resistance. It was decided to provide for opening the codend for the removal of herring, thus making it possible to handle substantial catches with a lighter net than is required if the whole catch is to be lifted aboard in the trawl itself. A number of means of keeping the mouth of the net open were explored and finally a special otter board was designed and tested, first on a small net and then on a full scale size. The board was suspended on a pennant so that it would be far from the mouth of the net, and some use was made of models in testing preliminary designs.

The net. The mouth of the net is 35 ft. square and the net is square in cross-section throughout its whole length of 180 ft. Fig. 1 shows its construction diagrammatically, indicating the size and number of the meshes in each section.

The mouth of the net is formed by lacing the forward





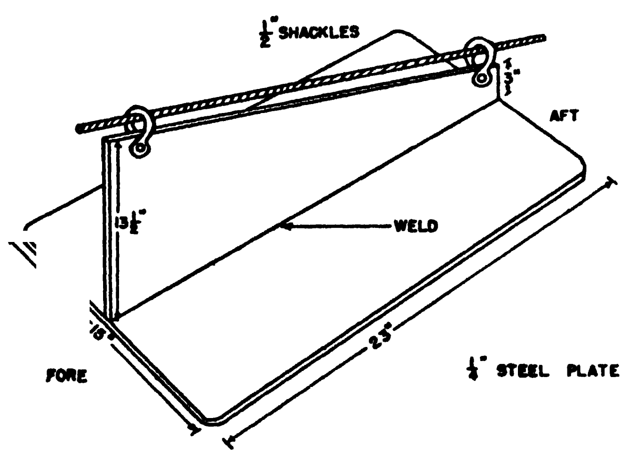


Fig. 2. Construction and position of the "zipper"
Fig. 3. Dual fin otter board.
Fig. 4. Moore depressor.

edges of the triangular wings and the free edges of the first body section ("square") to four lines of combination manila wire rope ("Belflex") cable each 75 ft. long. These headlines are extended forward three feet to eye-splices for attachment of the towing lines, so that the shackles can be kept free of the netting when setting or stowing the trawl.

The four edges of the net are supported by sidelines of $\frac{7}{16}$ in. braided nylon running from the tips of the wings to the end of the codend. An opening (the "zipper") is provided extending about 36 ft. from the forward end of the codend, back along the upper starboard seam (fig. 2). The sidelines are doubled to form this opening, which is closed by lacing the nylon rope through rings attached along each side at 18 in. intervals. The codend is closed by a "poke-string" of $\frac{7}{16}$ in. braided nylon which passes through rings near its end. The same rope is passed forward and attached to the foremost ring of the "zipper" to be available for hauling the codend forward along the side of the vessel when the trawl is brought to the surface.

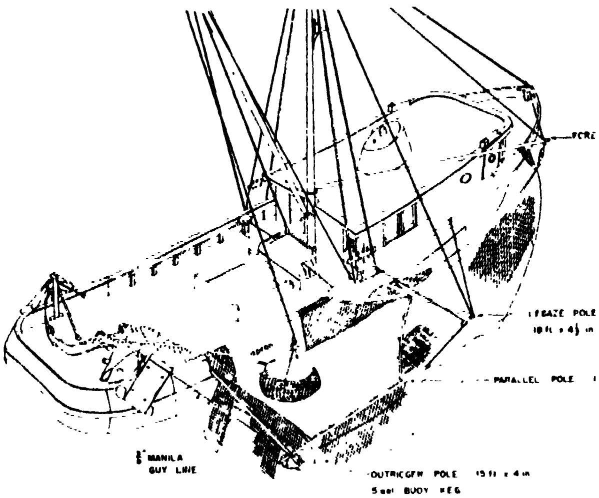


Fig. 5. Brailing from the "zipper."

Otter Boards, Floats and Depressors. The curved otter boards 5½ ft. long and 3 ft. high are constructed of laminated plywood bolted to angle-iron strips (fig. 3) to which upper and lower horizontal fins are attached for stability. The correct angle of attack is maintained by the length and position of the chain brackets and by small vertical fins. Proper balance of the otter boards is obtained by the adjustment of lead weights bolted parallel to the lower horizontal fin.

Eleven Phillips trawl planes are lashed about 2 ft. apart along the headline bosom. Braided nylon leadline, with about 25 lb. of small sectional leads, is attached at 18 in. intervals to the footrope.

Depressors (fig. 4) are used on the bridles just in front

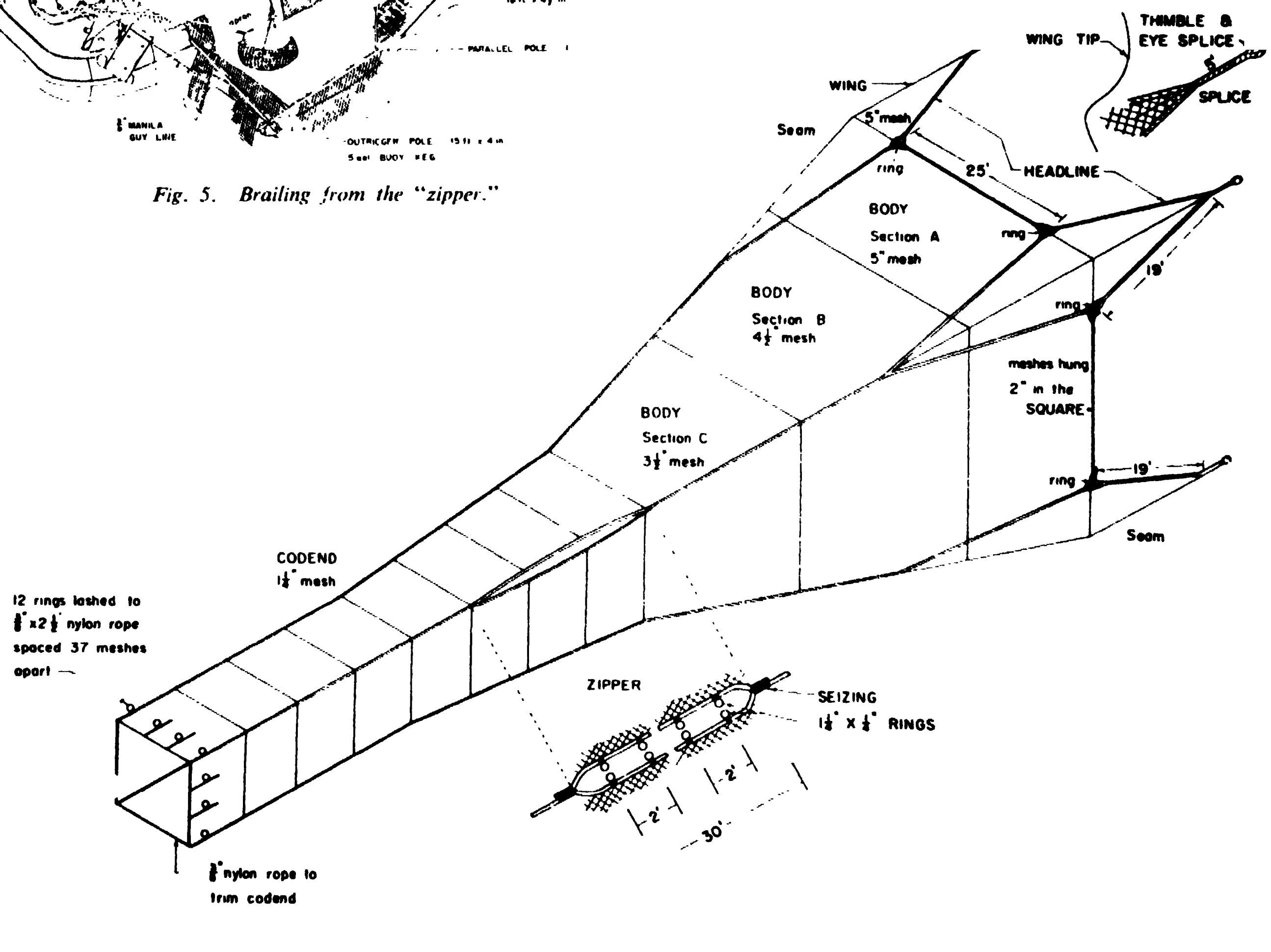


Fig. 6. Modification of the net for strengthening and reduction of the towing resistance.

of the lower wings to assist in keeping the lower side of the mouth opening down.

Bridles. Four 30 fm. lengths of ⅜ in. diameter galvanized wire rope are coupled with swivels to the eyes in headline at the tips of the four wings, the lower ones being lengthened with a fathom of chain for adjustment to make the trawl tow horizontally. The two bridles from each side of the trawl run forward to an eye or "tow-point" from which the warp runs to the vessel. The otter board on each side is attached to the tow-point by a 10 fm. pennant of ½ in. galvanized wire rope.

Operation of the Trawl. Schools of herring are first found by echo-sounder and the trawl then is set over the stern in much the same manner as the conventional otter trawl in British Columbia. The depressors are slid down the lower bridles as soon as the net is in the water. The otter boards are quickly shackled to the pennants as the latter are unwound from the winches with the bridles. The depth of the trawl is controlled by the towing speed and the length of the warps, and is calculated from the angle of the warps to the horizontal.

When the trawl is hauled the otter boards, depressors and body of the net are taken aboard and the end of the codend is then passed forward to be attached near the bow of the vessel (fig. 5), using the extension of the poke-string noted above. The "zipper" is released and the net held open with poles so that the catch can be removed by brailing.

Fishing Tests. Practical fishing tests were carried out in January and February, 1955, from a 62 ft. 175 h.p. trawler with typical British Columbia equipment and layout, i.e., free working space aft, two trawl winches and two gallows on the stern quarters. Herrings occur at this time of the year in dense layered schools 5 to 10 fm. thick which tend to rise off the bottom in the evening and descend at daybreak. Catches of 20 to 30 tons were made in 20 minute midwater tows at depths of 15 to 30 fm. but were smaller when the herring were more scattered during the night. Two daylight tows at between 45 and 50 fm. took 15 and 35 tons.

Although these trials were successful in catching herring in midwater in commercial quantities, two difficulties were emphasized. The plywood otter boards were designed for working only in midwater and were readily damaged by striking bottom, and difficulty was experienced in judging and controlling the depth of the net accurately. The combined result was that concentrations of herring close to the bottom could not be fished effectively.

ADAPTATION OF THE TRAWL FOR USE CLOSE TO THE BOTTOM

Modification of the Gear. By doubling the sidelines in the front part of the net and attaching them to the quarter points by rings, the trawl was made capable of standing greater towing strains (fig. 6). The resistance of the net was also reduced by using less webbing hung in such a way as to give the same mouth opening (fig. 7). The combined result was a stronger and lighter trawl.

By using conventional otter boards and by providing additional lift by special hydroplane floats on the upper bridles, the trawl could be used close to the bottom (fig. 8).

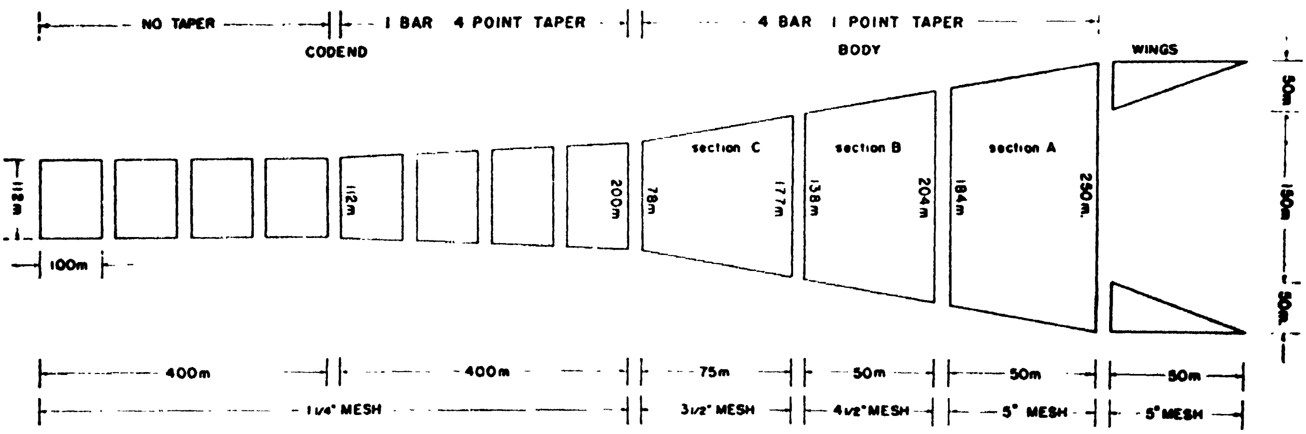


Fig. 7. Plan of the modified trawl net. Dimensions in meshes.

Material required:

Nylon seine netting

	Twine size	Mesh size	Depth	Length
Wings	*9*	*5 in.*	*50 m.*	*200 m.*
Body section A	*9*	*5 in.*	*50 m.*	*868 m.*
section B	*9*	*4½ in.*	*50 m.*	*684 m.*
section C	*9*	*3½ in.*	*75 m.*	*510 m.*
Codend	*6*	*1¼ in.*	*100 m.*	*4,440 m.*

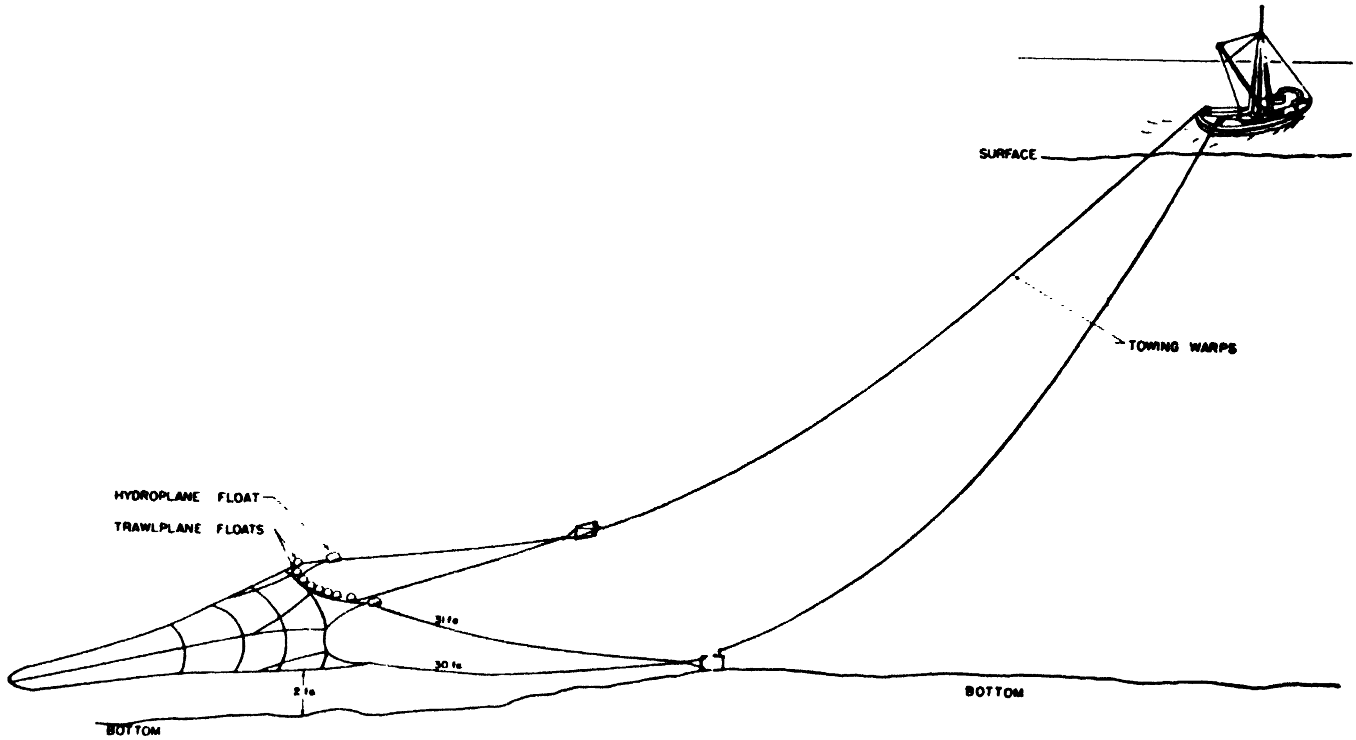


Fig. 8. Operation of the modified gear with the otter boards on the bottom and the net about 2 fm. clear of it.

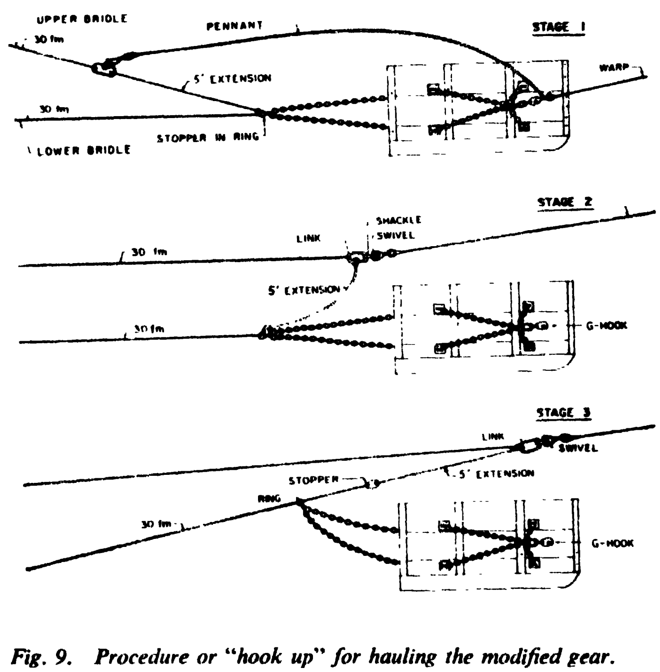


Fig. 9. Procedure or "hook up" for hauling the modified gear.

Stage 1. Otter board in trawling position. Pennant is slack. Note the 5 ft. extension in upper bridle.

Stage 2. Otter board unlocked from warp link. As hauling begins the pennant tightens and advances the upper bridle. The 5 ft. extension slackens as it advances.

Stage 3. Otter board free from strain. The 5 ft. extension is now switched to the lower bridle and the stopper has left the link, the lower bridle passing through the ring.

In order to have the net operate horizontally in this position it was necessary to make the upper bridles longer than the lower. This in turn required a special hook-up (fig. 9) to keep the headline evenly taut as the trawl is being hauled and thus avoid the fouling of the floats with the netting.

Fishing Tests. Attempts to catch the moderately active early autumn herring in 1955, using the stronger, lighter trawl in midwater with the special curved otter boards (fig. 3), met with moderate success. Numerous catches of 5 to 15 tons were made in 30 min. tows in depths of 30 to 50 fm.—below the normal fishing depth of the conventional purse seine. Catches of 20 to 75 tons were made in 20 to 30 min. tows in daylight in depths from 40 to 55 fm. when the trawl was used with conventional otter boards on the bottom, the net being about 2 fm. off the bottom.

Commercial use. A number of commercial trawlers, in the late autumn and winter of 1955-56, used the trawl close to the bottom with conventional otter boards. Seven trawlers took 2,000 tons of herrings averaging 5 to 6 tons per half-hour tow. In the winter of 1956-57, 19 trawlers took part in the fishery.

Development of a dual-purpose otter board. To facilitate quick changes from strict midwater trawling to trawling with otter boards on the bottom, or vice versa, a dual-purpose aluminium otter board was developed in 1956. A V-shape gives stability at speeds from 2 to 6 knots. Vertical stability is aided by an air tube along the upper edge and horizontal fins reduce oscillations. The

angle of attack of the otter board under tow is controlled by conventional chain brackets and a vertical stabilizing fin. These boards have now replaced the curved plywood otter boards and are manufactured under patent in Canada.

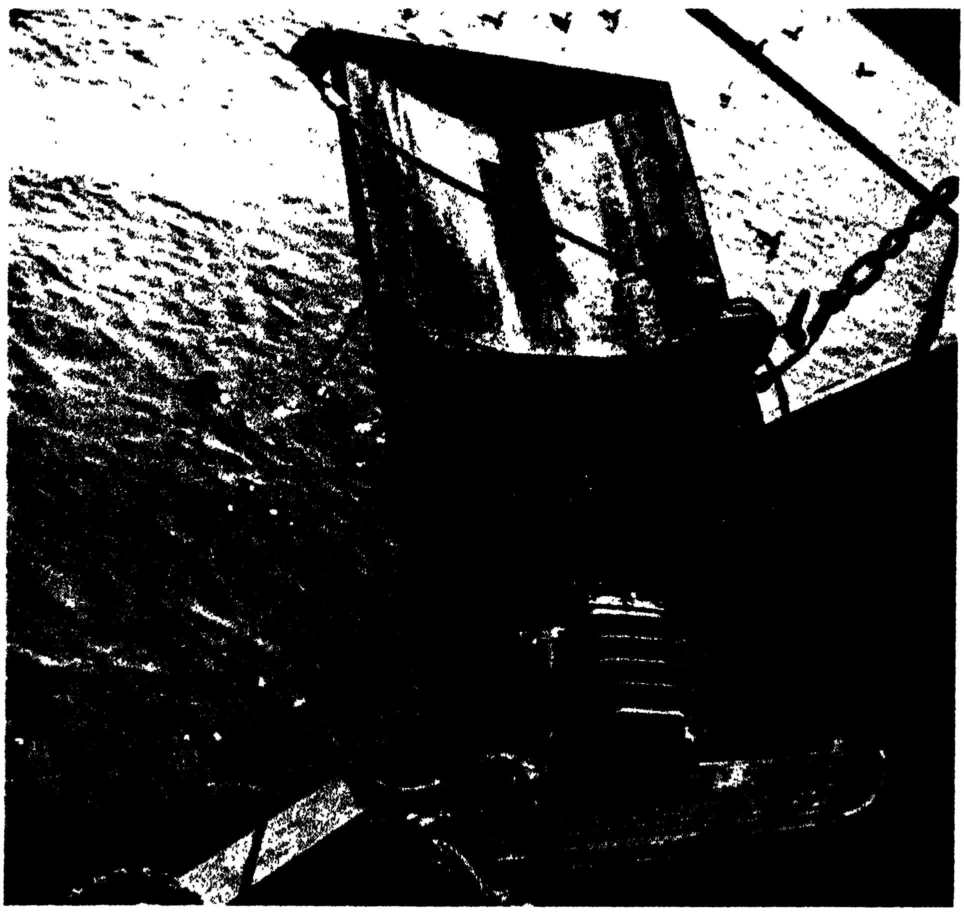
FURTHER DEVELOPMENTS

Midwater trawl for small vessels. A small version of the modified stronger trawl (fig. 6) was built for use on small trawlers of about 45 ft. When used with the aluminium dual-purpose otter boards in the autumn of 1956 it caught herring in commercial quantities both in midwater and at the bottom.

Midwater trawls for faster-swimming fish. Attempts are being continued to develop a midwater trawl for catching in commercial quantities summer herring and other fish more active than winter herring. Two approaches are being made using modifications of the midwater trawl described above—fast towing of a specially strengthened net and slow towing of a large-mouthed net. A trawl is also being tested which embodies the principle of the high-speed plankton net, i.e., free passage for water in the centre of the net, but it is too early to assess the performance of these nets.

CONCLUSION

The success of midwater trawls in catching winter herring is encouraging. Efforts to improve midwater trawls as tools for exploratory or commercial fishing for more active species seem highly desirable. The experiments described in this paper have been carried out with a practical trial-and-error approach. There is obviously need also for a fundamental scientific approach if the potential of this kind of fishing is to be fully explored, and physicists and engineers must be enlisted to help the fishermen and the biologists.



Big hydrofoil ("Süberkrüb") otter board rigged for bottom trawling. The attached casing contains the recording unit of a dynamometer measuring the resistance of the net during towing. Photo: J. Schärfe

ON THE USE OF MIDWATER TRAWLS FOR ANCHOVY IN THE BLACK SEA

by

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Abstract

This paper describes experiments made with a Danish Vinge-trawl (a high-opening ground trawl) which was rigged for fishing in midwater and towed by a single boat. Very dense schools of anchovy were found and hauls of over 1 ton were taken in about 10 to 20 min. A second series of experiments confirmed that the introduction of this type of gear would produce large quantities of anchovies in the winter months when the fish were readily accessible to the midwater trawl.

Sur l'emploi du chalut flottant pour l'anchois dans la mer Noire

Résumé

L'auteur décrit des expériences effectuées avec un chalut danois Vinge (un chalut de fond à ouverture élevée) qui était gréé pour la pêche entre deux eaux et était remorqué par un seul bateau. On a trouvé des bancs d'anchois très denses et des traits de chalut de plus d'une tonne ont effectués en 10 à 20 minutes environ. Une seconde série d'expériences a confirmé que l'introduction de ce type d'engin produirait de grandes quantités d'anchois pendant les mois d'hiver quand less poissons sont à la portée du chalut flottant.

Uso de redes de arrastre pelágicas para la pesca de anchoa en el mar Negro

Extracto

En este trabajo se describen las pruebas hechas con una red de arrastre "Vinge" (arte de fondo con boca de gran altura) construida para la pesca en medias aguas con ayuda de una sola embarcación. Durante los lances se encontraron cardúmenes muy densos que permitieron capturar más de una tonelada de pescado en 10 a 20 minutos. En una segunda serie de pruebas se confirmó que la introducción de este tipo de red permitiria obtener grandes redadas de anchoas durante los meses de invierno, cuando los peces pueden ser capturados con facilidad mediante redes de arrastre remolcadas a profundidades intermedias.

THE Turkish Meat and Fish Office has emphasized in development plans the importance of increased catches of anchovy in the Black Sea, as this fish is to be the principal raw material for the fish-meal plant which is being built in Trabzon. Until now, the anchovy has been fished by a two-boat purse seine (local name *girgir*) but, in February, 1956, experiments were made in Fatsa Bay, on the Turkish Black Sea coast, using a Danish Vinge-trawl. This was specially rigged for midwater fishing of the dense anchovy schools which are frequently found in deep water during the day time. This paper reports the results obtained and makes some suggestions as to the use of such trawls in this fishery.

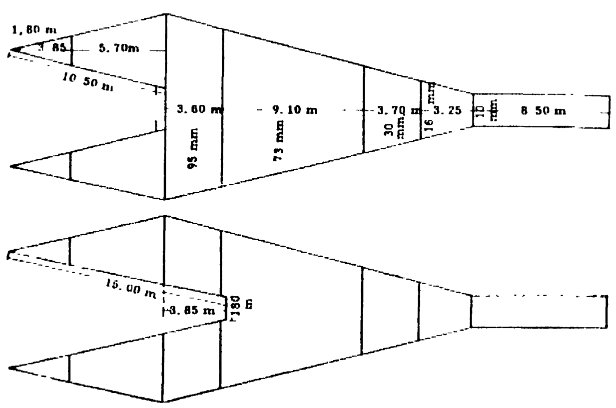

Fig. 1. Construction plan of Vinge-trawl net.

EXPERIMENTAL HAULS

Details of the vessel and gear and their operation are given below (figs. 1 and 2).

1. Vessel: *M/V Arar*, starboard side trawler; 380 h.p. diesel propulsion, 28 m. overall length, 173 gross tons.

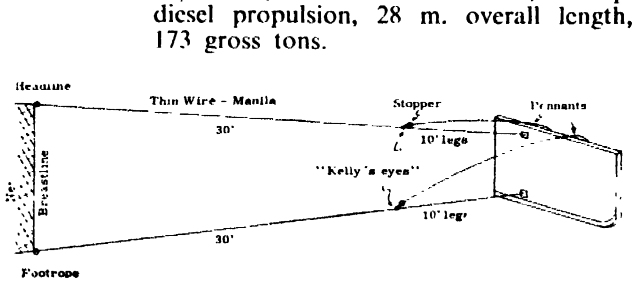

Fig. 2. Connection of wingtips to otter boards.

2. Gear: Danish Vinge-trawl, 23·6 m. long headline; 31·8 m. long footrope; 1·8 × 0·9 m. long otter boards.

Mesh size: upper wings 18/11 cm.; lower wings 18/11/9·5 cm.; square 9·5 cm.; belly and batings 7·3/3/1·6 cm.; codend 1 cm.

Eight hauls were made in all, and the duration of each varied from 10 to 15 minutes.

Date	*No. of haul*	*Duration*	*Warp paid out*	*Depth of Fish school*	*Time of day*	*Anchovy catch (tons)*
February 22, 1956	1	12 min.	25 fm.	10 to 40 fm.	Daylight	·3
	2	16 min.	75 fm.	8 to 30 fm.	,,	·8
February 24, 1956	3	15 min.	100 fm.	30 to 70 fm.	Daylight	
	4	15 ,,	75	10 to 40	Night	·2
	5	15 ,,	75	10 to 40		·2
	6	15 ,,	75	15 to 40		
	7	19 ,,	75	20 to 40		·4
	8	17 ,,	75	20 to 45		

Notes.— 1. Duration is the time in minutes from warps blocked-in to knock-out.
2. Engine speed in all hauls—230 r.p.m.

With the exception of the first haul, the quantities of fish caught did not vary appreciably. It is apparent that not enough warp was paid out during the first haul to enable the trawl to fish at the proper depth.

These few hauls give no indication of the relation between catch, length of haul, time of day, or the phosphorescence made by the net.

The time required for hauling and re-shooting (including the time spent searching for a new school or running back over the same school to shoot again) averaged 45 minutes. However, this time could be longer or shorter, depending on the amount of fish caught and the time taken in handling the catch.

The market value of the anchovy at the time of the experiment was 0·50 Turkish Lire per kilo and, with an average value of 500 Turkish Lire per haul, it seems that a highly profitable trawl fishery could be established.

Echo sounder observations showed that anchovies have a tendency to congregate in the submarine valleys, which may make trawling rather difficult.

At the time of these brief observations, the anchovy appeared to show negative reaction to both natural and artificial light. During the day the schools stayed very deep, the lower limit being 160 m. No fish school was detected below that depth, due, I believe, to the lack of oxygen.

DISCUSSION

No midwater trawl was available so a Danish Vinge-trawl was used. This high-opening bottom trawl was rigged for one-boat midwater trawling (see fig. 2) by FAO Master Fishermen (from Iceland) who worked in Turkey, helping to improve local gear and introduce new fishing methods. The results show that, in the anchovy fishery of the Black Sea, pelagic trawling would be profitable. Such trawls have some definite advantages over the *girgir* seines (the old, traditional two-boat purse-seines) such as possibility of fishing in rough weather, both day and night, and at greater depths than can be done with the seines. Introduction of this gear to the fishery would be a very useful step in creating a balanced industry because the fish are highly accessible to the trawl during the winter season.

In March/April 1957, a FAO fishing expert again fished experimentally for anchovy with a Vinge-trawl, rigged in a similar manner and operated from a 180 h.p. boat of the Pacific seiner type. He obtained catches of 10,000 to over 20,000 lb. per day (6 to 8 hauls of 20 minutes each) and once he got a full trawl in a 10 minute tow (approximately 10 tons).

The fish were landed in good condition and trucked to Ankara for marketing.

There is little doubt that pelagic trawls would be a very efficient gear for fishing anchovy. If schools are detected very deep during the day, their lower limit could be considered as a "bottom" and the trawls could be operated at that depth. This will minimise the escape of fish below the footrope. Furthermore, the trawl could be rigged with kites to lead the fish into the net, thus increasing their vulnerability to the gear. It is believed that the fish will not dive deep due to certain hydrographic conditions obtaining in these waters.

LITERATURE

Aasen, Olav and Akyüz, Erdogan (1956). "Fishery Investigations in the Turkish Black Sea Waters with Special Reference to Anchovy."
Reports from the Fishery Research Centre, Meat and Fish Office, Vol. I, No. 7, Istanbul.

OTTER BOARDS FOR PELAGIC TRAWLING

by

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Abstract

After discussing the disadvantages of the common, plane otter boards for pelagic trawling, a hydrofoil type of otter board constructed by the author is described. By using a simply curved profile, turbulence is avoided and towing resistance decreased. An unsymmetrical positioning of the bracket (for attachment of the warp) is suggested to gain a slightly upward directed component of the shearing power for facilitating the depth regulation of the trawl.

Les plateaux de chalut pour le chalutage entre deux eaux

Résumé

Après avoir examiné les inconvénients des plateaux de chalut ordinaires, plans, pour la pêche entre deux eaux, l'auteur décrit un plateau du type à surface hydro-dynamique qu'il a construit. En utilisant un profil simplement courbé, on évite la turbulence et la résistance au remorquage est diminuée. Il est suggéré de placer l'attache de la fune en position asymétrique pour tirer profit d'une composante légèrement dirigée vers le haut de la force d'écartement et faciliter le réglage de la profondeur du chalut.

Puertas de arrastre para redes pelágicas

Extracto

Después de analizar los inconvenientes de las puertas de arrastre comunes utilizadas en las redes pelágicas, el autor describe un dispositivo hidrodinámico que ideó para este tipo de arte de pesca. Al utilizar un perfil curvo sencillo se evita la turbulencia y disminuye la resistencia al arrastre. Para obtener un ligero esfuerzo separante hacia arriba que facilite la regulación de la profundidad de la red, se sugiere colocar asimétricamente el brazo de la puerta que se conecta con el cable de arrastre.

OTTER boards commonly used in bottom trawling are rigged in such a way that, when they are not in contact with the bottom, a certain part of their shearing power is directed obliquely downwards. This results in difficulties when such boards are used for midwater trawling and are lifted off the bottom.

The depth of a pelagic trawl can be regulated by altering either the towing speed or the length of the gear. At a constant speed of the vessel, the shortening of the warps produces an increased towing speed of the gear itself during the time of heaving, and this in turn increases the downward directed component of the shearing power of such boards. The result is that the lifting process is retarded. This also happens when the gear has to be lifted during fishing by increasing the towing speed of the vessel, especially when the gear operates near the surface. In this case, furthermore, the angle of the warps to the horizontal, and consequently the upward directed component of the towing force, becomes small, whilst the downward directed component of the shearing power of the boards remains unaltered.

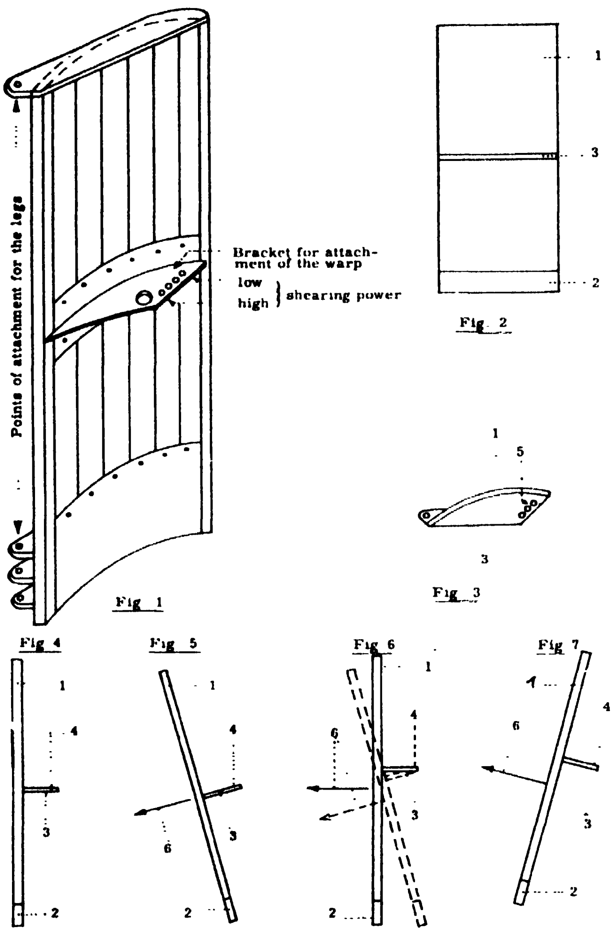
Another disadvantage of the common boards lies in the intermittent turbulence which is set up and detaches itself, causing variations of the shearing and resistance forces. In the same way as toy kites weave and stall, the boards travel unsteadily and may even turn over, fouling the gear extensively and with astonishing speed.

These are the main reasons why common otter boards are not suitable for pelagic trawling. Boards are needed which:

(1) Create little or no turbulence; and
(2) Have no downward shear and act only in a horizontal, or even in a slightly upward, direction.

The turbulence can be avoided by choosing short upper and lower edges and by using curved profiles instead of a plane. The author, therefore, constructed high and narrow boards with a curved profile. Figs. 1 to 4 illustrate constructional details, and figs. 5 to 7 show the board in different positions, according to different points of attachment of the bracket which takes the warp. To simplify the explanation, only one bracket is shown in the drawings.

With no other forces acting, the centre of gravity, as is well known, always takes a position directly below the point of suspension. If the bracket is fixed in the middle of the board, the board will therefore take up



LEGEND

1. - Board
2. - Ballast weight
3. - Bracket for attachment of the warp
4. - Point of application of the warp
5. - Holes for attachment of the warp
6. - Shearing power

an oblique position under tow and the outward tilt will produce a shearing power which is partly directed downwards (fig. 5).

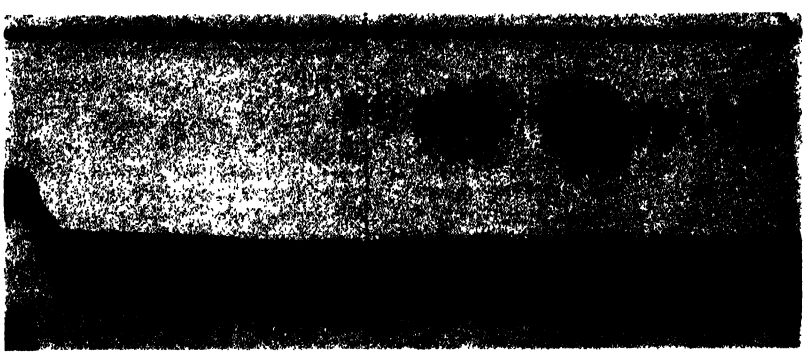
If the bracket is fixed above the middle of the board, the centre of shearing will lie below that point so that the lower part of the board will turn outwards and the board may take up a somewhat vertical position (fig. 6).

If the bracket is fixed higher above the middle, the shearing power of the lower part of the board will increase. As the downward directed power of the ballast remains the same, the lower part of the board will go beyond the vertical position and the board will gain a lifting component (fig. 7), the strength depending on the actual position of the board.

This position depends not only on where the bracket is fixed but also on the towing speed. This may be explained by an example: with an otter board of $4 m^2$ size the part below the bracket may be $2{\cdot}3\ m^2$ and the upper part $1{\cdot}7\ m^2$. If it is assumed that with a 3·5 knot towing speed the shearing power of the whole board is 800 kg., the part below the bracket would have 460 kg., while the upper part would only have 340 kg. The difference of 120 kg. would push the lower part of the board outwards.

If, in order to lift the gear, the towing speed is increased, for instance, to 4·0 knots, the shearing power of the whole board would be increased to 1,040 kg. (increasing as the square of the speeds). The lower part would then have 600 kg. and the upper part 440 kg., i.e. the difference would increase from 120 kg. to 160 kg. As the ballast remains the same, the lower edge of the board would be pushed outwards even more and the lifting component of the shearing power would become stronger. This, together with the increased pull on the warps, would aid in lifting the gear towards the surface.

Thus, by establishing the proper proportions for the upper and lower parts of the board and the ballast, and by selecting the suitable position of the bracket for the warps, it becomes possible in using such boards to obtain speedy depth-regulation of pelagic trawls.



Echo trace of a pelagic sardine school off the Brittany coast. Photo: Elac, Kiel

CONSIDERATIONS ON A NEW TYPE OF MIDWATER TRAWL

by

Y. GROUSELLE

Saint-Malo, France

Abstract

When considering the shape a one-boat midwater trawl should have, we find that the two most important factors are the total opening and the stability of the trawl during fishing.

The author claims that this can best be obtained by giving the net a triangular opening and by having a sufficiently powerful central lifting apparatus which would facilitate the stabilization of the net's position in the water when towing. Such a triangular opening would allow the net to have an apron instead of overhang, so that the headline would come well back of the footrope. By using suitable shearing apparatus, such a midwater trawl would be easier to keep at any required depth.

It is claimed that the Exocet board possesses the shearing power required, both for vertical lift of the headline and for opening the wings of the trawl. In the latter function, by adjusting the shear to the proper angle, it would mean an improvement on the present use of weights. The shearing power of the Exocet increases with the speed of towing, whereas the downward action of towed weights decreases as the speed increases.

The paper further gives details of the construction and operation of the Exocet.

Considérations sur un Nouveau Type de Chalut Flottant

Résumé

Quand on considère la forme que doit avoir un chalut flottant traîné par un seul bateau, on trouve que les facteurs les plus importants sont l'ouverture totale et la stabilité pendant la pêche.

L'auteur déclare que cela peut être obtenu de la meilleure façon en donnant au filet une ouverture triangulaire et en ayant un dispositif d'ouverture verticale suffisamment puissant qui faciliterait la stabilisation de la position du filet dans l'eau quand il est remorqué. Une telle ouverture triangulaire permettrait au filet d'avoir la partie inférieure de la gueule dépassant et ainsi la corde de dos serait bien en retrait par rapport au bourrelet. En utilisant un dispositif de plongée bien adapté, ce chalut flottant pourrait plus facilement être maintenu à la profondeur requise.

Le panneau élévateur Exocet possède la poussée ascensionnelle nécessaire pour lever verticalement la corde de dos et écarter les ailes du chalut. Dans cette dernière fonction en réglant le panneau selon le bon angle, il apporte une amélioration à l'emploi actuel de poids. La puissance ascensionnelle de l'Exocet augmente avec la vitesse de remorquage, alors que l'action de plongée des poids remorqués dimnue quand la vitesse augmente.

La communication donne des détails sur la construction et le fonctionnement de l'Exocet.

Consideraciones sobre un nuevo tipo de red de arrastre flotante

Extracto

Al considerar la forma de una red de arrastre flotante remolcada por una sola embarcación, encontramos que los dos factores más importantes son la abertura total de la boca del arte y su estabilidad durante el lance.

El autor afirma que esto puede lograrse, en mejores condiciones, con una red de boca triangular y mediante un poderoso elevador central que facilite la estabilidad del arte en el agua al arrastrarlo. Una boca como la descrita permitirá a la red disponer de una antecámara en vez de visera, de manera que la relinga superior se halle detrás de la inferior. Con dispositivos adecuados sería mucho más fácil mantener un arte de esta naturaleza a la profundidad deseada.

Se afirma que el elevador Exocet posee las condiciones requeridas tanto para elevar la relinga superior al nivel deseado como para separar las bandas de la red. Esto último se logra mediante la colocación del elevador en el ángulo adecuado, obteniéndose mucho mejor resultado que con los plomos de uso corriente. La acción del Exocet aumenta con velocidad de arrastre, mientras que la sumersión de los pesos durante el remolque es inversamente proporcional a la velocidad.

El trabajo también contiene detalles de la construcción y funcionamiento del Exocet.

IT is particularly important that a one-boat midwater trawl should have a large opening with good stability when fishing. Such stability cannot be obtained from the symmetry of the net alone; there must be a force acting in the vertical direction to counteract the wobbling and weaving of the otter boards.

It therefore appears logical to give the opening of the net a triangular or trapezoidal form because that would enable one or several lifting devices, acting at the summit of the triangle or trapezium, to produce a stabilizing effect.

The ordinary bottom trawl net has an overhang and the headline comes well ahead of the footrope. All fish passing under the headline are led to the codend, and the sea bottom forms, as it were, the complement to the overhang.

The case is different with midwater trawls as the fish, which have a tendency to dive, must be stopped and led further into the net by the belly webbing. In the midwater trawl, therefore, the footrope should jut further forward than the top of the net, which suggests that the tetragonal form (fig. 1*a*) or trapezoidal (fig. 1*b*) would be preferable to the pyramidical form. Such a form can be roughly obtained by turning the trawl on its back, so that the square is on the lower lip of the net, well forward of the rest of the body. It should be of rather smaller mesh to lead the fish, which tend to dive, further into the belly. The horizontal opening of the net could further be improved by the use of shearing devices, in which a suitable amount of depressor action could be introduced to help bring the trawl to the proper depth of operation. This is important as the diverging force of such deflectors increases with the towing speed, whereas the downward action of sinkers decreases with the speed.

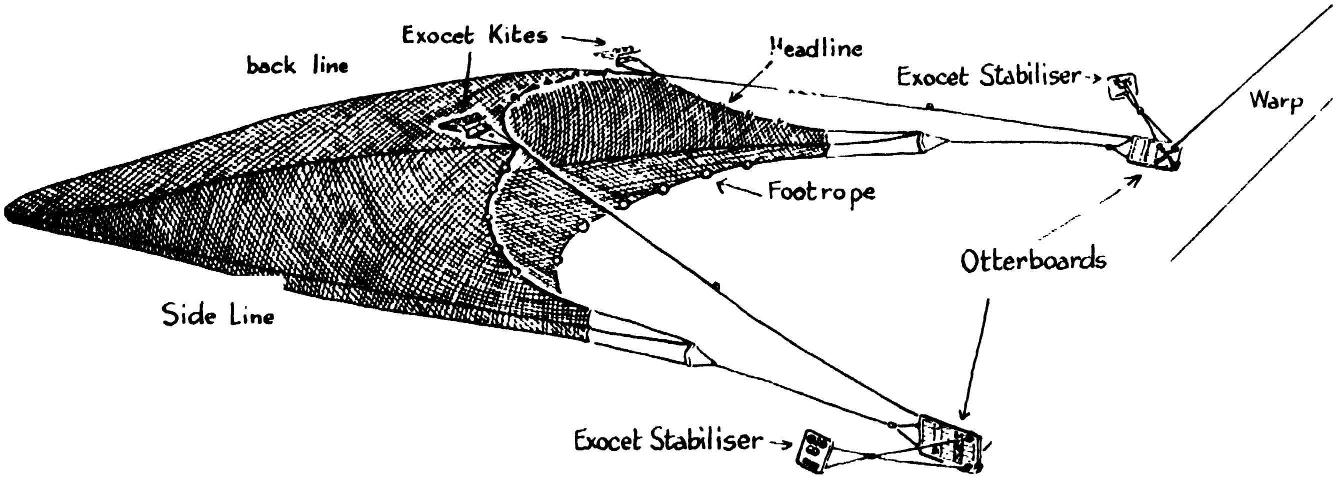


Fig. 2. Midwater trawl with 4 Exocet *shearing boards, two of which act as a kite.*

With the help of l'Institut Scientifique des Pêches Maritimes, experiments were carried out from the research vessel, *Président Théodore Tissier*, in July 1957, from which it appeared that, by using four Exocet boards on a net constructed as described above, good opening and stability are obtained (fig. 2).

THE EXOCET KITE

The apparatus consists of a board set in an aluminium frame and armed with two or three floats to give initial lift (fig. 3). The aluminium frame is attached to the middle of the headline and allows the shearing board freedom of movement. The board itself takes an angle of about 30 degrees to the horizontal as soon as the net is towed, thereby producing a lifting force which increases with the towing speed.

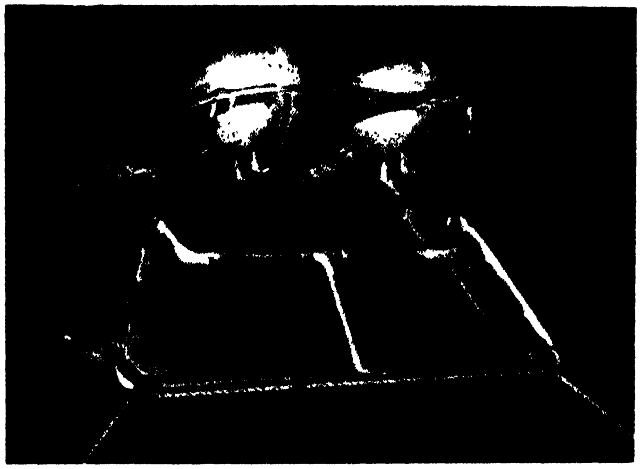


Fig. 3. The Exocet *kite.*

EXOCET STABILIZERS

In one-boat midwater trawling, one of the main problems is the instability of the otter boards. The Exocet stabilizer attached to the normal type of otter board makes it function efficiently in any weather and trawling conditions.

The stabilizer is a rectangular panel made of aluminium alloy to which are fitted 5 or 7 floats near the upper edge. The lower edge is ballasted so that the panel is completely stable in itself.

The stabilizer is attached to the otter board by rope brackets and a swivel joint, in such a way that the inherent tendency of the board to capsize is counteracted. As the outward and downward thrust of the stabilizer increases in proportion to the towing speed, the increased resistance of the net at higher speeds is counteracted by increased opening force. The net opening is therefore stable at all towing speeds.

The downward thrust of the otter boards equipped with Exocet stabilizers is governed by the towing speed, so that the depth of operation is fixed by the length of warps for a given speed.

When used in conjunction with lifting kites attached to the leadline, the whole net becomes a stable unit.

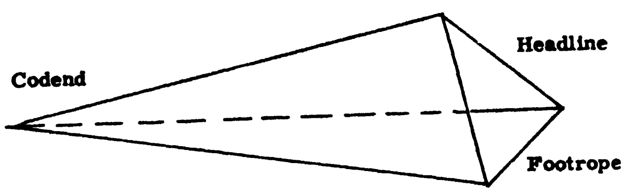


Fig. 1 (a). The shape of the proposed midwater trawl with triangular opening and protruding lower lip.

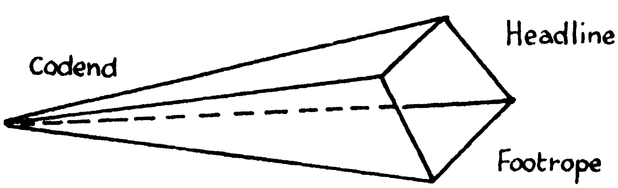


Fig. 1 (b). Proposed shape of midwater trawl of trapezoidal opening and protruding lower lip.

A PRACTICAL DEPTH TELEMETER FOR MIDWATER TRAWLS

by

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Abstract

A direct-reading electrical depth telemeter for midwater trawls has been developed and used successfully in the north eastern Pacific. The system utilizes an electrical trawl cable to transmit continuous depth information from a pressure-sensing unit on the gear to a pilot house meter which shows trawl depth in feet and fathoms. Slip rings and brushes on the trawl winch complete the electrical circuit, which is powered by a 45V. battery located in the control box in the chart room. Maximum depth range of the system with the present potentiometer is 225 fm., but this can be increased or decreased as may be required. Advantages of the system are its simplicity and practicability, requiring no extra handling on deck and no specially-trained operator. It has been tested and used successfully during the spring and summer of 1957 aboard the U.S. Fish and Wildlife Service's exploratory fishing vessel *John N. Cobb* based at Seattle.

Télémètre de conception pratique pour mesurer la profondeur des chaluts flottants

Résumé

On a mis au point un télémètre électrique à lecture directe indiquant la profondeur à laquelle opèrent les chaluts flottants et qui a été utilisé avec succès dans le Nord-Est du Pacifique. Le système comporte une fune câble électrique qui transmet d'une façon continue à un cadran monté dans la timoneri, la profondeur du chalut en pieds et en brasses indiquée par un appareil fixe sur le chalut et dont le fonctionnement est basé sur la variation de pression selon la profondeur. Des bagues et balais collecteurs montés sur le treuil du chalut complètent le circuit électrique qui est alimenté par une batterie de 45 volts logée dans le boitier de commande installé dans la chambre des cartes-radio. Le potentiomètre actuellement monté sur l'appareil permet une portée maximum de 225 brasses en profondeur, mais elle peut être augmentée ou diminuée suivant les besoins. Ce système a l'avantage d'être simple et pratique, de ne pas demander de manoeuvre supplémentaire sur le pont ni de spécialiste pour le faire fonctionner. Il a été essayé et utilisé avec succès au cours du printemps et de l'été 1957 à bord du navire américain *John N. Cobb*, basé à Seattle et opérant pour le compte du Fish and Wildlife Service des Etats-Unis.

Una ecosonda práctica para redes de arrastre que pescan a profundidades intermedias

Extracto

En el Pacífico nororiental se ha usado con éxito una ecosonda ultrasonora de lectura directa, ideada para determinar la profundidad de trabajo de las redes de arrastre que pescan a profundidades intermedias. Este instrumento se vale de un cable de remolque que actúa como conductor eléctrico para transmitir en forma continua la profundidad (en pies y brazas) mediante un dispositivo sensible a la presión montado en el arte, que se conecta con el medidor instalado en la caseta de gobierno.

Anillos y escobillas colectores dispuestos en la maquinilla de arrastre completan el circuito alimentado por una batería eléctrica de 45 voltios, localizada en la caja de control que se halla en el cuarto de derrota y radiotelegrafía. Este aparato permite determinar profundidades hasta de 225 brazas con el potenciómetro usado en la actualidad, pero dicho limite puede aumentar o disminuir según las circunstancias lo requieran. Entre las ventajas del sistema descrito figuran su sencillez y utilidad, no requiriendo ninguna manipulación adicional en la cubierta ni un operador especialmente adiestrado. Este aparato se ensayó y usó con éxito durante la primavera y verano de 1957 a bordo del barco de exploración pesquera *John N. Cobb*, del Servicio de Pesca y Vida Silvestre de los E.U.A., con base en Seattle, Wásh.

A DEPTH telemetering system, utilizing a low-voltage electrified trawl cable for determining the depth of midwater trawls, was installed and used successfully aboard the U.S. Fish and Wildlife Service's exploratory fishing vessel *John N. Cobb* in the north-eastern Pacific during 1957.

Accurate knowledge of the depth of the net is essential to successful midwater trawling as the net must operate at the depth indicated by fish signs on the echo sounder or other instrument. Many methods have been used in various parts of the world to determine the operational depth of midwater trawls, but there is still need for an instrument which is accurate, simple to use and reasonably economical for commercial fishermen. The electrical depth telemeter, which was designed, constructed and installed at Seattle by Service personnel, appears to meet this need.

Although midwater trawling by commercial fishing vessels thus far has been limited primarily to herring in northern Europe and British Columbia, there is evidence that other species of fish may be available to midwater gear, thus opening up vast new fishing areas of the ocean. Echo sounders and sonar-type instruments have shown that schools of fish may be found at any depth. Some schools of fish occupy a relatively thin vertical layer of water and can be missed easily if the net is a few fathoms too high or too low. During a single tow separate schools of fish may be found at different depth levels, necessitating raising or lowering the net[6]. Also, when attempting to catch fish very near a hard or uneven bottom, the position of the gear must be accurately known to avoid contact with the bottom which could damage the gear.

DESCRIPTION OF THE ELECTRICAL DEPTH TELEMETER

The system transmits continual depth information from the midwater trawl gear to the pilot house of the vessel. A small pressure sensing unit (see fig. 2), located on the

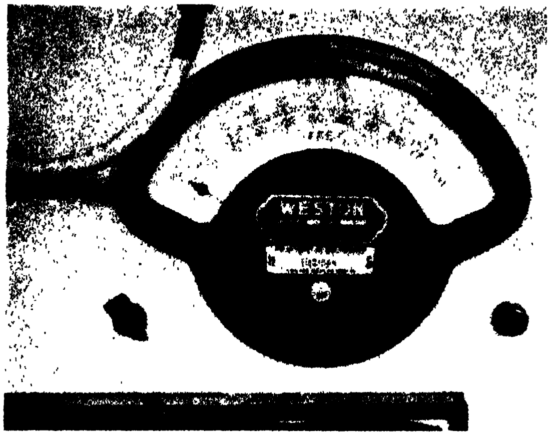

Fig. 1. Pilot house depth meter, calibrated to show depth of the trawl in feet and fathoms.

end of the trawl cable at one trawl door, actuates a milliammeter in the pilot-house which is calibrated to read depth in both feet and fathoms (see fig. 1). Electrical continuity at the trawl winch is through a slip-ring and brush assembly mounted on the outside of the winch drum. Steel trawl cable, having insulated conductors for a core, provides a full electrical circuit for the system.

The dial of the depth meter in the pilot house is calibrated in 1 fm. and 5 ft. intervals from 0 to 50 fm. and 0 to 300 ft. An off-on-range selector switch permits selection of successive 50 fm. segments from 0 to 225 fm. (the maximum depth of the particular pressure potentiometer used). The captain refers to the meter and adjusts the length of towing cable or speed of the vessel in order to raise or lower the trawl to any desired depth.

Sensing unit and housing. The sensing unit consists of a precision pressure potentiometer encased in a Tobin bronze pressure vessel $3\frac{3}{8}$ in. long and $2\frac{1}{16}$ in. in diameter (see fig. 3). Threaded cap and "O" ring seal provide a watertight access port. Stuffing-tube type feed-throughs for the electrical conductors are located in the housing cap. A small hole in the centre of the cap admits sea

Fig. 2. Pressure-sensing unit attached to the end of the electrical trawl cable just in front of one of the trawl doors.

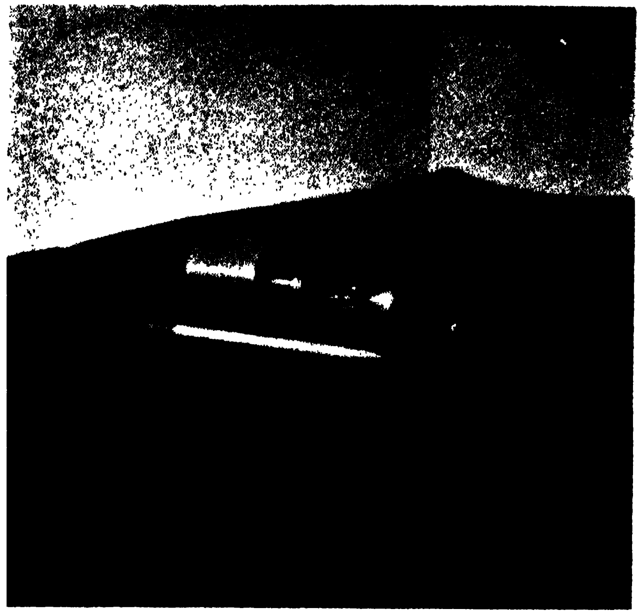

Fig. 3. Bronze pressure vessel with cap removed to show pressure potentiometer, feed-throughs, and "O" ring seal.

water pressure to the castor oil-filled bourdon tube of the potentiometer (see fig. 4). The sensing unit is placed inside a steel housing lined with sponge rubber, which screws on to the cable termination socket. There is a shackle hole in the opposite end of the housing for connection to the bridle lines or chain of the midwater trawl gear. The housing is $7\frac{15}{16}$ in. long by 3 in. in diameter, overall size.

The sensing unit potentiometer has a pressure range of 0 to 600 p.s.i. with an electrical resistance differential of 10,000 ohms, thus the depth range of the instrument is 0 to 225 fm. Linearity deviation is less than one per cent. with friction of the potentiometer slider accounting for the major part.

Other pressure potentiometers having greater or lesser pressure-resistance values are available commercially. The 225 fm. depth range was selected as the most practical for present use.

Cable and termination. The electrical trawl cable is ·528 in. outside diameter, double-armoured steel, consisting of an electrical conductor core and two layers of 24-strand opposed helical-wound high tensile galvanized steel (see fig. 5). The six rubber-covered conductors are each made up of seven strands of ·012 in. diameter copper wire and are wrapped around a solid-rubber centre filler. Only three conductors are used, the remaining three being spares. The wire size of each conductor is equal to No. 21 a.w.g., and resistance is 11·1 ohms per 1,000 ft. Nylon fillers and sheath encase the conductors, making a round electrical core approximately $\frac{5}{16}$ in. in diameter. Breaking strength of the cable according to the manufacturer, is 18,000 lb.

The type of termination developed for the cable used on the *John N. Cobb* is an extreme wide-angle and shallow poured-babbit socket (see fig. 4). Glass tape is wrapped around the conductors for protection during

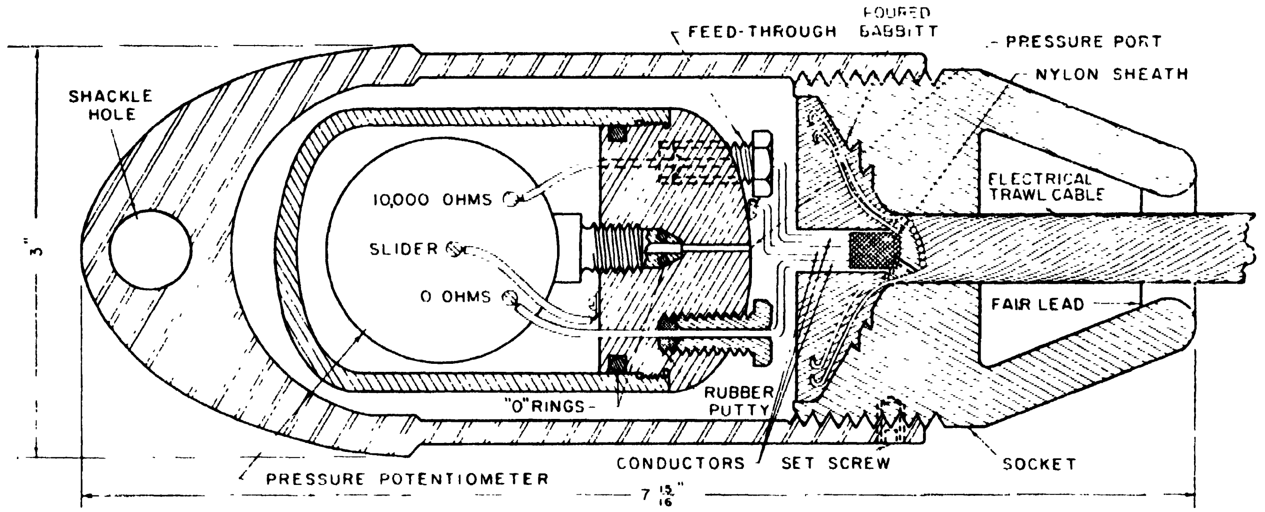

Fig. 4. Sensing unit, housing and cable termination of the electrical depth telemeter.

babbiting. This termination relieves external pressure on the conductors, as opposed to the common deep narrow-angle socket which tends to squeeze and cause shorting. The wide-angle socket also requires a minimum of length making it possible to contain the cable termination and pressure-vessel sensing unit in a single small housing which will pass through the trawling blocks and wind up on the winch (see fig. 6).

Slip rings and brushes. A set of three bronze face-type slip rings are groove mounted in plexiglass and installed on the outside of the drum near the shaft (see figs. 7 and 8). In order to utilize a minimum of space in the winch-drum housing area and avoid disassembly of the winch, the rings and mountings are split halves with the ring joints rotated 45 degrees so that on assembly around the winch shaft they become a solid unit. Jumper wires on the back of the mounting provide electrical continuity across the

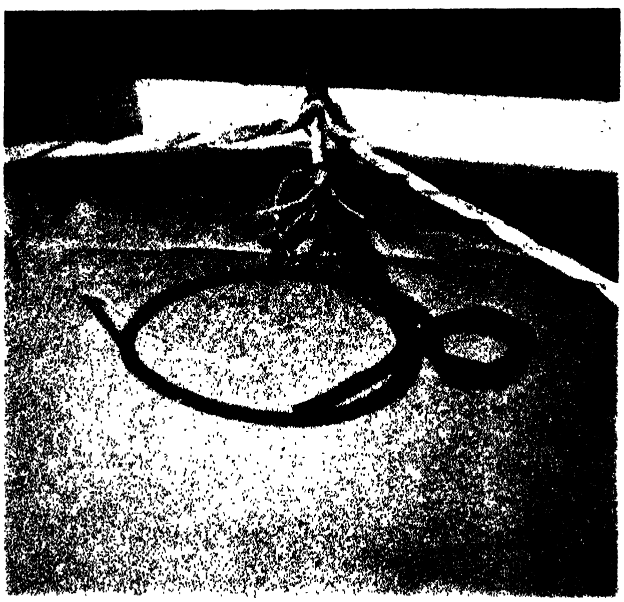

Fig. 5. Electrical trawl cable ready for splicing, showing core, fillers, conductors and the two layers of steel strands.

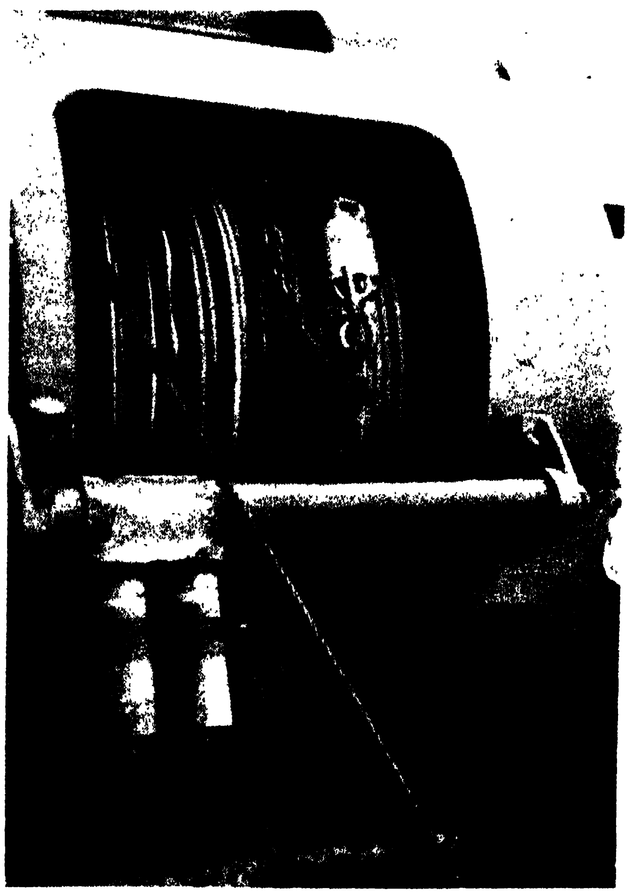

Fig. 6. Electrical trawl cable, midwater trawl bridles and the telemeter sensing unit on winch of the John N. Cobb.

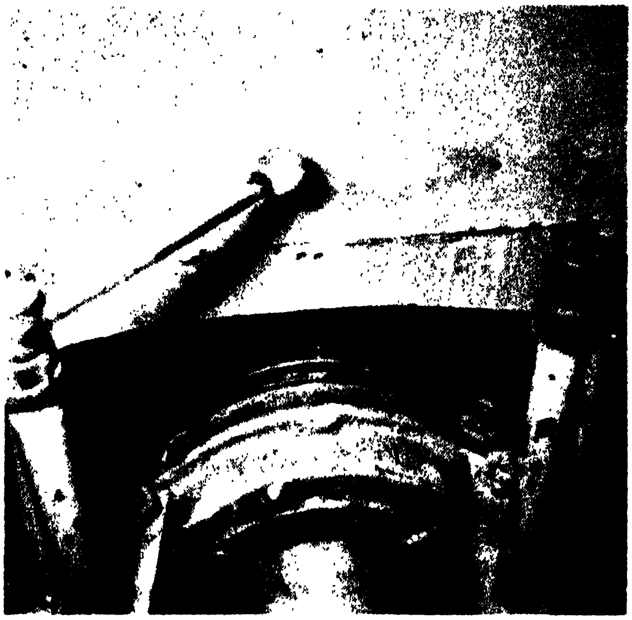

Fig. 7. Access port of the trawl winch showing location of the slip rings between the winch shaft bearing cap and the drum flanges.

ring joints. Spring-mounted, solid brass, button-type brushes with direct connected pilot house leads are bolted to the winch shaft bearing cap. The winch end of the electrical trawl cable is fed through the clamp hole of the drum, and the conductors are connected to the slip ring terminals to complete the circuit from potentiometer to pilot house. A weather-tight cover on the winch housing protects the slip ring assembly.

Indicator and controls. Electrical resistance differential in the precision potentiometer is measured by a simple electrical bridge circuit. This difference in resistance, when fed with proper line voltage, is shunted across a milliammeter calibrated to read depth in fathoms and feet. The meter is provided with a 100 ohm, one milliampere actuation coil for $\frac{1}{10}$ V full-scale deflection.

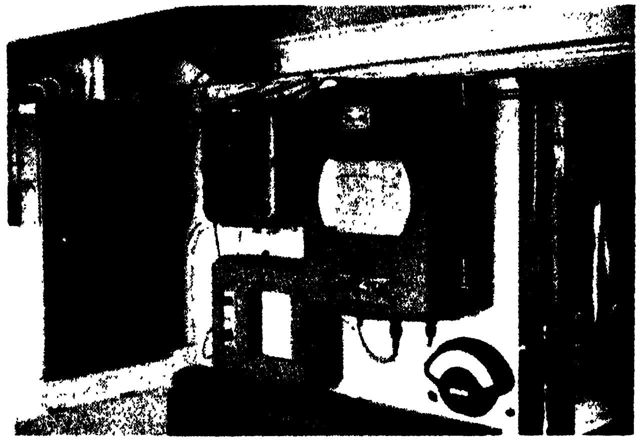

Fig. 9. Arrangement of instruments in the pilot house of the John N. Cobb *showing trawl depth meter in lower right corner.*

With a bridge unbalance of ·095 V. giving a readout of 50 fm., the remaining five per cent. of the available pointer travel is used as a line voltage test. A small three-pole triple-throw rotary selector switch connects either the pressure potentiometer or a pre-set calibrating test potentiometer to the meter bridge circuit (fig. 11).

Circuitry, battery, control and test mechanisms are housed in a small metal box mounted on a bulkhead in the chart room in a manner that allows the depth meter and the line control and off-on-range selector switch knobs to be mounted on the opposite side of the bulkhead in the pilot house (see fig. 10). Holes drilled in the bulkhead connect the two units and provide compactness of installation. A 45 V. "B" battery located in the control box is the voltage source. Battery drain is 4·2 milliamperes, which should require a minimum of battery replacements. Actual line voltage is 28 V.; thus the 32 V. battery system carried on most fishing vessels could be used as a power source provided that voltage changes were checked and compensated for during telemetering operations. The low voltage used presents no hazards to personnel.

Range selection is divided into 4½ 50 fm. increments. To accomplish this, eight precision 2222 ohm resistors

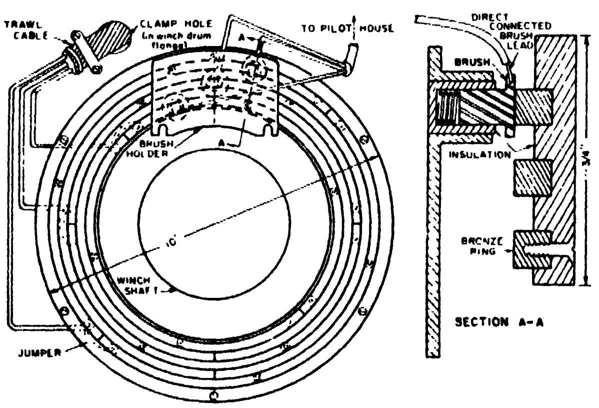

Fig. 8. ***Slip-ring and brush assembly of the electrical depth telemeter.***

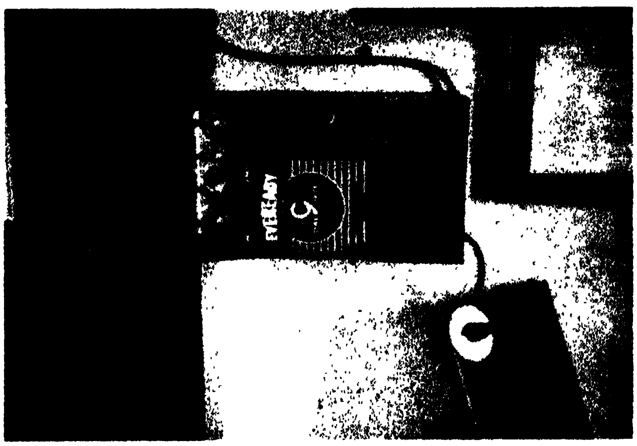

Fig. 10. ***Control box in radio-chart room with cover off to show battery, controls and test mechanisms.***

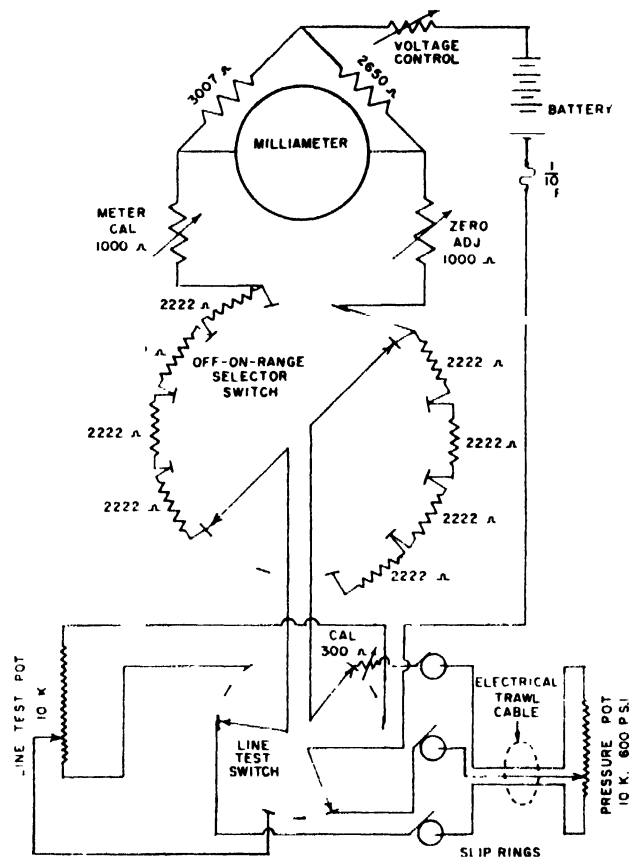

Fig. 11. Schematic layout of electrical depth telemetering system installed on M.V. John N. Cobb.

are mounted on a two-pole six-throw rotary selector switch, which is used to return the meter pointer to zero at the end of each 50 fm. deflection.

SEA TESTS AND TRIALS

A series of calibration tests was made aboard the *John N. Cobb* at sea by lowering and raising the sensing unit to measured depths. A ten-minute warm-up period with the sensing unit immersed in sea-water, to neutralize capacitance and temperature effect, preceded all tests. Accuracy of the electrical depth telemeter was found to be at least 98 per cent. A slight lag of ½ fm. was noted during ascending and descending at normal winch speed. Depth readings of the telemeter agreed closely with two types of echo depth sounders during comparison tests when the sensing unit was dropped to the bottom at intervals to a maximum depth of 187 fm.

Chief concern during construction, testing and early use of this new telemeter, was the questionable ability of the electrical trawl cable to withstand the punishment of regular fishing operations. Full power test runs towing a 70 ft. square-opening nylon midwater herring trawl were executed with normal turns and excess cable played from the opposite drum to put the greater load on the electrical trawl cable. A cable dynamometer showed a maximum cable strain of 4,700 lb. at full throttle with 360 fm. of cable out and the net at 83 fm. To date the cable has been used during some 50 tows with no sign of damage or fatigue. There has been no apparent damage to the electrical conductors.

ADVANTAGES AND DISADVANTAGES

The greatest advantage of the electrical depth telemetering system is its simplicity and practicability. Since it is a direct-reading instrument with a simple off-on-range selector switch and line control rheostat to set, no specially-trained operator is needed. Likewise, no special handling on deck is required as the sensing unit is attached as a permanent part of the fishing gear.

Being electrical, the system is not affected by distance, directivity, water currents, wake, ambient sea noises, etc., as are acoustic telemeters.

The 225 fm. range can be increased by the installation of a suitable pressure potentiometer, and recalibration.

Use of the system on bottom trawls is feasible due to the small size and rugged construction of the sensing unit and housing.

Routine maintenance can be performed by relatively unskilled personnel.

The accomplishment of connecting an electrical circuit from the pilot house of a fishing vessel to a trawl deep beneath the ocean surface makes possible the transmission of other types of information to the vessel operator. Constant monitoring of water temperature at trawl depth is possible with the addition of a small thermistor inside the pressure housing of the sensing unit, similar to the S-T-D used by oceanographers[5].

Ink pen recordings of depth and temperature can be made if permanent records are desired. Also, graphic presentation of telemeter depth readings on to the echo-sounder recording paper used during fishing operations is entirely practical. Even some form of automatic or adjustable controls on the fishing gear could be installed if found to be desirable and practical in the future[4].

Apparent possible disadvantages of the electrical depth telemeter are few and may prove to be of minor importance with continued use of the system.

Splicing the electrical trawl cable is more difficult and time-consuming than splicing standard cable used on fishing vessels. A 50 ft. long-splice is required, which was found to be not unduly difficult after some experience. The 3,000 ft. cable in use on the *John N. Cobb* is made up to two sections which were spliced together by two staff members in approximately two working days.

The present cost of the electrical cable is roughly 60 per cent. higher than the cost of regular plow steel trawl cable, but this cost differential cannot be properly evaluated until the life expectancy of the new cable is determined through actual service over an extended period of time.

REFERENCES

[1] Barraclough, W. E. and Johnson, W. W. 1956. A new midwater trawl for herring. Bulletin No. 104, Fisheries Research Board of Canada, Ottawa.

[2] Collias, E. E., with Barnes, C. A. 1951. The salinity-temperature-depth recorder. University of Washington Oceanographic Laboratories, Seattle, August.

[3] Dow, Willard. 1954. Underwater telemetry: A telemetering

depth meter. Woods Hole Oceanographic Institution Ref. 54-39, Woods Hole, Mass.
[4] Fryklund, Robert A. 1956. Controllable depth maintaining devices. U.S. Patent Office publication, Patent No. 2,729,910, Washington, D.C., January 10.
[5] Richardson, I. D. 1957. Some problems in midwater trawling. World Fishing, vol. 6, No. 2, John Trundell, Ltd., London, February.
[6] Smith, Keith A. 1957. An experimental air-pressure depth-meter for use with mid-water trawls. Commercial Fisheries Review, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C., vol. 19, No. 4, April, pp. 6-10.
[7] Stephens, F. H. Jr., and Shea, F. J. 1956. Underwater telemeter for depth and temperature. Special Scientific Report—Fisheries No. 181, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C. June, 15 pp.

Three-drum winch on a Swedish cutter fitted for trawling over starboard side. The after warp is hauled on the starboard drum, forward warp on the port-side drum, while the anchor line is hauled on the centre drum. Photo: FAO.

OLYMPIC TRAWL CABLE METERS

by

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Abstract

This is a device for measuring the amount of trawl warp being paid out, and the importance of being able to match the two warps, especially in deep water, cannot be over-emphasised. The meters are fitted, one for each warp, close to the winch, and irrespective of any stretching that may have taken place in the warps, the exact length paid out is always visible on the counters. The meters are claimed to supersede the old method of measuring warps by markers. They are sturdy in construction, unaffected by corrosion and are easily maintained.

Compteur Olympic pour funes de chalut

Résumé

Cet appareil permet de mesurer la langueur exacte de chaque fune de chalut qu'on laisse filer et l'on ne saurait attacher trop d'importance à la possibilité de pouvoir donner exactement la meme longueur aux deux funes, surtout, en eaux profondes. Les appareils sont placés, un par fune, près du treuil, et indépendamment de toute élongation subie par les funes, on peut toujours lire sur les compteurs la longueur filée. Ces appareils remplacent la vieille méthode de mesure des funes au moyen de repères. Ils sont de construction robuste, résistent à la corrosion et leur entretien est facile.

El medidor "Olympic" para cables de arrastre

Extracto

Este dispositivo tiene por objeto medir la longitud exacta de los cables largada durante un lance con red de arrastre, dada la gran importancia que tiene la igualación del largo, especialmente en aguas profundas. Junto a la maquinilla de arrestre cada cable se hace pasar por uno de estos medidores que permite leer su longitud, pero no asi el alargamiento experimentado durante el curso del lance. Este método reemplaza al antiguo procedimiento de medir el largo de los cables de arrastre mediante marcas. El instrumento esde construcción fuerte y no sufre los efectos de la corrosión.

THE importance of being able to balance the warps, especially in deep water trawling, cannot be over-emphasized. A new Trawl Cable Meter, manufactured by the Olympic Instrument Laboratories, Vashon, Washington, U.S.A., is meant to replace the markers generally used for trawl warps. It gives a continuous indication of the length of trawl warp as it runs off the winch.

Marking of cables has several obvious disadvantages:

(1) Markers frequently need replacing which means additional work;

(2) if either trawl warp stretches, the markers become inaccurate and cause improper alignment of the otter boards:

(3) a parted trawl warp requires a splice which makes the other markers inaccurate;

(4) trawl warps can be damaged by the markers, increasing the possibility of a break where markers have been inserted.

When a pair of Trawl Meters is used, the true length of stretched or repaired cable is indicated at any stage of the operation.

Model 685 Olympic Trawl Cable Meters are made of bronze and stainless steel, are watertight and corrosion is reduced to a minimum (fig. 1).

The meters will accommodate cable from $\frac{3}{8}$in. to $\frac{3}{4}$in.

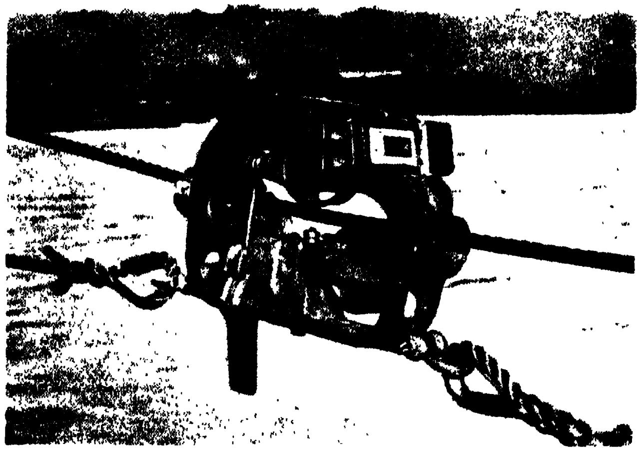


Fig. 1. Model 685 Olympic Trawl Cable Meter for wire rope to $\frac{1}{2}$ in. diameter including splices and markers, on to $\frac{3}{4}$ in. diameter without splices or markers.

diameter, with or without markers, but are limited to about ½ in. diameter cable when normal splices are used. The meters are easily fitted and operate close to the winch in plain view of the operator. They are secured by preventers which permit the necessary movement as the warps wind off and on. Lengths are indicated in fathoms to 999 and repeat, if necessary. The counters may be set to zero at any time. No special tools are required and only average mechanical ability is needed to replace worn parts. The meters are in use commercially and in scientific work in many parts of the world, particularly in the Pacific northwest of America.

As many big trawlers use warps as large as 1in. diameter, a Trawl Meter with capacity from ⅛in. to 1 in. cable plus any splices or markers has been designed. This new Meter, Model 750, reached the semi-production stage in June 1957 (fig. 2).

Prototypes have received extensive tests ashore and afloat, and are proving quite satisfactory in midwater trawl tests in Atlantic coastal waters.

A pair of Model 750 Meters mounted on similar warps will normally measure consistently within 1 fm. in 500. Counters can be furnished to indicate in fathoms, feet or meters. Remote indicating electrical counters are available on special order.

Careful selection of aluminium and stainless steel alloys achieves light weight (about 10 kg.) while assuring adequate strength and corrosion resistance in Model 750.

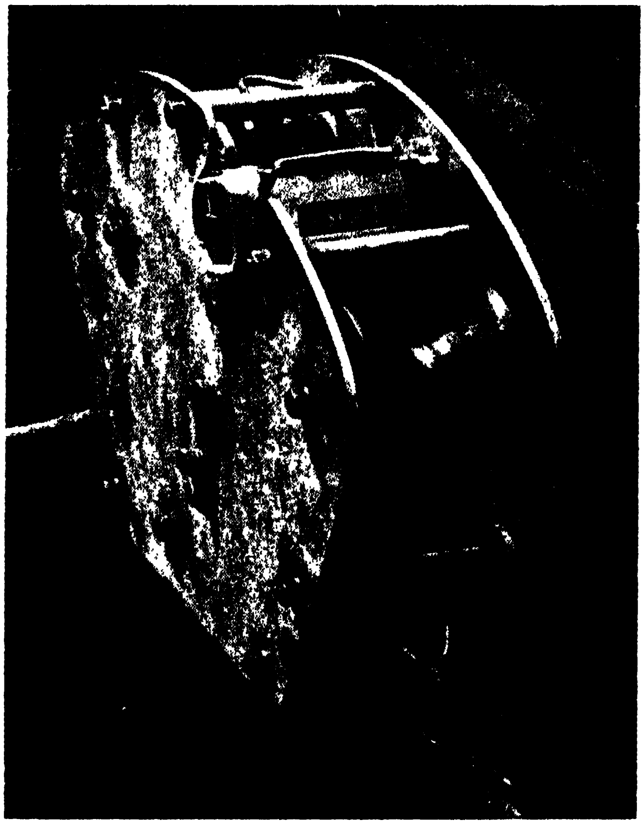
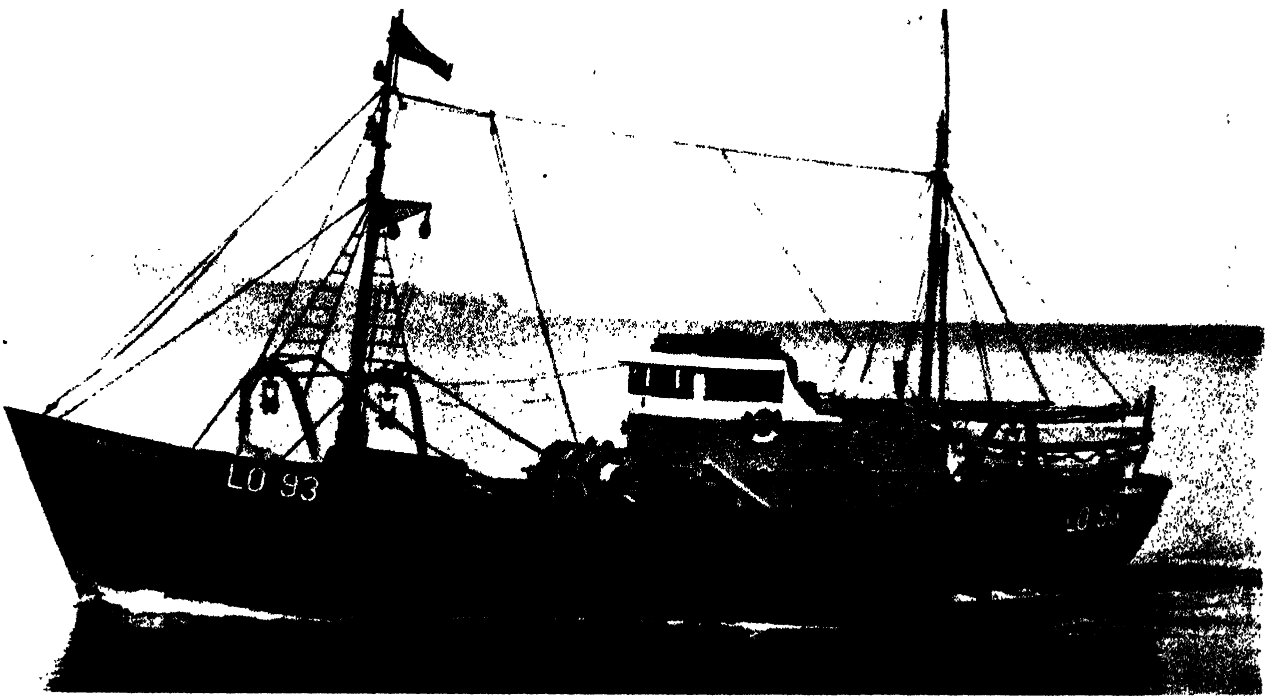


Fig. 2. Model 750 Olympic Trawl Cable Meter for wire rope ⅛ in. to 1 in. in diameter including splices and markers.



The "Janet Helen"

OCEAN CABLES AND TRAWLERS
THE PROBLEM OF COMPATIBILITY

by

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Abstract

Both the fishing industry and the ocean cable companies make use of the seabed and this paper expresses the hope that the two can carry out their respective duties without damaging each other. The problems of the cable companies are discussed and it is pointed out that, between 1946 and 1950, 367 cable-days were lost in the Trinity and Conception Bays area of Newfoundland through trawler damage and until 1946 the cables had been untouched since they were laid – some of them 75 years ago. The cable service is increasing and the trawlers are seeking new grounds, so the risk of damage is always there. A British publication in 1908, commenting on the recommendations of an Interdepartmental Committee on damage to submarine cables, asked "Why should not the onus of initiating fair play be put upon the fishermen?"—and from the cableman's viewpoint, this is still a good question.

Les câbles sous-marins et les chalutiers

Résumé

L'industrie des pêches et les compagnies de câbles transocéaniques utilisent le fond des mers et les auteurs expriment l'espoir qu'elles pourront toutes deux accomplir leurs taches sans se nuire réciproquement. Ils examinent les difficultés des compagnies de câbles et font observer que de 1946 à 1950, 367 jours de fonctionnement de câbles ont été perdus dans la région des baies de la Trinité et de la Conception (Terre-Neuve) par suite des dégâts provoqués aux cables par les chalutiers, tandis qu'avant cette période les câbles étaient demeurés intacts depuis leur pose, qui remontait pour certains à 75 ans. D'un côté, le nombre de câbles sous-marins augmente et de l'autre les chalutiers recherchent de nouveaux lieux de pêche en sorte que les risques d'avaries sont toujours présents. Commentant les recommandations d'un Comité inter-ministériel sur les dégâts subis par les câbles sous-marins, une publication britannique posait en 1908 la question suivante: "Pourquoi ne pas laisser aux pêcheurs l'initiative du fair play ?" ce qui, du point de vue des compagnies de câbles, est encore valable aujourd'hui.

Los cables oceánicos y los arrastreros

Extracto

Como la industria pesquera y las compañías de cables oceánicas utilizan el fondo del mar, en este trabajo se expresa la esperanza de que ambas continúen sus funciones sin causarse daños. Al analizar los problemas de estas últimas se hace notar el hecho de que entre 1946 y 1950 se perdieron 367 días-cables en la zona de las bahías de Trinidad y Concepción, en Terranova, a causa del daño producido por los arrastreros a conductores que no fueron tocados desde que se tendieron—en algunos casos hace 75 años—hasta 1946. Al aumento del servicio de cables submarinos se suma la búsqueda de nuevos bancos de pesca de arrastre, lo cual constituye un continuo peligro. En una publicación británica de 1908 comentando las recomendaciones de un Comité Interdepartamental sobre el daño ocasionado a los cables submarinos se preguntaba: ¿ por que no dejar en manos de los pescadores la responsabilidad de proceder correctamente ? Desde el punto de vista de las compañías de cables oceánicos ésta es todavia una buena pregunta.

WHEN commercial fishing was carried on largely from dories or other small craft with handlines, there was no appreciable menace to ocean cable telegraphy, but as soon as trawling became popular the otter board became, and has remained, a most serious menace. Today, with more powerful trawlers in greater numbers going farther afield and using gear which reaches to greater depths, the risk of fouling cables has greatly increased. To satisfy the rising demand for communications facilities, new cables of high message capacity have been laid and older cables adapted for transmission at much higher speeds. Many of the older transatlantic telegraph cables, normally still serviceable and dependable, are not as well equipped as a new cable would be to withstand damage from sharp blows, or the fouling of otter boards, particularly when a skipper, in an understandable effort to free his gear, causes the board to ride along the cable, straining, and often breaking it.

COST OF CABLE INTERRUPTIONS

An outbreak of cable interruptions by trawlers may occur quite suddenly in an area where it has not happened before. For instance, Western Union has transatlantic cables landing in Trinity and Conception Bays, Newfoundland. All of these had remained undisturbed by trawlers on the western side of the Atlantic since they were laid, some of them for almost 75 years; then in 1946 the trouble began. Within 10 weeks one of our cables was broken three times by trawlers working on the northern edge of the Grand Banks off St. John's. Here is the record for this area for five years:

Year	*No. of W.U. Cables affected*	*Total No. of Failures*	*Total Cable Days Lost Time*
1946	1	3	32
1947	2	5	32
1948	5	15	116
1949	3	13	57½
1950	4	10	130

The Commercial Cable Company and Cable and Wireless Ltd., also suffered heavily.

By 1950 costly large-scale diversions of Western Union cables were initiated which resulted in substantial relief for several years, but in 1955 the trawlers extended their fishing ground again and the trouble recommenced. This time it was just off the mouth of Trinity Bay where there was no previous record of damage and where, due to the restricted area and the presence of other cables, diversions to avoid the damage are not practicable. The record to 22nd August, 1957, for trawler damage off Newfoundland is given below:

Year	*No. of W.U. Cables affected*	*Total No. of Failures*	*Total Cable Days Lost Time*
1955	5	11	66
1956	7	18	102
1957 (to 22nd August)	7	17	79

The repair of each break usually reveals several miles of trawler-ridden cable, broken armour wires, electrical faults and a strained condition throughout which makes it impossible to lay the cable flat on the bottom again.

The value of cable which has to be renewed per repair commonly runs anywhere from $2,000 to $20,000, depending upon the length and armour type. A cable ship has to carry a crew many times larger than a trawler's, a number of whom are highly trained specialists, in addition to an expensive stock of repair cable. The cost of operation therefore is correspondingly higher. At present cable damages off Newfoundland are costing the Company $720 an hour, and the total loss for this season can be expected to run over half-a-million dollars.

THEORIES AS TO HOW FOULING OCCURS

All sorts of statistical studies have been made in an attempt to co-ordinate the hooking of cables with such diverse things as the phases of the moon, the design and maintenance of the boards, the habits of fish, the manoeuvring of the trawlers, etc.

It seems reasonable that boards which are well maintained have a better chance of keeping clear, and that the design of the leading edge, the towing bracket, and other details can influence this, but it is not easy to establish scientific proof, since cables must be crossed hundreds of times for every time the boards foul them. It also appears that whenever a trawler finishes its tow and swings around to heave in its catch, the boards fall flat and in being dragged home any board may work its leading edge under a cable.

A flat even bottom offers more security than an uneven one because, particularly in the shallower depths, it is difficult to lay cable without some residual bottom tension and thus there is always the tendency for the cable to remain suspended over indentations in an irregular bottom. If slack is paid out it may accumulate and not lie flat in places. Some cable men have tried laying cable bar-tight, with no slack, through trawling areas, as the lesser of two evils.

Repair ships have to work under emergency conditions to restore communications as speedily as possible, and cannot pick up and re-lay the cable from one end of the trawling area to the other. That would be prohibitively costly and time-consuming. Wherever a repair ship finishes her work, she must leave some excess cable on the bottom because her last, or "final" splice has to be made on the bight. Efforts to lay out the slack bight laterally have not resulted in much improvement because even if it is weighted down with chain, the slack cable may not lie flat on the bottom. Thus, the more the cable is repaired, the more vulnerable it becomes.

EFFORTS TO MINIMIZE DAMAGE

In 1884 an International Convention was called which made recommendations for legislation, later enacted by participating countries, making it a misdemeanour wilfully to damage or break a telegraph cable, to approach within a nautical mile of a ship engaged in laying or repairing a cable or within a quarter of a mile of a buoy marking the route of a cable being laid or undergoing repair.

An exhaustive report made to the British Parliament by an Inter-departmental Committee in 1908 showed that these measures did not have the desired effect. Great hopes were placed upon being able to persuade trawler fishermen to use otter boards of a design recommended as being best able to avoid fouling cables and also to keep their boards well maintained. Many official bulletins have been issued to fisherman containing instructions, warnings, admonitions, etc., but they have not solved the problem of two expanding industries attempting to occupy a common domain.

The cable companies have often issued charts showing the locations of their lines, to the extent permitted by security regulations, but without much effect. In general, the fishermen must know pretty well where the cables lie because they have encountered them so many times. Unfortunately, fish do not seem to mind the presence of cables and when they congregate in areas where cables lie it is only natural for fishermen to seek them out unless prevented by *force majeure*.

The old argument runs: "The fish were here before the cables" and the time-worn counter-argument is: "Not the fish which *you* are catching!"

In the early 1920's seven cable companies—Western Union, The American Telephone and Telegraph Company, Imperial and International Communications Ltd., The Commercial Cable Company, The Great Northern Telegraph Company, the French Cable Company, and the Deutsche - Atlantische Telegraphengesellschaft—jointly employed an ex-officer of the British Navy to act as a "Cable Damage Inspector". He spent several years visiting trawler ports on the European side, inspecting trawl gear, calling the fishermen's attention to conditions which he considered liable to cause cable damage, and generally acting as a liaison with the fishing industry. He developed an otter board and towing bracket which he claimed were relatively safe from fouling cables. A trawler was chartered to prove his claim and the gear was towed over the known line of an abandoned cable without hooking it, but, in the absence of any conclusive data that he was catching more fish with it, the fishermen remained unimpressed.

When trawlers were small and their gear weak, heavier armour cable could be counted upon to be effective. The skipper who fouled his gear slid it along the cable until he freed it or lost it. Today, heavier armour helps, chiefly in enabling the cable to withstand sharp blows from otter boards without becoming electrically faulty. But any trawler which actually fouls the cable and has power enough to raise it to the surface on the bight can cut it easily with an acetylene torch.

Three factors limit the size and weight of cable which can be used in trawler areas: the storage capacity of the repair ship which has to transport it, the power of her cable-handling gear, and the cost. With no positive assurance that still more expensive cable will be effective against the ever-growing size and power of the trawling vessels, there is a natural reluctance to embark on such big expenditures. The most which can reasonably be done is to provide and lay new cable of fairly high strength and weight along the best available route. A renewal, to be effective, must be done in one continuous operation, avoiding all bight splices and, if possible, any and all ship-made splices because of the relative inflexibility they introduce where the armour is overlaid for five or six fathoms on one end.

In the early 1930's trawler damage southwest of Ireland became so troublesome that Western Union developed a tool for trenching a cable into the ocean bottom. This was used successfully on four transatlantic cables across an active trawler area of some twenty miles wide and between the depths of 100 and 400 fm. Unfortunately, the tool has a very limited application. The bottom must be free from out-cropping rock so that a continuous trench can be dug and surface currents must be moderate enough to enable the ship to manoeuvre when towing the plough at slow speed. The operation, once begun, must be continuous and requires navigation and seamanship of the highest order by specialists with many years of training. Had conditions off Newfoundland been favourable, trenching would have been attempted. However, before this can be considered, a better tool must be developed to deal with rock and to stand up to much longer continuous operation. Surface currents are a problem but this part is felt to be surmountable in time through use of modern navigational aids of greater accuracy and ships of greater manoeuvrability at slow speed.

DISREGARD OF REGULATIONS

It is regrettable that in many instances cables heaved to the surface when fouled by trawl gear are deliberately cut with a saw, axe, or acetylene torch, these being the quickest and easiest methods of freeing the otter board. It is almost impossible to establish the responsibility of the trawler concerned because of the unavoidable lapse of time between the act of damaging the cable and the arrival of the repair ship. The prevalence of ice and fog in some areas adds to the difficulty. It is not uncommon to find as many as thirty trawlers all working across the cable line in the vicinity of the break or fault and in some cases the repair ship reports a portion of the cable missing entirely. For instance, recently off Newfoundland $1\frac{1}{2}$ nautical miles of cable were removed in one case and 3 n.m. in another, with a large group of trawlers working unconcernedly through the gap thus created.

On two occasions this summer a Western Union cable ship, while picking up cable, has had a trawler cross directly ahead in spite of whistled warnings. In both cases the cable ship has stopped and eased away the cable at the bow in an attempt to avoid a foul. In both cases the cable has been fouled and the ship has had to cut it away under heavy strain without being able to identify the trawler. On other occasions the moorings of the buoys streamed by the cable ship to mark the line of the cable have been fouled by trawlers working close to them and cutting-corners around them.

Anonymity has given these fishermen freedom to flaunt the regulations with impunity and some of them are not loath to do so wherever and whenever the cables or the repair ship are obstacles to good fishing.

Lest this be interpreted as a diatribe against the fishing fraternity in general, let us say that it is not so intended. Several times a year Western Union and the other cable companies receive claims filed by fishermen who have cut away their gear when foul of a cable and reported to us the position and depth. In all such cases where the data given warrants the conclusion that the cable was ours, and that the amount claimed is reasonable, payment in full is made promptly and with gratitude.

NEED FOR CLOSER CO-OPERATION

The pressing need for closer co-operation between the fishing and communications industries must be evident to both parties. There can be little doubt that fishermen lose too much gear and valuable time because of cables. The most hopeful sign on the horizon is the discovery that fish communicate by sound and that it may be possible to devise an acoustical method of attracting fish into nets. Think of the saving in wear and tear, not to mention ship's fuel! The converse idea of repelling fish from cables raises certain bothersome problems of power distribution and range of emission. It also would be of no benefit to fishermen. But, seriously, would it not be worthwhile to put some money and effort into finding a better method of fishing than that involving the otter board? The method of using two ships, popular with the Spaniards some years ago, was much less destructive to cables. There must be others.

Despite wireless communication, the cables remain the work horses of the trans-ocean communication system and perform a vital role in the world's business. Ocean cables, apart from trawler-damaged portions and shore ends, have an average life of well over fifty years and with normal maintenance can be gradually renewed to last so long that obsolescence, rather than physical depreciation, tends to be the limiting factor in their useful economic life. Recently there have come into the picture two new factors which have revolutionized cable design. These are the submerged "repeater" or amplifier, and the coaxial cable, together capable of handling voice frequencies across the ocean. Such cables can be used for telephone or telegraph or a combination of both. It is a well-known fact that any voice channel can be made to handle 20 or more telegraph channels. The capacity of the recently-laid transatlantic telephone cables is so great that it does not take much imagination to visualize either the replacement of the older telegraph cables with relatively few telegraph cables of modern coaxial design using fewer submerged repeaters than are required for telephony, or the gradual assignment of more frequency space in telephone cables to telegraphy.

Whichever takes place, the result will benefit fishermen for a time, since the number of cables laid across fishing areas probably will decrease rather than increase. However, it would be unsafe to count on this for long, since overseas telecommunications, as the result of recent strides in transmission techniques are getting cheaper. If this is accompanied by improved quality and dependability, the result is bound to be a tremendous increase in demand and soon there will be just as many cables as before.

At the present time a new all-British transatlantic telephone cable is projected which will extend from Canada to Scotland and another, to be jointly owned by the Americans, French, and Germans, will run from Canada to France. A telephone cable has been laid from the United States of America to Alaska and one has just been completed to Hawaii.

The point which the fishing industry should ponder is that coincidentally with the rapid growth of trawlers in size, range and power, there has come a corresponding growth in the importance of ocean cables. Whereas a further increase in the world catch of fish may deplete areas so that new grounds must always be under exploration, the communications industry thus far has barely scratched the surface of its world market and there is no corresponding scarcity of product to hamper its rapid future expansion.

Breaking or damaging an ocean cable handling communications valued at more than $50,000 a day—and such cables already exist—is going to cause quite an international furore. Would it not be well for the fishing industry to discipline itself before this happens?

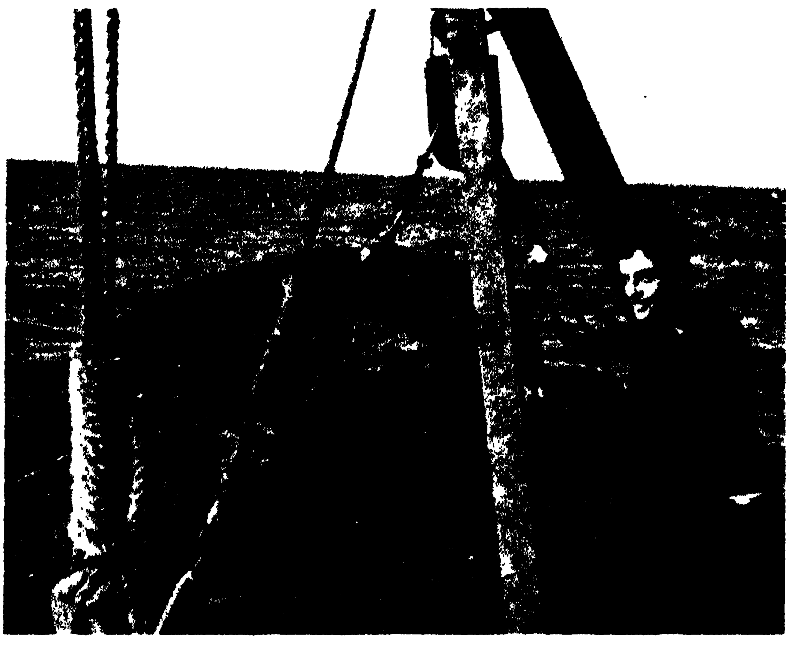
In 1908 a British publication commenting upon recommendations made by the Interdepartmental Committee in its report to Parliament on damage to Submarine Cables, posed this question:

> "To put the matter on another footing, it may fairly be asked, why should it be the cable companies' duty to cultivate the trawling community? Why should not the onus of initiating fair play and good feeling be put upon the fishermen, who have the whole sea in which to pursue their calling?"

This still is a good question from the cableman's point of view if the present methods of catching fish commercially are to be perpetuated.

HOPES FOR THE FUTURE

Industries which have made the greatest strides in this modern world are those which have had the foresight to set aside some of their earnings regularly for development and research. It is the earnest hope of those of us who are engaged in the business of communications that the fishing industry will find a way to lean less upon governments in this respect and more upon its own resourcefulness, perhaps using the facilities of oceanographic institutions more effectively. It will take organization, but the job is rewarding enough to make it well worth doing. You will find the communications people ready and anxious to do everything within reason to promote collaboration because it is their belief that, once aware of the growing seriousness of the problem, the fishing industry can bring about another transformation in fishing methods no less spectacular than the change from linefishing to trawling. If, in doing so, it can eliminate the hazard to cables it will have performed a great service to both industries.



An oval otter board for bottom trawling of Russian design. Besides its other advantages this type of board should be more suitable to avoid fouling with underwater cables than the common otter boards. Photo: FAO.

THE USE OF THE DANISH SEINE NET

by

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Abstract

A comparison is made of the relative advantages and disadvantages of Danish seining versus trawling. A detailed description is given of anchor seining and fly dragging, with particulars of the gear, boats, and fishing operations.

Pêche a la Senne Danoise

Résumé

L'auteur compare les avantages et inconvénients relatifs de la senne danoise par rapport au chalut. Il donne une description détaillée de la pêche à l'ancre et de la pêche en route, avec les particularités de l'engin, des bateaux et des opérations de pêche.

Pesca con red de arrastre danesa

Extracto

Se comparan las ventajas e inconvenientes relativos de la pesca con redes de arrastre de tipo danés y con las de tipo corriente. Se describen minuciosamente las operaciones de la pesca con el arte anclado y las de la pesca en marcha, dando noticias de los artes, embarcaciones, y métodos de pesca aplicados.

DANISH seining is a method whereby, without the use of otter boards, a net can be dragged across the sea bottom by one boat. The gear in the water consists in essentials of nothing more than two long ropes and the net. The pattern in which the gear is laid is roughly pear-shaped, with the net where the eye would be and the boat where the stalk would be. The boat may be either moored (anchor seining) or moving (fly dragging). As the warp is hauled aboard the boat, the net is hauled forward, closing gradually but held open for a time by the friction of the ropes on the bottom and by their resistance to the water. A general impression of the operation of the gear is given in fig. 1.

DANISH SEINING VERSUS OTTER TRAWLING

Danish seining, henceforward simply referred to as seining, has certain points of superiority as well as certain disadvantages compared with otter trawling.

Advantages

(1) Seining is a mechanically efficient method of fishing, in that a comparatively large net can be worked with only a modest expenditure of power.

(2) The encircling movement of the net and warps gives a high fishing efficiency, and a seiner can often compete to advantage with larger otter trawlers.

(3) It can be worked from relatively small boats, 30 to 80 ft. (9 to 24 m.). The smallest need no winches, two powered warping drums being sufficient.

(4) The method allows pinpoint searching as compared with trawling, where it is not clear at what point during a long tow fish have been struck.

(5) It is possible to work small patches of good ground among the rough provided their extent is known.

Disadvantages

(1) The seiner is more limited in the areas it can work in that it is not possible to work on as rough ground as can be done with the otter trawl.

(2) The strength of tide imposes a greater restriction in its use.

(3) Much time is lost because of *snags*, with consequent retracing and lifting some or all of the warps and net.

(4) Operations are held up by fog unless navigational aids are available to bring the boat accurately back to the dahn when shooting.

(5) It is usual to work by day only.

(6) The gear needs constant attention during fishing operations, and to this extent work on deck tends to be more protracted, if not harder, than in trawling.

(7) The set cannot be much speeded up without altering the length of warp so that the duration of a haul is not a matter of choice as it is in trawling.

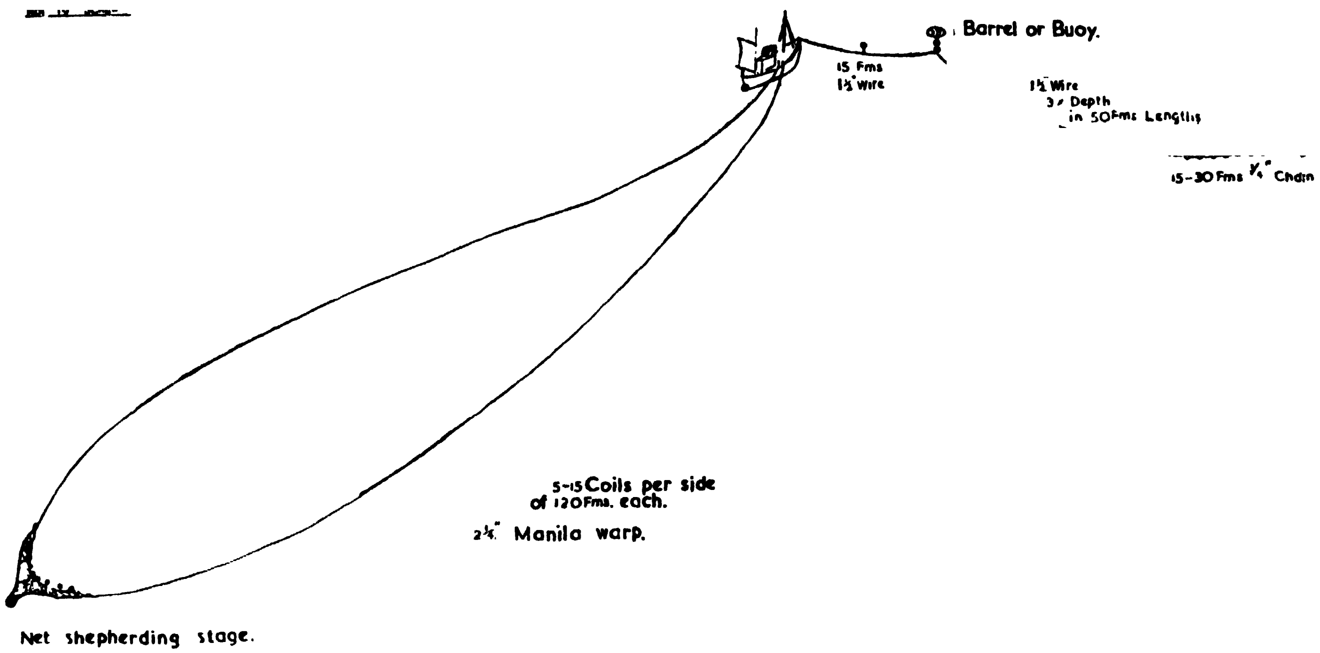


Fig. 1. Anchor seining operation.

ANCHOR SEINING VERSUS FLY DRAGGING

Fly dragging, being half way between trawling and anchor seining, has its own advantages and disadvantages. The relative merits of these two seine net methods are hotly argued. The following gives a comparison of the salient differences between them.

Anchor Seining

(1) Reputed to be better for flatfish.
(2) More economic in conditions of light fishing.
(3) Smaller crew required, usually four.
(4) Not so much power required, and fuel consumption lower. Greater mechanical efficiency.
(5) Fewer gears required on the winch, usually three. Winch speeds in the early stages of hauling are comparatively fast. Anchor windlass required.
(6) Less stress on the gear and thinner warp than needed for fly dragging.
(7) The ground can be covered more systematically, and towing back to the dahn puts the gear in a better starting position.
(8) More comfortable for the crew with the vessel at anchor.
(9) Gear stays open longer.

Fly Dragging

(1) Can sometimes be better for demersal roundfish.
(2) Less time to shift ground.
(3) Crew size four to seven.
(4) More independent of direction of tides and can be worked in stronger tides, hence more freedom to tackle a patch of ground from any advantageous direction.
(5) Winch usually has four, and sometimes even six, gears. Winch speeds in early stages of hauling are comparatively slow; no windlass required.
(6) Net moves further across the bottom before closing, but gear closes with less warp inboard.

THE DEVELOPMENT OF DANISH SEINING

The development of the method has encountered a series of obstacles but overcoming these has led each time to an expansion of its use. To *Jens Vaever* of Denmark goes the credit of introducing the method just over one hundred years ago. A rowing boat was then used to shoot the gear, ready for hauling by hand from an anchored cutter. Similar methods are still in use today, such as with the *Paithu vala* or boat seine of the Malabar coast of India. At the turn of the century, first the cutter, and later the auxiliary boat, were powered with hot-bulb engines. The elimination of the small boat and the introduction of a powered winch followed. The scene was then set for a rapid development of the method but there was a limit to the amount of rope that could be coiled by hand, and it was not until after the introduction of the mechanical coiler in the 1920s that its greatest development took place, spreading outwards from Denmark to Sweden, England, Scotland, Ireland, Iceland and farther to Australia, New Zealand and Newfoundland. During this time the method was adapted to fishing for roundfish as well as flatfish. The Swedes now use the anchor seine in deep water up to 100 fm. (183 m.) and the Scots work just as deep by fly dragging. But a difficulty is now being met in that it is not convenient so far as coiling, handling and stowing the required length of rope is concerned, to work with ropes larger than 2½ in. (6·4 cm.) circumference. The bigger fly dragging seiners, of about 75 ft. (23 m.) in length, put a high stress and cause rapid wear on such ropes.

Meanwhile, the Japanese have been developing fly dragging along somewhat different lines, using much heavier warp. Their warp is shackled together in lengths

ANCHOR SEINER SHOOTING.

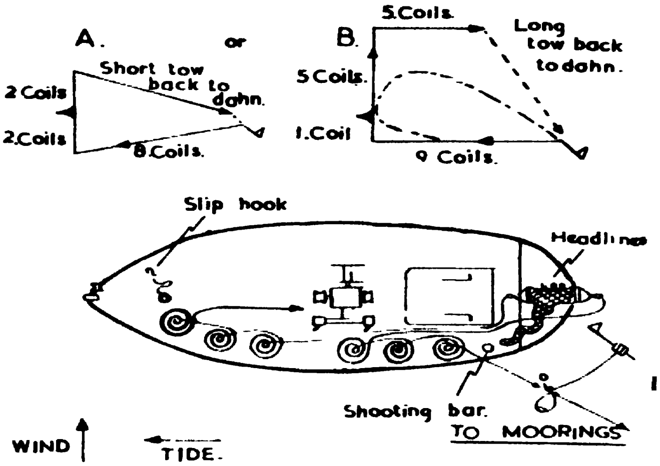


Fig. 2.

ANCHOR SEINER HAULING.

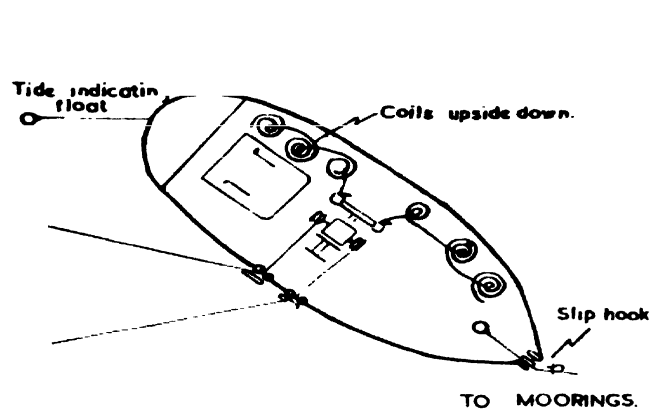


Fig. 3

FLY DRAGGER SHOOTING.

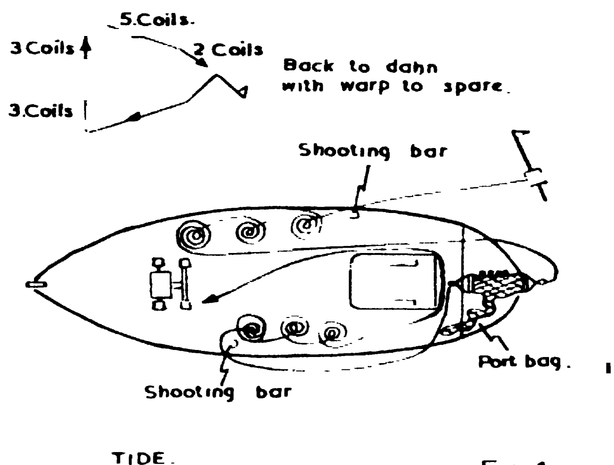


Fig 4.

FLY DRAGGER HAULING.

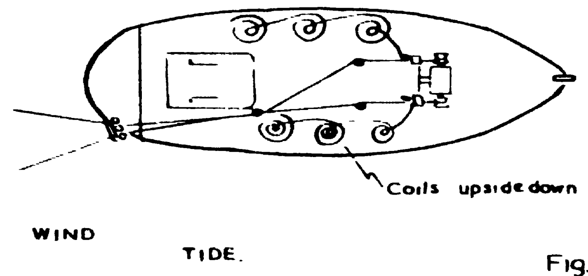


Fig. 5

AUSTRALIAN.STYLE FLY DRAGGER SHOOTING.

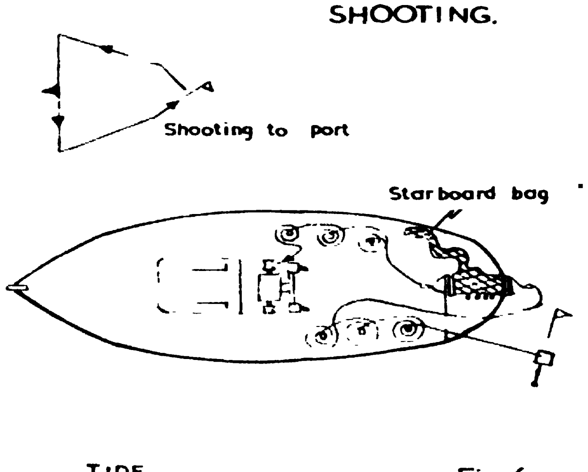


Fig. 6.

AUSTRALIAN STYLE FLY DRAGGER HAULING.

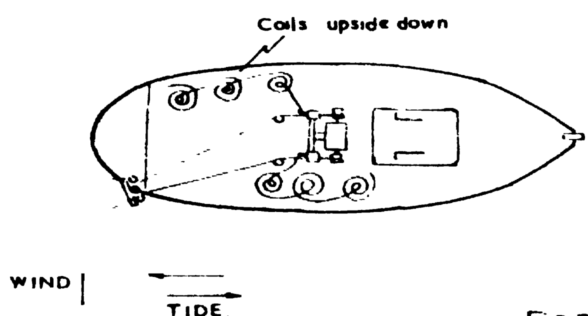


Fig 7

Figs. 2 to 7. Deck layout of the boats and operation of the main seining methods.

increasing from 3 in. (7·6 cm.) circumference at the ship to as much as 5½ in. (14 cm.) circumference at the cross-rope (that part of the rope which, together with the net, forms the base of the triangular pattern in which the gear is shot). It is usual to introduce a length of heavy chain at the end of the cross-rope and this, together with the large and changing diameters of the warp, precludes the use of a coiler. The length of warp that can be so handled is limited to about four coils per side. With this heavier gear a larger net, called *Teguriami*, is used. The gear is towed to a close with the tide and then winched-in over the stern by warping drums located on either side of the engine casing, aft of the wheelhouse. Naturally they use their own traditional style of boat.

BOATS

The lengths of most seiners fall between 30 ft. (9 m.) and 80 ft. (24 m.). An engine upwards of 15 h.p. is required for anchor seining, and 30 h.p. rising to 160 h.p. is required for fly dragging. Towing capabilities are essential for a fly dragger, and the usual practice in Scotland at least, is to have a medium speed engine (600 to 1,000 r.p.m.), with a reverse reduction gear (2:1 to 3:1). Although not in common use in Scotland as in the Scandinavian countries, the variable pitch propeller would appear to have certain advantages for fly dragging. The propeller must also be deeply enough immersed. It is essential for any seiner to have the main engine controls, throttle, ahead and reverse gear, or propeller pitch control, operable from the wheelhouse. It is also highly desirable to have a meter in the wheelhouse to show the engine revolutions.

Some boats are purely seiners and their usual deck layout is shown in figs. 2 to 7, but often enough with these small boats seining is not the only purpose for which they are used. Their layout and the layout of their deck machinery must then be designed to meet other demands. Some Swedish and Danish anchor seiners can also trawl, two extra trawl barrels being fitted in line with the barrel containing the mooring wire. Some Irish fly draggers have a combination winch containing two small trawl barrels in line with the warping drums, together with an extended coiler. With the Scottish drifter/seiners, all that is required to make the conversion is the replacement of one of the warping drums by a larger drift-net one, but the boat must also have the large hatch required for drift netting.

An essential requirement for any seiner is that the deck and rail, from which the warps have to be shot, must be clear of obstructions. There should also be a clear space aft, usually with a built-in platform on which the net is stacked ready for shooting. It is a considerable encumbrance to have a small boat aft, although it is still possible to shoot the net over the quarter.

If the sequence of shooting and hauling on a fly dragger are thought out (figs. 4 to 7), it will be seen that positioning the winch aft of the casing, and having a clear working space aft, holds some advantage in the readiness with which the ends of the warp can be led direct to the winch. Such a re-arrangement of deck machinery and wheelhouse must mean a corresponding re-arrangement of fish-hold, engineroom and crew's accommodation below decks, not to mention the effect of these on hull design. Whether in total all these changes are so advantageous is another question. The Australians, at any rate, have chosen this alternative arrangement. On Japanese seiners, too, with their winch barrels protruding from either side of the winch casing itself, the warps can be handled in a similar manner.

Many factors other than those concerning the successful operation of the fishing gear affect the choice or design of a good seiner. It is up to the intending owner to make his own choice of boat type and size in the light of local conditions and the fishery to be exploited.

WINCHES

Figs. 8 to 10 show an anchor seiner's winch and two fly draggers' winches, the last with a rather novel design of coiler. Seine net winches are, for the most part, belt-driven off the fore end of the main engine, but some hydraulic winches have also made their appearance. The warping drums are often about 8 in. (20·3 cm.) in diameter but may be bigger to advantage, thus causing

Some details of the design of a Scottish type drifter/seiner, the *Silver Scout* are to be found in Jan Olof Traung's "Improving the design of fishing boats" - F.A.O. Fisheries Bulletin Vol. 4, Nos. 1 to 2, Jan./Feb.-Mar./April, 1951.

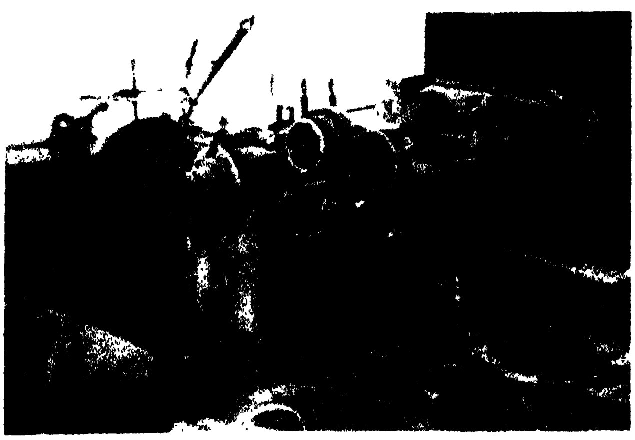


Fig. 8. Anchor seining winch.

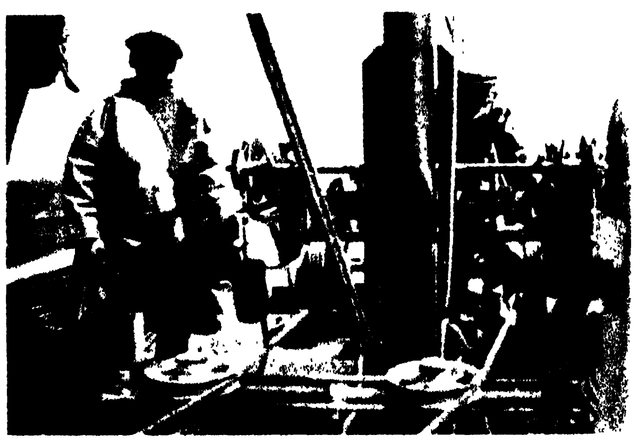


Fig. 9. Fly dragger winch.

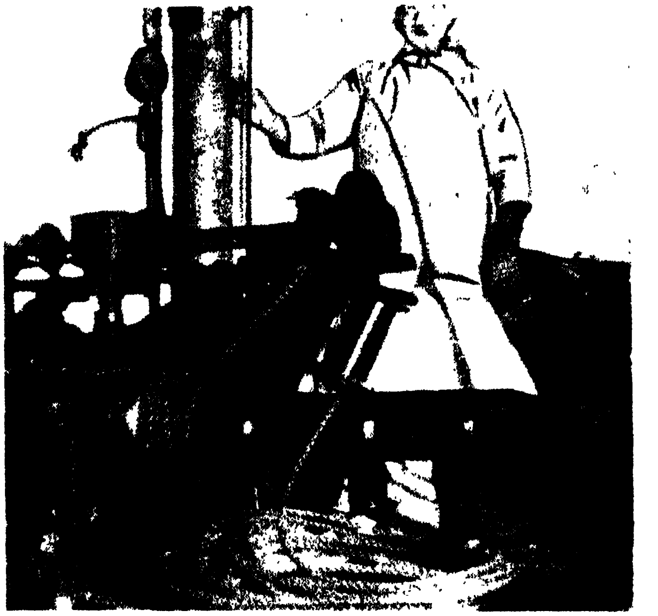


Fig. 10. Fly dragger winch with novel coiler design.

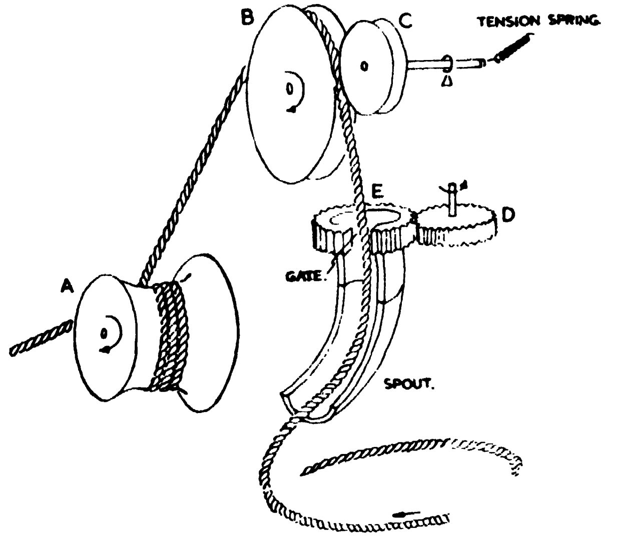


Fig. 12. Operational principle of the warp coiler.

less wear on the ropes. Having made the choice of engine with a known maximum r.p.m., and of winch with a known number of gears and their ratios, the one must be matched to the other to give the desired hauling speed on the warps. This can be done by choosing the ratio of the down-drive (if there is one) at the forward end of the main engine and also by choosing the sizes of the pulley wheels on the up-drive between the forward transmission shaft and the winch driving shaft (fig. 11).

The tables of winch revolutions which follow are typical though not universal.

Anchor Seining

Main Engine Revs. r.p.m.	Winch Revs. r.p.m.	Winch Gearing		Hauling Speed	
305	65	2⅜:1	—1st gear	130 ft./min.	(40 m./min.)
350	100	2:1	· 2nd gear	200 ft./min.	(60 m./min.)
660*	250	1½:1	—3rd gear	500 ft./min.	(150 m./min.)

*The hauling speed shown in 3rd gear was not measured when hauling the net but when winching back the warp to a fastener. It is included to show just how fast warp can be brought in and coiled down.

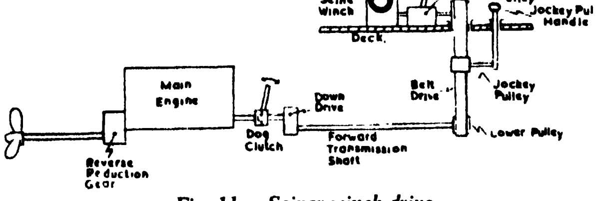


Fig. 11. Seiner winch drive.

The boat in question had a 95 h.p. main engine at a maximum speed of 900 r.p.m. There was a 1¾:1 reduction in speed between the main engine and the winch gear box.

Fly Dragging

Main Engine Revs. r.p.m.	Winch Revs. r.p.m.	Winch Gearing		Hauling Speed	
315	21	15:1	—1st gear	42 ft./min.	(13 m./min.)
315	42	7½:1	· 2nd gear	84 ft./min.	(26 m./min.)
320	80	4:1	—3rd gear	160 ft./min.	(50 m./min.)
320	160	2:1	—4th gear	320 ft./min.	(100 m./min.)

This boat had a main engine of 132 h.p. at a maximum speed of 750 r.p.m., with the propeller driven through a 2:1 reduction gear. The speed ratio between the main engine and the winch driving shaft was 1:1. For such a boat the warp tension has been observed to rise to as much as ½ ton. The brake h.p. delivered by such a winch then rises to 20 h.p. during fast hauling and it may at times be greater.

There are many makes of coilers and winches, but the operational principle most common is shown diagrammatically in fig. 12. After the warp leaves the warping drum A, usually after four turns, it passes over the grooved wheel B and between it and the idler wheel C. Wheel B is chain driven from the winch itself and is either of the same diameter as the warping drums with a 1:1 gear ratio, or is geared to have the same peripheral speed. The idler wheel C puts tension on the warp, so that, on releasing the tension spring, the warp slips on the warping drum without hauling. This is called surging. The warp is led through the gate into the middle of pinion E which is driven by pinion D at a reduced speed, so that, after emerging from the spout attached to E, the warp is coiled in a convenient diameter.

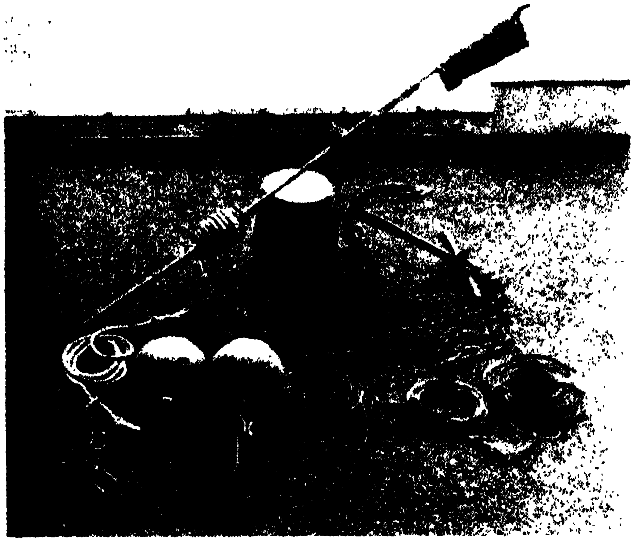


Fig. 13. Mooring gear for anchor seining.

Fig. 14. Clip spliced into the warp.

Fig. 15. Warp splice.

GEAR

Moorings

An anchor seiner's mooring gear is set out in fig. 13. The anchor itself is 1¼ to 1¾ cwt. (63 to 98 kg.). The flukes must be broad or have flat plates bolted to them. The stock should be long enough so that if the end of it touches the ground first, the anchor rolls on its crown without the flukes touching the ground until the anchor rolls right over. The ¾ in. (19 cm.) heavy chain, with a swivel at each end, may be 15 to 30 fm. (27 to 54 m.) long, depending on the weight of the ship. Of course, very small boats would have lighter gear. The mooring wire is about three times the depth, with a basic length of, say, 50 fm. (90 m.), extra lengths with swivels between them are kept for shackling on as necessary. The arrangement here depends on the depth of water in which it is customary to fish. A 50 fm. (90 m.) and a 25 fm. (45 m.) length are shown in fig. 15. There is then a large link into which a barrel or buoy on 6 to 9 ft. (1·8 to 2·7 m.) of chain is shackled. The barrel must have its own swivel. It is nowadays customary to use a large canvas buoy because it is lighter to handle, but a barrel serves quite well and should have false ends fitted to it to protect the weakest part. Between ship and buoy there is a further 15 fm. (27 m.) of mooring wire. All the mooring wire is 1½ in. (38 mm.) or even 2 in. (51mm.) in circumference. A slip hook over the roller in the bows of the vessel clips into a large link or bow shackle at the end of the mooring wire. A 4 fm. (7 m.) rope picking up piece is clove-hitched on to the end of the mooring wire. The dahn is clipped into the long end and the warp to the shorter. A couple of smaller canvas buoys at the end of the mooring wire serve to keep the picking up end afloat. Sometimes a third is put further along the wire.

Warp

Figs. 14 and 15 show a clip spliced into the warp and a warp splice. Note the staggering of the ends, which would, of course, be cut off. The splices are made this way so that there is less chance of them sticking in the coiler. The most common size of warp is 2¼ in. (5·7 cm.) but the larger fly draggers use 2⅜ in. (6 cm.) circumference. The rope must be hard laid and is made of manila. Manufacturers make seine net warps specially for the purpose. When splicing on a new coil, it is laid in position on the deck and the inside end is spliced to the end of the previous coil. It must be ensured that the rope is coming out of the inside of the new coil in the opposite direction to that in which it was coiled. Seine net rope, being always right-hand laid, is coiled down right-handed and shot so that it comes out of the coils anti-clockwise.

Nets

In anchor seining, the size of the net is more dependent upon the size of the crew available to handle it than upon the weight and power of the vessel. The fly dragger's net must not be beyond the towing capabilities of the ship. All seine nets are long in the wings so that headline length is a poor determination of the size of a net. Much better, as a rough determination of its relative size, is the number and size of the meshes round the mouth of the bag.

Seines are made in quite a different manner from trawls. Whereas a trawl comprises an upper and lower half, a seine is made by joining together identical right-hand and left-hand halves. The component parts of a seine are: the wings, shoulders, crowns, bag or funnel, and codend. As a result of this construction, the bating meshes, giving the taper to the bag, are to be looked for down the middle of the net and, again unlike a trawl, there are no selvedges. In plaice seines, the shoulders are either small or absent; the net is made in large mesh, with the bag and codend usually made of sisal or manila, although completely cotton plaice seines are also made. The bating meshes in the wings are down the middle. The headline is little longer than the footrope. Sometimes, if there are a lot of shells on the ground, a few rows on the under side of the bag are replaced by extra large mesh to allow the shells to fall through.

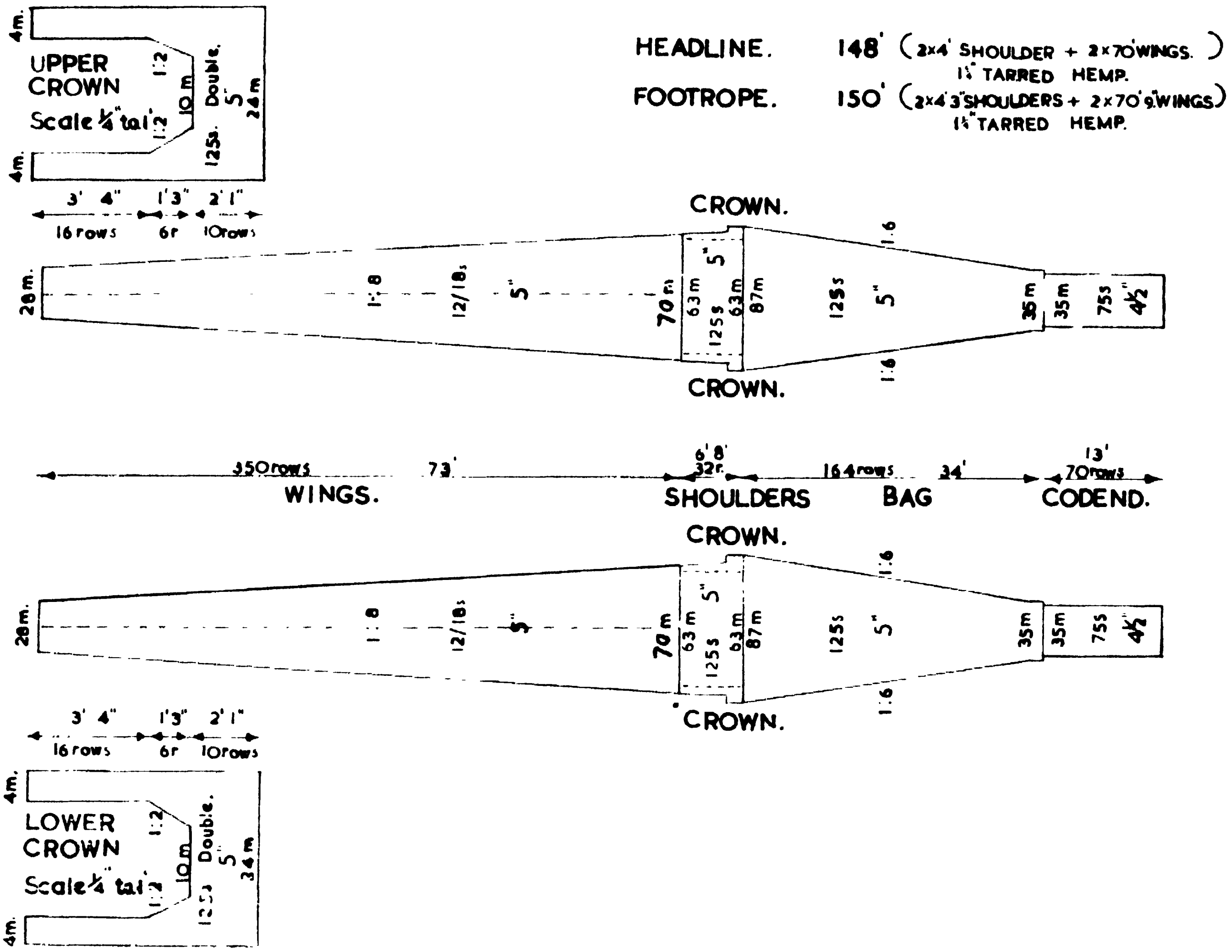


Fig. 16. Plan of a plaice seine.

A plan of a plaice seine is given in fig. 16. Typical flotation for such a net is 5 × 5 in. (12·7 cm.) diameter balls on each wing and a 1 × 8 in. (20 cm.) diameter ball to mark the crown at the centre. Mounted on the footrope are 236 × 2 oz. (57 gm.) conical leads (8 at the crown and 114 on each wing). A bosom is formed by reeving a 2 in. (5 cm.) coil rope round the footrope, closely wound at the lower crown and more sparsely towards the wing tips. The codend, being of such heavy twine, contains 4 × 5 in. (12·7 cm.) balls to help float and keep it from chafing on the bottom.

Specification of a Plaice Seine

Headline	148 ft.	(2×4 ft. shoulders+2×70 ft. wings) 1¼ in. tarred hemp.	
Footrope	150 ft.	(2×4 ft. 3 in. shoulders+2×70 ft. 9 in. wings) 1¼ in. tarred hemp.	
Wings		71 m./28 m./350 rows (73 ft.) long 12/18s tarred cotton twine 5 in. mesh	71 28
		Baiting up the middle of the net every 8th row for 43 baitings	43 8
			344
Shoulders		63 m./63 m./32 rows (6 ft. 8 in.) long 125s tarred manila twine 5 in. mesh shoulders only extend to the end of the crowns.	
Crowns (upper and lower) the same)		24 m./4 m./32 rows (6 ft. 8 in.) long 125s tarred manila twine, double 5 in. mesh Set up at 24 m. across in double twine Continue for 10 plain rows Then leaving 10 bosom meshes 3 fly meshes on insides to bring each side to 4 m. across Then plain to the end	
Bag		174 m. round/70 m. round/164 rows (34 ft. 2 in.) long 125s tarred manila twine 5 in mesh	87 35
	87	52 baitings on top and 52 underneath baiting every 3rd row then plain to end	52 3
			156
Flapper		None	
Codends		70 m. round/70 rows (13 ft. 1½ in.) long, 75s, 4 strand tarred manila 4½ in. mesh	

m. = meshes

The haddock seine is made entirely of cotton, occasionally even of nylon. It has large shoulders which together with the bag and codend are, in the North Sea at least, of the 70 mm. (stretched) regulation mesh size. The batings in the wings and shoulders are in the headline side only. The net usually has a considerable overhang. the headline being markedly shorter than the footrope, As the stress of towing is thus put predominantly on the headline, it is often made of combination rope. The footrope is not made of combination rope but hemp, so that, if it does become solidly snagged, it will part and the net may not be wholly lost. As the hemp shrinks much more than the combination rope, it must be ensured that the footrope is wetted and stretched before the net is mounted; otherwise the proportional lengths of headline and footrope will be wrong after the net has had its first wetting.

Specification of a Haddock Seine (Stuart No. 18)

Headline	190 ft. (2 × 18 ft. shoulders + 2 × 77 ft. wings) 1¼ in. combination rope	
Footrope	197 ft. (2 × 20 ft. 6 in. shoulders + 2 × 78 ft. wings) 1¼ in. tarred hemp rope	
Wings	100 m./45 m./440 rows (91 ft. 8 in.) long 12/12s twine 5 in. mesh	100
	Bating every 8th row on top only	45
		55
		8
		440
Shoulders	188 m./175 m./220 rows (26 ft. 9 in.) long 12/12s twine 70 mm. mesh	188
	38 plain rows then bating every 14th row	175
	on top only.	13
	Join on to wings by taking up 3 meshes in	14
	7 in sequence 1:2, 1:2, 1:2, 1:1	182
	196 rows set on to headline	
	210 rows set on to footrope	
Crowns	5 m. + 20 m. + 5 m. 20 rows (2 ft. 5¼ in.) long Double 12/24s twine 70 mm. mesh Set up at 30 m. across for 10 plain rows, then leaving 20 bosom meshes carry on fly meshing on the outside for 10 rows more. The uppercrown has an additional 14 rows (1 ft. 8½ in.) in single 12/12s twine.	
Bag	416 m. round/192 m. round/84 m. round/52 ft. long 12/12s, 12/18s, 12/36s twine 70 mm. mesh	
	1st sheet 208 m./96 m./230 rows (28 ft.) long.	208
	12/12s twine	96
	6 plain rows then bating every 4th	2/112
	row for 56 batings	56
		4
		224
	2nd sheet 96 m./42 m./118 rows (14 ft. 4 in.) long	96
	12/18s twine. Bating every 4th row	42
	for 27 batings	2/54
		27
		4
		108
	3rd sheet 42 m./42 m./ 9 ft. 8 in. long 12/36s twine	
Flapper	90 m./30 m./60 rows (7 ft. 3½ in.) long	
	12/12s twine 70 mm. mesh	90
	Bating every 2nd row	30
	Join on 8 rows from end of	2/60
	1st sheet of the bag	30
		2
		60
Codend	84 m. round/100 rows (12 ft. 2 in.) long 12/42s twine 70 mm. mesh	

The plan of a large haddock seine is given in fig. 17.

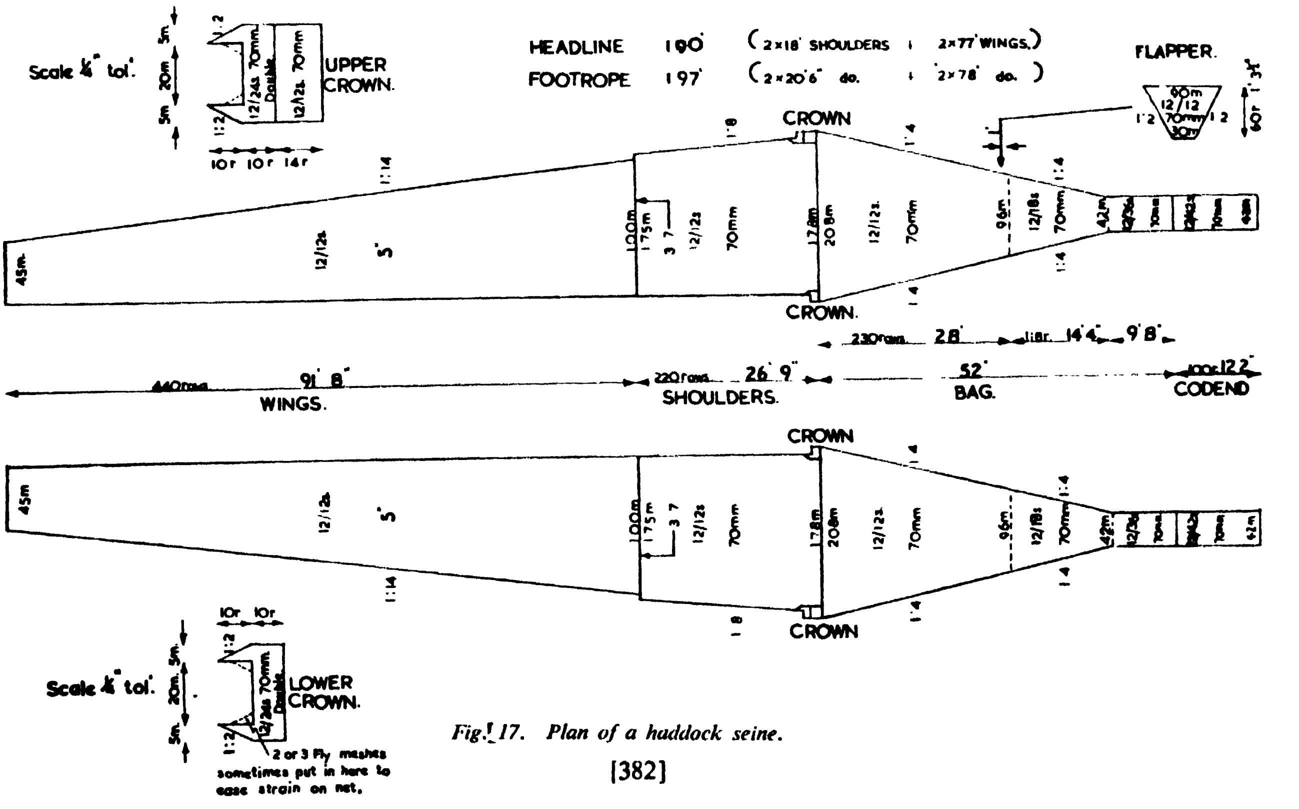


Fig. 17. Plan of a haddock seine.

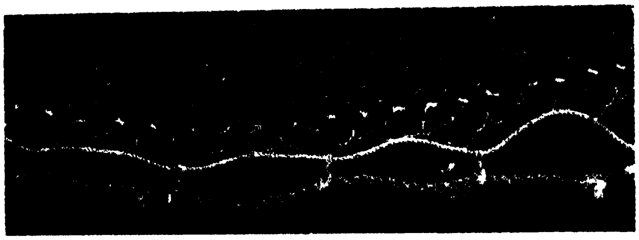


Fig. 18. Footrope of a haddock seine, showing the ring leads and the attachment of the net.

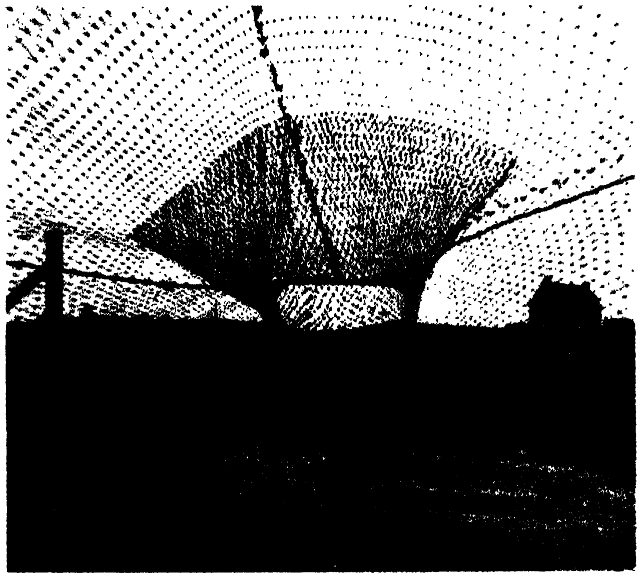


Fig. 20. View into a haddock seine, showing the attachment of the flapper.

The net rides more lightly on the bottom than does a plaice seine, by virtue of its proportionally shorter head-line, its greater flotation and its looser method of attachment to the 3½ in. (9 cm.) coir rope (fig. 18). Mounted on this coir rope are 166 × 4 oz. (114 gm.) ring leads. Typical flotation is 43 × 5 in. (12·7 cm.) balls, 10 on each wing, 9 on each shoulder and 5 on the crown. Fig. 19 shows the details of the upper crown of a smaller haddock seine. The double row at the bottom of the picture marks the join of bag and shoulders. Note the extra five rows of overhang on top between crown and bag. The harness lines run down the net diagonally to the point where they meet similar ones coming from the lower crown and thence to the codend. The detail of the stitching-in of the flapper is seen in fig. 20. Note the join of the two halves of the net above and below. The normal type of danleno, with its bridles, swivel and clip link, is shown in fig. 21. A length of ¼ in. (6·3 mm.) or ⅜ in. (9·5 mm.) chain, between 4 ft. (1·2 m.) and 24 ft. (7·3 m.) long, is often connected between the danleno and the warp. Fig. 22 shows the hoop type with a wrapping of lead sheet at the bottom. This type has the advantages that it is less apt to stick in muddy bottom and also, if and when a splice does stick in the coiler during fast hauling and when the wing tips are together, the danleno is less likely to catch and tear the opposite wing.

The specifications of a Japanese seine net and associated gear are given in fig. 23.

GENERAL DESCRIPTION

It is instructive to take a length of light rope and a piece of light chain to simulate the net, to lay them out on a sandy beach in the same pattern as seine net gear, then to haul them in by hand. The sequence of events is better understood from such a rough working model than from pages of explanation. At first the net does not move at

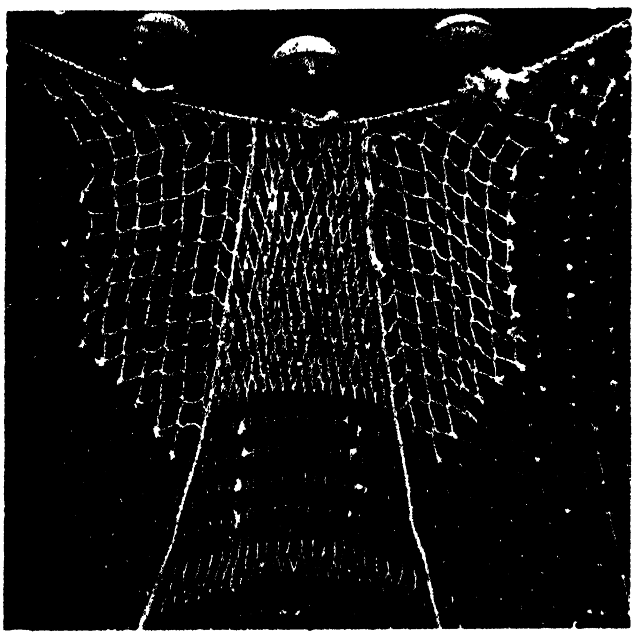


Fig. 19. Upper crown of a smaller haddock seine.

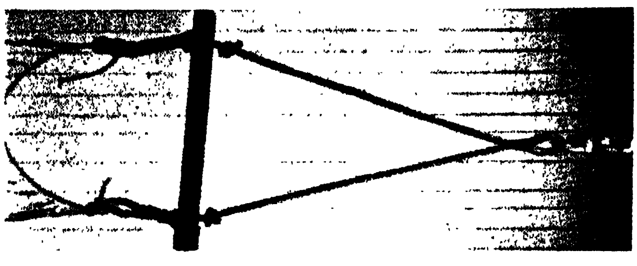


Fig. 21. Common danleno.

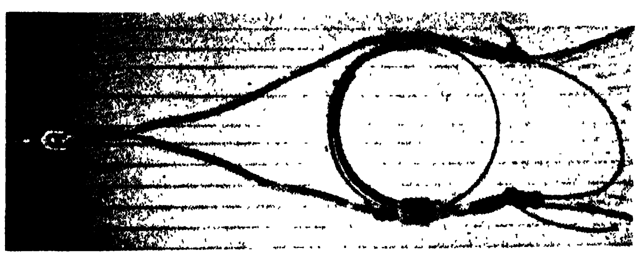
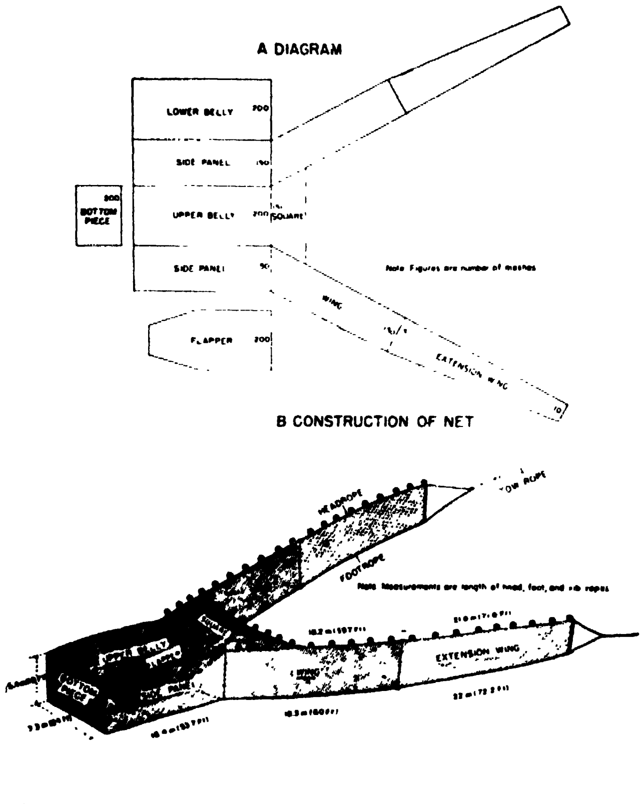


Fig. 22. Hoop type danleno.

all, but the pattern of the warp changes (fig. 24), tending to shepherd the fish into the path of the net, which only starts to move after warp and wing tips have assumed a position in which the tension in them has a significant forward component. The ground rope of the net now shepherds the fish forward and inward, but as yet few go into the net. As the warps become straighter the speed of the net increases and fish pass down the funnel to the codend (fig. 25). The headline height gradually falls towards a steady level and the net takes up its fishing shape very much like that of a trawl. The height of the headline depends on the rig of the net and the amount of flotation, but a final steady value of 8 ft. (2½ m.) may be taken as represe ative of a medium sized haddock seine. The net gradually closes (fig. 26) until it has ceased fishing, with the codend, we hope, swollen ou like a balloon. After that it is a case of bringing the ne back to the boat, as fast as possible, depending on th stress on the ropes.



NETTING

Part of Net	Material	No. of Strands	Size of Mesh (cm.)	Size of Mesh ins.	Length (Stretched) (m.)	Length (Stretched) (ft.)
Lower belly ..	Cotton	45	6	2·4	22·7	74·5
Side panel	Cotton	30	6	2·4	22·7	74·5
Upper belly ..	Cotton	30	6	2·4	22·7	74·5
Bottom piece ..	Cotton	45	6	2·4	7·3	23·8
Square . ..	Cotton	30	6	2·4	7·3	23·8
Flapper	Cotton	21	6	2·4	14·6	47·7
Wing	Cotton	36	6	2·4	21·8	71·6
Extension Wing ..	Hemp or Manila	3	48	19·0	27·3	89·5

ROPES:

Headrope: Manila diam. 33 mm. with glass floats (diam. 20 mm.

Footrope: Manila diam. 45 mm.

Tow rope: 6 pieces of manila rope shackled together. Diameters from 45 to 25 mm. decreasing from wing to ship chain of about 37 kg. Total length of tow rope: about 900 m.

Fig. 23. Japanese seine. (F.W.S. Fishery Leaflet 389.)

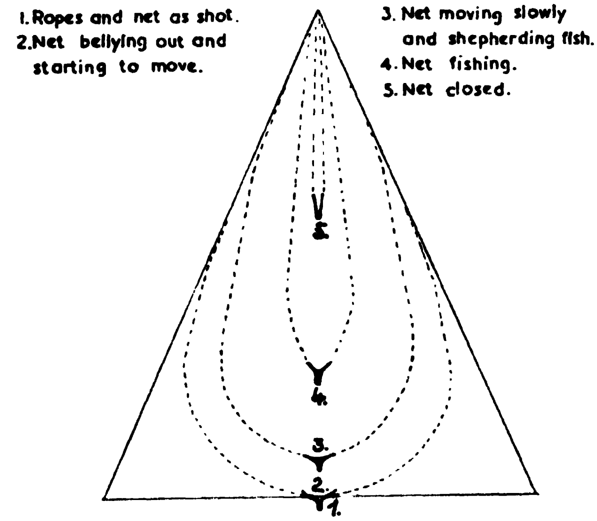


Fig. 24. Simplified diagram showing the stages of hauling.

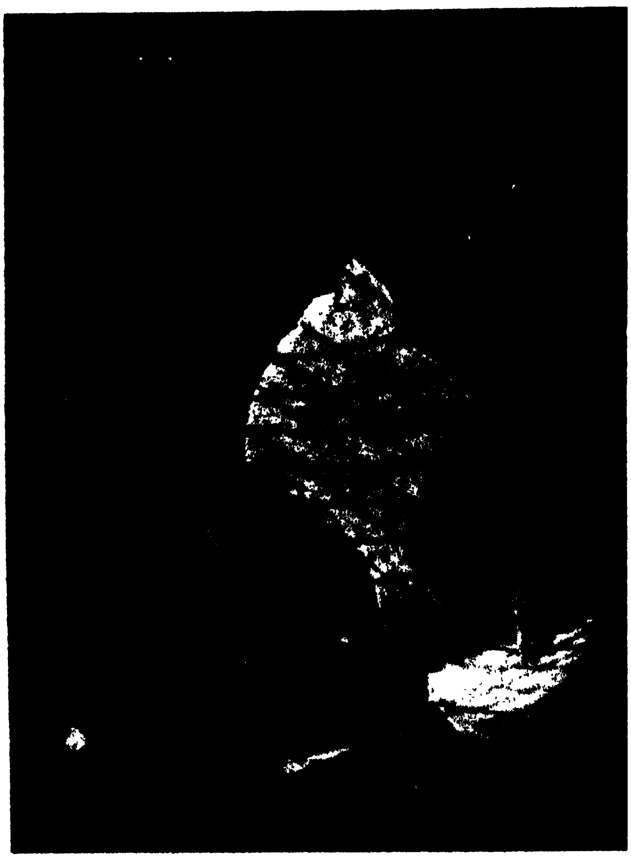


Fig. 25. Flatfish in the codend.
(A Still from the Scottish Home Department's film, "Fish and the Seine Net.")

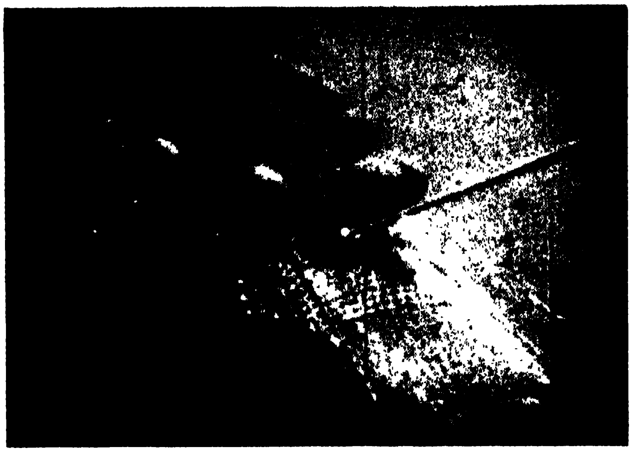


Fig. 26. The shape of the headline with the wings almost closed. (*Still from the Scottish Home Department's film "Fish and the Seine Net."*)

Warp Length

The length of warp used increases with the depth worked, with the stowage space for it on the boat and with confidence in the knowledge of a clear bottom. A small boat of 40 ft. (12 m.) may use five to six coils per side in water up to 40 fm. (73·10 m.). A large seiner may use ten or a dozen coils per side in water up to 100 fm. (183 m.), but even in depths of a few fathoms, where it is known there is clear ground, anchor seiners fishing for plaice may use up to sixteen coils per side. It is common practice to have a set of warps of the minimum length used and to clip on to these a set of extra coils as necessary. A rough guide to the amount of rope used by fly draggers is as follows:

For a boat with an engine	40 to 50 h.p.—	5 coils a side
	60 to 70 h.p.—	7 „ „
	80 to 90 h.p.	9 „ „
	130 to 140 h.p.—11	„ „

Echo Sounder

A reliable echo sounder is an important adjunct in seine netting, not so much from the point of view of fish finding, as yet, but for determining the nature of the bottom. It is common practice on unfamiliar ground to keep the sounder running all the time when the warps are running out, and often enough the pattern of the set has to be modified on "advice" from the echograph. It is well to have an echo recorder with a paper speed on which the whole of the ground covered during shooting can be surveyed at a glance, neither too cramped not too extended. Secondly, it is well to have a paper recording from which the nature of the bottom can be interpreted. This is one of the arts of seining.

ANCHOR SEINING OPERATION

When an anchor seiner reaches the ground, it is common enough to have a fly drag before deciding to lay her moorings. The Danes and Swedes, with variable pitch propellers on their boats, can adjust the pitch until the boat is just making headway. This can be tested in shallow water by keeping a sounding lead bouncing across the bottom.

The decision whether to shoot to starboard (clockwise) with a port bag, or vice versa, must be made before the set commences because of the way the net must be stacked down. With a port bag the left-hand wing is flaked down first so that it runs off the stern platform last, the headline is to the starboard side and on top, the footrope to port and underneath. The danleno at the end of the right-hand wing is left hanging just over the stern, allowing the net to start running away clearly. The set is made so that, if possible, the net is shot before the wind and on returning to the dahn all the gear is then on the weather side. Attention has also to be paid to the manner in which the tide is changing. During the tow back to the dahn (fig. 2B) the net moves sideways, and it should finish in such a position that the tide flows through it during the haul. A tide float is sometimes hung over the stern of the vessel while she is at her moorings. This helps the skipper to judge the best way to make his next set.

Once the moorings are laid, the dahn with its picking-up piece is attached to the end of the mooring wire. The dahn must be tall enough to be seen at a considerable distance and yet light enough to be easily brought on board. The end of the seine net warp is clipped into the end of the mooring wire and the boat commences its set, shooting down with the tide. The warp can, with practice, be run out at full speed, but here is one of the most dangerous aspects of seine netting, because a man can be snatched overboard through stepping inside a coil or bight of rope. If he is, the rope should not be cut as he will go down with the rope unless he frees himself. It is better to bundle slack warp overboard and then come back on it. The boat is slowed down just before the net runs out and is speeded up afterwards. As the last few fathoms of warp prior to the net run out, a bight of rope is lifted over the shooting post (fig. 2), otherwise the net will be dragged round it instead of going over the stern. As the crown of the net comes over the rail, the codend is thrown by hand clear and to the outside of the rest of the net. Often enough, the last danleno to go overboard is held for a moment by hand, helping to spread the net as far as possible. The boat carries on shooting her cross-rope before turning back to her dahn. An anchor seiner shoots all her rope out, keeping to the outside of her dahn and then towing her end of the warp back to it. By doing this, strain is put on the gear, which is brought into a more advantageous position for hauling by the winch. The engine is slowed down before the warp is all run out, and the tow back to the dahn is made at $1\frac{1}{2}$ to 2 knots. The nature of the ground may preclude shooting as much cross-rope on one side as the other, and it is not always desirable to do so. The amount of cross-rope to shoot and the length of tow back to the dahn is a matter for the skipper's consideration.*

The Danes have evolved a special method of shooting in fishing for plaice (fig. 2B). Here one side of the warp acts as a shepherding arm and the set covers a much larger area of ground than usual. In such circumstances, it may take anything up to $1\frac{1}{2}$ hours to tow back to the dahn. In these days of various radio navigational aids, the moorings can be laid with precision. Ground can then be covered systematically by working right round the moorings as the tide turns. This is known as *star* *ringing*. For roundfish, and in deep water, a tow back to the dahn buoy of half a coil's length is more usual.

If the tide is very strong, the mooring barrel and the dahn can be ridden down during this towing stage. Even less tide than this can cause the gear to close quickly after hauling commences and the net to make very little advance before closure.

Due to straining the ropes on obstacles, as well as to shrinkage and to splicing, there is always some difference in the lengths of the two warps. Yet it is necessary for the net to be brought in evenly. If it is not, pockets form in the net out of which fish can escape. The shorter warp, which has the greater tension in it, rides high and so meets the water further away from the ship's side. By surging at the winch on the tight one, the two warps can again be brought level. It is possible, using this judgment by eye, to bring up the danlenos level with each other to within a few inches. Another help is to press down on the ropes as they come over the rail to judge by their resistance the evenness of the tension in them.

It must happen sooner or later that the gear comes fast. What is to be done then depends on the stage of hauling reached when this occurs. If but little warp has been brought abroad, the free end is made fast to the moorings, which are then slipped, and the boat winched down to the fastener on the other end. On clearing it, the boat returns to the moorings, shooting out the warp again, and resumes hauling. If, however, the haul is well advanced, then the moorings have to be slipped completely and the boat winched back along both warps until they come clear. If both warps are fast, a time will come when one will be pointing one way and one the other. The procedure is then to cut and buoy one, at a splice if possible, and winch along the other. Once the warp is cut it may help to take the free end down tide of the fastener.

The coils have to be removed from below the coiler to be dragged, one set forward and one set aft. To do this, a 4 ft. length of old rope is placed below the spout of each coiler, and, when the warp is piled high enough, the end of this piece is brought up through the centre of the coil and used to drag the coil along the deck. In figs. 2 and 3 it can be seen that, as far as the shooting sequence is concerned, the after coils are coiled upside down as they come from the winch. The usual practice is to turn the first after coil upside down on the deck as it is dragged from the winch and to stack the remaining coils against it. These can then be quickly flicked over just prior to the next set. It would also be possible to change the after coils end for end without turning them over, but this is not good practice. The rope nearest the net wears most, and it is better to keep the wear in one place, cutting off the worn coils and adding new ones at the other end, so that the warp is renewed continually.

For plaice, the winch may be kept in first gear until the warps close; for other species, hake, for instance, the hauling speeds can be faster. The time taken for a set depends on several factors, but an estimate of it can be made beforehand, which, apart from snags, is usually correct to within a few minutes. It is here that a knowledge of the winch gear and pulley ratios come in useful. The length of warp and the speed of the boat shooting it are known. The length of tow back to the dahn is determined by the pattern of the set, while the speed of tow can be chosen. There is usually an engine revolution meter in the wheelhouse, so that the engine speed can be set to give the desired hauling speed on the ropes. To all this must be added a few minutes for clipping on to the moorings and for the lifting aboard of the net.

FLY DRAGGING OPERATION

As the movement of the net is due partly to the headway of the ship and partly to the hauling of the winch, the winch speeds in the early stages of the hauling are kept slow. In general, a set tends to take longer by this method, but there can be no certainty about this because, even with the hauling period longer, due to the time spent in towing before the winch is started and to the slower initial winch speeds, the shooting period is shorter since no tow back to the dahn is made. Some skippers like to start the winch as soon as the gear is "all square", while others prefer to tow for anything up to 20 minutes before starting the winch. With a very small boat and little power, it is quite a successful practice to tow the gear to a close and then to use the power for winching in over the broadside.

The speed at which a fly dragger's engine is set is not dependent upon the requirements of the winch but upon what is necessary to make headway over the ground. Against wind and tide, more engine revolutions are required, and it is such considerations that lead to the greater number of winch gears, though all of them may not be used every drag. Similarly, the choice of the pulley ratios is a matter to be given some thought. An inch or two more on the upper or lower pulley can make quite a difference.

By steaming ahead, the seiner makes its own tide, as it were, so reaping certain advantages. It is possible to work against a stronger tide and to tow before it or even partly across it. There is more freedom to tackle a piece of ground from any advantageous direction, remembering amongst other things that there are some types of grounds, like the belly of a sprat, where net and ropes will come one way but not the other. In towing before the tide, two things to be remembered are:—

(1) The net moves a long way before it closes, so good ground is needed.

(2) As the net sinks, the codend trails above it and may be carried over the top of the headline when the net reaches the bottom and becomes stuck inside it when the net starts to move. A whole drag can be lost in this way though the shooting has been perfect, and it is a precaution either to weight or float the codend on such occasions.

The gear takes some time to sink to the bottom, and under the action of the tide it will not reach the bottom directly below where it is shot. Allowance has to be made for this on some confined grounds. The ropes themselves sink at about 12 fm. (22 m.)/min. They sink faster than the light haddock seine and carry the net down with them. When intending to tow partly across the tide, the uptide warp should be shot first or the gear will tend to close up on itself.

Just how far and fast the boat advances from the point at which the dahn is lifted, and how far the net advances,

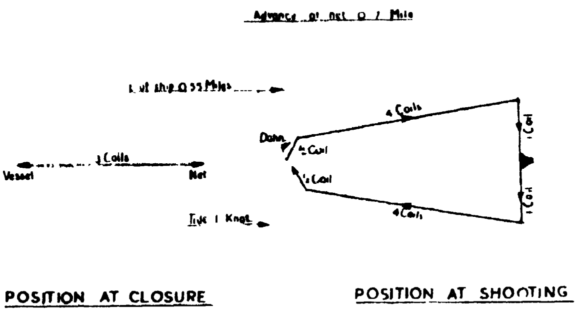


Fig. 27. Fly dragging operation.

depend on many factors, tide, winch speeds, length of rope and the pattern of shooting, power of the vessel and times of changing gear. If too much rope is used, the vessel can be as good as anchored, the advantages of fly dragging being lost without securing the advantages of working at moorings. In general, a fly dragger would use less rope than an anchor seiner of the same size. Fig. 27 gives some idea of what can be done with comparatively little rope. A typical example for a small 40 ft. (12 m.) boat is to tow for 10 min., take half a coil in 1st gear, one coil in 2nd, one and a half coils in 3rd, by which time the net is closed, and the remaining three coils in 4th. A small boat scores in this respect because once the net is closed she can take in all remaining rope in top gear, thus saving time. With a larger ship, and particularly with a following sea, one has to take things more gently. The speed of advance of the boat across the ground may be taken roughly as falling from 2 knots when towing, to standstill in top gear, with the speed of the net rising from zero to a maximum of $2\frac{1}{2}$ knots at closure. The amount of cross-rope to shoot is a matter of choice dependent on the total length of rope and nature of the ground. It is a mistake, however, to think that the more cross-rope shot, the further the net will advance before closure. Too much cross-rope simply means that the boat has to move farther ahead and winch in more rope before the net starts to move at all.

The shooting procedure is much the same as in anchor seining except that the coils are laid out on either side of the vessel, as shown in figs. 4 to 7. The shooting bar on the rail is shown in fig. 28. The vessel's head is, as before, kept to the outside of the dahn on the return journey to it, but enough warp is left to reach the dahn and the slack warp is thrown overboard as the dahn is approached. When hauling, the warp is led through a single roller (see fig. 29). The roller is let into any of several holes along the rail on the weather quarter. The stronger the wind, the further forward the roller is put to maintain steerage. A mizzen sail is often a help, too. The procedure on coming fast is the same as for anchor seining, except that there are no moorings to slip.

Fig. 28. Shooting bar.

Fig. 29. Rail-roller for hauling.

CONCLUSION

Compared with trawling on a heavy ship, seining is as the rapier to the sledgehammer, not necessarily always more effective but requiring a difference of outlook and technique. The beginner need hardly expect immediate success with either of the two methods of seining, but, with practice, these can be most effective in the right places. Accurate knowledge of the grounds and tides must be acquired, and knowledge of echo sounder interpretation is a great help. Seining has its physical dangers, too, particularly those of being hauled overboard by the warp during shooting and being carried into the winch at high speed when hauling. The shooting procedure is often different from one set to the next, and this is difficult for a raw crew to master and learn to accomplish with precision. In spite of its difficulties, the reward of persistence at Danish seining has been sufficient to bring it, within recent years and in more than one country, to being a principal method of fishing for demersal species.

COMPARISON OF STARBOARD AND PORT SIDE OPERATION FOR (DANISH) SEINING

by

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Abstract

In most Japanese boats the fishing gear has generally been worked from the port side, merely as a matter of custom, due no doubt to the fact that the earliest boats were steered by an oar, mounted on the port quarter. The author, after observing the operation of the seines (similar to the Danish seine), deduces that better and safer handling of the net is obtained if the starboard side of the vessel is used.

Comparaison de l'utilisation a tribord et à babord d'un filet de pêche de type senne danoise

Résumé

La plupart des bateaux japonais utilisent généralement les engins de pêche à babord, simplement par habitude, sans doute parce que les premiers bateaux étaient gouvernés au moyen d'un "Ro," ou aviron, monté sur l'arrière à babord. Dans cet article, l'auteur, après avoir observé le fonctionnement d'un chalut moyen à un bateau (en fait, une variété de senne danoise) conclut qu'il est préférable et moins dangereux de manoeuvrer le filet à tribord. Il montre comment, avec une hélice tournant vers la droite, on doit logiquement opérer à tribord

Comparación del calamento de una red de arrastre danesa por babor y estribor

Extracto

A causa de la costumbre, y quizàs por el hecho de que las primeras embarcaciones eran timoneadas mediante un "ro" o remo montado en el cuarto de babor, la mayoría de los barcos japoneses calan los artes de pesca por ese costado. En este articulo el autor después de observar el calamento y recogida de una red usada por un "arrastrero mediano" (en realidad un tipo de barco para red de arrastre danesa), deduce que la red se manipula en mejores condiciones y con menor peligro por el costado de estribor de la embarcación. También demuestra como al usar una hélice que gira a la derecha, estribor sería el costado lógico de trabajo

THE seining method discussed here has been devised in Japan and is most popular. The boats of 15 to 75 gross tons used for this seining are the most numerous in the Japanese fishing fleet. The operation of the gear (which is practically identical with Danish seining.—The Editor) is as follows:

The two manila ropes may vary in length from 1,600 and 3,200 m. A buoy fixed to the free end of one rope is thrown overboard, and the warp, the net and the second warp steamed out according to the scheme shown in fig. 1. After having picked up the buoy with the free end of the first rope, both ropes are hauled while keeping the boat before wind and current.

In Japan the gear is customarily operated on the port side but the reason for this is not clear. In the early days the "Ro" (Japanese oar) for steering was set at the port side of the stern, so the fishing was also done from the port side. This is still the practice even though the boats are now equipped with propeller and rudder.

According to seamanship theory, the starboard side should be used. The author (1949) pointed out that, for otter trawling, the starboard side is preferable because of the effects of propeller and rudder, and because of the rules of the International Regulations for Preventing

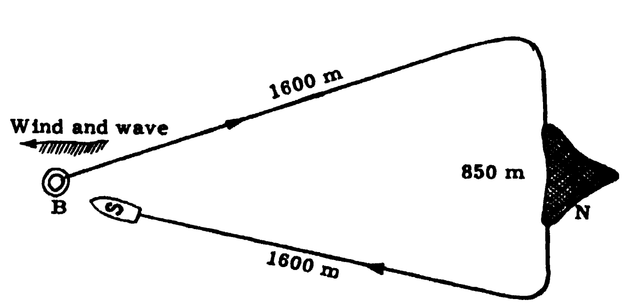


Fig. 1. Method of steaming out the gear when fly-dragging.

Collisions at Sea (1948). As seiners usually have a right-handed propeller, seining should also be done from the starboard side. The author's studies of commercial seining have confirmed this.

The relation between the ship and the net in port side hauling is shown in fig. 2. From the positions b and c, to the situation shown in d, the ship is propelled backward, and the net is taken in. When using the engine for going astern, the righthand propeller turns the stern of the ship to port and the head to starboard so that the after-wing of the net is in danger of becoming entangled with the propeller (fig. 2, e). The helm must be hard

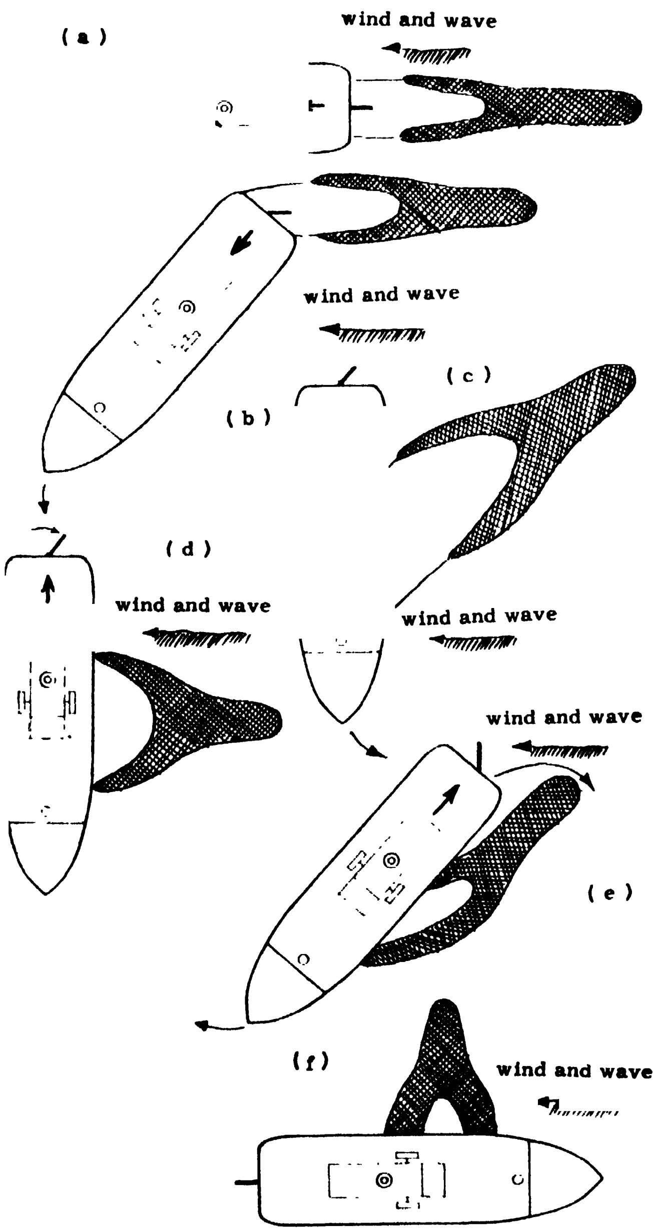


Fig. 2. Operation of the net and movements of the boat when fishing over the port side.

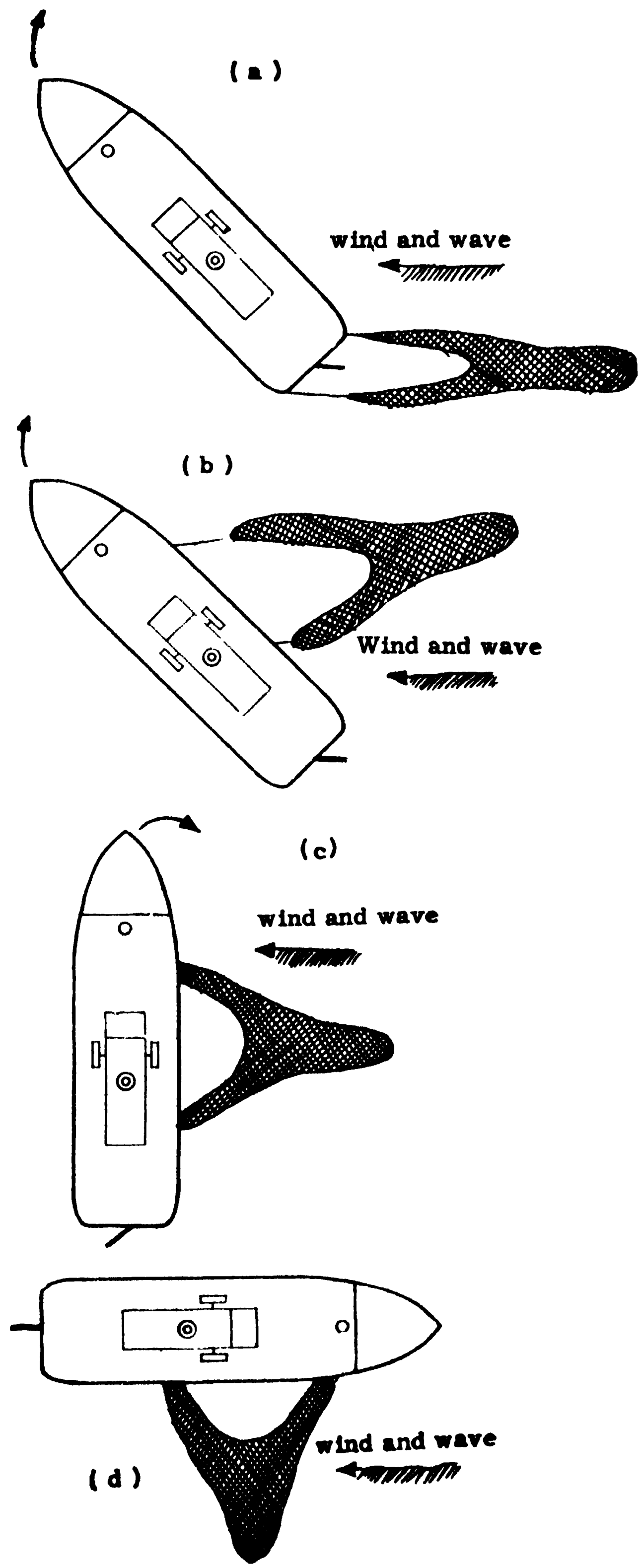


Fig. 3. Operation of the net and movements of the boat when fishing over the starboard side.

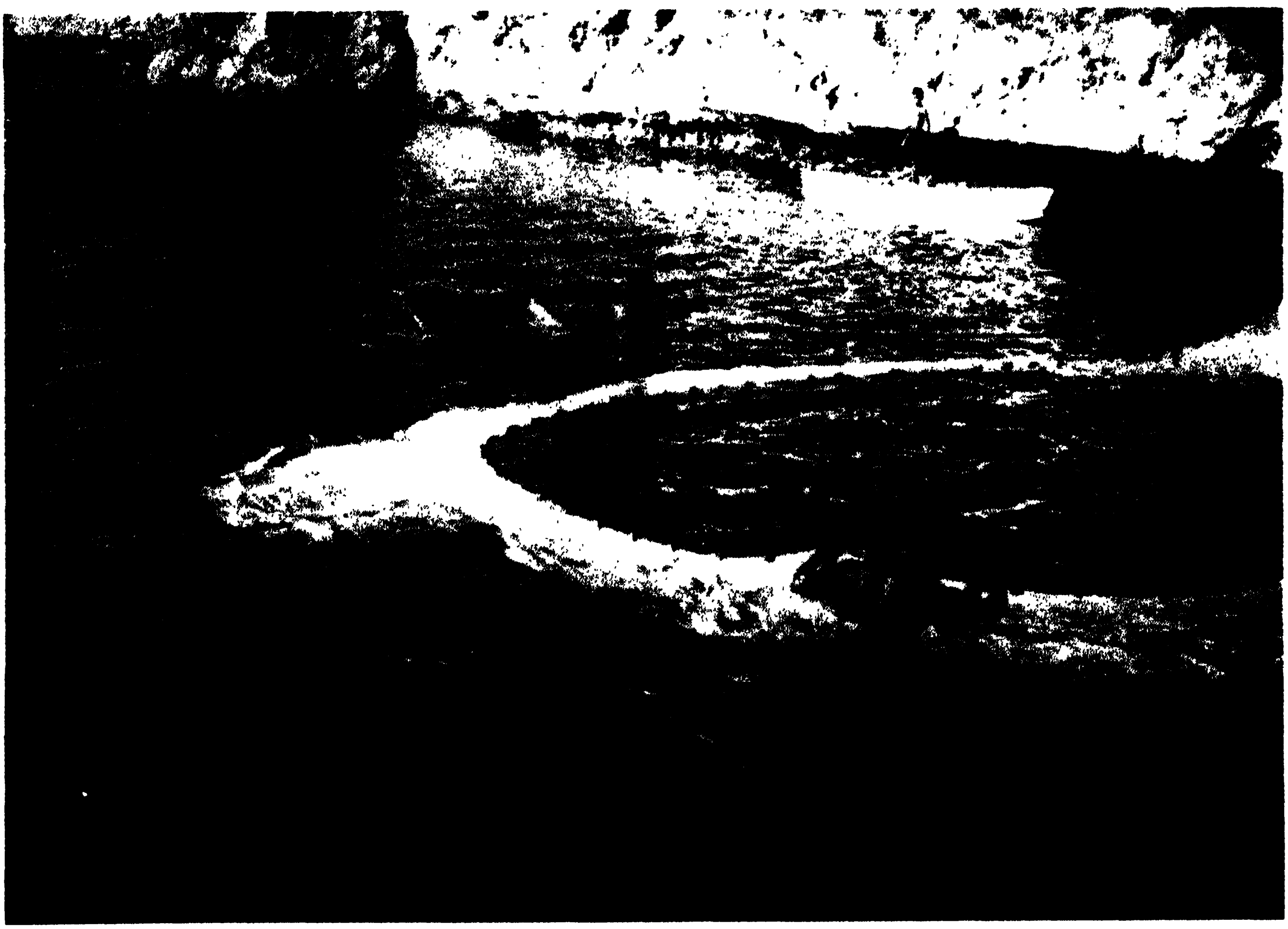
to port and the skipper must depend on the action of the propeller to reach the situation in fig. 2, d. The effect of the rudder is very slight at such low speed so steering is difficult.

When the wind exceeds Beaufort Scale 4, it is better to have the net with the ship heading to the wind and sea. But, as for this purpose the engine must be used ahead and astern, there is still danger of the net at port side being drawn in the propeller because of the port side tendency of the boat.

The reasons for this effect of the propeller on the boat are the following: While the engine is going ahead, the discharge current of a righthand propeller strikes the lower part of the rudder on the starboard and the upper part on the port side. In the usual type of rudder, which is narrow in the upper part and wide in the lower part, the pressure on the lower part is stronger, which tends to turn the stern to the port and the head to starboard.

When the propeller goes astern, the discharge current strikes the upper part of the stern on the starboard side, and the lower part on the port side. Most of the pressure on the lower part escapes under the keel, therefore the pressure on the starboard side is greater, tending also to turn the stern to port and the head to starboard. The magnitude of this effect, of course, depends on the construction of the stern and rudder and also on the actual weather and current conditions.

Seiners with a righthand propeller should, therefore, fish from the starboard side, particularly in stormy weather because the vessel can turn in a smaller circle and the danger of fouling the net in the propeller is avoided (fig. 3).



Beach seining for Anchoveta and other small fish for use as live bait in tuna fishing—Haiti. **Photo: FAO.**

FISHING WITH SOUTH AFRICAN PURSED LAMPARA

by

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Abstract

This short paper gives a constructional picture of the pursed Lampara net used in South Africa for catching Pilchard, Maasbanker and Mackerel. The net is made of Marlon (a synthetic material consisting of a mixture of nylon and vinylon) and comprises 16 panels of netting arranged around a central bag in the orthodox manner. This gear has been in use in South Africa for about 15 years, and with the exception of minor variations according to the ideas of individual fishermen, has become a standard.

Pêche a la senne tournante au lamparo en Afrique du Sud

Résumé

L'auteur décrit dans cette courte étude le filet utilisé en Afrique du Sud pour la pêche au lampare du Pilchard, du Chinchard et du Maquereau. Le filet est en Marıen (matériau synthétique constitué d'un mélange de Nylon et de vinylon) et comprend 16 pièces de filet disposées selon la méthode habituelle autour d'un sac central. Cet engin est utilisé depuis une quinzaine d'années en Afrique du Sud, et, si l'ou excepte de légères modifications dictées par les idées personnelles de certains pêcheurs, il est devenu un modèle standard.

Tipo de red "lampara" con jareta usada en la Unión Sudafricana

Extracto

En este breve estudio se describe la construcción de una red "lampara" típica de la Unión Sudafricana para pescar sardina, jurel y caballa. El arte está compuesto por 16 paños de "marlón" (producto sintético que consiste en una mezcla de nylón y vinilidón), distribuídos alrededor de una bolsa central en la forma acostumbrada. Esta red se ha usado en la Unión Sudafricana durante unos 15 años con sólo pequeños cambios, según las ideas de cada pescador, convirtiéndose en un método de pesca corriente.

THIS method of fishing has been in use for about 15 years and has been considerably modernized during this time. The advent of synthetic fibre netting, more efficient winching systems, and craft of greater carrying capacity have been the main influencing factors in the evolution of the gear and the method of operation. Today, the construction of the net and its operation are almost standard with only minor variations due to the idiosyncrasies of individual fishermen.

CONSTRUCTION OF GEAR

Fig. 1 (not to scale) shows a typical lampara net made of Marlon, a mixture of nylon and vinylon which is widely used in the pilchard, maasbanker and mackerel fisheries.

The net is seamed in approximately 170 fm. corkline and approximately 145 fm. leadline. The netting itself is 1¼ in. mesh throughout and comprises a set of panels each of the same width on either side and the same width top and bottom. Particulars of these panels (see fig. 1), are as follows: —

Panel No.	*Meshes wide*	*Meshes deep*	*Twine (Marlon Number)*
1	800	900	M4
2	800	950	M4
3	800	1000	M4
4	800	1050	M4
5	800	1100	M4
6	800	1150	M6
7	400	1200	M8
8	400	1250	M10
9	1000	400	M12
10	900	400	M12
11	800	300	M10
12	700	250	M10

To create the curvature or bulge, the outer side of each panel is reduced by stealing or tucking in an appropriate number of meshes to match the depth of the inner side of the adjoining panel. This procedure is followed throughout the wings with the result that the bottom of the net lies straight yet tapering towards the wing ends.

The corks are attached directly to a ⅝ in. diameter synthetic rope and the leads to a ½ in. diameter synthetic rope. Approximately 1,000 5 in. corks are used for the bag and shoulders and from 750 to 1,000 4 in. corks for the wings. The weight of the leads and the distance between them depend on the thickness of the twines used in the various sections of the net.

The purse lines, each approximately 80 fm. long and usually of manila rope of about 3 in. circumference, are shackled to the tongue (i.e. the deepest portion of the bag, at

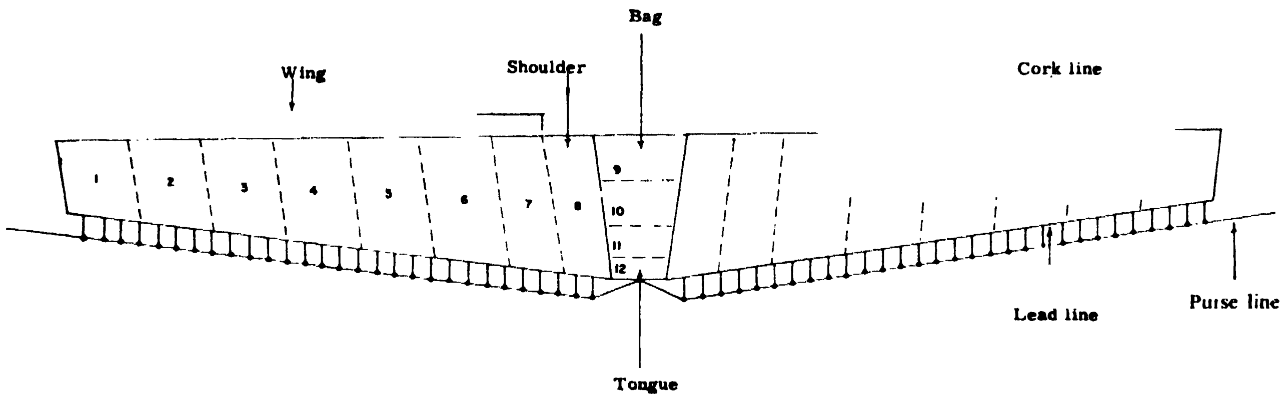


Fig. 1. Construction diagram of a Lampara seine net.

which point about 600 meshes are bunched together to cover an area of not more than 18 in. wide) in the following manner: a strop about 2 ft. long with a swivel at each end is attached to the leadline of the tongue and the purse lines are attached to these swivels. Below this strop another rope is attached, about 1½ in. in circumference, carrying up to 3 dozen leads to weight the bag.

The purse lines are passed through rings about 4 in. in diameter which are hung from the leadline by the ring lines, which are 1½ in. in circumference, 1 fm. in length and spaced 2 to 3 fm. apart.

OPERATION

The average vessel using a net of the above size is 55 ft. overall, has a beam of 19 to 20 ft., an engine of 150 h.p. and a total carrying capacity of about 100 tons of fish, i.e. 80 tons in the hold and 20 tons on deck. Its superstructure is well aft and comprises mainly a wheelhouse, skipper's cabin and galley. The average number of crew is 10. Most boats have R.T. and echo sounding equipment.

The lampara net is used on the starboard side of the boat. The front wing, which is stacked on top of the net, is first released. The purse line attached to this wing is made fast to a one-man rowing boat (dinghy) about 14 ft. long, while the purse line on the other wing is usually attached to the mast.

The method of coiling is to begin from the tongue at the front wing, care being taken to match the lengths of the leadline, the ring lines and the purse line. This wing is coiled over the starboard gunwale in such a manner that the weight of the net is distributed evenly in- and outboard. The back wing and the purse line on this side are coiled on the starboard foredeck.

As the amount of netting in the water increases while the boat moves in a circle to encompass the school of fish, the purse lines are pulled through the rings and, on the tightening of the leadline, the ring lines pass over the side. When the school is encircled the man in the dinghy throws up a heaving line to which the purse line is attached. The two ends of the purse lines are passed over

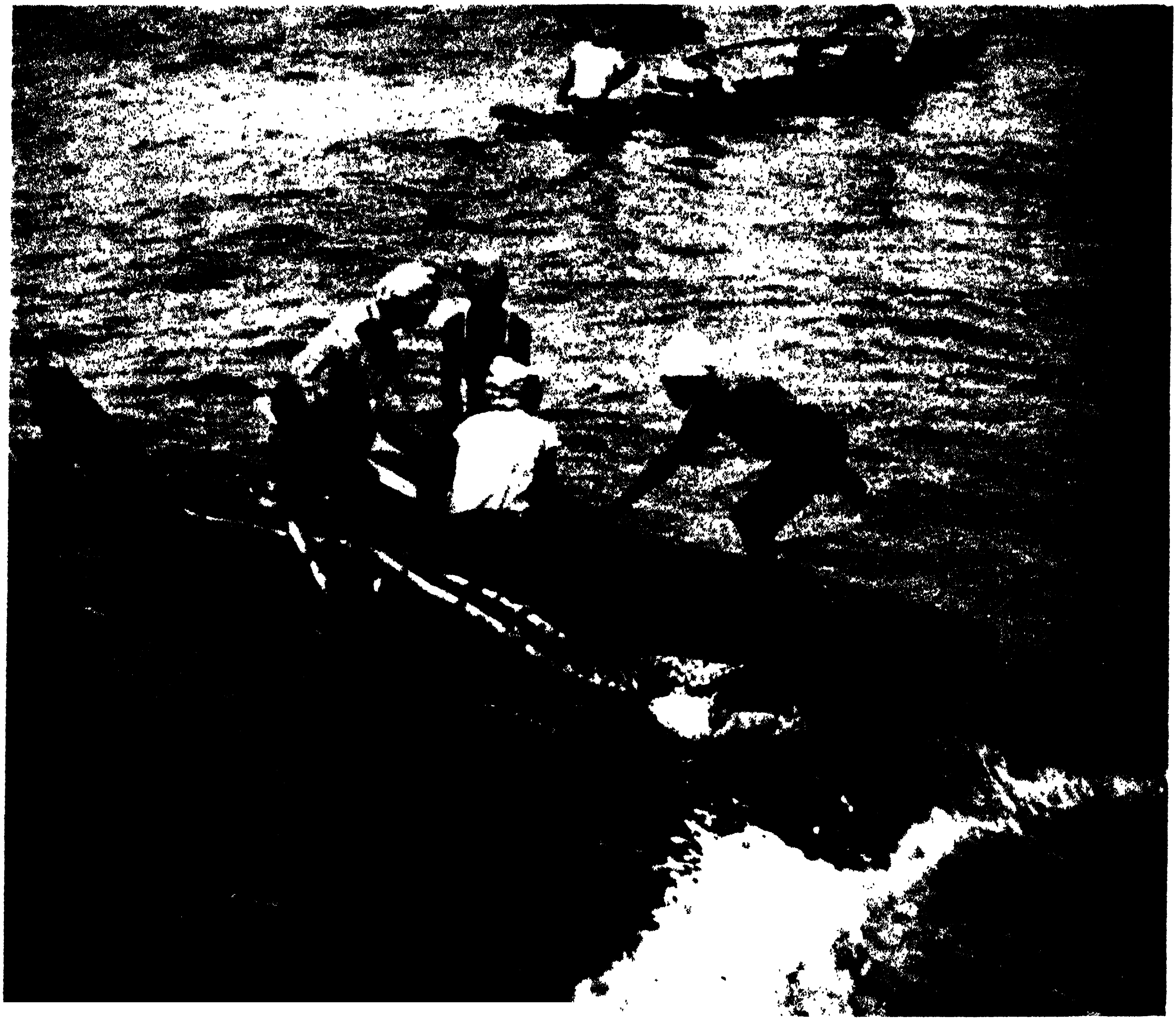
Fig. 2. The net is being hauled in after pursing with a winch set at an angle in front of the wheelhouse.

a roller on the gunwale on to the winch drums and hauling commences. The dinghy proceeds to the corkline of the bag and the dinghy-man makes fast to the shoulders of the net two sealed empty drums and then fastens his dinghy to the centre of the bag corkline. This is to prevent the net from sinking through an excessive weight of fish.

The wings are drawn in evenly or one before the other, depending upon the behaviour of the fish. The opening between the purse lines decreases as the tongue is brought nearer the surface and as soon as the purse lines lie parallel, the tongue is brought alongside. The winch is stopped and the tongue made fast, thus enabling the crew to retrieve the leadlines which at this stage hang in bunches in the water alongside the boat. While the leadlines are retrieved and the wings brought in, the area of the net in the water decreases until finally the fish are contained in the bag and inner portions of the shoulders.

It is at this moment that brailing begins by means of a steel pole about 10 ft. long, attached to a steel hoop and a bag of 2 in. stretched mesh synthetic fibre netting with a capacity of about 500 lb. of fish. The bottom of the brailer contains a number of cringles through which passes a zipper chain. The brailer is attached to a derrick on the mast and is manipulated with the aid of the winch. Up to 60 tons of fish can be brailed in an hour.

Sometimes up to 400 tons of fish are encircled in one set. When this happens other boats are called and they help to manage the net while the catch is brailed into their holds.



Indian fishermen on the Coromandel Coast hauling the bag of their lampara type bag net between two log rafts.

MENHADEN PURSE SEINING

by

JOHN S. ROBAS

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Abstract

Vessels, gear and fishing operations are described in detail. In U.S. menhaden purse seining, fish concentrations are located visually from the crow's nest of the main vessel or by aircraft spotting, with one airplane usually serving 5 seiners. About 22 to 30 men are needed to handle the big purse seine which is about 16,000 to 22,000 meshes (¾ in. bar) long and about 800 to 1,000 meshes deep. The purse seine is operated by two motorized purse boats, each about 34 ft. in length, which are carried to the fishing grounds by the main vessel (100 to 200 ft. overall). These big seiners often have refrigerated fish holds to carry between 150 and 1,200 tons of fish. The catch is generally transferred from the net into the main vessel by fish pumps. Synthetic materials are replacing the conventional cotton and cork in nets and floats. A top seiner will catch between 5,000 and 10,000 tons in a 5-month season.

La Pêche du Menhaden a la pêche Tournante

Résumé

L'auteur décrit en détail les bateaux, les engins et les opérations de pêche. Dans la pêche du menhaden aux Etats Unis, les concentrations de poissons sont repérés visuellement du nid-de-pie du navire principal ou par repérage aérien, avec avion opérant généralement pour 5 senneurs. Il faut environ de 22 à 30 hommes pour manipuler la grande senne tournante qui mesure environ 16,000 à 22,000 mailles (de ¾ de pouce, soit 2 cm. entre noeuds) de long et environ 800 à 1,000 mailles de chute. La senne tournante est manoeuvrée par deux bateaux à moteur, d'environ 34 pi. (10,36 m.) de long, qui sont amenés sur les lieux de pêche par le navire principal (100 à 200 pi., soit 30,48 à 60,96 m., hors-tout). Ces grands senneurs possèdent souvent des cales à poissons réfrigérés pouvant porter entre 150 et 1,200 tonnes de poissons. Généralement on utilise des pompes à poisson pour transporter la pêche du filet à bord du navire principal. Dans la fabrication du filet, les matériaux synthétiques remplacent le coton du filet et le liège des flotteurs. Un excellent senneur pêche entre 5,000 et 10,000 tonnes de poisson en 5 mois de campagne.

La Pesca de lacha con red de cerco de jareta

Extracto

Se describen minuciosamente las embarcaciones, artes y procedimientos pesqueros. En la pesca de lacha con red de cerco de jareta en los Estados Unidos, las concentraciones de peces se localizan visualmente ya sea desde la torre del vigia del barco principal o mediante su señalamiento desde un avión que sirve por lo general a 5 pesqueros. Se precisan alrededor de 22 a 30 hombres para manejar la grandisima red que tiene de 16.000 a 22.000 mallas (¾ de pulgada el lado del cuadrado) de longitud y unas 800 a 1.000 mallas de profundidad. El arte se acciona desde dos embarcaciones motorizadas de 34 pies eslora, a las que lleva hasta los bancos de pesca la embarcación principal (de 100 a 200 pies de eslora total). Estos barcos grandes disponen a veces de bodegas refrigeradas para transportar de 150 a 1.200 toneladas de pescado. La pesca se traslada generalmente desde la red al barco principal por medio de bombas de pescado. Los materiales sintéticos están sustituyendo al algodón y corcho usados normalmente en las redes y en los flotadores. Uno de estos barcos grandes captura entre 5,000 y 10,000 toneladas de pescado en una campaña de 5 meses.

THIS fishery is based on the menhaden, a herring-like fish of the genus *Brevoortia*, which migrates along the Atlantic and Gulf coasts of the United States, usually in the shallow waters near shore. This fish is used exclusively for reduction purposes and the production of meal, oil, and condensed solubles.

In the Gulf of Mexico, the catching season usually starts in May and extends through September; along the Atlantic coast, the season starts in April in Southern waters and is followed by the northern fishery near Virginia and New Jersey in May. Only one winter fishery is worked in the waters of North Carolina, where migrating spawning fish are caught near Cape Hatteras from November through December.

VESSELS

In the United States fishing fleet, the menhaden purse seiners are distinguished by their size, which reaches 200 ft. in length, with a carrying capacity of approximately 1,200 tons; the smallest profitable vessels in use are approximately 100 ft. overall and have a carrying capacity of about 150 tons of fish. Most of the newer boats being built are of steel, and many of them are being equipped with refrigeration facilities to keep the fish fresh. A typical menhaden seiner, however, still returns to port each day or every two days to unload the catch.

The actual fishing operation is done from two steel purse boats, each handling one half of the large purse seine. The industry is still largely dependent on manual labour and for this reason the crew of a typical menhaden vessel numbers 22 to 30 men, the majority of whom are used in the purse boats, pulling the net by hand. The function of the main vessel, therefore, is merely to carry the fishing gear and crew to the fishing grounds and to return home with the catch as rapidly as possible.

It goes without saying that speed is an important characteristic of the menhaden vessel: some of the larger vessels are powered with two 750 h.p. engines driving

Fig. 1. View from the mast-head of a menhaden purse seiner towing her purse-boats and the striker boat. The steel davits on each side of the engine house are used for carrying the purse seine boats to the fishing grounds.

twin screws and attain a speed of 16 knots. Vessels working in northern waters, where fog is encountered, usually have radar and, of course, most of them carry depth finding and radio-telephone equipment, particularly of the FM, private-channel variety.

The menhaden seiner can generally be distinguished by her high mast, topped by a crow's nest, her large and roomy deckhouse forward, and a relatively low engine house aft, with her purse boats suspended from davits on each side of the engine house.

The purse boats are generally powered with 100 h.p. gasoline engines, and are used to set the purse seine around the school of fish. The *captain boat* is commanded by the master of the seiner and the *mate boat* by the mate. Pursing the net is done by gypsy spools in the *captain boat*.

The striker boat or drive boat is a 12 ft. dory rowed by one man, and is used to keep track of a school of fish until the captain is ready to set. After setting the striker boat helps hold up the net opposite the purse boats.

OPERATION

The actual fishing is done from the two 34 ft. by 8 ft. gasoline-powered purse boats. When the captain sees a school of fish he orders his purse boats lowered, manned by almost the entire crew; only the engineer, the pilot, and the cook remain aboard the main vessel. The small 12 ft. wooden striker boat is quickly picked up by a winch and is also lowered into the water. The striker boatman jumps into this little dory and rows quietly standing up and facing the fish, to the edge of the school. He then keeps track of the movements of the fish while the captain is readying his purse boats. As the purse boats approach the school in setting positions, usually with the sun behind them so that the tendency of the fish to rush toward the sun will carry them further into the net, the striker boatman indicates the extent and direction of travel of the fish by signalling with his oar. The purse boats then shoot the net and surround the school, meeting on the far side with the fish trapped within. Once in the net, the goal is to purse the bottom of the net before the fish can escape. Pursing is done with a ⅝ in. Italian hemp purse line running through the brass purse rings along the bottom edge of the net, which is hauled by means of the winch located in the captain boat.

The menhaden generally strike horizontally, rather than vertically, and thus a small delay in pursing can be tolerated. The menhaden pursing technique is radically different from any other method used in the United States. Since the fish strike horizontally the water usually is shallow enough to permit the lower edge of the seine to reach bottom, a 600 to 700 lb. lead weight is first dropped over the side. Called a *tom weight*, or *tom*, it has two brass blocks attached. The purse line thus

Fig. 2. Menhaden purse boats preparing for the set: note the thick webbing used in the centre of the seine to stand heavy stresses during brailing of fish. These purse-boats are of wood construction covered with three plies of fibreglass *armour. Natural corks shown on seine have been largely replaced by synthetic foamed plastic floats.*

runs through the brass purse rings along the lower edge of the net, passes through the two blocks on the *tom weight* and then goes vertically to the surface whence it is led to the barrels of the winch in the captain boat. The *tom weight* thus counteracts the tendency of the seine to rise off the bottom and, if pursing is carried out properly, the lower edge of the seine moves inward to the closed position without rising in the water. When pursing is complete, the *tom weight* is taken back aboard and stowed until the next set.

With the net tightly closed at the bottom, the crew commences to haul in the wings, carefully piling each end in the purse boats as it comes in until they have the fish pocketed in the heavy centre section.

The captain then signals the seiner to come carefully alongside the net, which is then fastened to her, and the crew commence the operation of drying up the fish for brailing. While the crew harden up the fish, the engineer aboard primes his 10 in. centrifugal fish pump.

The 10in. rubber suction hose is lowered into the fish and pumping starts at the rate of 1 ton of fish/min. It does not take long to load the average catch of perhaps 20 or 25 tons of fish which land in the hold undamaged and alive. As soon as pumping is finished, the purse boats go to the stern of the seiner and are hooked on for towing to the next set.

Individual sets of fish may run as high as 200 tons but anything in the neighbourhood of 100 tons is considered exceptionally good. When his vessel is loaded, the captain picks up his purse boats in the davits and heads home to the reduction plant where he is unloaded very quickly by suction pumps on the dock.

Some mention of quantity is also indicated: a first class vessel operating in the northern fishery will catch 10,000 tons of fish in a 5 months' fishing season; in the Gulf of Mexico the average catch is probably half this amount of fish for a slightly longer season.

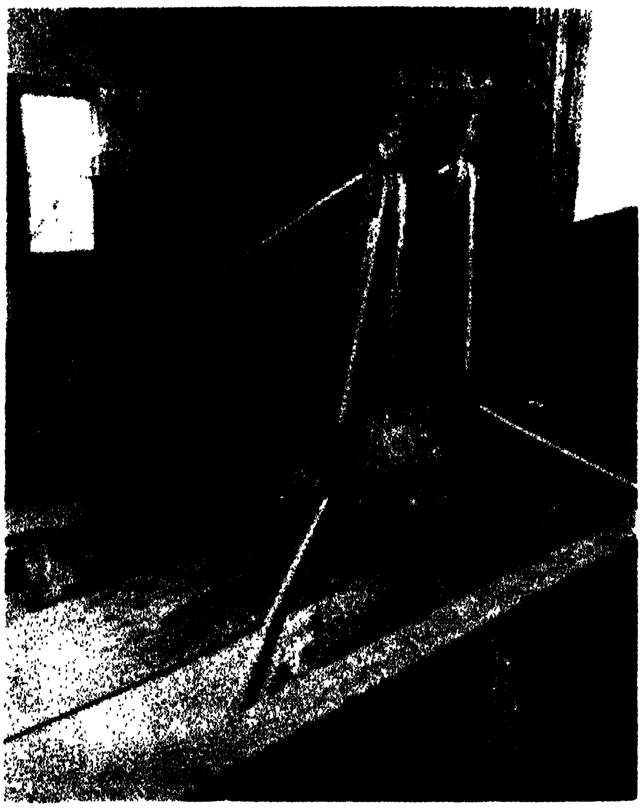


Fig. 3. The 600 to 700 lb. tom weight *insures that the net stays on the bottom during pursing.*

PURSE BOATS

The menhaden purse boat was, many years ago, built of wood, usually thin cedar planking over oak frames. Caulking and other maintenance expenses were high so the industry switched to steel welded construction with built-in air flotation tanks. Despite expensive galvanising these steel purse boats were still costly to maintain and there has been a trend recently toward using wooden boats again, this time covered with a three-ply layer of "fibreglass" armour.

Built as a double-ender boat, the propellers are well protected by metal baskets. Since the net is set from the after quarter of the boat, the engines are located forward and a roomy cockpit is left aft for piling the net. With a 100 h.p. gasoline engine, the boat is relatively speedy when running light but the drag of the net during setting cuts speed sharply and it takes 1 min. to set a 1,200 ft. seine around a school of fish.

SEINE NET

The outstanding characteristic of the menhaden purse seine is its *hanging*. Unlike Pacific coast seines, which are hung to capture vertically striking fish, the menhaden seine is hung to capture a horizontally striking fish. This, simply stated, means that when the fish rush toward the sun (as they usually do) there will be ample loose webbing to contain their rush without sinking the cork line.

Since there are major differences in hanging a net, depending upon area, type of fish, and many personal prejudices by individual captains, no attempt will be made here to detail the procedure. However, a first-class Virginia captain reported his hanging technique as follows:

> "With respect to my seine, a tarred cotton net with wings of 20/9 twine, 2-½ in. stretched mesh, 13,000 meshes long by 800 meshes deep, I start at the centre of the net and hang toward each end. I commence by hanging 72 meshes to each fathom of line; I hang this amount of webbing per fathom for 5 fm., then drop to 71 meshes/fm. for the next 5 fm. I continue dropping one mesh per fathom each 5 fm. until I reach the end of the net. I hang the foot- and headlines alike. To rig the purse ring bights, I start at the centre of the net and work toward the ends, tying one ring-bight per 5 fm.; after the 5th ring I space them 4-½ fm. apart until the 11th ring. From the 11th ring out to the end of the net I space them 4 fm. apart. Length of the ring bights is approximately 2 ft."

Floats of foam plastic are used today. Between 1,600 and 2,000 4in. × 2in. plastic floats are required for one

Fig. 4. Team work is required to dry up the fish prior to pumping. Note the purse line coiled on spool, right foreground. To the left of the purse line spool is the double barrel winch used for pursing.

seine. Smooth brass purse rings each weigh about 2 lb. and have a 2 in. centre opening.

Formerly, cotton nets were used exclusively and the crew had the extra work of *brining* the net each day after fishing, using strong salt solution, to slow down rotting of the tarred seine. A typical cotton seine, for example, would be 16,000 meshes long by 1,000 meshes deep, ¾ in. bar (1½ in. stretched mesh) made of 20/9 hawser twine, scotch knot. The centre of the net would be heavier twine to accommodate the strain and extra wear of brailing the fish.

Net size varies by locality and while a Gulf of Mexico

Fig. 5. Pumping the catch aboard the seiner. The captain, left foreground, signals the engineer that the hose is lowered sufficiently. The 10 in. I.D. rubber suction hose is specially reinforced with stainless steel internal wires. Fish discharge from chute, right, and excess water passes overboard through another chute.

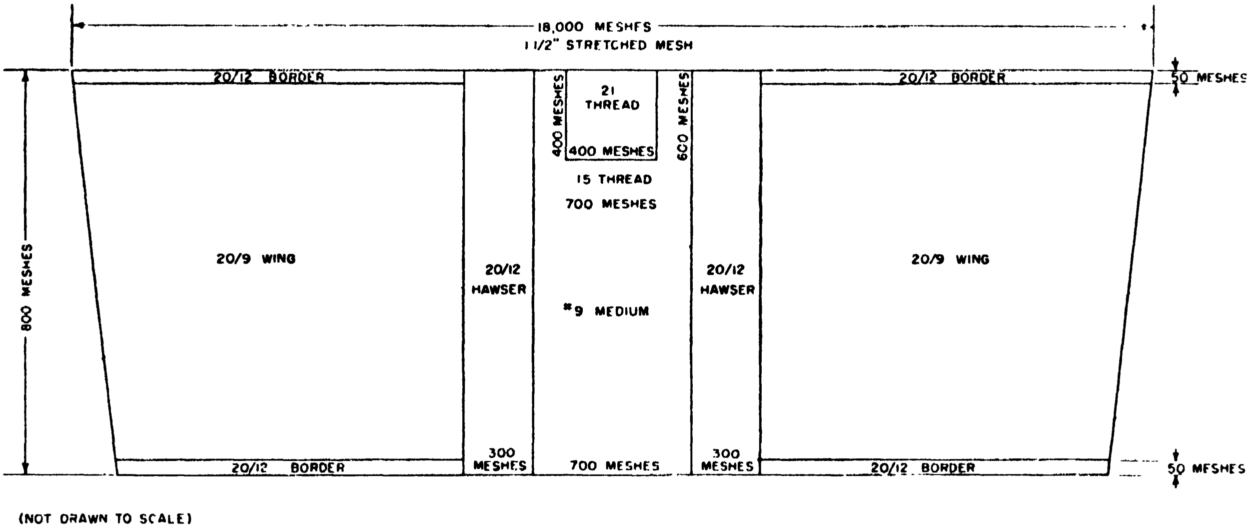


Fig. 6. Typical Gulf of Mexico menhaden purse seine.

fisherman would probably use a ¾ in. bar seine, a New Jersey or New England fisherman would prefer to use 1⅛ in. bar or possibly 1¼ in. bar webbing. The size of the webbing naturally depends on the smallest fish likely to be captured, for if a large mesh seine is set around a school of small fish, the fish will gill in the webbing and cause the crew much extra work in their removal. Likewise the depth of water has much to do with the depth of the seine and every individual captain has his own preferences in this regard. Length again depends upon local conditions but a length of 22,000 meshes of ¾ in. bar webbing might be considered the practical maximum.

With the advent of synthetic webbing, the industry is trending toward the complete abandonment of cotton. At present, the Japanese synthetic nettings seem the most popular, along with United States nylon nets. Additional interest is being shown in *knotless* webbing and several *knotless* nets are under test. In Florida, trials with inexpensive tarred spun nylon webbing from Scotland seems to be working out well and, as yet, no knot slippage problem has been encountered. Unless an extremely efficient cotton net preservative can be offered the industry quickly, it seems a foregone conclusion that it will shortly abandon cotton webbing completely.

FISH PUMPS

Fish pumps have been almost generally adopted by the industry over the past five years. Built around a 10 in. diameter centrifugal pump, they bear a strong resemblance to sewage pumps. Pump speed reaches a maximum of 550 to 600 r.p.m., when powered by a 90 h.p. gasoline engine, and will deliver 1 ton of fish/min. to the fish hold.

Fish are sucked up through a 10 in. heavy duty rubber suction hose roughly 36 ft. long, pass through an inclined de-watering screen (whence excess water returns overboard) and fall into the fish hold undamaged and alive.

A subsidiary advantage of the system is that menhaden have a tendency to lay in the bottom of the seine and resist efforts to raise them. The long rubber hose lowered into the bottom of the net helps reduce the labour required to dry them up.

RADIO-TELEPHONE EQUIPMENT

In the past, conventional radio-telephone equipment operating on the 2,000-3,000 kilocycle band was used but over-crowding of the airwaves from other vessels plus the advent of the spotter airplane has, in the past five years, caused a shift to FM (frequency modulated)

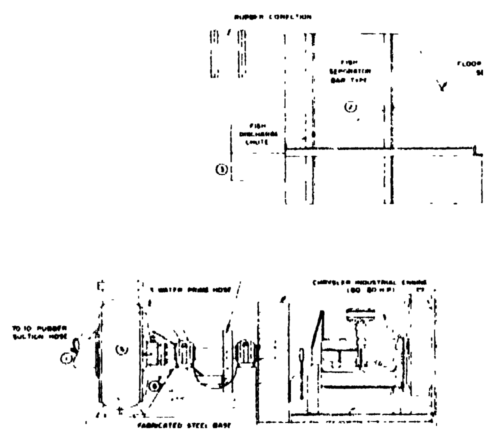


Fig. 7. Schematic diagram of a fish pump installation.

private-channel equipment. Most fleets of menhaden vessels are now linked together and to the reduction plant and spotter planes by such FM equipment. In addition, the captains carry portable FM transmitters into the purse boats with them.

Operating on the 154 megacycle band, or near it, this VHF system provides privacy, freedom from static, and crystal clear reception over line of sight distances. For spotter airplanes it is almost mandatory.

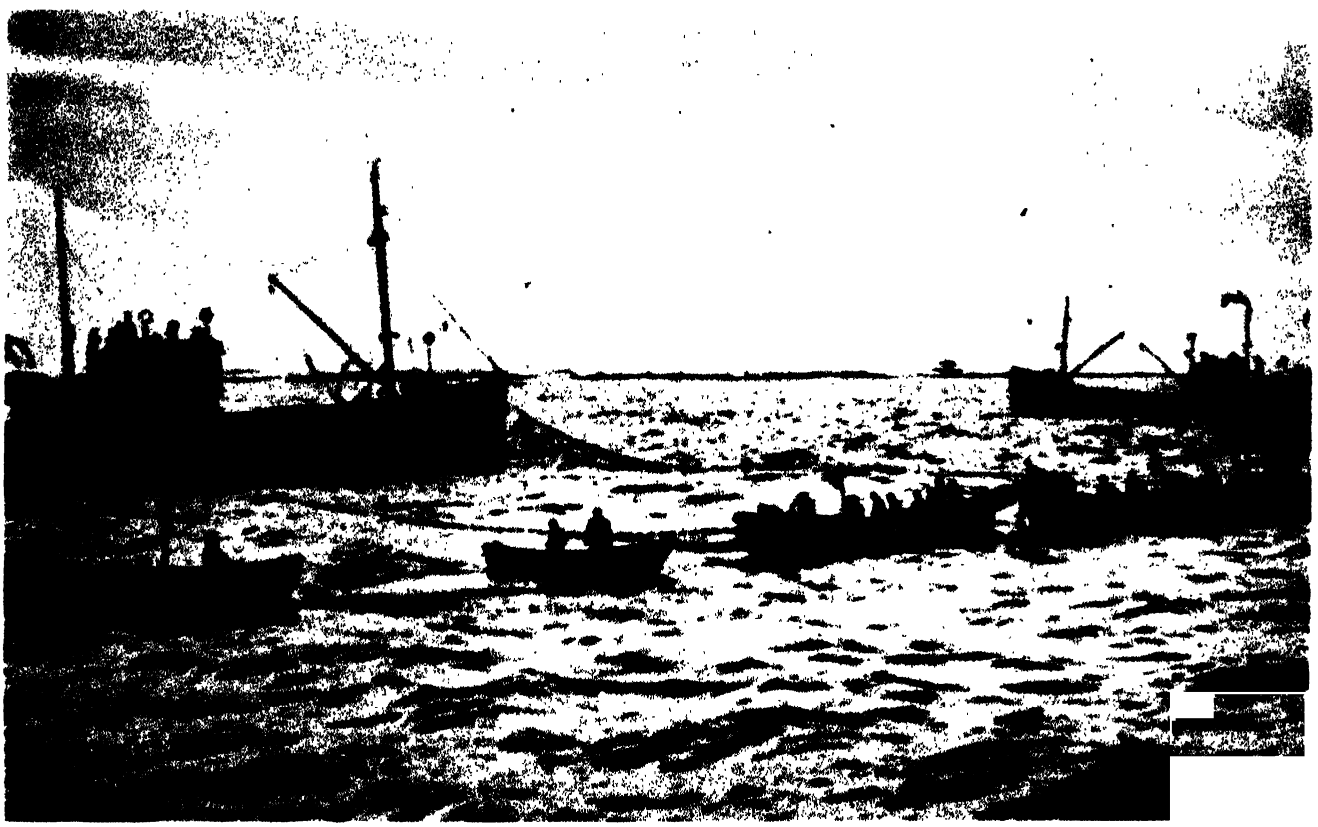
AIRCRAFT SPOTTING

The importance of aircraft spotting to the menhaden industry can be shown by the following example: Ten years ago captains stubbornly dismissed the spotter pilot as an unskilled nuisance who led them on wild goose chases. Today it is considered most efficient to have one airplane serving each five vessels on the fishing grounds.

Capable of long range reconnaissance flights along the shore, the typical spotter plane is a single engine, high wing monoplane, similar to the Piper *Super Cruiser* or the Cessna 180. A plane on floats may be used over swampy areas which are devoid of good landing sites.

A skilled spotter pilot will not only accurately locate the fish for his vessels but also estimate the quantity of fish in the schools, frequently to quite narrow limits. He is in constant radio contact with his vessels during the daylight hours and also renders other valuable services: supply of spare parts and gear, removal of injured men to hospital, etc.

In the fall and early winter, the spotter is invaluable. At this time of year the fish have a tendency to run "sunk" under the surface where the captains cannot see them. But flying up to perhaps as much as 6,000 ft. instead of the usual 800 ft. the spotter pilots locate these hidden schools. Communicating to the purse boats via the portable FM transmitters carried by the captains, the spotter pilots guide the purse boats to the fish, tell them when to separate so as to set the net and when to come together so as to trap the fish. Many startling and successful catches have been made this way and it is now considered a standard, every-day procedure.



Portuguese purse seine net.

THE PURETIC POWER BLOCK AND ITS EFFECT ON MODERN PURSE SEINING

by

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Abstract

This paper describes the latest development in the power-handling of large nets of the purse seine type. The self-powered sheave can accommodate the passage of the entire net and the angle of the sides of the sheave has been so designed as to allow the float line and the leadline to pull evenly and thus avoid tugging the net out of square during hauling. There are two methods of driving the block—the rope drive and the hydraulic drive—and these together with the details of installation in many kinds of fishing craft are discussed fully. The effect of the power block on present fishing methods, net size and design, and its influence on the type and design of fishing vessels is also mentioned.

La poulie mécanique Puretic

Résumé

L'auteur décrit l'appareil le plus récent mis au point pour la manoeuvre mécanique des grands filets du type de la senne tournante. Le réa mécanique permet le passage du filet tout entier, et l'angle donné aux bords du réa été calculé de façon à permettre une traction égale de la ligne de flottes et de la ligne de plombs, et d'éviter ainsi de tirer le filet en biais pendant le relevage. Il existe deux systèmes d'entrainement de la poulie: hydraulique et par courroie de corde, dont l'auteur fait une étude approfondie en donnant également les détails d'installation à bord d'un grand nombre de types de bateaux de pêche. Il indique l'effet de la poulie mécanique sur les méthodes de pêche actuelles, sur la dimension et la forme des filets, ainsi que sur le type et la conception des bateaux de pêche.

La polea motriz "Puretic"

Extracto

En este trabajo se describe el último invento en materia de manipulación mecánica de grandes redes de cerco de jareta, que consiste en una polea o motón motriz el cual permite el paso del arte por su caja. Los ángulos de las paredes de la garganta de la roldana de este motón se calcularon de manera que tiren-las relingas de plomos y corchos en forma pareja evitando, de este modo, esfuerzos diagonales sobre las mallas al izar la red a bordo. Existen dos métodos para accionar la roldana—mediante una transmisión de cuerda e hidráulicamente—que se analizan en forma muy completa con los detalles de la instalación en diversos tipos de embarcaciones pesqueras. También se menciona el efecto de la polea motriz sobre los métodos de pesca usados en la actualidad, tamaño y modelo de las redes e influencia sobre el tipo y proyecto de. embarcaciones pesqueras.

NEARLY all fishing operations have been improved with mechanization except the handling of large nets which are hauled from the sea by brute strength.

The search for new methods of hauling such nets has led, during the last thirty years, to the development of the power roller on the smaller purse seine vessels, and the strapping method on the larger vessels. The power roller helps bring the net aboard, but falls far short of being a mechanical system. The strapping method takes advantage of the mast rigging and the long, sturdy boom, whereby the net is brought aboard in bights by the use of winch and single fall from the end of the boom. This method also falls far short of providing a satisfactory means of hauling the net out of the water because it is slow and tedious. The next major development was made in 1951, when Nicholas Kelly of Nanaimo, British Columbia, introduced a drum with level winding mechanism for handling an entire purse seine. Between 1951 and 1957, some fifty purse seiners in the Pacific Northwest have been equipped with some type of drum for handling purse seine nets and the drum has also met with some success in handling certain types of salmon purse seines. It is, however, too complicated, and not nearly adaptable enough, to be the ultimate solution for handling large fish nets.

A mechanical method was needed that would lift a large net out of the water and deposit it on the deck. The net should be hauled much faster than by present means, use less manpower, and cause no damage to the net. The mechanism should be relatively inexpensive, simply constructed, easily installed, allow fishing in rough weather, and be adaptable to all types of fishing vessels and as many types of nets as possible.

THE CONCEPTION OF THE POWER BLOCK

In 1953 Mario Puretic,* an experienced tuna and sardine fisherman of San Pedro, California, U.S.A., conceived

* U.S. Patents 2,733,530 and 2,733,531, Canadian Patent 522,263 have been granted on the Puretic Power Block and method of hauling nets; and patents have been granted or are pending in all principal maritime countries of the world. Marine Construction and Design Co., 2300 Commodore Way, Seattle 99, Washington, is the exclusive licensee under Puretic's world-wide patents.

the basic idea of passing the entire purse seine net through an elevated free-swinging, self-powered V-sheave, so constructed that gravity would wedge the net into the sheave, giving it the necessary traction to pull the net out of the water. In 1954 Puretic built the first power block, which was tested on December 22 of that year on the tuna seiner, "Anthony M"—the largest vessel purse seining on the Pacific Coast at that time.

In April of 1955 the first power block was introduced in the Pacific Northwest area of the United States and in British Columbia, Canada, and its success has been phenomenal. In the 2½ fishing seasons since the power block was introduced, approximately 1,000 purse seine vessels, primarily on the Pacific Coast from Alaska to South America, have been equipped with this device. At present, the power block is being used in small but increasing numbers on the East Coast of the United States.

Introduction of the power block has started in many other countries, including Iceland, Norway, Portugal, South Africa, Morocco, Pakistan, Korea and Mexico.

ADVANTAGES OF THE POWER BLOCK METHOD

As soon as fishermen began using this new method, many additional advantages became apparent.

Fishing in rough weather is possible with the power block because of the greater force exerted on the net and the stabilizing influence of the net on the vessel.

Net wear has been reduced in many of the types of fishing.

The power block is of particular help to the fisherman in loading and unloading the net from the vessel and in handling the net while stacking and making repairs, and has resulted in a large increase in manpower efficiency.

The power block increases the efficiency of the fishing operation, particularly when sets are made in which there are little or no fish. In this case, the net can be retrieved in, say, 10 min. for a 300 fm. seine, allowing the vessel to make repeated sets on the school that it missed.

The power block makes it possible to save nets in times of emergency, such as when the net and catch are attacked by sharks, when the net is snagged or when, during strong tides and winds, it is necessary to get the net aboard in a hurry.

DESCRIPTION AND APPLICATION OF THE POWER BLOCK

Principle and Construction

The power block (fig. 1) is a large self-powered, free-swinging V-sheave, supported by a rigid frame at an elevated position on the fishing vessel, such as from the end of a boom, crane, etc.

The basic components of the power block are the sheave, the frame, the chutes—which are the smooth guiding surfaces extending above the frame—the supporting yoke or eye, and the power source. The sheave is so designed that it can accommodate the passage of the entire fish net, and so shaped that the net will be wedged, due to its weight, which provides the necessary traction for pulling. Most of the sheaves which have been used to date are covered with vulcanized rubber and vulcanized rubber cleats, which increase the traction, but experiments are being made with aluminium surfaces and aluminium cleats on the sheave. The angle of the sides of the sheave has been determined by experimenting with various types and sizes of nets to give maximum grip and to allow the net to come in evenly—that is, to allow the cork line and lead line to pull evenly so that the net does not come unnecessarily out of square during the hauling. The root at the bottom of the sheave varies from approximately ½ to 4 in. depending on the type of net and its bulk.

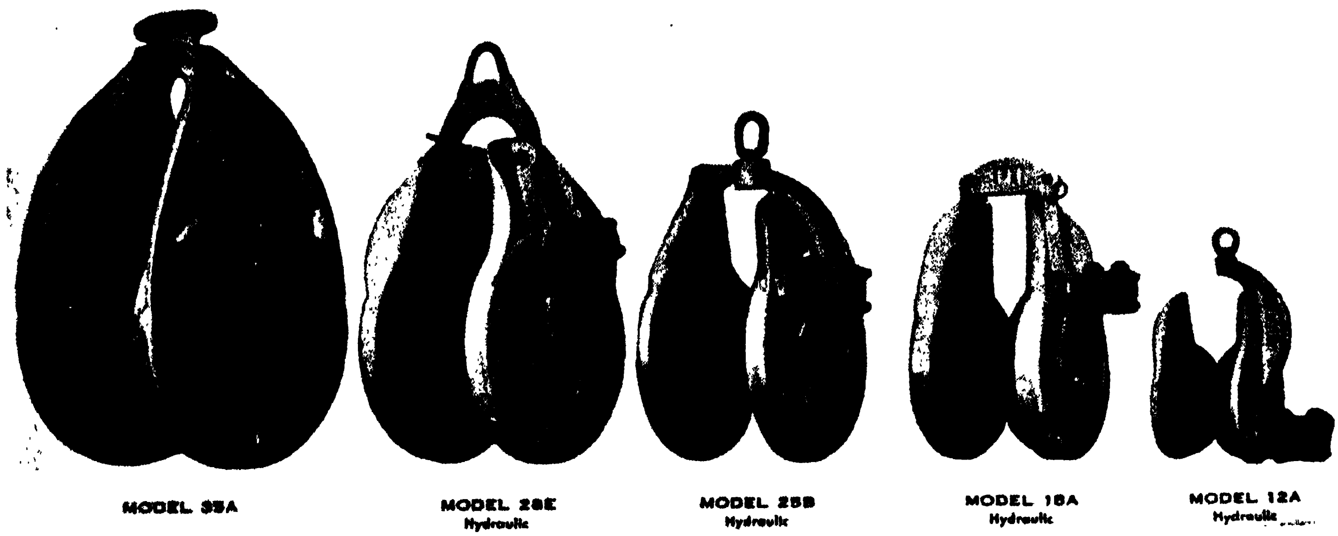

Fig. 1. Puretic power blocks.

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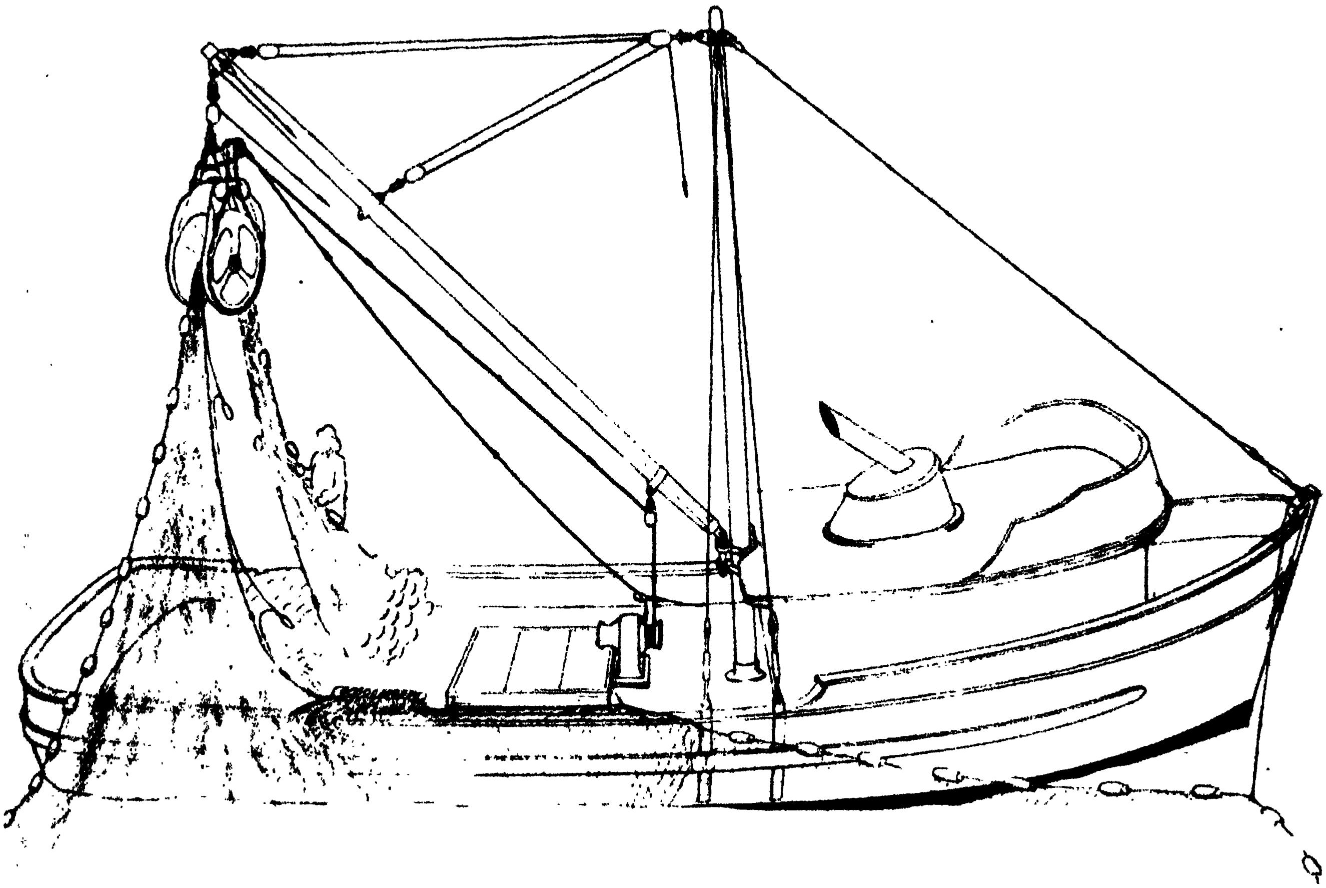


Fig. 2. Western style purse seiner, illustrating installation of rope drive.

The power block is constructed primarily of cast aluminium, using a zinc aluminium alloy which has high tensile strength and is extremely resistant to salt water corrosion. Aluminium answers the problem of providing a strong, lightweight, rigid structure. The shafts and all pins are made of stainless steel, and aluminium is used for the gearbox housing and all other small fittings.

Drive

The power block can be driven in two different ways. The first, devised by Puretic to aid in the initial introduction of the power block, is the rope drive (fig. 2).

It consists of an endless rope or cable, running through small fairlead pulleys to a V-sheave which is on the side of the main net sheave. The fairlead pulleys are so arranged that they lead to the driving sheave, regardless of how the power block swivels. The endless rope or cable is then led to a gypsy head of the purse winch. Several turns are taken around the gypsy head and a small tightener pulley is employed on the slack side. The rope drive made it possible for nearly 300 boats to adopt the power block within two months of its introduction on the Pacific coast. As each purse seine vessel had a purse winch, it only required hoisting the block to the end of the boom and splicing a suitable drive rope, to convert the purse seiner from hand hauling to the Puretic method.

Mechanical drives of all types have been considered for the power block, including air, electric and hydraulic. Of these, the hydraulic drives provides the ideal solution. The power requirements on the various models of the power block are from 2 to 20 h.p., depending on the size of the boat and size of net. The speed requirement varies from about 20 to 30 r.p.m. The high pressure hydraulic drive is ideal for meeting these requirements. It provides the necessary high starting torque together with:

- Low initial cost per h.p.
- Small size and weight
- Low maintenance cost
- Flexibility of control
- Simplicity of installation and maintenance
- Dependability

A typical hydraulic installation diagram for a Model 35 power block is shown in fig. 3.

High pressure hydraulic systems have been selected rather than the lower pressure type commonly used in Europe, to obtain maximum torque with the smallest possible size and least weight. The hydraulic equipment selected is manufactured by Vickers, Inc. 1400 Oakman Boulevard, Detroit, Michigan, U.S.A., and is of the vane

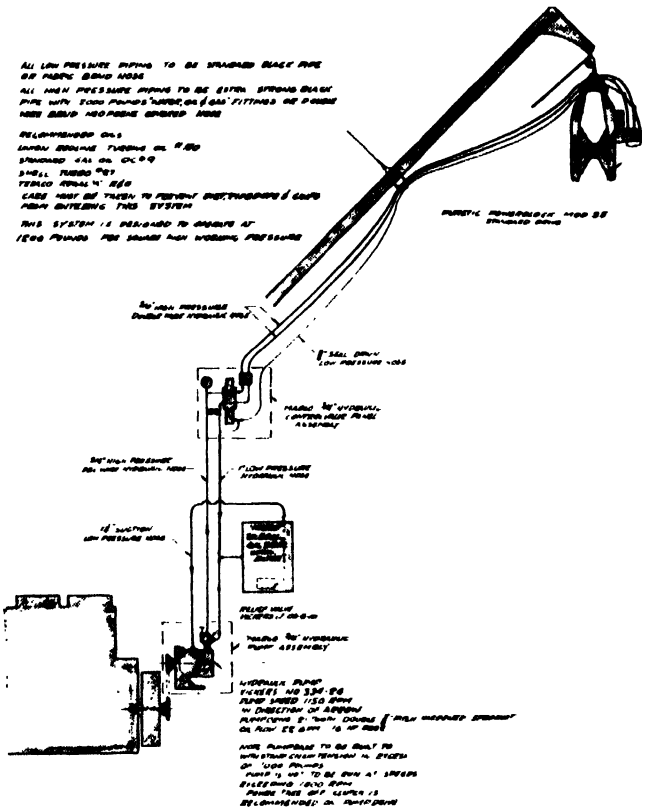


Fig. 3. Typical hydraulic drive installation diagram.

type. Its normal operating pressure is 1,000 lb./sq. in. (68 atm.); however, a relief valve setting of 1,200 lb./sq. in. (81·6 atm.) is used in most cases. In a few cases, this equipment is being operated up to maximum pressures of 1,500 lb./sq. in. (102 atm.).

Installation

A high pressure, vane type hydraulic pump is installed and driven in one of the following ways:

1. Through a power take-off from the main engine. In this case, a pump size is selected to produce the required volume of oil while the engine is operating at its normal idling speed, but which can run up to full engine speed without being damaged. Normally, however, when the engine is running at full operating speed, the clutch would be disengaged.
2. By an auxiliary engine in the engine room.
3. On boats with large capacity of 110 or 220 V. A.C. or D.C., an electro-hydraulic power unit may be installed.

The hydraulic pump takes the oil from an expansion tank through a suitable filtration system (fig. 3). The hydraulic fluid then passes to a control panel which, on most of the Pacific Coast-type vessels, is located on the after side of the main deckhouse. The control panel consists of a reversing control valve and a by-pass or needle valve for regulating power block speed. A relief valve is generally built into the system at this location, and a pressure gauge installed convenient to the operator. The control valve is operated in such a manner that in the first position the power block rotates in one direction; in the middle position the power block is locked hydraulically; and in the third position the power block rotates in the opposite direction. From the control panel the hydraulic fluid goes to the power block and returns through hydraulic hoses to the expansion tank. For this purpose, wire braid, neoprene-covered hydraulic hose is used, which is good for working pressures of approximately 2,000 lb./sq. in. (136 atm.). Single wire braid is used, for hose up to ½ in. diameter, and double wire braid for hose from ½ to 1 in. diameter.

In most cases to date, the power block has been supported from the end of the boom on the fishing vessel. Some fishermen support the block from a single fall at the end of the boom so that it can be raised and lowered as necessary for inspection, maintenance and, in some cases, to allow the block to be opened to insert or remove the net. In this case, the hydraulic hoses are run from the control panel to the power block in one or two large bights, generally supported in the middle by a line carried to a small block on the mast, or in the rigging. In other cases the power block is shackled to the end of the boom, and the hydraulic hoses are strapped or lashed to the boom. In some installations, black iron pipe is used in piping up the hydraulic circuit from the engine room to the control panel and along the boom, with hydraulic hose being used only where flexibility is desired. In general the most satisfactory installations have been made using hydraulic hose throughout.

PRESENT MODELS OF POWER BLOCK

The model number of the power block designates the size of the sheave in inches. The letter following indicates the type of or modification of the given model. Each one of the five power blocks shown (fig. 1) was originally designed for a specific fish net and area of fishing. The range of blocks, however, has been found to cover most new applications to date. In general, all power blocks are designed on the snatch block principle, which allows the top to be opened for removal of the net, if this should be necessary.

The first power block to receive wide acceptance was the Model 28, which was originally designed to handle the 300 fm. long salmon purse seines used on boats from 40 to 80 ft. in length on the Pacific Northwest coast. Originally, most of these boats were equipped with the rope drive model (fig. 2) but more than half have converted to hydraulic drive. There are approximately 500 seine boats using the 28 in. power block which is the most universal of all models, as it has been successfully applied to the smaller herring nets used in the Pacific Northwest, California sardine nets, Peruvian bonito and anchovy seines, and the smaller Southern California tuna seines. This model would also be adequate in size to handle the Icelandic and Norwegian herring seines, Portuguese sardine seines, South African lampara seines, and East Coast menhaden seines. The 28 in. power block has also been built with two types of hydraulic drive which are capable of exerting line pulls up to 1½ tons. Its weight is 210 to 260 lb., depending on drive arrangement.

The next model developed was the 35 in. power block,

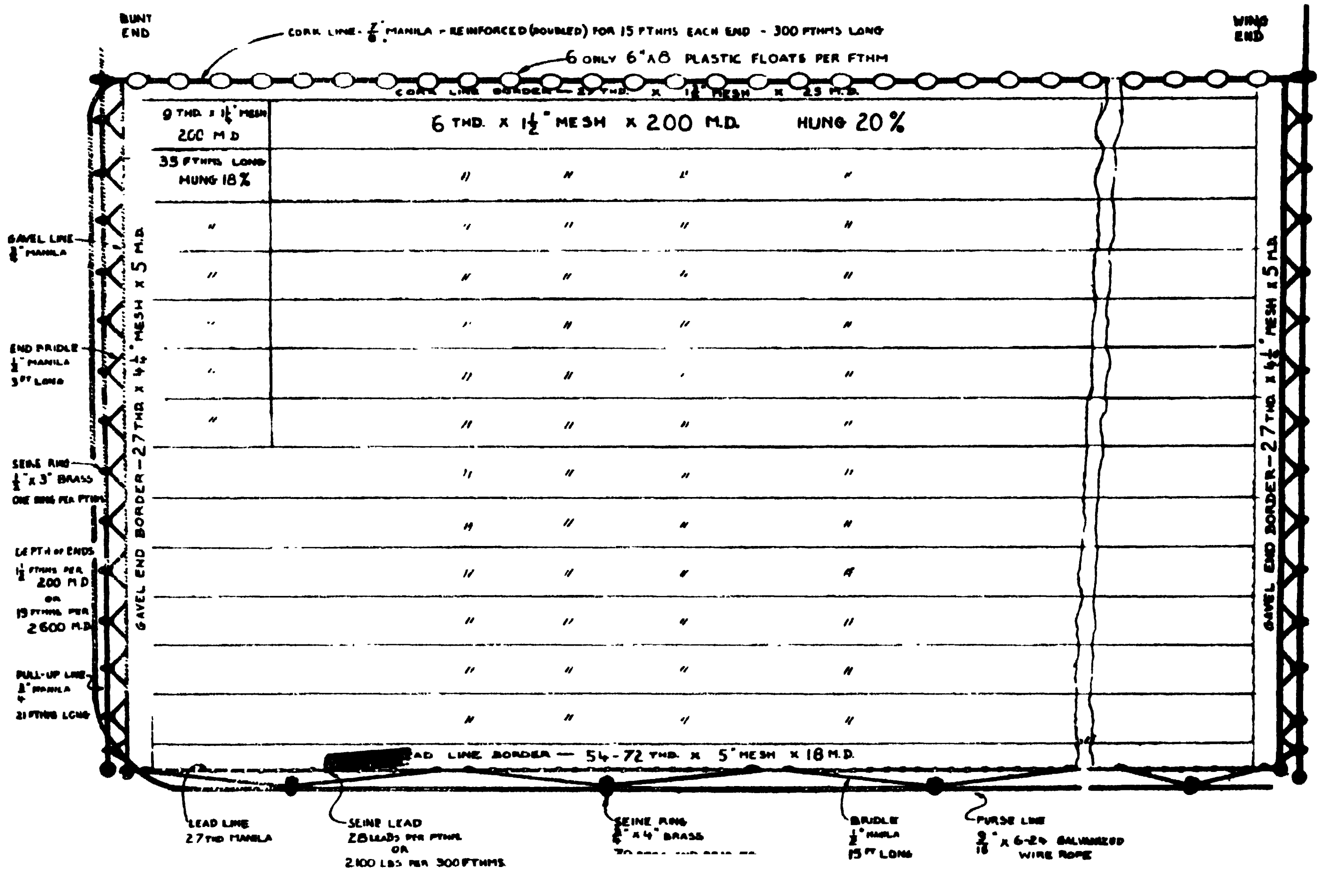


Fig. 4. West Coast Canadian herring seine.

for use on the large Canadian and Alaskan herring seines, and large Southern California seines. This model has ample power and capacity to handle efficiently the largest purse seines known to the author. Currently, the model is being used in Alaska and British Columbia, Canada, on herring seines similar to that shown in fig. 4.

It is also being used in Southern California boats purse seining for tuna, and in Iceland on a Canadian style herring seine. This model weighs approximately 425 lb. including the hydraulic drive, but is not available for rope drive.

The next model developed was the 18 in. power block weighing from 95 to 125 lb. designed to handle small nylon and dacron salmon purse seines used on boats of 30 to 40 ft. length in the shallow fishing areas of Alaska, principally around Kodiak Island. Over 200 of this model are in use, both with rope and hydraulic drive, and a few are being used for handling gillnets.

The Model 25 power block weighing 250 lb. including the hydraulic drive was designed to meet the requirements of the menhaden fishery on the East Coast of the United States. This power block is unique in that it is entirely supported from one side, with the other side hinged (fig. 1). This feature was necessary, because, in menhaden fishing, a considerable amount of cork line is pulled while the net is being pursed. By hinging the side open and lowering the block, the cork line only can be inserted into the sheave to aid in this operation. After the net is pursed, the entire net is inserted, the side closed, and the power block elevated while pulling the remainder of the webbing.

The 12 in. power block was developed for pulling very small nets, such as small gillnets and lead nets used in connection with the larger salmon purse seines and certain types of fish traps (fig. 9).

SELECTION OF PROPER SIZE AND TYPE

It has been found advantageous in selecting the type and size of power block to have the information shown in fig. 5.

The factors that influence the size of the power block are the depth of the net, which may be indicated both in fathoms and by total number of meshes, the size of twine and size of mesh. In general, there is adequate reserve capacity at the top of the power block between the chutes to handle any necessary size of cork line, even including inflatable floats such as the montara float, used in California, and the inflatable floats used in some of the larger herring seines in Canada and Alaska. Likewise, there is ample space at the top of the power block to pass the cork line should it become bunched up, and a nominal quantity of gilled fish.

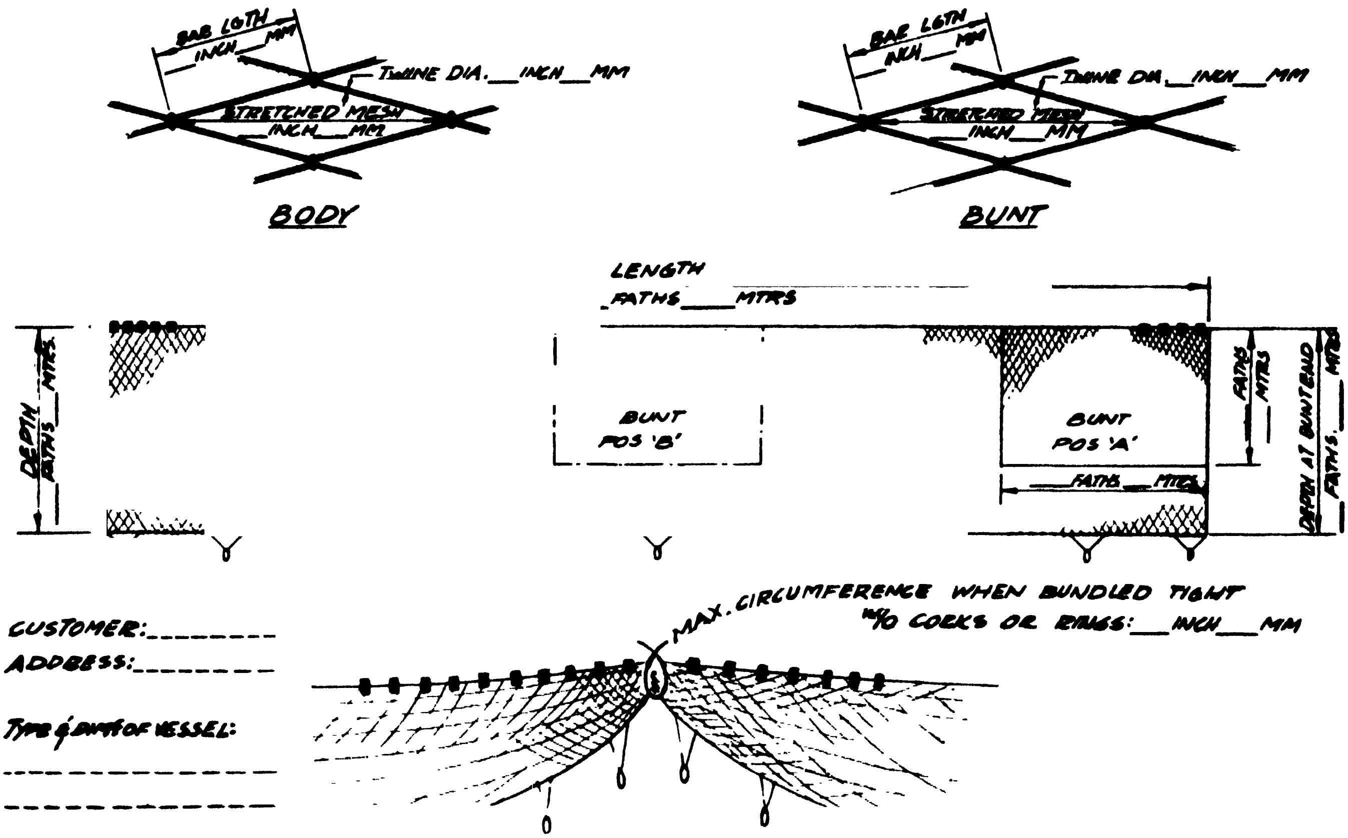


Fig. 5. How to measure nets for the Puretic power block.

The Model 35 power block is adequate to pass gilled tuna and occasional sharks. The best indication of the size of the net as regards selection of the power block is the circumference measurement of the net when gathered together and measured by a tape. This measurement is taken in between corks with the tape clinching the net firmly, but not tightly, at the deepest part and also through the bunt. It is best that the webbing, when in the power block, does not fill the block much higher than the sheave. This allows reserve space on top for the corks, miscellaneous gilled fish, and the extra, heavier webbing which may be in the bunt. Typical power block capacities for different types of nets are indicated in the table below and include ample reserve for leadline, purse line, corks and floats. Capacity is increased by 10 to 30 per cent. when nylon nets are used. Particular attention is directed to the column showing maximum circumference of compacted webbing.

TABLE I

Capacities of the different power block models for different types of net

Power Block Model	*Max. Circum. of Compressed webbing, inches*	*Tuna Webbing 4½ in. stretched; 42 thread*	*Salmon Webbing 4½ in. stretched; 15 thread*	*Menhaden or Herring webbing 1½ in. stretched 9 thread*
35	48	900 meshes max.; 300 meshes min.	1500 meshes max.; 450 meshes min.	3000 meshes max.; 800 meshes min.
28	38		750 meshes max.; 200 meshes min.	1600 meshes max.; 400 meshes min.
25	34			1200 meshes max.; 600 meshes min.
18	23		300 meshes max.; 50 meshes min.	800 meshes max.; 100 meshes min.
12	13		150 meshes max.; 50 meshes min.	

BASIC SYSTEMS OF HAULING WITH THE POWER BLOCK

The first system can be called the Western, or American style, in which large purse seines are hung with the bunt in the end of the net. Normally, in this system, the vessel has the machinery and deck house forward, with the net stacked on a turntable at the stern of the vessel. All boats of this type are equipped with substantial rigging and booms, which provide an adequate support for the power block (fig. 6).

To convert to the Puretic system, these vessels require only the addition of the power block. The nets, which are 250 to 400 fm. in length, are shot from the stern of the vessel, generally with a power skiff at the end of the net.

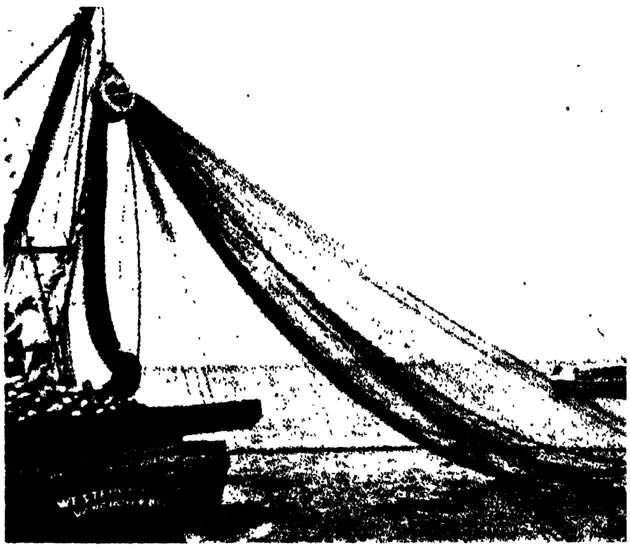


Fig. 6. Power block in operation, showing Western method of hauling purse seines. Top: Alaska type salmon purse seiner; bottom: Canadian herring seiner.

After completing the set, the seine vessel picks up the end of the net from the skiff. Purse lines are led to the purse winch, which is generally located just aft of the deck-house. When pursing is complete, the rings are hoisted on deck, using a winch and a sling from the boom. The purse line is then split in the middle by opening a connector or a figure eight link which is pulled out of the rings. The wing of the net is then started through the power block, either by lowering the block or pulling it up with a light line which has been reaved through the power block sheave for this purpose. The entire net is then pulled through the power block, with the rings and leadline coming from the deck of the vessel, as shown in fig. 2, an operation which takes from 8 to 15 min. for nets of 300 fm. in length. The speed of hauling depends on the speed at which a man can stack the cork line. In British Columbia and Canada it is common for 3 men to stack herring nets up to 400 fm. long and 45 fm. deep in approximately 20 min.

The net is hauled until the fish are hardened up sufficiently for brailing. With large catches of tuna, sardines, or herring it may be necessary to "cut the net", i.e. section off the catch and brail the haul in several "cuts". With adequate hydraulic power, it is possible to harden up completely even large sets of around 500 tons. During the hauling operation, it is common for the power skiffs to take a towing bridle on the side of the seine vessel opposite the net, towing the vessel sideways from the net and into the wind. When most of the net is aboard and hardening of the fish commences, the skiff takes a position along the corkline to help support the bunt for brailing.

The second basic system of fishing with the Puretic power block can be called the small seine boat system or purse boat system - see figs. 7 and 8.

This system employs two small open boats of approximately 32 ft. in length. It is used on the East Coast of the United States for catching menhaden, where there are approximately 300 pairs of such boats operating, but the largest use of this system is in the Norwegian herring fishery and in Iceland. The power block was originally conceived and devised for use on the larger Western style boats. A successful adaptation of this idea to small purse boats has required a considerable amount of experimentation and instruction to local fishermen to evolve a method and arrangement which would obtain the maximum benefit from the power block.

The lampara seining system would employ the use of two power blocks on one vessel to haul in both ends of a lampara-type seine, which has the purse bag in the middle. This system of fishing is most widely used in the Union of South Africa.

The fourth basic purse seining system is that used by some of the mackerel seiners in New England and some herring seiners in Iceland, where one small net carrying seine boat is towed alongside a larger vessel. The small boat, in most cases, has no power. In this system, the power block would be installed on the larger vessel, which, after the net is pursed, would lift and deposit it in the small boat, where it would be stacked.

There are two other types of purse seine fishing systems. In the first, the vessel carrying the net also carries the fish, and in the second, the net-carrying vessel is used only for hauling and setting the net, while the mother vessel brails or pumps the fish and carries them.

ADAPTATION OF THE POWER BLOCK TO DIFFERENT METHODS OF PURSE SEINING

In each area where the power block has been introduced, the first attempt has been to use the equipment as a substitute for manpower in hauling the nets. In some of the fisheries, the power block has been applied with practically no change in method, net, or basic system. In others, it has been necessary to devise additional equipment, make minor modifications to boat and equipment, and develop modifications to the traditional fishing systems. In a number of fisheries, it has been apparent, that through the use of the power block and its ability to handle larger, longer, and deeper nets rapidly, there would eventually be a change in size and design of net and, very possibly a complete change in the basic system of purse seining.

Described now are the various types of fishing where the power block is currently being used and in many cases adopted as the standard method of fishing.

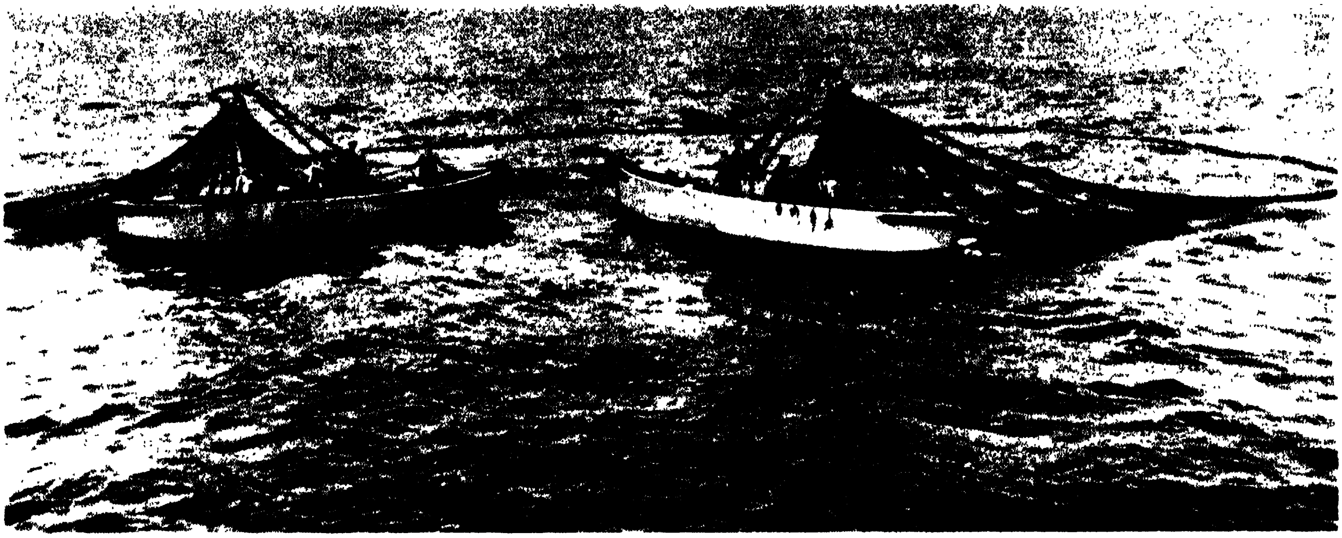
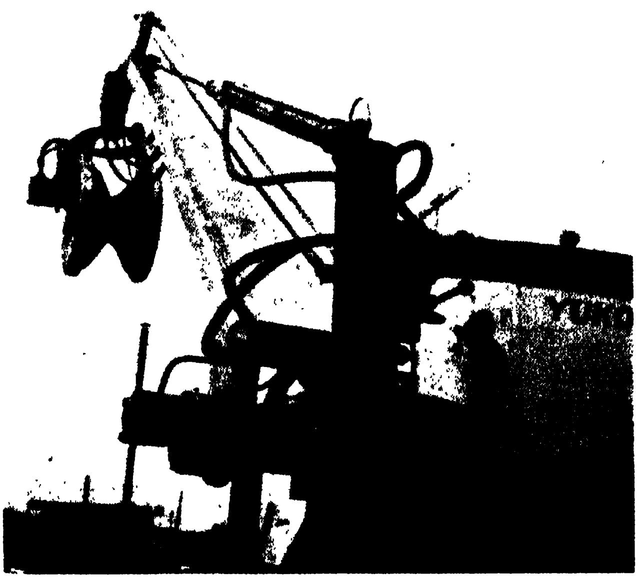


Fig. 7. Menhaden purse seining with the Puretic power block, using new aluminium purse boats.

WEST COAST SALMON FISHING

Salmon is one of the major fisheries in the North Pacific where seine vessels range from 30 ft. in length to about 85 ft. Power blocks of 18 in., 28 in., and 35 in., are used on these vessels depending on the size of the vessel and



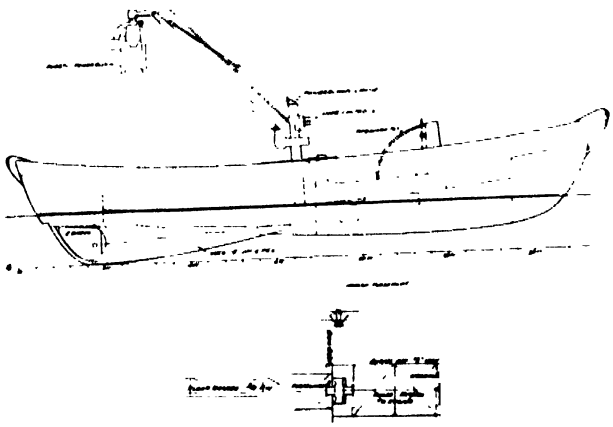


Fig. 8. Improved power block crane and its installation in steel menhaden purse seine boat.

size of net. The 12 in. power block is used in the skiffs which are carried by the salmon seiners for pulling the lead nets to lead the salmon into the larger purse seines. Previously the normal crew consisted of 8 to 9 men, including captain and the man in the skiff. With the application of the power block, most vessels have cut at least 2 men from their crew. Further reduction in the crew are possible with improvement in the pursing and other operations.

After the first season's operation, the International Sockeye Commission, which is the conservation authority for the red salmon resource of the great Frazer River spawning area, reported that the power blocks increase the efficiency of the seiners by more than 15 per cent. However, it appears that in some types of purse seining the increase in productivity may be many times higher.

The only basic change in the salmon vessels to date has been the strengthening of their booms, while new vessels are being built without turntables.

PACIFIC COAST HERRING FISHING

The vessels used in this fishery are of the western style, with deckhouse and machinery forward and large turntable aft, on which the net is stacked. These vessels are very similar to the California sardine and tuna seiners and to the smaller salmon purse seiners. In this fishing, the power block replaced the strapping method and speeded up the operation by as much as 300 or 400 per cent.

The 35 in. power block is used by the herring vessels, with a few of the smaller ones using the 28 in. block. A typical Canadian herring seine is shown in fig. 4. These nets are usually about 300 to 400 fm. long. The depth varies, depending on the time of the year and area fished, and it is not uncommon for the nets to be as deep as 45 fm. The vessels fish with a crew of 8 men, including the captain and the man in the skiff. They can handle sets which frequently run to 500 tons and have occasionally exceeded 1,000 tons. The vessels both carry fish themselves and brail their large sets into carrier vessels operating with the fleet. Everything is operated by power, and nothing depends on the physical strength of the fishermen. The operations sometimes take place in very rough winter weather in open water, while at other times these 80 to 90 ft. vessels fish in small fjord-like inlets similar to the herring fishing areas of Norway.

WEST COAST SARDINE SEINING

The power block is beginning to be used by the West Coast sardine fleet, but as this fishery has been unusually inactive, very few vessels have been fishing it since the advent of the power block. The vessels and the system of fishing are very similar to that used in northern herring, and the power block functions in a similar manner.

TUNA SEINING OFF THE COASTS OF SOUTHERN CALIFORNIA, MEXICO AND SOUTH AMERICA

The nets used in this fishery are probably the largest purse seines in the world, while the vessels measure from 70 to 130 ft. in length. A normal crew is 12 men.

The vessels are similar to the western sardine and herring seiners, but larger. They are equipped with 220 V. A.C. throughout, and the prime source of their hydraulic power is a 220 V. electro-hydraulic power plant. Through their fishing off South America, the vessels have helped introduce the power block to Peru, where it is being installed on a number of bonito and anchovy seiners. The Peruvian boats are installing 28 in. power blocks, while the American boats which fish in Peruvian waters primarily use 35 in. power blocks.

Tuna in these areas are caught both by purse seining and by large tuna clippers. The increase in efficiency of the seine boats due to introduction of the nylon nets handled by the power block, has created interest in converting some of the larger tuna clippers, of 130 to 150 ft. length, to purse seiners, handling the larger tuna net on the stern after the style of the other western seiners. One boat has already been equipped in this manner.

MENHADEN SEINING

The menhaden fishery on the East Coast of the United States, from New England to the Gulf of Mexico is one of the largest reduction fisheries in the world. More than 1,000,000 tons of menhaden are caught each year. The vessels—which are still called steamers—are diesel-propelled. They range from about 90 to 220 ft. in length, and operate up to approximately 100 miles from the reduction factory. Each steamer carries, in davits at the stern, two purse boats of approximately 32 ft. in length by 8 ft. beam. These boats are similar to the Norwegian herring seine boats, except that the gasoline engines are in the bow rather than the stern. Each boat carries half of the seine net, which is approximately 200 fm. long by 1,000 meshes deep, of 1½ in. mesh stretched. Each boat has a crew of about 12 men, a total of 24 fishermen, which is an extremely large crew to handle a relatively small purse seine.

Puretic devised a hydraulically-operated power block crane which is installed in the purse boat (fig. 8).

The two purse boats set around the fish and purse in the usual manner. The author and Puretic introduced the Norwegian type of snap purse rings to solve the problem of having to split the purse line in the middle in each set. While the net is being pursed, the specially constructed menhaden power block, model 25B (fig. 1), is hinged open and the cork line is hauled. As soon as pursing is completed, the entire net is put into the power block, the crane is elevated and swung to convenient position and hauling commences. The crew has been reduced by about 6 by using this system, constituting a saving of 25 per cent. in manpower.

The power block crane is so designed that it can be swung in a 90 degree arc from side to side and raised and lowered by hydraulic power. Puretic provided a pantograph motion on the extended jib so that the power block could be semi-rigidly attacked through rubber mountings and yet would remain level at all heights of the crane. This was an important feature, as it is necessary for the power block to be able to swivel freely; but in small boats of this type, the power block had too violent a motion when hanging loose and unrestricted. Another unique feature of the design is that the oil reservoir is in the column of the crane, with all

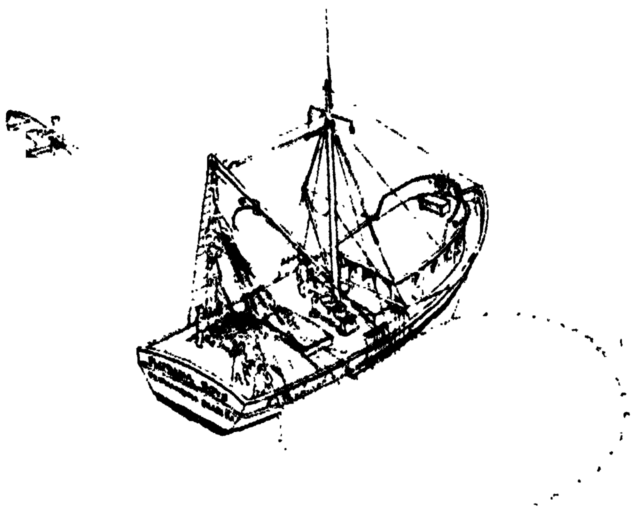


Fig. 9. American shrimp boat rigged for purse seining menhaden.

hydraulic piping and controls mounted in the unit. Installation requires only the mounting of the hydraulic pump on the engine power take-off, running two hydraulic hoses to the crane. The 3 levers on the crane actuate the power block, swing the crane, and raise and lower it as required.

Most of the leaders of the menhaden industry realize that this is only an initial step in increasing the efficiency of their catching operations and considerable work is being done by several of the leading firms in using a modified western technique for catching menhaden. Conversion of an American shrimp trawler for purse seining menhaden is shown in fig. 9.

ANCHOVY SEINING

There is a considerable amount of anchovy purse seining in Peru, done by boats under 50 ft. in length, with rather short, but very deep, nets of approximately 24 fm. of $1\frac{1}{2}$ in. mesh, stretched. Several 28 in. power blocks are being introduced into that fishery.

EUROPEAN HERRING SEINING

The European system of herring seining, as used in Norway and Iceland, is similar to the menhaden seining described above. As yet, no attempt has been made to introduce the power block in this fishery, but it appears that the block can be used in much the same way as in menhaden. Applying the power block to large nets which are handled from very small boats presents a difficult problem, because it is not possible to get the required height and have the necessary stability for ideal operation. A stable fishing platform is desirable for proper use of the power block.

LOFOTEN COD SEINING

In the northern part of Norway in the Lofoten Islands, codfish are caught by using purse seines. The method of fishing this seine is, in many respects, similar to the methods used in handling the West Coast salmon net. Driftnet-type boats handle the nets in the small area aft of the deckhouse. One 28 in. power block has been sent to one of the leading Lofoten fishermen and, in his opinion, it can be successfully applied to handling the cod purse seines.

PORTUGUESE-STYLE SARDINE SEINING

The Portuguese and Angolan purse seiners fish long, deep nets. The system and nets are very similar to those used for sardines on the West Coast of the United States. The only basic difference is that the Portuguese

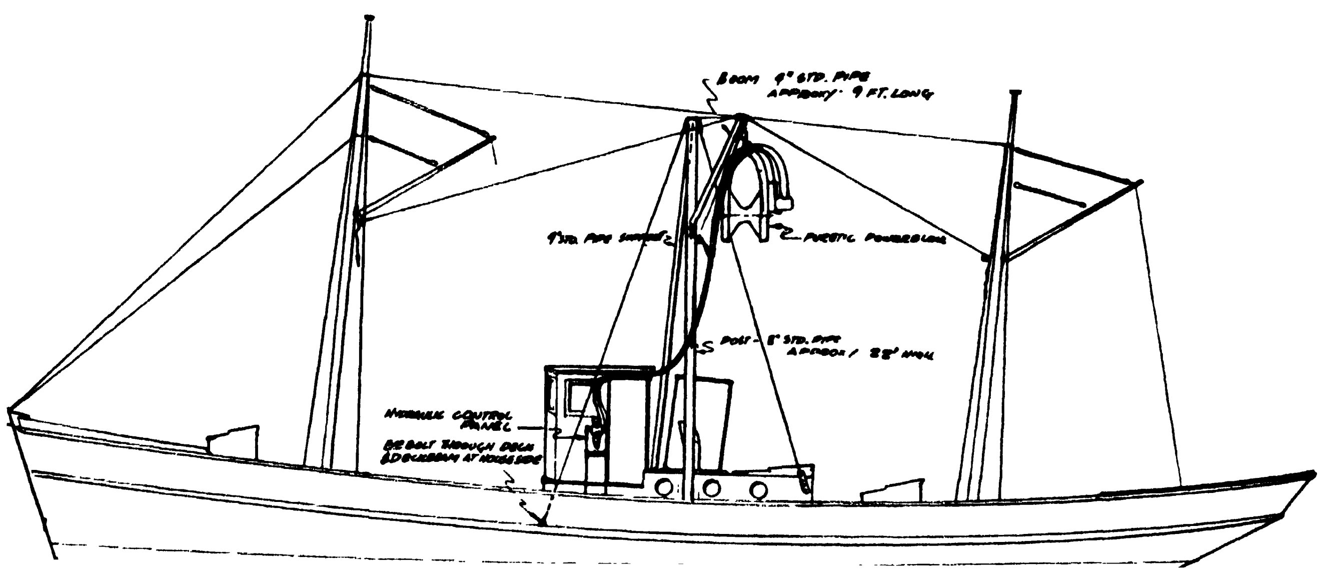


Fig. 10. Portuguese type seiner, equipped with power block for pulling net amidships, similar to present system.

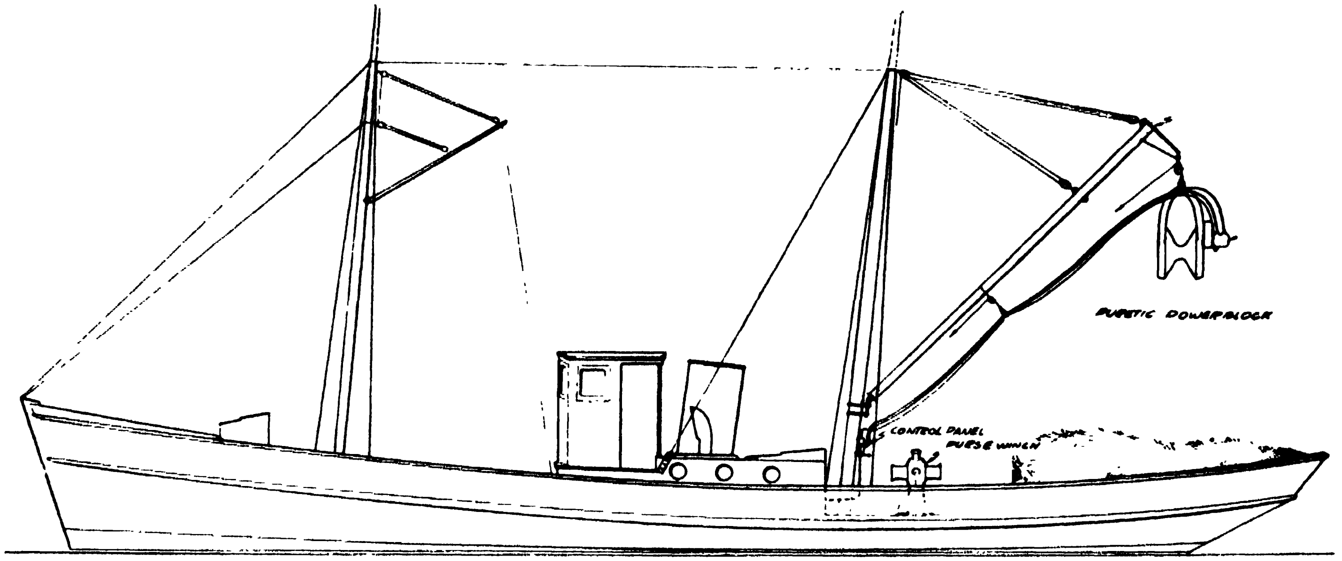


Fig. 11. Portuguese type seiner, showing power block installed for pulling net on stern.

vessels have their machinery and deckhouse amidships, and pull the net over the side. The traditional reason for this seems to be that their system has been developed on the availability of plenty of manpower for pulling the webbing. The American boats of this type previously used the strapping method. A crew of about 30 pull the Portuguese net abroad, while on American and Canadian boats, using large nets and a crew of 8, the net is pulled aboard far more rapidly. Two methods of rigging the power block on Portuguese-type vessels to handle the sardine purse seines are shown in figs. 10 and 11.

No basic changes in procedure or design of the vessel need to be made. It is believed by the author that this would produce a very efficient purse seining operation. The first introduction of the power block has been made in Portugal, and more activity is expected to follow in the near future.

SOUTH WEST AFRICA LAMPARA SEINING FOR PILCHARD AND MAASBANKER

In South West Africa, vessels of 55 to 65 ft. length, of the type shown in figs. 12 and 13, are used operating with small, shallow lampara-type purse seines.

Instead of pulling each wing of the net into separate small boats as is done in Norway, Iceland, and on the East Coast of the United States, the South Africans pull each wing on to the purse seine vessel. The vessels are fine, modern boats which carry a tremendous load for their length.

In December of last year, the author, in co-operation with Wilbur, Ellis Company and Cooper-Wolmarans and

Fig. 12. Typical South African purse seiner, equipped with one power block for experimental operation.

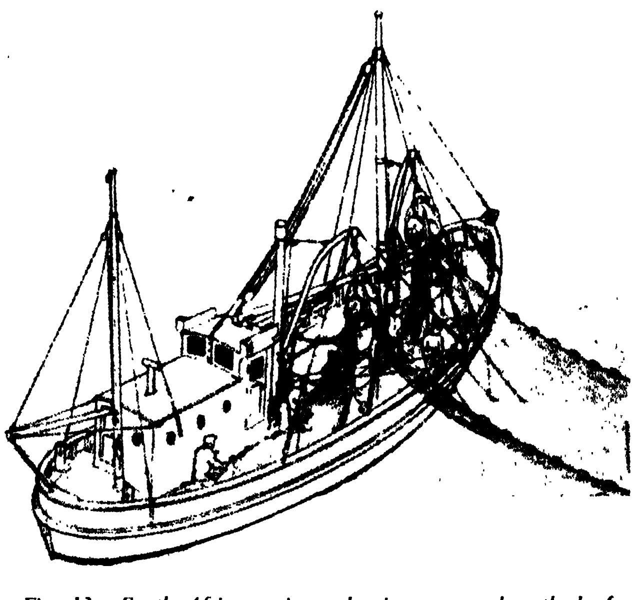


Fig. 13. South African seiner, showing proposed method of hauling lampara seine with two power blocks.

Company, rigged one 35 in. power block on a typical South African boat (fig. 12) to see if both wings of the lampara seine could be pulled through one power block. The results of the experiment showed definitely that this could be done but several small difficulties were encountered which indicated that it would be better to use two smaller blocks rigged as in fig. 13. No operating results have as yet been obtained from this system, but there is no reason why it should not be very satisfactory and rapidly handle the lampara nets.

The efficiency of the South African system depends entirely on speed and crowding the fish. It would be possible to use much larger and deeper nets by introducing the power block to this type of fishing while using the same number of crew or even fewer. By using a fast, mechanical means of handling the net, the need to pull both wings simultaneously is eliminated, which suggests that, with the advent of the power block, a modified Western system can be adapted to this South African fishery.

BEACH SEINING

In many areas of the world, large nets are hauled on to the beach. Generally, these nets have long wings which are simultaneously hauled. An application of the power block may be useful in this type of fishing, the block being supported on a boom or A-frame on the back of a truck or other piece of mobile equipment. The hydraulic pump would be run from the vehicle's engine to provide the power source. The webbing could be dropped on the flat bed of the truck or on the beach.

LEAD NETS

In many types of fishing, including certain types of herring traps, long lead nets are used. These in general, have little bulk, and small skiff or launch, with a power block mounted in davits, would be of great aid in picking up the net. Salmon lead nets, used from the skiff of the salmon purse seiner, are successfully being hauled with the 12 in. power block (fig. 14).

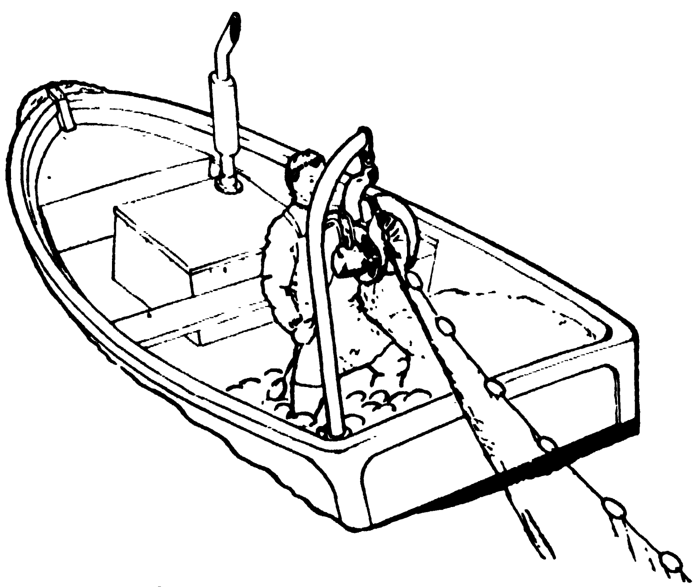


Fig. 14. 18 ft. Salmon skiff, hauling lead net by means of a 12 in. power block. Similar arrangements are reported to work satisfactorily in handling gillnets.

POWER BLOCK PRINCIPLE USED FOR GILLNETS AND DRIFT NETS

Salmon Gillnets

A large percentage of West Coast salmon is caught in gillnets, of 25 to 150 meshes deep, of 5½ in. nylon webbing. In some areas, such as Bristol Bay, all of the fish are caught by gillnets, and the Japanese ocean salmon fishing is done almost entirely with gillnets. At present, American boats are equipped in one of two ways. The first uses a small drum which winds up the entire gillnet, the fish being picked out of the net before it gets to the drum. This is a one-man operation, and is relatively efficient, but is applicable only in those areas where a high concentration of fish is not frequent. The second, found in the Bristol Bay area where 500 to 1,000 gillnetters fish, uses a power roller over which the nets are hauled. Huge concentrations of fish occur in this area, which make the application of a mechanical hauler of any type extremely difficult. The power roller now used is only an aid and is of little assistance when a large quantity of fish is in the net.

The power block is being applied to handling gillnets in a variety of ways but as this is a new field the work on it can still be considered experimental. A number of fishermen have reported success in hauling gillnets—some picking the fish before reaching the block and others letting the fish go through. Puretic has devised a complete salmon gillnet method which seems promising but is still in an experimental stage.

Herring Drift Nets

There are many thousands of boats fishing herring using drift nets in Europe and Iceland. A proposed system for using the power block principle to aid hauling these long nets has been devised by Puretic and the author. Basically, the net would be hauled in the same manner as at present, using the cable around the winch with a modified power block supported by the boom across the vessel from the hauling side. The power block would take the strain on the net, which would be controlled by a foot pedal or knee-actuated lever on the gunwale, operated by a man located in the usual position for shaking out the fish. The net would come across the gunwale, where two men would pull it apart, shaking out a small amount of the catch at a time.

EFFECT OF POWER BLOCK ON PURSE SEINING METHODS

Existing purse seining methods are based on conditions which no longer exist and although improvements were developed as modern appliances became available, the basic operational methods have never been revised. With the advent of a mechanical hauling apparatus which reduces the most time-consuming part of the operation, i.e. the hauling, the entire method of fishing should be re-analysed. As an example, the use of two small seine boats, practised in Norway, Iceland, and on the East Coast of the United States, was developed before boats had engines. It was necessary to carry these small boats to the fishing grounds on larger vessels—originally, sailing vessels, and, later, steamers—and the boats had to be kept small enough so that they could be propelled by oars around the fish. This, then, also controlled the size of the net. Two boats were used because, without power, one boat could not be rowed around the fish fast enough. Half of the net was placed in each boat.

The Western style of purse seining was tried on the East Coast of the United States, and even in Norway, but was not successful because of inexperienced crews and the slow strapping method used. Though efficient as regards manpower, it is not as fast as the two-boat method.

In the opinion of the author and fishing gear experts, such as Icelandic Captain Ingvar Palmason, the purse seining system used by the British Columbia herring seine boats is, in general, the most efficient yet devised, but it cannot be copied outright for use in all areas and must be adapted. In most fisheries where the power block has been introduced, it is already having an effect on the size and style of the net in that fishermen begin to think in terms of longer and deeper nets.

EFFECT OF THE POWER BLOCK ON THE DESIGN OF FISHING VESSELS

There have already been some changes made in purse seine vessels because of application of the power block; turntables are being removed because they are no longer essential and new vessels are being designed with smooth bulwarks. Wood booms are being replaced by steel booms of new design, the most notable development in this line being the Puretic power boom, as shown in fig. 15.

This steel boom is provided with a gooseneck extension on the end to support the power block clear of the boom. It is fitted with a hydraulic topping lift and hydraulically-actuated vangs (guys). Hydraulic cylinders mounted on the side of the boom keep tension on the vangs at all times and allow the boom to be positioned in the most convenient stand. The power slewing, together with the hydraulic topping lift, provide complete flexibility, both for use with the power block and in brailing.

The improved menhaden purse boat shown in fig. 8 was designed by the author's company. In addition to the crane and power block; the boat has other innovations, i.e. the captain's controls are placed forward

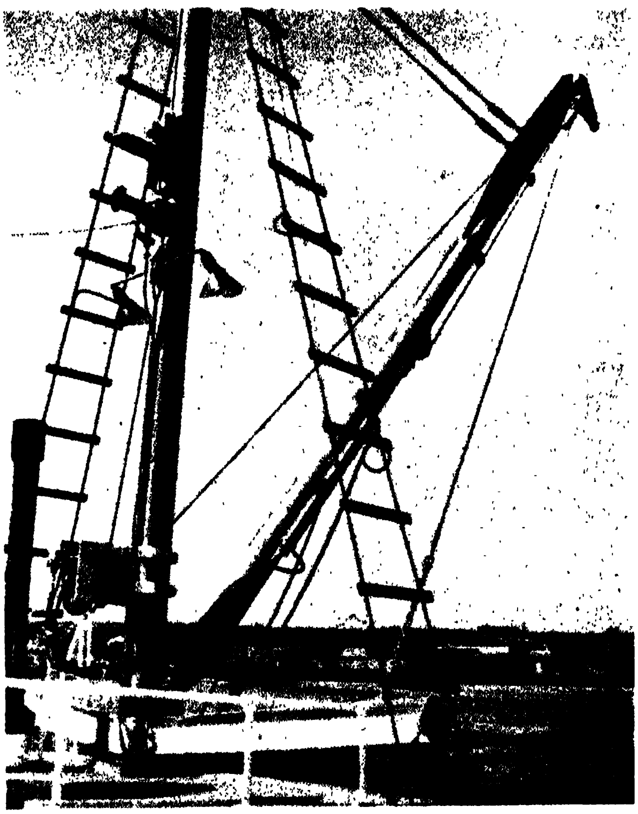


Fig. 15. Hydraulically-operated power boom for use with Power Block. Boom is raised and lowered and slewed hydraulically.

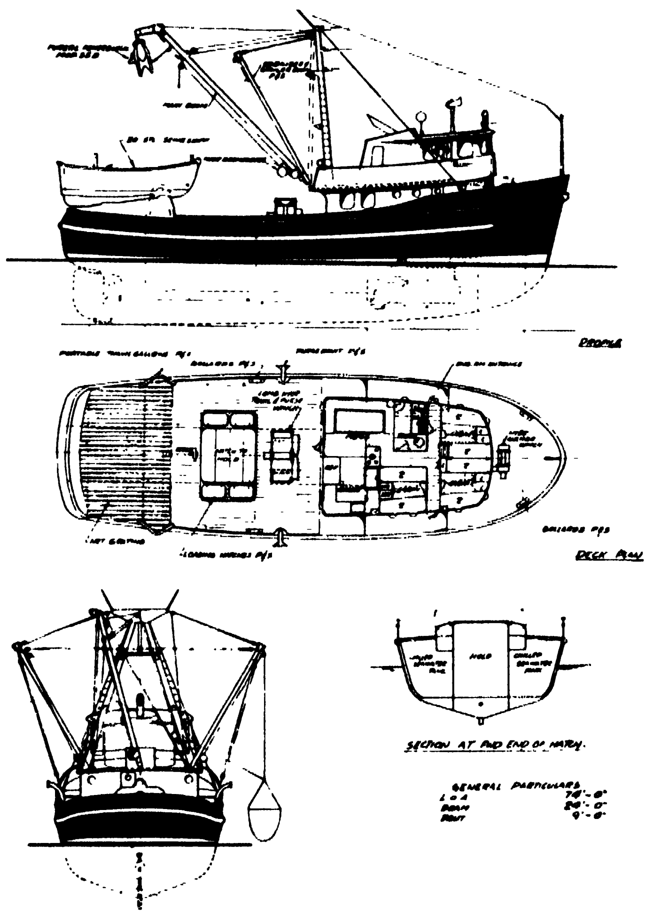


Fig. 16. A steel 74 ft. purse seiner-trawler proposed for the Icelandic fishery. Designed after West Coast-style vessels.

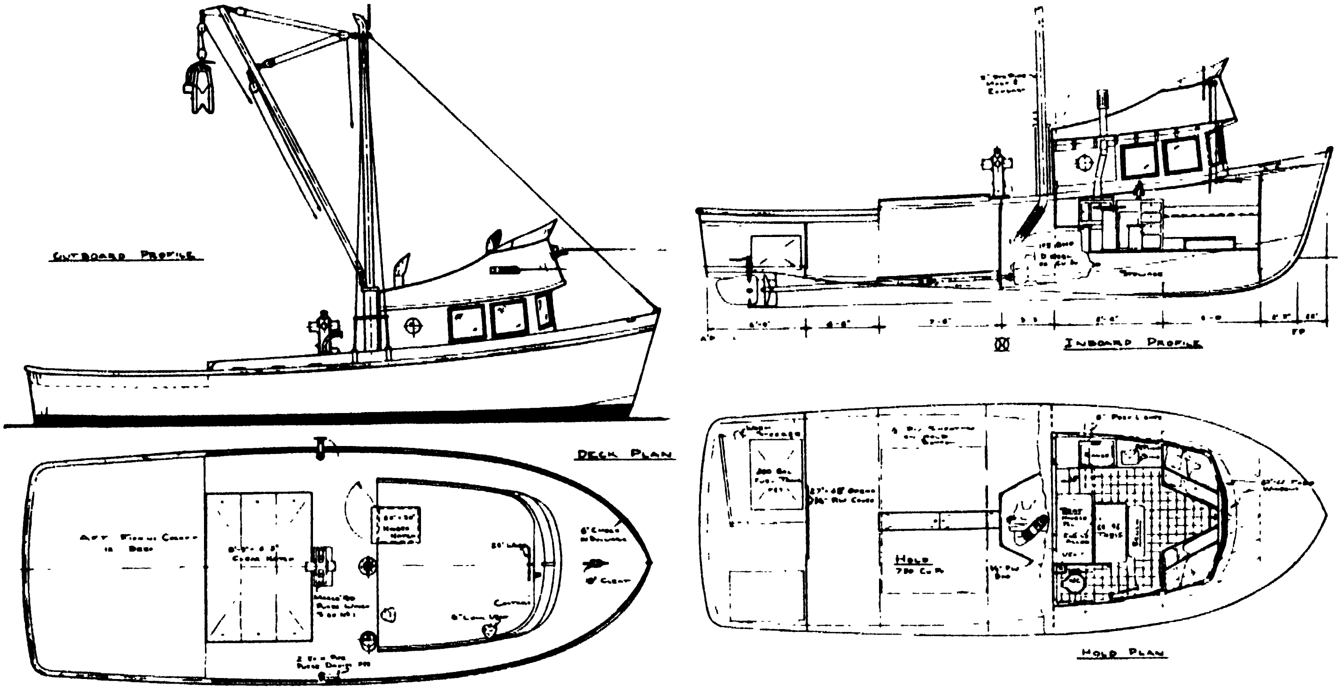
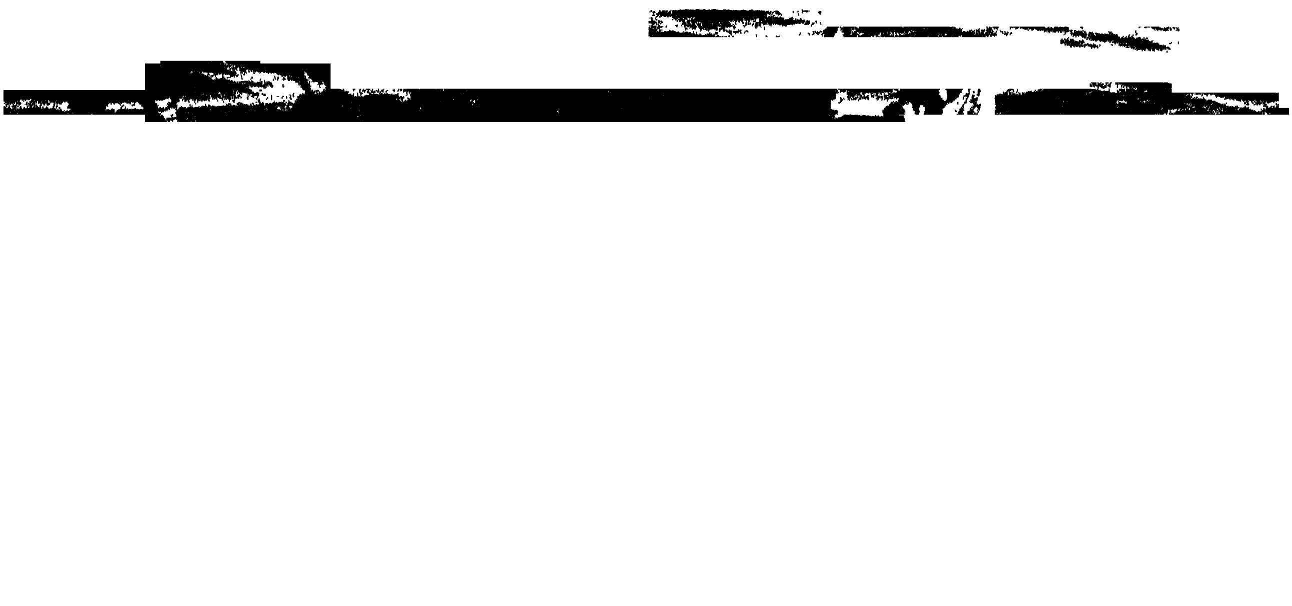


Fig. 17. 39 ft. by 14 ft. steel purse seiner.

where he can steer and handle the throttle without depending on an engineer. This position allows better visibility for setting the net and handling the boat. The double skeg arrangement underneath, with the propeller located in the tunnel, is designed to facilitate the use of the new system of fishing by keeping the net out of the propeller.

Fig. 16 shows a steel vessel designed for trawling and purse seining. It is patterned after West Coast-style vessels, but takes into account the rougher weather conditions experienced around Iceland. Fig. 17 is a modified West Coast-style vessel with a raised fo'c'sle, again designed for combination trawling and purse seining. Both of these vessels would be very efficient purse seiners with their broad, clear decks providing excellent platforms for stern trawling.

Although the new system of handling nets is having an effect on methods of fishing, size and design of fish nets, and the design of fishing vessels, the principle is so adaptable that it can be applied to most existing vessels whether the net be hauled over the stern, amidships, or in the fore part of the vessel.



Conventional hand hauling of a Norwegian herring purse seine. Photo: FAO.

THE USE OF FISHPUMPS IN THE U.S.A.

by

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Abstract

The United States fishing industry has found through 12 years use of hydraulic fish handling systems that loading and unloading boats with pumps is equivalent to increasing the number of fishing vessels at a comparatively insignificant cost, and to extending the fishing operations by at least 13½ per cent. Briefly, ocean-to-boat and boat-to-dock fishpump systems have led to more fresh, salted and preserved fish for the table—more pharmaceutical and vitamin products—more poultry and livestock feed—more oils and fats for food and industrial purposes—all without increase in fishing boats and manpower. The centrifugal type vacuum suction pressure fishpump is now the accepted method of fish handling in the U.S.A. when the requirements are 8 or more tons per day of any type of shoaling fish such as sardine, herring, mackerel, menhaden, red fish, etc. Smaller wharfs can be used by the factories, for the fishpump system itself is small and compact, and space is not required for boats to wait for unloading. The economic advantages of this type of mechanization extend from the owners and operators down to the crews whose work is not only easier and cleaner, but whose income is higher.

La pêche industrielle aux E.-U. avec le système de pompe à poissons

Résumé

L'industrie de la pêche aux E.-U. a trouvé, après 12 ans d'emploi des systèmes hydrauliques de manutention du poisson, que le chargement et le déchargement des bateaux par des pompes, équivaut à augmenter le nombre de bateaux de pêche pour un coût comparativement insignifiant et à augmenter les opérations de pêche d'au moins 13½ pour cent. En bref, les systèmes de pompes à poissons de la mer au bateau et du bateau au quai ont donné plus de poisson frais, salé et conservé pour la table—plus de produits pharmaceutiques et de vitamines—plus d'aliments pour la volaille et le bétail—plus d'huiles et de graisses pour les fins industrielles et alimentaires—tout cela sans augmentation des bateaux de pêche ni de la main-d'oeuvre. Le type de pompe à poissons centrifuge à aspiration sous vide est maintenant la méthode reconnue de manutention du poisson aux E.-U. quand les exigences sont de 8 tonnes ou plus par jour pour n'importe quelle espèce de poissons vivant en bancs comme les sardines, harengs, maquereaux, menhadens, chèvres, etc. Les usines peuvent utiliser de petits quais car les pompes à poissons elles-mêmes sont petites et compactes et il n'y a pas besoin de prévoir d'espace pour les bateaux attendant d'être déchargés. Les avantages économiques de ce type de mécanisation s'étendent des armateurs et conserveurs jusqu' aux équipages dont le travail est non seulement plus facile et plus propre mais dont les revenus sont plus élevés.

Pesca comercial en los E.U.A. con bombas de pescado

Extracto

La industria pesquera de los E.U.A. ha encontrado durante los últimos 12 años que el empleo de bombas hidráulicas en la manipulación de pescado durante la carga y descarga de las embarcaciones equivale a aumentar el número de éstas con un costo insignificante y a ampliar las operaciones pesqueras cerca de un 13½ por ciento. En resumen, los sistemas de bombeo de pescado desde el océano al barco y de éste al muelle han permitido obtener mayor cantidad de: pescado fresco salado y preservado, productos farmacéuticos y vitaminados, alimentos para aves y ganado, aceites y grasas para la alimentación y fines industriales, sin aumentar el número o tonelaje de las embarcaciones pesqueras ni la tripulación. En la actualidad en E.U.A. toda la industria acepta la bomba aspirante de tipo centrífugo como método para manipular diariamente 8 o 100 más toneladas de cualquier tipo de pescado que vive en cardumen, a saber: sardina, arenque, caballa, lacha, cabracho, etc. Las fábricas pueden usar pequeños muelles, en atención a que el sistema de bomba es pequeño, no requiriéndose espacio para los barcos en espera de ser descargados. Las ventajas económicas de este tipo de mecanización alcanzan desde los armadores a la tripulación cuyo trabajo es más fácil y limpio, además de permitirle aumentar sus entradas.

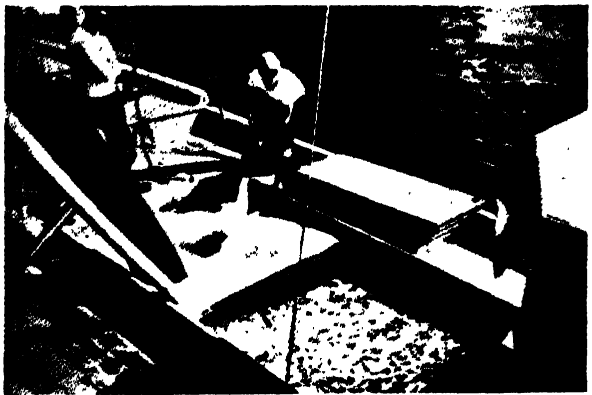
AFTER 12 years' experience of hydraulic fish handling systems the United States fishing industry has found that loading and unloading boats with pumps is equivalent to increasing the number of fishing vessels at little cost, and to extending fishing operations by at least 13½ per cent. Briefly, it means an increased turnover without increase in fishing boats and manpower.

Early attempts to pump fish had presented problems and the systems had several drawbacks; only small fish could be handled; operations were limited to the flood tide timetable to obtain ideal conditions and prevent damage to the fish; the systems were complicated by auxiliary valves and control equipment with attendant high labour and maintenance costs. In 1943 Yeomans designed a pumping system for unloading fishing vessels.

THE BOAT-TO-DOCK SYSTEM

The first fishpump system was installed commercially in 1945 in Portland, Maine, to unload herring or sardines directly from the fishing vessels to storage bins in the cannery. This installation was successful, 800 bushels (about 29 cu. m.) of fish being moved from the boat into the factory in 17 min. by only two men, as compared to the six or more hours and 10 men previously required.

Within 4 seasons, 80 such installations had been made, including some in Norway, Iceland, Newfoundland, and South Africa. As would be expected, the fish unloading system was extended to include shrimp, mackerel, red fish, pogies, menhaden, sild and brisling. Most varieties of pelagic fish up to 36 in. long now are handled easily without damage to the fish, the capacities ranging from



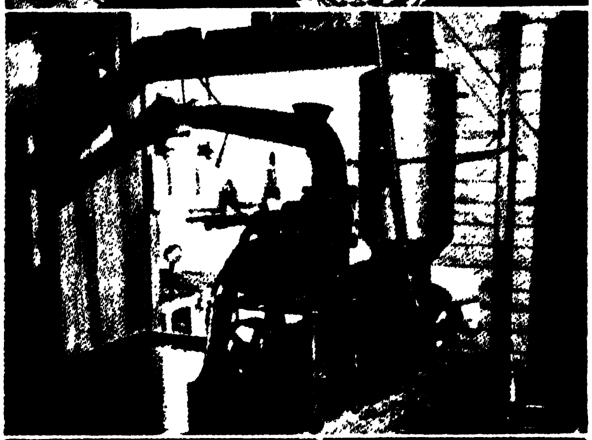


Fig. 1. Boat-to-dock. Water for flotation is introduced and the flexible suction hose lowered into the hold.
Fig. 2. A Yeomans boat-to-dock installation.
Fig. 3. Fishes being discharged on to a dewatering sluiceway.
Fig. 4. Final transport of fishes by a conveyor system into the storage tank.

TABLE I

Boat-to-dock System. Capacity in tons/min **— Dimensions *Head distance from water to pump plus distance from pump to highest point. **1 ton 2,000 lb.

Size of Pumping Unit in inches.	Head in Feet* 20	30	40	50	80	Size of Fish in inches	Approximate Dimensions see fig. 5. Fish Pump A	B	Water Supply Pump
6	2 ton	1 ton	¼ ton			12	6 ft 0 in.	7 ft. 0 in.	C = 52 in.
8	4 ton	2 ton	1 ton			20	6 ft. 0 in	10 ft. 0 in.	
10	5 ton	4 ton	3 ton	1 ton		20	6 ft 6 in.	11 ft. 3 in	D 18 in.
12	12 ton	11 ton	9 ton	6 ton	4 ton	Up to 36	7 ft. 6 in.	12 ft. 6 in.	

2 tons/min. with the smallest system up to 12 tons/min. with the largest system available. Decks as well as holds can be unloaded.

The Yeomans boat-to-dock fishpump system operates on the simple, efficient vacuum suction pressure principle. The basic equipment consists of an automatic vacuum priming system and a horizontal non-clog centrifugal pump with a specially designed and treated impeller. The system is operated by two men—one at the pump on the dock and one in the boat. There are no complicated controls or valves requiring extra attendants. Only one valve is used, this being opened by the pump operator at the beginning of the pumping cycle and closed when the hold and deck have been unloaded. A minimum of water is used as the carrying media for the fish, the amount depending upon the type and the freshness of the fish (the fresher the fish, the less water required).

The operation is simple and can be handled successfully by non-skilled personnel. A flexible hose attached to the suction of the pump is lowered into the fish until its end is covered. Then the discharge valve of the main

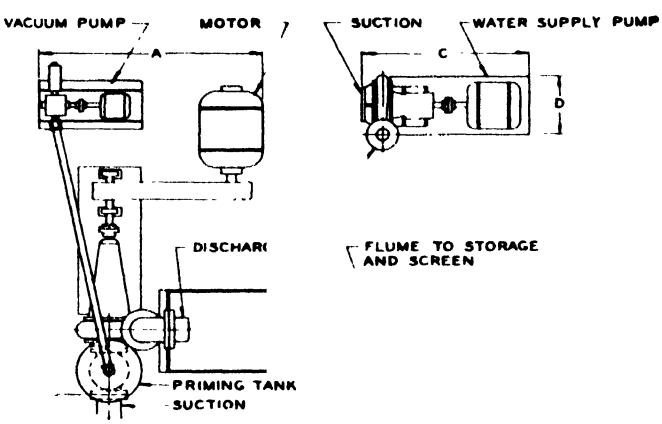


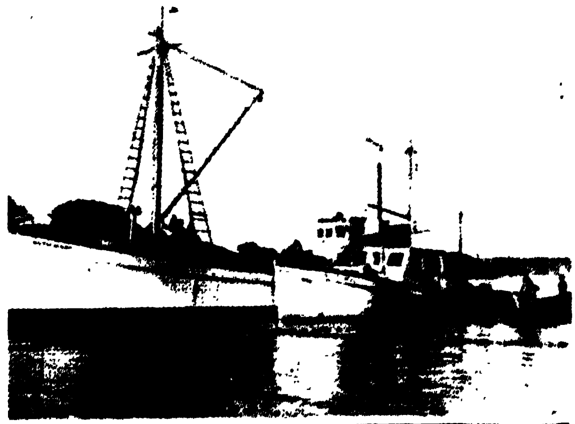
Fig. 5. Typical layout of a boat-to-dock installation. Plan view.

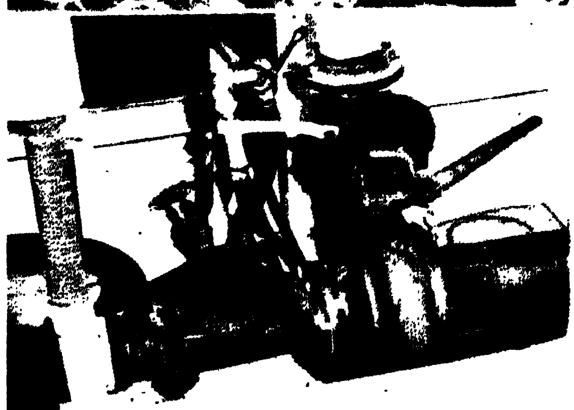
Fig. 6. Ocean-to-boat. Two vessels are brought alongside the seine. The bigger boat is loaded by means of the pump installed on the smaller one.

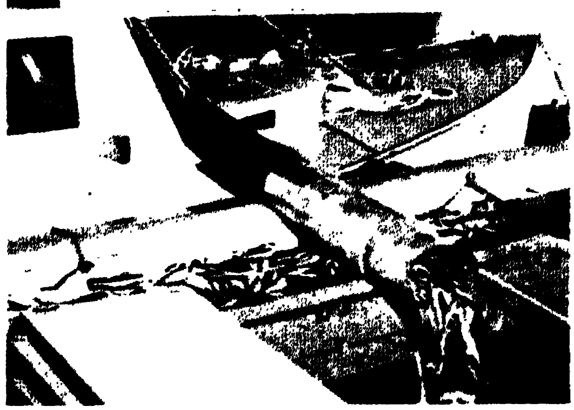
Fig. 7. The flexible suction hose is lowered overside into the net.

Fig. 8. The Yeomans ocean-to-boat pump installation.

Fig. 9. Fish being discharged from the pump hose in to the hold.







pumping unit is closed. Only enough water is introduced at the end of the suction hose to keep it covered, and to prevent air entering it. The operator starts the priming system with a push button control. This sytem is automatic and needs no further attention. When the priming system stops the actual unloading begins. The fishpump is started, the discharge valve is opened manually, and the unloading through the pump is continuous as long as the end of the suction is kept covered with fish and water. The fishpump is under the control of the operator at all times. While no changes are required for handling fish of different sizes, the capacity, or rate of delivery, can be altered within limits by an adjustment of the discharge gate valve. No changes are required for tide conditions as the fishpump is designed to operate within a 25 ft. suction lift range.

Fish are discharged from the pump through piping to a flume or sluiceway, or on to a conveyor, or through piping to the factory or storage bins. The fish either travel over a stationary screen or through a revolving screen, for dewatering and then the dry fish can be measured or weighed by a quartering box or electric weighing device. The water, which has been screened out, can be flumed or pumped back into the hold of the boat for re-use in the pumping operation.

The fishpump is a compact unit, requiring only approximately 6 by 7 ft. for the smallest unit—7½ by 12½ ft. for the largest. It can either be permanently installed and housed at the end of the wharf, or mounted on a truck and brought forth for use as required.

The savings in manpower and manhours vary with the plant. For example, we can state that one plant effected a total saving of $24,900 in the first 100 operating days, including depreciation on the system which had cost approximately $6,000.

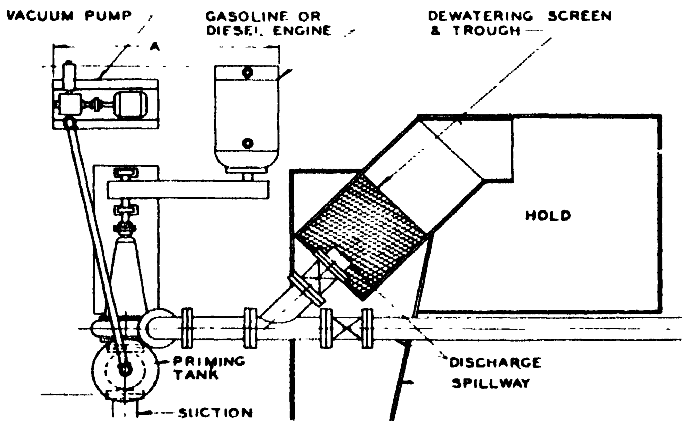


Fig. 10. Typical layout of an ocean-to-boat installation. Plan view.

TABLE II Ocean-to-boat System. Capacity in tons/min.** --Dimensions. *Head—distance from water to pump plus distance from pump to highest point. **1 ton - 2,000 lb.

Size of Pumping Unit in Inches.	*Head in Feet** 10	20	30	*Size of Fish in Inches*	*Approximate Dimensions see Fig. 10* "A"	"B"
6	1 ton	3/4 ton	½ ton	Up to 12	6 ft. 0 in.	7 ft. 0 in.
8	4 ton	2 ton	1 ton	Up to 20	6 ft. 0 in.	10 ft. 0 in.
12	10 ton	8 ton	6 ton	Up to 28	7 ft. 6 in.	15 ft. 0 in.

THE OCEAN-TO-BOAT SYSTEM

The first ocean-to-boat pumping installations were made in 1949. Like the unloading fishpump, the initial installation was successful and the following season nearly a dozen boats belonging to the sardine and herring fleet were equipped with the ocean-to-boat units.

Ocean-to-boat equipment is now considered essential on U.S. fishing vessels when the crew is working on a share basis, and when the season is limited.

In operation, the boat is brought alongside the net, the suction hose is lowered into the seine, the seine is dried up, and the fish are pumped directly across a screen to eliminate water, and into the hold alive. A special device on the end of the suction hose serves the dual purpose of protecting the net and keeping it from being sucked itno the hose, as well as preventing large fish from being drawn into the system.

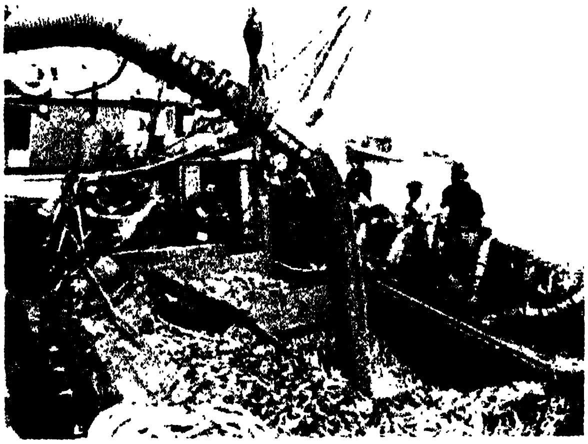
The smallest of the three ocean-to-boat fishpumps available has an average rated capacity of 1 ton/min., handling fish up to 12 in. in length, the largest unit handling an average of 10 tons/min. and fish up to 28 in. long. Power for the pump can be taken either from an auxiliary, or from the main engine of the vessel, if sufficient generator capacity is aboard.

One branch of the fishing industry which has found the ocean-to-boat fishpump useful is the by-products group interested in scale recovery for pearl essence and similar uses. When used in this operation, fish are pumped from the seine through a scaler and then into the hold of the carrier boat. In this manner the intermediate scale boat is eliminated. The fish are delivered alive into the hold after having passed through both the pump and the scaling equipment.

While more than 200 of these two fishpump systems have been installed in various countries, the manufacturer does not produce the fishpump as a "stock" unit. Each is made specifically for the user and the service required. The variables of the requirements include: type and size of fish to be handled; capacity of the boats to be loaded and/or unloaded; power available and current characteristics, in the case of electric power; and, for fish unloading systems, the capacity of the plant, the type of equipment now used for moving fish into and within the plant, vertical distance from the pump to low and high tide marks, vertical distance from wharf to point of discharge, and horizontal distance from the wharf to the point of fish discharge.

The centrifugal type vacuum suction pressure fishpump is now the accepted method of handling in the United States for 8 or more tons a day of any school fish, such as sardine, herring, mackerel, menhaden, red fish, etc.

The economic advantages of this type of mechanization extend from the owners and operators, who save on handling costs while being able to handle more fish, down to the crews, whose work is made easier and cleaner while receiving much higher wages because the faster loading and unloading means that more fishing can be done, yielding a greater total catch in the proceeds of which they share.



South African fishing vessels unload their catch of pilchards/masbanker by means of a pump. On the left are vessels of different design pulling into the jetty while view on the right shows the pumping process in action.

THE DEVELOPMENT OF THE PHILIPPINE BAGNET *(BASNIG)* FOR INCREASED EFFICIENCY

by

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Abstract

The bagnet, or *basnig*, is of local origin. It has reached its present stage of development through gradual evolution from a simple contrivance for sustenance fishing to one which is operated on a commercial scale for the catching of pelagic species, such as anchovies, herrings, sardines and mackerel. The net was formerly rectangular or trapezoidal in shape made of coarse abaca fibre cloth and operated with the aid of a torch, but it later assumed the form of a large inverted box-like mosquito net whose size depends upon the size of the boat from which it is operated. The boa is propelled by motor power and equipped with electric lights supplied by a generator.

This gradual developmentthas been attained through the ingenuity of the fishermen in order to achieve better efficiency, and these changes are fully described and illus trated in this paper.

du filet-sac philippin (basnig) pour en augmenter l'efficacité

Le filet-sac, ou basnig, est d'origine locale. Il est arrivé a sa forme actuelle par une évolution progressive qui, d'un simple dispositif pour la pêche de subsistance, en a fait un engin utilisé à l'échelle commerciale pour la capture d'espèces pélagiques, telles que anchois, harengs, sardines et maquereaux.

Initialement, ce filet, de forme rectangulaire ou trapézoide, était fait d'une toile grossière en chanvre de Manille et utilisé à l'aide d'une torche. Il a pris ultérieurement la forme d'une moustiquaire inversée, comparable á une boîte dont la dimension est fonction de celle du bateau partir duquel on l'utilise. Le bateau, propulsé par un moteur, est muni de lampes électriques alimentées par un générateur.

Cette évolution progressive a été réalisée grâce à l'ingéniosité des pêcheurs qui s'efforcent d'atteindre une meilleure efficacité et ce document donne une description détaillée et illustrée de ces modifications.

Perfeccionamiento del "cielo" (basnig) filipino para aumentar :

Extracto

El "cielo", conocido localmente como *basnig*, ha alcanzado el estado de perfeccionamiento actual por una evolución paulatina de un arte sencillo para la pesca de subsistencia, hasta llegar a una red perfeccionada que, en la actualidad, se usa en la captura de diversas especies pelágicas de importancia comercial, como: anchoa, sardina, arenque, caballa, etc. Originalmente este arte de forma rectangular o trapezoidal, era tejido con gruesas fibras de manila y durante su calamento se empleaba una antorcha. Con el tiempo tomó la foıma de un mosquitero rectangular cuyas dimensiones dependen del tamaño de la embarcación motorizada desde la cual se cala, que cuenta con luces eléctricas alimentadas por un generador.

En el trabajo también se describen e ilustran, con detalle, las modificaciones de este arte y su perfeccionamiento gradual gracias a la ingeniosidad desplegada por los pescadores para aumentar su eficacia.

THE bagnet, a fishing gear widely used in the Philippines and domestically called *basnig*, is of local origin, having evolved from a simple sustenance fishing method. Today, it is commercially operated in most fishing grounds of the Philippines during dark nights to catch sardines, herrings, anchovies, mackerel, and other fishes which frequent sheltered waters. Of the 1,238 commercial fishing boats of more than three tons gross, licensed by the Bureau of Fisheries in 1955, 670 were *basnig* boats, producing 30 per cent. of the total production of fish in that year.

This gear (fig. 1) is a rectangular bagnet, its size varying according to the size of the boat from which it is operated. The netting is made of 6 strand twine of 1 to 2·5 cm. stretched mesh. *Basnig* boats range from 53 to 136 ft. in length, are engine driven, provided with electric generators and temporary booms and masts. The generator supplies the power for 6 to 14 bulbs of 1,000 candle power each. The booms, with the aid of guys, ropes and pulleys, serve to spread the net under the boat.

Some 12 to 24 fishermen operate this type of *basnig*. When the boat reaches the fishing ground at dusk, the lamps are lit to attract the fish, then the net is dropped on the windward side and allowed to hang far underneath the boat. After fish have been attracted, all lights except the two amidships, are doused and the fish concentrate in the lighted area. The net is raised, and the lights are extinguished or covered. The windward side of the net is passed under the boat to the leeward side and hauled in until the fish are concentrated in a small area of the net, ready to be brailed and taken on board.

THE DEVELOPMENT OF THE GEAR

The *balasnig* (of northern Capiz, northern Negros, Bantayan Island and Iloilo) is a forerunner of the *basnig* and is still used by subsistence fishermen. It consists of a rectangular or trapezoidal net made of coarse cloth of

Fig. 1 Construction of the modern basnig *net.*

Fig. 3. The bintol.

abaca (*Musa textilis* Née) or *maguey* (*Agave tantala* Linn) fiber. It is used to collect the fish from the crib of fish traps as set up in the 5 to 10 fm. zone (fig. 2).

The net is made of several strips of *abaca* cloth sewn together to fit the size and shape of the crib. Its edges are strengthened with *manila* rope, about ¼ in. in diam. which is 25 per cent. shorter than the stretched length of the cloth to form a bulge. Each corner and the middle of the sides are provided with slings and ropes for hauling.

The use of light for attracting the fish into the trap increases the efficiency. In the early days, a torch was used for this purpose but in 1924 kerosene lamps with mantles came into use and the fishermen observed that bigger catches were obtained with the brighter lights.

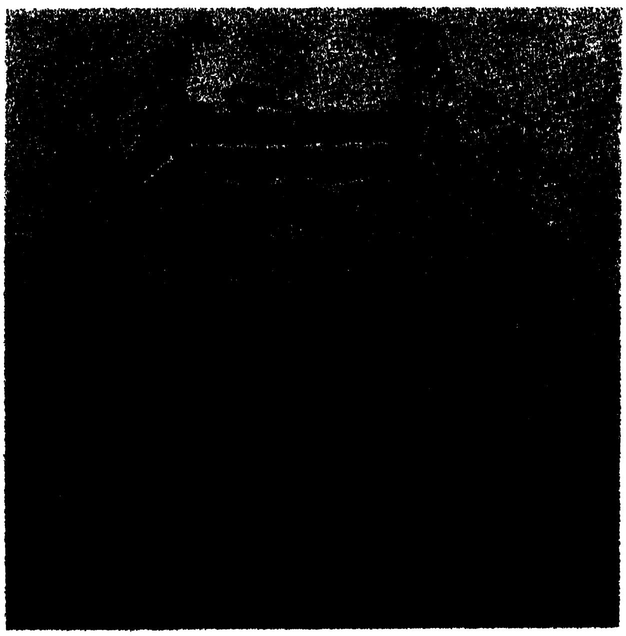


Fig. 2. Operation of the balasnig, *a forerunner of the* basnig.

The *bintol*, which is a further step in the direction of the lift net principle, is used in Bohol province. It came into popular use as early as 1920 because it was cheaper (fig. 3).

The *bintol* net was formerly made of coarse *abaca* cloth, rectangular and hung with a 25 per cent. slack. Later fine handbraided *abaca* webbing, of 2 in. stretched mesh, came into use, hung with 50 per cent. slack, thus assuring greater bulge. A bamboo frame has the same size as the net and is supported close above the water surface by means of vertical posts rammed into the bottom. The lamp for attracting the fish is fixed over the centre of the frame.

Four fishermen, one at each corner of the frame, handle the net by means of ropes attached to the corners.

The so-called *new look*, which first appeared in 1946, is a further development of the *bintol*. The main improvement is the introduction of additional posts to make the gear more resistant to high waves and strong

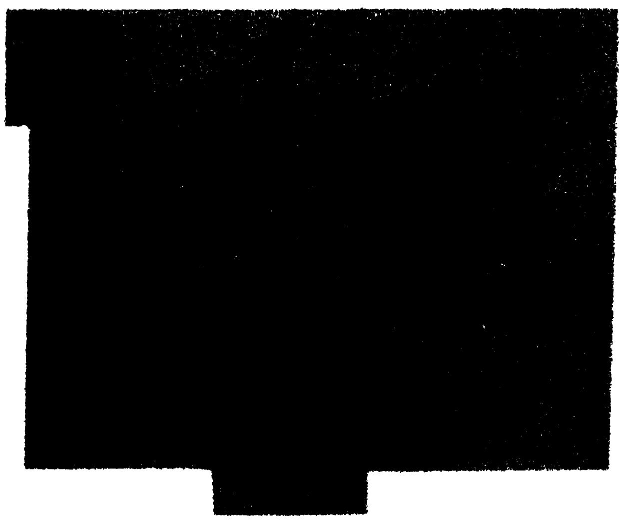


Fig. 4. The new look, *an improved form of the* bintol.

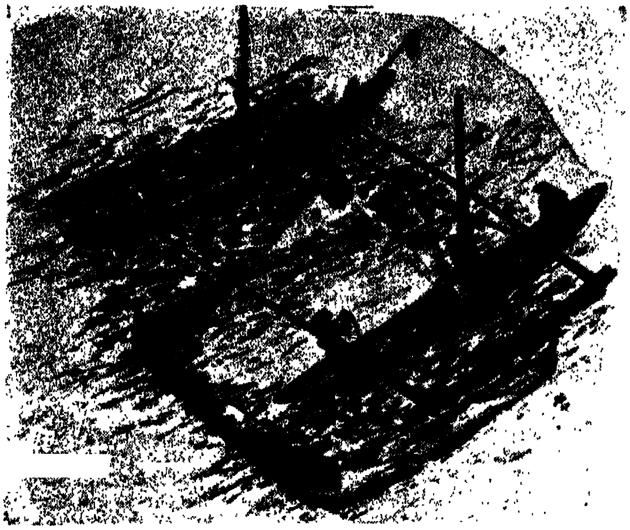


Fig. 5. A basnig *operated with two small dugouts.*

current (fig. 4). The net, which is made of *cotton*, 1 to 2 cm. stretched mesh, is bigger and shaped like an inverted mosquito net. Small light-boats are sometimes used to attract fish outside and lead them into the enclosure. The fish are caught by lifting the net after all lights except one over the net have been dimmed.

In 1924 the operation of the *basnig* net from boats of about ½ ton gross was started in northern Negros, Leyte and Panay. Lights were used to attract fish but the real lift net principle was not adopted until the handliners began to catch their bait by scooping small fish gathered under the bright lamp of the boat. They found that brighter lights attracted more fish and eventually used bigger nets handbraided of fine *abacá* twine and operated by four men. This became the forerunner of the modern *basnig*.

The use of these bigger nets was made possible by joining two boats together with a common outrigger (fig. 5) and operating the net between them. This stage of development remained until 1935.

THE MODERN *BASNIG*

The transformation from sustenance to commercial fishing was brought about in 1935 by the conversion of several *sapiao* (scoop seine) boats each operated by 40 to 60 fishermen, into *basnig* boats. The reason was that many operators were experiencing a decline in their catch as well as difficulties in the hiring of fishermen, who had to be recruited from places other than the operation headquarters, taught fishing operations and provided with food and cash advances. This amounted to a sizeable investment for the capitalist and with this high cost and the unpredictable labour market, fishing became unprofitable. Moreover, only about 50 per cent. of the fishermen continued to operate during the entire fishing season. The operators, therefore, had to find other fishing methods which required fewer fishermen.

One *sapiao* operator of Punta Buri, Tagubanhan Island, converted his boat to *basnig* fishing in 1935, operating with pressure gas lamps of 1,000 to 1,500 candle power. Only 8 fishermen were employed but he was able to land almost the same quantity of fish as when operating with *sapiao* gear.

Consequently other *sapiao* operators lost no time in converting to the *basnig* method too. The oval *sapiao* nets were made rectangular and given more bulge to obtain a shape similar to an inverted, rectangular mosquito net. Lights of 1,500 to 2,000 candle power were used. In 1936 also boats of more than 3 tons gross were used, towed by motor launches to and from the more distant fishing grounds.

Surplus engines after World War II contributed to further improvement. Engines from 25 to 120 h.p. were installed and electric lights came into use.

Formerly the size of the net depended on the size of the

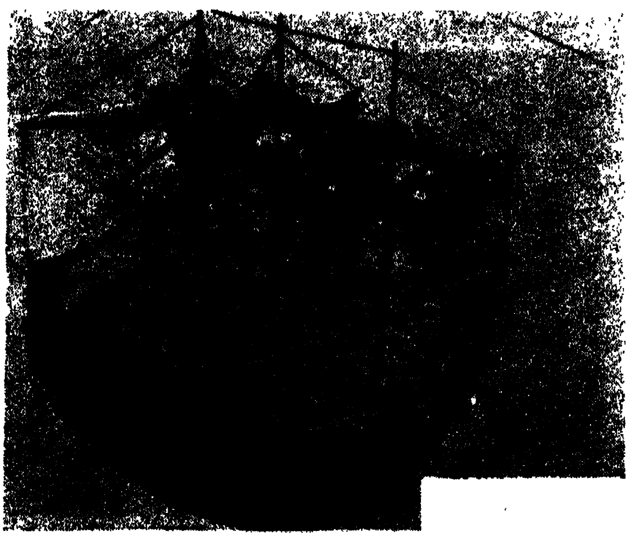


Fig. 6. A modern basnig *operated with masts and booms from an outrigger boat.*

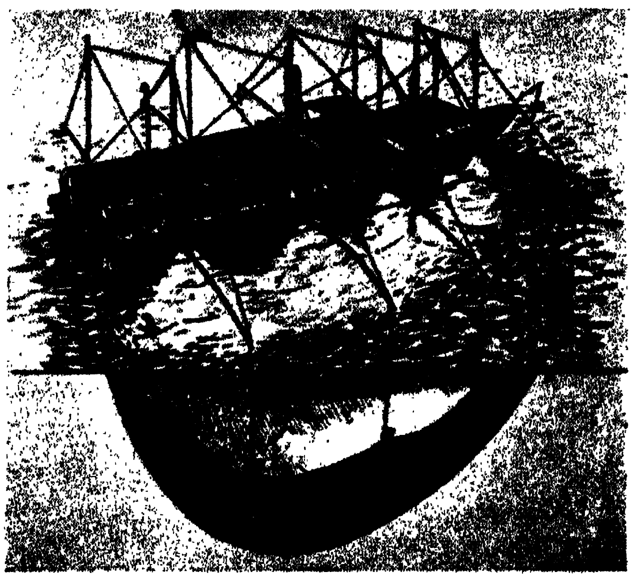


Fig. 7. A modern basnig *operated from a 17½ ft. motorboat.*

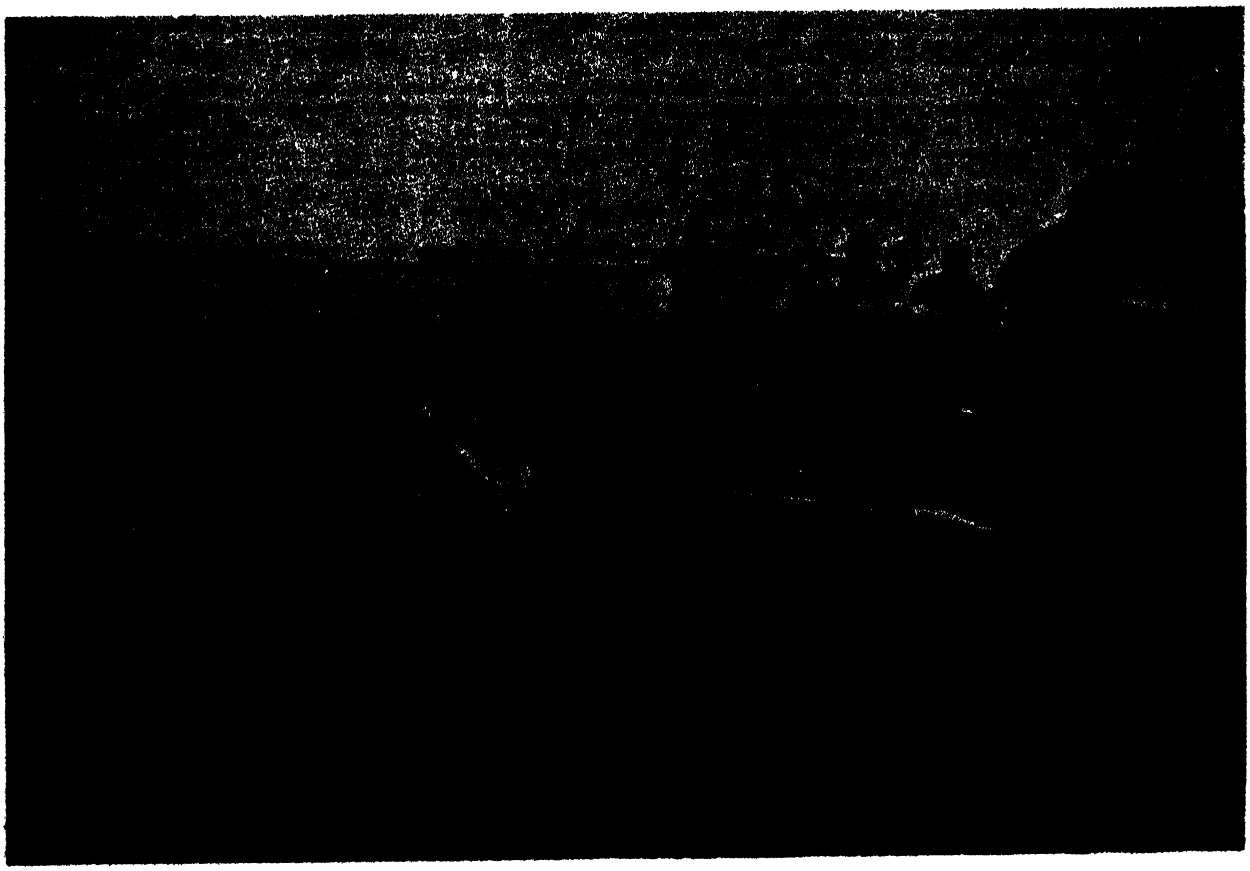
outrigger of the boat. Now temporary booms (fig. 6) have been introduced to increase the net size without increasing the size of the boat or its outriggers. Sometimes 2 or 3 additional light boats are used to attract schools of fish and lead them to the fishing boat.

In 1950 also trawlers and fish carriers, ranging from 70 to 136 ft. in length, 16 to 24 ft. beam and 5 to 8 ft. draft, with a speed of 7 to 14 knots, were converted to *basnig* boats (fig. 7). As they carry more supplies and provide storage space for more fish they permit operation in more distant fishing grounds.

They are equipped with high speed engines and a generator of 10 to 30 kw. with 10 to 20 specially constructed electric light bulbs. Bamboo booms, 3 to 6 m. long, are installed along the sides, held in place by stays and shrouds supported by an auxiliary mast.

The temporary booms which spread the net under the boat as well as the auxiliary mast are detachable and set only on the fishing grounds.

As the gear is still operated by hand, hauling is rather slow, with the result that big fish such as mackerel, tuna and bonito, which are also attracted by light, are rarely caught. This leads operators to use explosives which not only kill all marine life near the blast but sometimes injure the fishermen themselves. But with the introduction of multiple winches the net can be hauled in faster so that the bigger fish can be caught and, at the same time, fewer fishermen need be employed per boat.



Taking the catch out of a big tuna set net in Lybian waters. Photo: FAO.

SOME IMPROVEMENTS IN THE STICK-HELD DIPNET FOR SAURY FISHING

by

AKIRA FUKUHARA
Hokkaido Fisheries Experimental Station, Japan

Abstract

The usual method of catching saury is by the dipnet supported on sticks which are fixed to the ship's side. The fish are attracted into the net by lights, but, owing to the construction of the bag of the net, many fish escaped from the sides and the operation had to be repeated many times. In addition the net was inclined to fold flat when there was little wind and weak currents, and when the wind was strong it tended to rise to the surface, rendering it very inefficient.

By altering the shape of the net and making it more box-like, and by making the sides more buoyant, the author has increased the efficiency of the method, and by using less webbing, he has reduced the weight and made it easier to handle. The author hopes that it may lead to a revival of the saury fishery which has become difficult owing to increasing cost of materials.

Amélioration apportées aux épuisettes soutenues par des piquets, pour la pêche au scombrésoce

Résumé

On capture habituellement le scombrésoce au moyen d'épuisettes soutenues par des piquets fixés aux flancs du bateau. Les poissons sont attirés dans le filet par des lumières mais, en raison de la construction du filet, un grand nombre de poissons s'échappent par les côtés et l'opération devait être répétée un grand nombre de fois. De plus, lorsqu'il y a peu de vent et que les courants sont faibles, le filet a tendance à se replier à plat et, lorsque le vent est fort, le filet a tendance à remonter vers la surface, ce qui lui fait perdre la plus grande partie de son efficacité.

En modifiant la forme de l'épuisette et en la faisant ressembler davantage à une boîte et en allégeant les côtés, l'auteur a donné plus d'efficacité à la méthode. En utilisant moins de corde, il a allégé le filet et l'a rendu plus facile à manipuler.

Le document donne tous les détails concernant le nouvel engin et contient de nombreuses illustrations. L'auteur espère que cet engin pourra contribuer à redonner de la vogue à la pêche au scombrésoce, devenue difficile du fait du coût croissant des matériaux.

Mejoramiento del "cielo" empleado en la pesca de "saury"

Extracto

En la pesca de "saury" se utiliza usualmente un "cielo" que cuelga de tangones fijos al costado del barco. Los peces son atraídos a la red mediante el empleo de luces pero, dada la construcción de la bolsa del arte, gran número de ellos escapa por los costados, debiéndose repetir esta operación muchas veces. Además, la red tiende a plegarse cuando hay poco viento o corrientes muy débiles y a subir a la superficie en caso de soplar viento, disminuyendo considerablemente su eficacia.

Al modificar la forma, darle una estructura más parecida a un cajón y aumentar la flotabilidad de los costados, se logró una mayor eficacia con este arte de pesca; por otra parte, el uso de menos red redujo el peso y facilitó su manipulación.

En el trabajo original el autor incluye gran cantidad de detalles y numerosas ilustraciones de la nueva red con la esperanza de inducir al establecimiento de la pesca de "saury" que se ha tornado difícil a causa del mayor costo de los materiales.

IT is said that the Japanese saury fishery off the Pacific coast was started about 280 years ago. At that time a very ancient kind of blanket net was used, the *Yatsude-ami*. This was first replaced by a primitive type of seine net and, later, by drift nets. Recently the use of the stick-held dipnet, together with electric lamps, has led to a rapid development of the saury fishery. The number of vessels employed exceeds 2,000 and the annual catch is now 375,000 tons.

Although the stick-held dipnet is economical and effective, and also very efficient for taking other pelagic fish, it has some defects. As a result of his experience the author has invented a new type of net.

PRESENT STICK-HELD DIPNET AND ITS DEFECTS

The present stick-held dipnet, as shown in fig. 1 and fig. 2, has a flat form. It becomes baglike only under the influence of current. Fishing with the net is simple because no ground bait is needed and the saury shoals, once attracted by light, do not scatter easily.

The operation is as follows:

The vessel arrives at the fishing ground at dusk and as soon as the sun sets, the search for fish starts. When a satisfactory school of fish is located, the vessel is stopped with the fishing side to windward and the lamps lit on the opposite side. Fish begin to gather under the lamps 5 to 10 min. later, and when the shape of the net, which is cast when the vessel is stopped, becomes baglike (it usually takes about 5 min.), lamps on the fishing side are lit and the others are extinguished. This induces the fish to pass under the bottom of the vessel into the net. They are then brailed into the vessel by a scoop net. As all the fish crowded around a vessel cannot be captured at once, the operation described above is usually repeated several times.

Although a vessel which finds a large school may be fully loaded (about 37·5 tons) in 3 to 4 hours, the boats usually return to port at dawn.

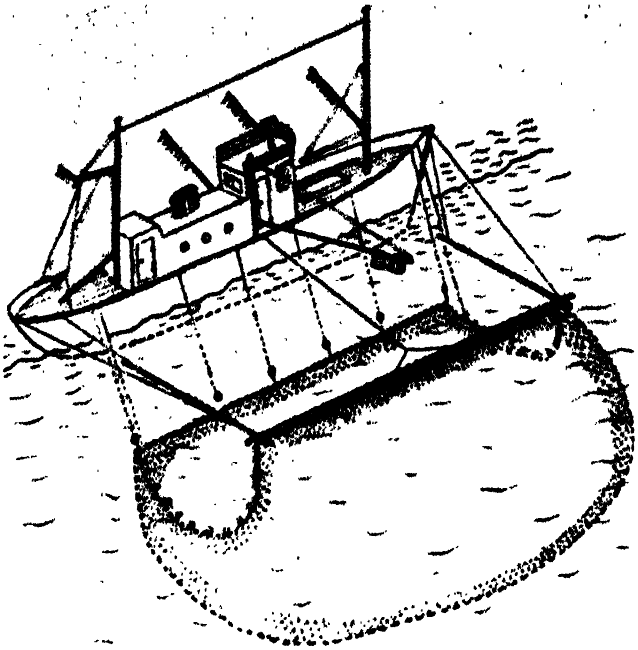


Fig. 1. Present type of stick-held dipnet.

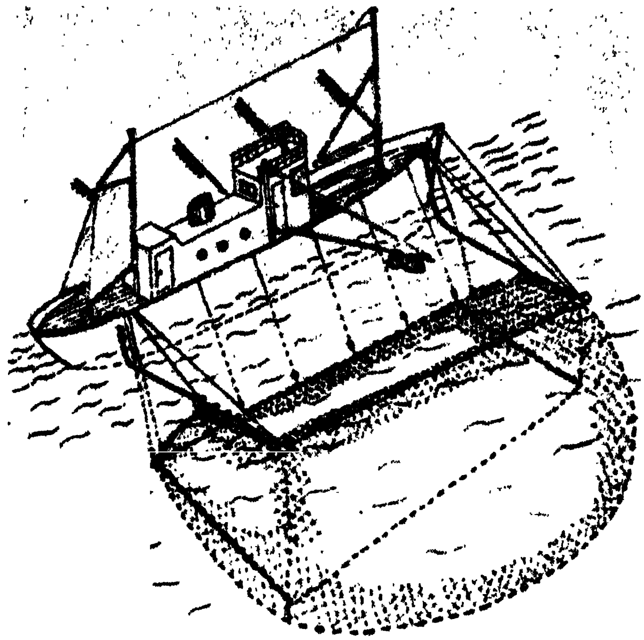


Fig. 3. Newly devised type of stick-held dipnet.

The present stick-held dipnet has the following defects:

(1) The net form is flat in itself and, in spite of a certain amount of bulging, it folds up flat when wind and current are weak, and rises to the surface when they are strong.

(2) A large amount of webbing is used to increase bulging so that much labour is needed to lift the net.

(3) Because of the net-form, the upper edges of both sides of the net sink and 70 to 90 per cent. of the school escape this way. Consequently, the operation must be repeated many times.

(4) As the net sinks slowly, it takes some time before it assumes the correct shape.

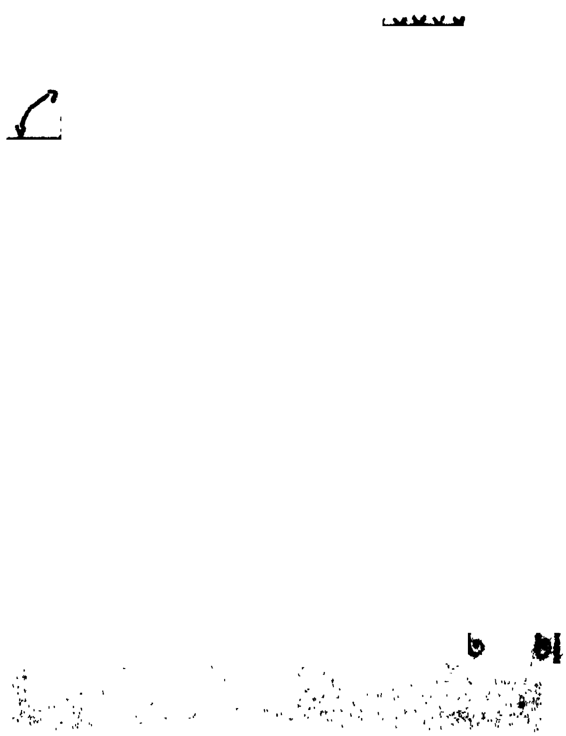


Fig. 2. Construction of present stick-held dipnet.

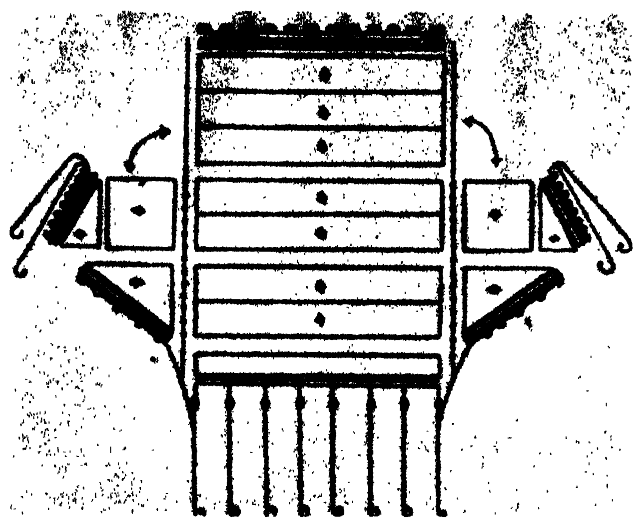


Fig. 4. Construction of newly devised stick-held dipnet.

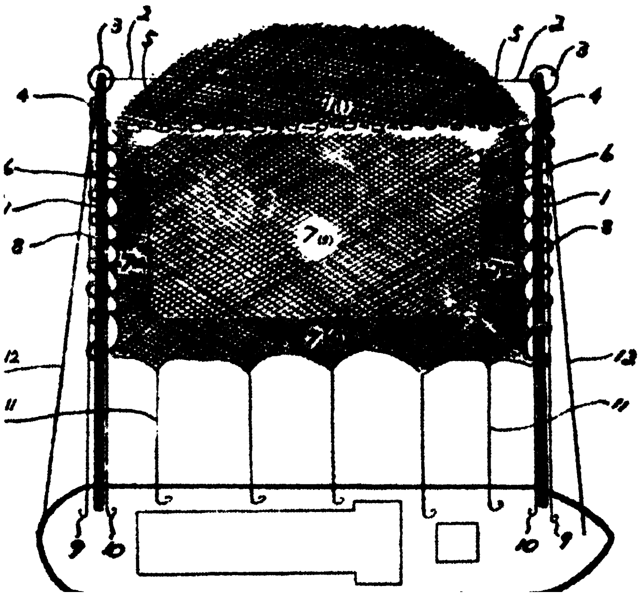


Fig. 5. Newly devised type of stick-held dipnet. 1. Sticks; 2. Stretching line; 3. Big floats; 4. Blocks; 5. Floats; 6. Sinker lines; 7. (1) Fish gathering part of net, (2) Side parts, (3) Bottom, (4) Vessel side of net; 8. Metal rings; 9. Towlines for setting the net; 10. Towlines for hauling the net; 11. Towlines for hauling net aboard; 12. Guys.

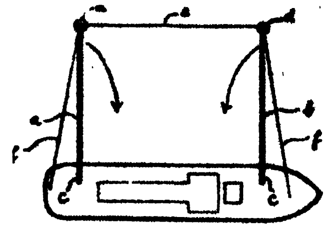


Fig. 7. Operation of sticks of large and medium-sized vessels.

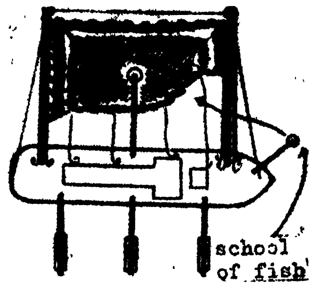


Fig. 8. Leading a school of fish round the bow.

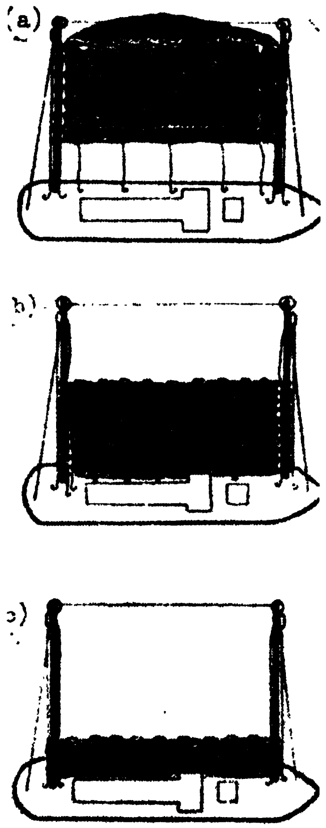


Fig. 6. Operation of newly devised stick-held dip net.

PARTICULARS OF NEWLY DEVISED STICK-HELD DIPNET

The newly devised stick-held dipnet was used with great success in the Pacific and the Okhotsk Sea in October 1952 from the research ship, *Hokko-Maru*. The greater part of schools were captured by only one operation and the ship was fully loaded by 3 to 4 operations. The research ship of the Hokkaido Regional Fisheries Research Laboratory, *Tankai-Maru No.* 3, captured 22·5 tons in 4 operations on September 8, 1956, and *Koyo-Maru* of the Hokkaido Fisheries Experimental Station, 48·7 tons in 4 operations.

Some advantages of improved net are as follows:

(1) As the net form is cubic, the shape of the net is nearly constant irrespective of wind and current, thus increasing the fishing efficiency.

(2) The new net required only 70 to 80 per cent. of the webbing used in the old type net and only two thirds of the labour for lifting the net.

(3) As the net form is cubic and the upper edge of both sides of the net are buoyant, fish are induced easily into the net and cannot escape.

(4) Three sides of the net float, therefore the fish do not escape even if lamps with intensive light are used.

(5) As both edges of the bottom net have lead sinkers, the net takes up its proper shape more rapidly.

(6) The fishing rate per operation is doubled, so the time taken to load the boat is shortened.

Construction and operation

The construction of the new net is shown in figs. 3 to 5. The net is hung down in the water from metal rings which are carried by two sticks (bamboo, wood or metal) projecting from one side of the vessel. Lamps, reflectors, ground bait and so on are used to attract the fish.

When a school of fish is located, the vessel is stopped with the wind and tide on the fishing side. Ropes of certain lengths keep the net in position when the tow-line (figs. 5 and 6) is pulled.

Just before the operation begins two sticks (1) are projected outward and are fixed by guy (12) ropes, and the net is set by pulling the tow-lines (9). After the fish have entered the net, the tow-lines (11) are pulled, and

Fig. 9. Departure of vessels.

the catch is safely confined. Then, by means of the tow lines (10), the net is hauled towards the vessel and fixed to the ship's side (fig. 6, a-c)

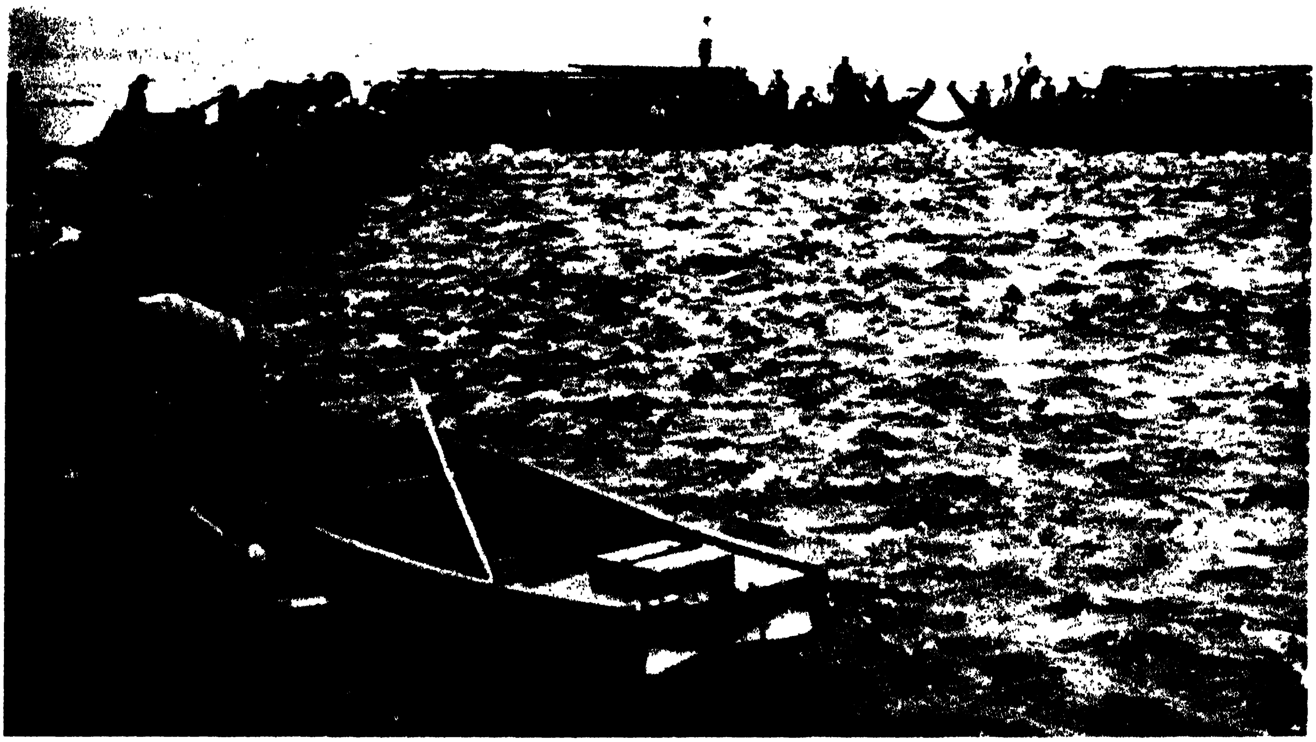
Fig. 10. Operation of newly devised stick-held dipnet.

After the trapped fish have been brailed by a scoop net, operated from a boom, the net is set again.

In the case of medium-sized and larger vessels the following particulars are of advantage (fig. 7). The sticks should be made of metal. A line (e) is stretched between the two sticks to prevent any change in the net shape, big floats are attached to the top of the sticks, and the sticks are connected with the vessel by universal joints (c). Universal joints are particularly useful in case of rolling and pitching in stormy weather. They also simplify the shipping and unshipping of the sticks.

In rough weather a spanker with two sails is used to hold the vessel with the wind about 2 points on the quarter and with the fishing side as the weather-side. If, with larger vessels, the attraction of fish into the net under the bottom is impossible because of the draft, fish are led round the bow (fig. 8). In this case, the side of the net nearest the bow can be opened or closed by means of ropes and pulleys, to enable the fish to enter.

This improved gear is called a moving dipnet (Ido-Kaku-Ami). It is easily assembled and dismantled. It is effective for fish such as mackerel, squid and sand-eel, which can be attracted by light, shadow, ground bait and sound.



Hauling up the bag of a large Japanese setnet Photo: Japanese Fisheries Agency

THE METHODS AND GEARS USED FOR MACKEREL FISHING IN JAPAN

by

KEISHUN MIHARA

Chiba Prefectural Fisheries Experimental Station, Japan

Abstract

This is a detailed account of the handline and pole and line fisheries which are generally used along the Japanese coast. There is complete description of the assembly and use of the handlines and the rate of fishing can be judged by the fact that a small boat of 3 to 5 tons can catch more than 2 tons of fish per day. At night, the most efficient system is the pole and line, which is simply a bamboo pole carrying a line of red or green nylon of the same length as the pole itself. The fish are attracted by scattering bait and also by lights and enormous rates of fishing are possible by this method. A single fisherman can take 500 to 800 kg. of mackerel per night, and an 80-ton boat with a crew of 45 can catch more than 25 tons per night. The paper is well illustrated.

Méthode et engins utilisés pour pêcher le maquereau au Japon

Résumé

Cet article décrit en détail la pêche aux palangres et aux lignes à canne courte utilisées communément le long du littoral japonais. On y trouve une description complète du montage et de l'utilisation des palangres et on peut juger de l'importance de cette pêche par le fait qu'un petit bateau de 3 à 5 tonnes peut capturer plus de 2 tonnes de poisson par jour. La nuit, le système le plus efficace est la ligne à canne courte qui est une simple perche de bambou portant une ligne de fil de nylon rouge ou vert, de même longueur que la perche elle-même. On attire le poisson on appâtant et aussi en utilisant des lumières; on peut capturer ainsi d'énormes quantités de poisson. Un pêcheur opérant seul peut capturer de 500 à 800 kgs. de maquereaux par nuit et un bateau de 80 tonnes monté par 45 hommes peut capturer plus de 25 tonnes par nuit. L'article est abondamment illustré.

Método y artes usados en las pesquerías japonesas de caballa

Extracto

Este trabajo contiene una relación detallada y gran número de ilustraciones sobre la pesca con liña y caña usadas a lo largo de la costa japonesa. Se da una descripción completa de la confección y uso del primero de estos aparejos, pudiendo juzgarse la proporción de la pesca por el hecho de que una pequeña embarcación de 3-5 toneladas puede capturar diariamente más de 2 tons. de pescado. En la noche, el método más eficaz es la caña que consiste simplemente en una vara de bambú con una linea de nylón rojo o verde de la misma longitud. Los peces son atraidos esparciendo carnada y también con luces, obteniéndose enormes cantidades de pesca. Un solo pescador puede sacar unos 500-800 Kg. de caballa y una embarcación de 80 tons. con una tripulación de 45 hombres más de 25 tons. por noche.

MACKEREL fishing in Japan is carried out by surrounding nets, longlines, handlines and pole and line, of which handlining and pole and line fishing are the most common methods. Pole and line fishing is generally used at night and handlining during the day.

These methods have recently been improved and fishing boats are now equipped with modern auxiliary equipment which is available at reasonable cost. (Table I).

TABLE I

Equipment and crew of mackerel handlining boats

Gross Tonnage	1—2	2--5	5—10	10—20	20—40	40—80
Horse power of Engine	17—25	25—45	30—75	60—110	90—200	200–250
Crew	5—8	8—10	8—15	15—20	20—30	30—45
Fish Finder	Rare	Rare	Common	Common	Common	Common
Type of Radio			A_3 5–25W.	A_3 10—35W.	A_1 35W. A_3 10—35W.	A_1 75W. A_3 30W.

HANDLINING

Handlining, which has developed most in the Chiba Prefecture, is practised in every part of Japan. Boats from 1 to 40 tons are used, but the trend of development is toward bigger boats. Artificial bait is particularly effective in deep water where the fish cannot be enticed up because of low water temperature near the surface.

Construction of the gear. *Shibuasa,* the mainline, is a Japanese hemp line made of two strands (approximately 250 g./150 m.). Cotton would not be strong enough, and the larger diameter of a cotton line of equal strength would cause too much resistance to water currents. Nylon is suitable but too expensive.

Fishermen repeatedly dip the hemp line in persimmon juice and dry it in the sun. The resultant thin film on the line reduces resistance to currents and preserves the rope, which retains its elasticity and strength and becomes easy to handle. Fishermen use 300 m. mainlines with depth marks every 30 to 50 m.

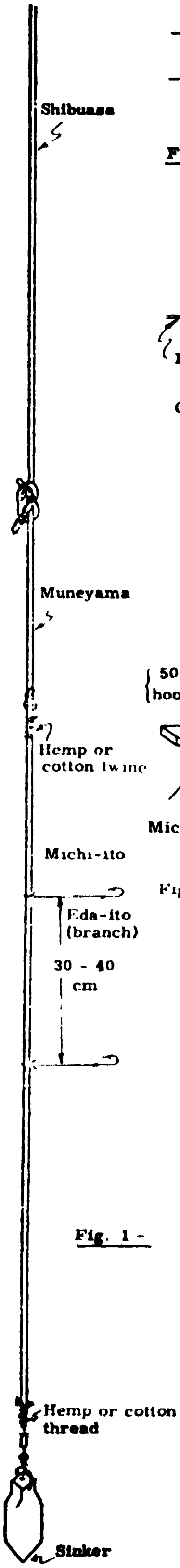


Fig. 1 -

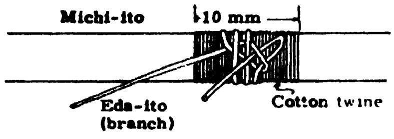


Fig. 2

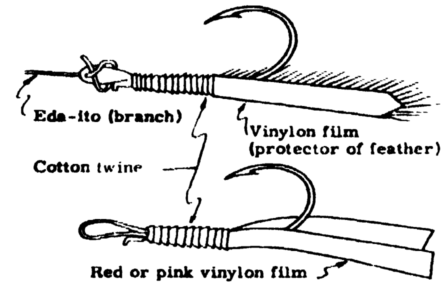


Fig. 3

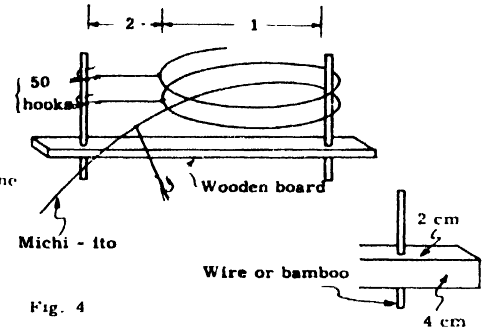


Fig. 4

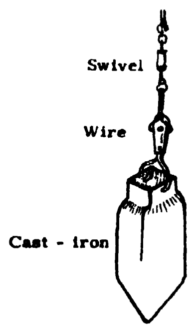


Fig. 5

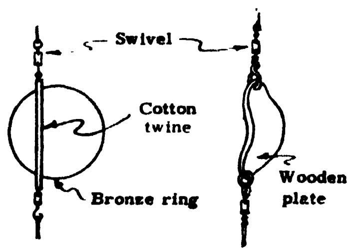


Fig. 6

Muneyama, an intermediate piece, is made of three strands of nylon monofilament weighing 75 g. per 150 m. and with 0·74 mm. diam. The piece is 7 to 8 m. long and is intended to act as a shock absorber.

Michi-ito, the lower part of the mainline, is usually made of nylon monofilament which has a high breaking strength. A draw-back is that the monofilament twists when it is stretched, but this can be avoided by boiling before use, although such treatment slightly reduces its strength. The thickness of the line varies according to season, size of fish, catch, number of hooks and current strength; generally speaking, a thinner line means a greater catch. A line of 2 to 2·6 *fungara** (0·74 to 0·84 mm. in diam.) is needed to carry 50 hooks. Red or pink dyed cotton twine (No. 20, 2 × 3) is used for fixing the nylon branches to the line (fig. 2).

Nylon monofilament between 1 and 1·2 *fungara* (0·52 to 0·57 mm. in diam.) and 10 cm. long is used for the *eda-ito*. Snoods are attached to the *michi-ito* (main line) as shown in fig. 2. The tying method is important for the operation of the gear. The distance between the snoods is usually 30 to 40 cm., depending on the size of fish to be caught.

The hook is zinc plated and 40 to 50 mm. long (fig. 3). Two or three pieces of rump feather (5 to 6 cm. in length) from a white leghorn cock, are dyed red or pink and are attached to the hook. When fish are plentiful, fishermen also use red or pink vinilon film (5 × 70 mm.) instead of feather. Each handline has fifty hooks, and 2 or 3 lines are put together to make one set of gear.

A gear coiler, holding one set of line with hooks, is shown in fig. 4. The distance 1 is little narrower than half of the space between the snoods while the distance 2 is equal to the length of the snoods.

The sinker (fig. 5) is tied to the end of *michi-ito* by hemp or cotton twine. It is spindle-shaped, made of cast-iron and weighs 1 to 1·5 kg. A heavier sinker is used when the current is strong or more hooks are put on.

Yoridome, the twist stopper (fig. 6), is either a ring (diam. 15 cm.) made of bronze wire of 5 to 6 mm. diam., or a semicircular wooden plate.

A spanker is used to keep the boat "lying-to" the wind, and the engine helps to maintain that position when fishing.

Operation of the gear. The fish are located and the size of the school determined by means of echo sounding (using a fishfinder). If the school is big enough, the boat lies-to and immediately the crew shoot the lines from the

* 1 fungara = $\frac{0{\cdot}3750 \text{ gr.}}{150 \text{ cm.}}$

Fig. 1. Construction of the handline gear.

Fig. 2. The way of connecting the branchlines to the mainline.

Fig. 3. Artificially baited hooks.

Fig. 4. Line coiler.

Fig. 5. Sinker.

Fig. 6. Twist stopper.

starboard side. The lines are veered to the required depth while the men hold the "gear coiler" in their hands. The captain, meanwhile controls the boat to prevent fouling of the lines. According to the "feel" of the line fishermen can assess where the fish are biting and adjust the depth accordingly.

The line is hauled in after passing through the fish school although the fishermen allow the line to go down again as the hooked fish work against the pull. When resistance is no longer felt, the line is hauled up.

The lines, complete with hooked fish, are stored in baskets or barrels, and new lines are shot as quickly as possible because the period in which the fish bite is very short. Later, when fishing is finished, the fish are unhooked and stored in tanks with chilled water.

Fishing is usually stopped at dark and the gear is cleared while going home or in the port. For this purpose, the *michi-ito* part of the mainline is unfastened at both ends and the snoods removed.

A boat with a crew of five fishermen usually has 100 sets of *micho-ito* with hooks, and a boat of 10 to 15 men has 250 to 300 sets. If lines get entangled, they are pulled in together. A boat of 3 to 5 tons can often catch over 2 tons of fish a day. It is estimated that 380 m. is the maximum depth for economic operation of this type of mackerel handlining.

POLE AND LINE FISHING

Pole and line fishing is the most efficient mackerel fishing method at night. The boats are from 1 to 150 tons; the larger ones are equipped with D.F. and radar. The fishing grounds extend from 2 to 3 miles off the Japanese coasts to the East China Sea and the northern waters of Formosa Island. The length of a cruise may range from one night to two weeks. In future, fishing at distant grounds may be improved by the use of a mother-ship.

The principle of this method is to attract the fish school to the surface by light and by scattering bait (chopped sardines). All hands fish continuously, using one pole each. When the school is large, one man is able to catch from 500 to 800 kg. a night. A boat of 80 tons (250 h.p., 45 crew) can often catch more than 25 tons of fish a night at a good ground, such as in the East China Sea. The equipment and the method vary little between the boats of different size.

Construction of the gear. Bamboo pole (fig. 7). Fishermen prefer bamboo poles, produced in Japan, because they are light and pliable. The poles usually range from 1 to 2 m. in length, according to the size of boat.

Fishing line and hook (fig. 7). The mainline, made of red or green nylon monofilament of 1 *fungara* (0·522 mm. in diam.), is exactly as long as the pole. A hook is joined to the mainline by a 10 to 15 cm. nylon snood (*chimoto*) of 0·6 to 0·8 *fungara* (0·40 to 0·47 mm. in diam.), similar in colour to the main line. In boats bigger than 20 tons, the line is 30 to 40 cm. longer than the pole. Round shaped hooks of 4·8 cm. length (1·6 *sun*) are generally used, but it is better to change the hook size according to the size of fish available.

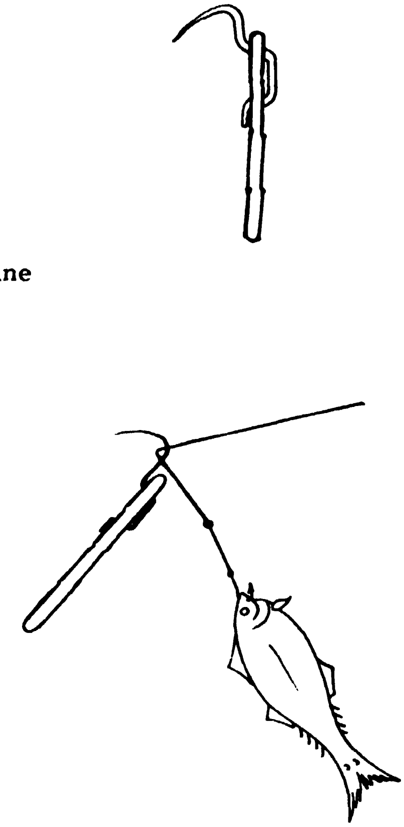


Fig. 8

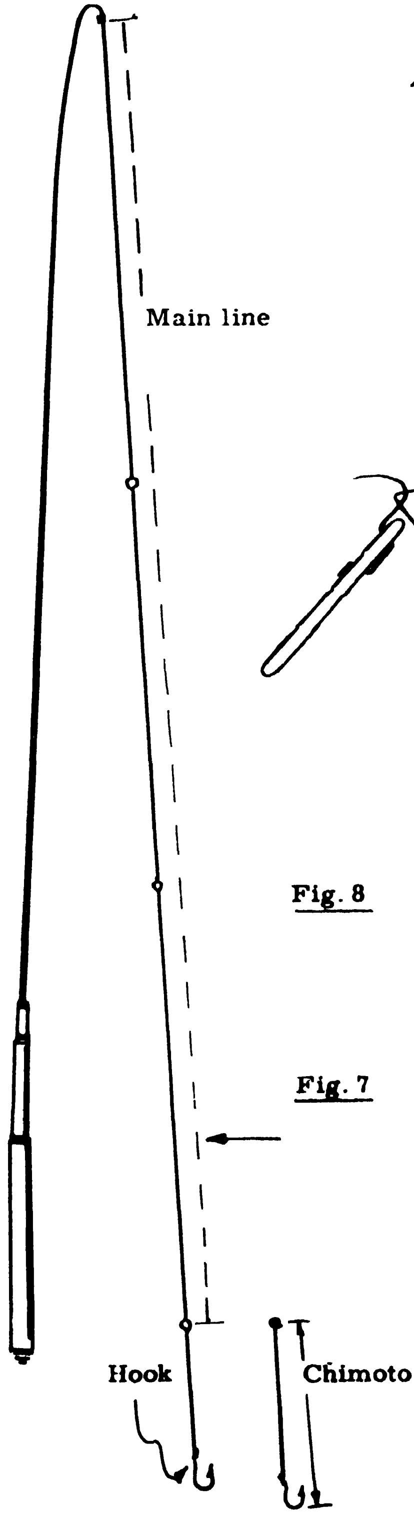


Fig. 7

Fig. 7. Pole and line fishing gear.
Fig. 8. Gaff.

TABLE II

Relation between light equipment and tonnage of mackerel pole and line fishing boat

Gross Tonnage	1	2–5	5–10	10–15	15–30
Power Source	D.C. 1 kW. 24 V.	D.C. 2–3 kW. 24 V.	D.C. 3–5 kW. or A.C. 3–5 kVA. 24–110V.	D.C. 5–7 kW. or A.C. 5–7 kVA. 110V.	D.C. 7–10 kW. or A.C. 7–10 kVA. 110V.
Candle Power and number of bulbs	100 W. or 200 W. (3–9)	100 W. or 200 W. (5–7)	300 W. (5–9)	300 W. or 500 W. (8–13)	300 W. or 500 W. (10–19)

In strong wind, or when the fish cannot be attracted to the surface, a small sinker is fastened to the snood just above the hook to sink it deeper and quicker.

A gaff is used to detach the fish from the hook. It consists of a wooden handle (20 cm. in length, 2 cm. in diam.) and a piece of nickel silver wire (2 mm. in diam.), bent as shown in fig. 8.

All boats are equipped with D.C. or A.C. generators, with automatic voltage regulators, to provide light for attracting the fish. Incandescent bulbs are normally used but recently fluorescent lighting has been tested. A final opinion on this lighting has not yet been formed. The relation between light equipment and tonnage of boats is shown in Table II.

Most important for the efficiency of electric bulbs is the angle of their reflectors. The best angle is considered to be one which illuminates the water from the boat to the end of the line. But when many boats are together, the illuminated area must be enlarged to prevent fish being attracted by the light from other boats, so light reflectors are hung above the heads of the men sitting on the boat side.

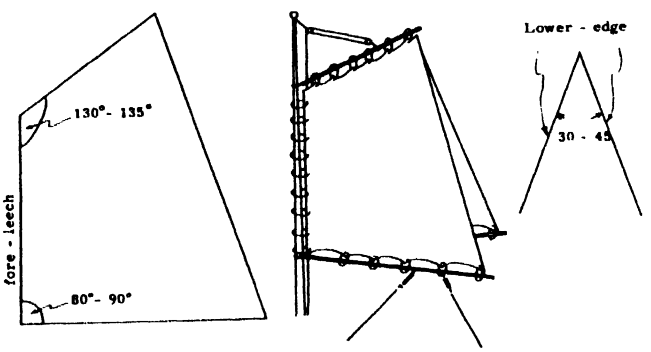


Fig 9

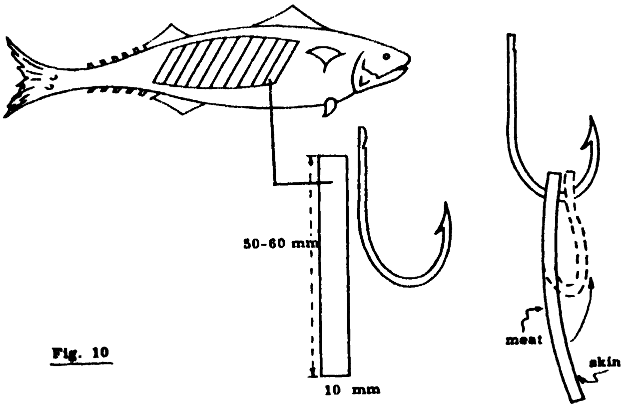


Fig. 10

Fig. 9. Spanker.
Fig. 10. Method of baiting the hook.

The spanker (fig. 9) consists of two sails, and is used very effectively for both line and net fishing. It is an effective rudder in the wind, so it is better to remove the ship's rudder while fishing. The rudder usually can be unshipped in boats of less than 40 tons.

The chopper is a mincing machine, worked from the engine, to prepare the bait for scattering.

There are two kinds of bait, i.e. for the hooks and for scattering. Bait for the hook, *tomoe*, is mackerel meat, off the side of the mackerel, 10 mm. in width, 50 to 60 mm. long and 2 to 3 mm. thick. Ten such pieces can be taken from on side of a fish of 500 gr. The pieces are fixed on the hooks, skin inside, meat outside (fig. 10).

Chum bait is usually made from frozen sardines, ground by the mincer and mixed with water. Fat sardines are favoured because the meat does not sink quickly. Fishermen usually expend about 350 to 400 kg. of bait to catch 8 tons of mackerel.

Operation of the gear. The baited hook is thrown toward the fish and the pole is raised as soon as it approaches. After a fish is hooked, the fishermen draw the line through the gaffhook and force the mackerel to drop off the hook on to the deck, and immediately throw hook and line out again. Only about 2 seconds are necessary to land a fish and fishing, therefore, is practically continuous. If the fish cease to react well to the bait, it is renewed at once.

The men fish from one side of the boat only when the schools are scattered. This saves bait, makes the best use of manpower, and simplifies control. They fish from both sides of the boat when schools are dense.

Chopped bait, diluted by sea water, is thrown into the water above the fish school by hand or by spoons. Usually one man of a team of 3 to 5 scatters the bait. The mixture of water and chopped meat is adjusted to regulate the speed at which it sinks. The bait must be scattered very carefully to keep the fish near the surface, and ensure good fishing.

The captain uses the spanker and the engine to keep the boat lying-to, maintaining constant contact with the school. Fishing ceases at dawn when the boats return to port.

A NEW METHOD OF HANDLING LONGLINE GEAR
A DESCRIPTION OF POFI "TUB" GEAR

by

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Abstract

Modifications to Japanese-type longline gear, by the introduction of a large, rotating tub from which the line is handled, have resulted in a considerable saving in manpower. Conventional gear can be operated in this manner with few changes. Instead of using individual baskets of line which must be separated and joined together for each day's fishing, a continuous mainline is set from, and hauled into, a wooden storage drum. This innovation is the product of continuing studies to increase the efficiency of longline gear.

Une nouvelle méthode de manipulation des palangres Description de la baille à lignes POFI

Résumé

On a obtenu une importante économie de main-d'oeuvre grâce à des modifications apportées aux palangres japonaises par l'introduction d'une grande baille tournante dans laquelle se trouvent les lignes. L'engin habituel peut être manoeuvré de cette façon avec peu de changements. Au lieu d'utiliser des paniers individuels de lignes qui doivent être désassemblées et réassemblées chaque jour pour la pêche, on met à l'eau et on récupère dans une baille de bois une ligne principale continue. Cette innovation est le résultat de recherches en cours pour augmenter le rendement des palangres.

Nuevo método para manipular palangres. Descripción del "tambor" POFI para enrrollar palangres

Extracto

Las modificaciones introducidas a los palagres de tipo japonés mediante el uso de un "tambor" rotatorio desde el cual se manipula este aparejo de pesca economiza bastante mano de obra; además permite usar unidades de tipo convencional con sólo pequeñas modificaciones. En lugar del empleo de varias cuerdas madres que es necesario unir y separar en cada salida, se procede a calar y a levantar una sola almacenada en el "tambor" de madera. Esta innovación es el producto de continuos estudios para aumentar la eficacia de los palangres.

THE Pacific Oceanic Fishery Investigations (POFI) of the U.S. Fish and Wildlife Service has found longlining to be an effective means of catching tunas in the relatively baitless waters of the central Pacific. This report describes a new method of fishing longline gear recently developed at POFI following a suggestion by Mr. A. K. Akana Jr., POFI fleet supervisor.

The longline gear previously used by POFI was copied from conventional Japanese designs and, although adequate as a sampling tool for exploratory fishing, it required too many men, by American standards, to be ideal for commercial use. The so-called "tub" gear described below is the most successful effort to date to improve the efficiency of gear in this respect, in that it permits a material reduction in the manpower required to operate longline gear.

The essence of the tub method lies in a novel means of handling the mainline. Instead of the individual baskets of conventional gear, which must be separated and joined together for each day's fishing, tub gear has a mainline of one continuous length which is shot from and hauled into, a large wooden storage drum or "tub". Branchlines and floatlines are removed from the mainline as they come aboard and are reattached during shooting operations.

The tub method requires only minor changes in the design of conventional longline gear. Standard POFI gear, or any longline with detachable branchlines and floatlines, may be used by adding "D" rings (described below) to the mainline.

DESCRIPTION OF THE GEAR

The gear is of a flexible design so that it can be altered readily to meet the changing requirements of an exploratory fishing programme. Components are detachable and can be assembled so as to fish varying numbers of hooks at different depths.

Shown in fig. 1 is a schematic representation of a single unit, or basket, of POFI gear of the latest type. Sixty to a hundred such baskets are joined together to make a fishing set.

Mainline

The mainline of each unit is made up of fourteen identical sections knotted together by double sheet bends. Each

POFI LONGLINE TUB GEAR

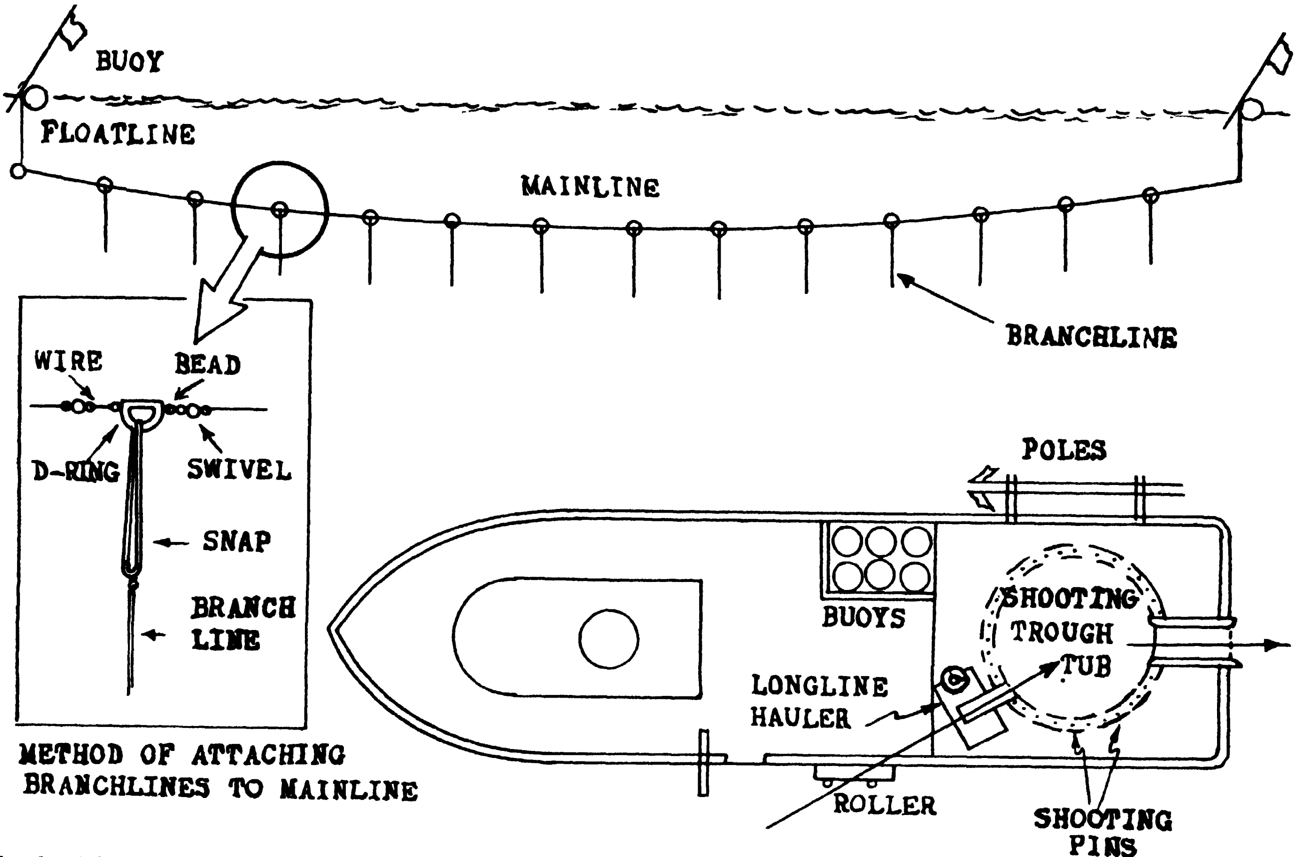

Fig. 1. Schematic drawing showing the arrangement of a single unit, or "basket", of POFI longline gear, and the location of the line storage tub on the stern of the vessel.

section consists of a 15 fm. length of preserved 261 thread hard-laid cotton twine with an eye splice in one end and a wire bridle with swivels, "D" ring, and pigtail at the other. Baskets are joined by a clover-leaf knot which is formed with an extra loop for attachment of the floatline.

Attachment of branchlines

The branchlines are attached to the mainline by the "AK" snap and "D" ring arrangement shown in fig.1. The "D" ring eliminates a troublesome defect of old gear. Formerly, "AK" snaps were clipped directly to a wire bridle. This type of attachment permitted the branchline to swivel around the mainline and prevented tangles when gear was being hauled aboard ship. But sometimes it failed to function properly when large fish pulled the branchline parallel to the mainline. At acute angles of pull, the snap ceased to have any swivelling action and sometimes was pulled out of shape or broken. The "D" ring maintains proper swivelling action. Rings are fabricated from stainless steel tubing with a lower section formed in a U shape and welded to the upper, straight tube section through which the bridle is rove. The wire bridles are made of a 6 in. length of 3/32 in. diameter 7×7 stainless steel wire rope with swivels connected to each end by means of Nicopress fittings. These fittings consist of malleable copper sleeves which are pressed on the wire by a hand tool. Brass beads threaded on the wire on both sides of the "D" ring act as miniature thrust bearings, and aid the swivelling action of the "D" ring. The brass swivels relieve torque on the mainline which occurs when the line is being brought in by the hauler.

Branchlines, snoods and hooks

The branchlines are made of 2 fm. lengths of 261 thread line. An "AK" snap is spliced into the upper end. The lower end terminates in an eye splice for securing snood and hook. The snoods are fashioned of 6 ft. lengths of ·066 in. diameter 7 strand galvanised wire. The upper end of the snood is fitted with a section of ⅜ in. rubber tubing which serves as chafing gear. The hooks, 8/0 or 9/0 tinned, are of a special shape with bent shank which allows them to hang in line with the snood.

Floatlines

Floatlines are made from 10 fm. lengths of 261 thread line. The lower end of each line has an "AK" snap for attachment to the mainline. Snaps are clipped to loops in the line, rather than to "D" rings, since it has been found that "D" rings and wire bridles do not hold up under the incessant jerking caused by the rise and fall of floats with sea and swell.

Storage tub

Shown in fig. 1 is a schematic drawing of the wooden tub used for storage of the mainline. The experimental model used aboard the Fish and Wildlife vessel, "John R. Manning", is a double-walled plywood cylinder measuring 12 ft. in diameter and 4 ft. in depth. The capacity is sufficient for the storage of 100 baskets of gear. For greater ease in shooting the tub is mounted near the stern of the vessel, but adequate space between tub and railing is left all around. The drum is supported in the centre by a heavy bearing bolted to the deck; the outer edge runs on cast iron rollers of the type used to support the turntable of a purse seining vessel. Reinforcing bands of 3 in. strap metal are welded around the outside of the tub for extra support, and 33 stainless steel shooting pins are spaced at equal intervals inside the tub.

The gear is hauled by means of a longline winch of conventional Japanese design. Electrically powered by a 3 h.p. motor, the winch brings the line in at a maximum rate of about 1,000 ft./min. and coils it down automatically with only slight assistance from the winch operator. The hauler is mounted so that the line is thrown just over the edge of the tub.

The shooting trough, similar in design to that used in the Northwest Pacific halibut fishery, is a demountable sheet metal form used to guide the outgoing mainline during shooting.

OPERATION OF THE GEAR

Preparation

Before sailing, baskets of mainline are joined together and fed through the Japanese line hauler into the tub. No attempt is made to coil the line down uniformly into regular piles, but it is deflected by hand so that it is evenly distributed in thickness over the bottom of the tub. As the "D" rings pass through the hauler, they are caught and threaded upon the shooting pin nearest the hauler. All fourteen rings of one basket are placed on the same pin and the knot marking the end of the basket is looped on top. The tub is then turned by hand until the next shooting pin comes in line with the winch. To avoid piling up the line, the baskets are spaced on every other pin; when the tub has completed one revolution, a second and finally a third layer of line is laid over the first so that 99 baskets are held on 33 shooting pins. The tub is covered with a canvas tarpaulin to prevent the line from being displaced in rough weather.

Shooting

When shooting the tub is rotated by hand until the uppermost basket comes under the shooting trough. The vessel is steered on a steady course at a speed of up to 9 knots. The buoy and floatline, marking the end of the set, are attached to the mainline, which in turn is led through the trough, and the assembly is thrown overboard. Thereafter the drag of the gear pulls the mainline overboard as the vessel proceeds.

Hooks are baited with sardines, *Sardinops caerulea* (Girard), or herring *Clupea pallasii* (Valenciennes). Individual branchlines are attached to the mainline by clipping the "AK" snap at the upper end of the branchline to the uppermost "D" ring. They are then laid in the shooting trough one by one with the hook and bait dangling overboard. Floatlines are attached in the same manner. As the end of each basket leaves the shooting pin, the tub is turned to keep successive baskets in line with the shooting trough.

Hauling

The gear is hauled through side rollers on the starboard side of the vessel. The mainline is led through the hauler and coiled into the tub. As branchlines come aboard, the winch is stopped momentarily and the "AK" snaps are removed from the "D" rings. The branchlines are coiled in specially built plywood boxes and are stowed with hooks exposed on one side and with the "AK" snaps held by clips on the other. Fish are gaffed and brought aboard through an opening in the bulwark. The line is stowed in the tub as described before, with three baskets of "D" rings being placed upon each pin.

Broken or tangled portions of mainline are removed by unknotting the line section junctions, repaired, and joined to the end of the mainline when fishing finishes. Because the sections are identical they need not be restored to their original positions.

CONCLUSIONS

Tub longlining, in particular, seems applicable to small vessels carrying a limited number of men.

The saving in labour is considerable. Since a basket of POFI gear weighs about 40 lb. when wet and a day's set may consist of up to 100 baskets, about 4,000 lb. of wet line would have to be cleared out and restowed by hand for each day's fishing, when using conventional methods. The POFI tub method eliminates all man-handling by flaking the line directly into the tub.

Five men were found sufficient to operate the gear, as against a crew of 11 men required for conventional gear. Both methods require, for each basket of line, about 1½ min. for shooting and 3½ min. for hauling.

Some difficulties in operation have been experienced, the most troublesome being excessive wear and tear on the mainline, due to the "D" rings running at high speed through the overside rollers and longline hauler. At high hauling speeds, "D" rings strike the rollers or hauler with enough force to bend the rings or break wire bridles. Much needed is a method of joining branchlines to the mainline by a system which permits swivelling freely in any direction but which offers little resistance to passage through the line hauler.

One difficulty anticipated, which failed to materialize, was fouling of the mainline during shooting operations. Provided that the shooting trough is properly designed, the outgoing mainline runs smoothly in it and fouling is less than when shooting by conventional methods.

All POFI tubs are rotated manually. Mechanical rotation has not yet been installed but, if used commercially, powered tubs should increase efficiency.

DRIFTING LINES FOR LARGE PELAGIC FISH

by

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Abstract

This paper describes a floating longline which is left free to drift independently of the boat handling it. It is used for the capture of pelagic fishes, such as swordfish, and different species of marlin, bill-fishes, sharks and big tuna, in the open sea.

Each fishing boat works with several sections of line but independently from one another and at a certain distance apart, usually about 150 to 200 m.

Les palangres dérivantes pour les grands poissons pélagiques

Résumé

L'auteur décrit une palangre flottante qu'en laisse dériver librement sans relation avec le bateau qui la pose. Elle est utilisée pour la pêche des grands poissons pélagiques tels que l'espaden, le marlin, le voilier, les requins et les grands thons en haute mer. Chaque bateau met plusieurs lignes à l'eau, généralement à 150-120 m. l'une de l'autre et elles sont transportées sur une grande surface de la mer par les courants. Chaque ligne se compose d'uns grande bouée, une ligne principale et trois ou quatre petites bouées portant chacune une ligne de pêche avec avaçon de fil d'acier et hameçon. Les lignes sont marquées par des pavillons le jour et par des lampes la nuit.

Los palangres de boyas para pesca en deriva de grandes especies pelágicas

Extracto

En este trabajo se describe un palangre flotante de deriva para la pesca de grandes especies pelágicas como emperador, aguja, tiburón y atún de gran talla en alta mar. Cada beta tienoe varias secciones de palangre que se sitúan a 150 o 200 m. aparte unas de otras, y son arrastradas a gran distancia por las corrientes. La sección está compuesta por el siguiente equipo: una boya de caja de aire, la cuerda madre, 3 o 4 boyarines, cordeles de pesca y "pelos" de alambre de acero galvanizado, banderolas para localizarla de diao y faroles que permiten determinar su posición durante la noche.

LARGE pelagic fish such as the several species of sail-fish, swordfish, sharks, and, occasionally outsize tunas have for many years been caught by Cuban fishermen along the north coast of the province of Havana and zones close to Pinar del Rio and Matanza, with small boats measuring from 16 to 25 ft. (5 to 7·5 m.). The boats carry a crew of two men, hooks being usually baited and the gear generally prepared before sailing. When bait is not available on the market, the fishermen first go fishing for sandeels (*Malacanthus plumeri*, Bloch) which they then use as bait. These are found on sandy bottom in between 12 and 30 fathoms depth.

Usually three sets of handlines were operated; one called "el hondo", which was the longest, reaching a greater depth, and taken care of by the fisherman seated at the stern; the other, called "de la mano", attended by the skipper from the central seat, and the third on the prow, fairly short and suspended from a pole.

THE FISHING GEAR

From the above system the presently used method was evolved which consists of fishing several independent sections of "short longlines" with four hooks each. Each motorboat (see fig. 1) can set from ten to fifteen sections (40 to 60) hooks. Each section of line consists of a mainline made of hard twisted cotton of 7 mm. diameter, to which the four branch lines made of No. 180 extra hard-laid cotton are attached.

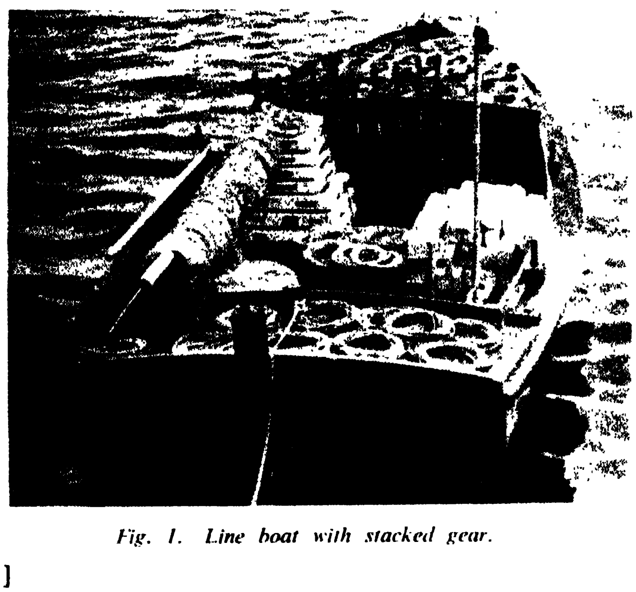


Fig. 1. Line boat with stacked gear.

Fig. 2. The hooks used in this fishery.

When fishing for shark or swordfish each branchline has a snood made of galvanised wire cable with a breaking strength of 920 kg., and No. 2 heavy type steel wire to which the No. 16 Mustad hooks are attached (see fig. 2). When fishing for smaller fish species lighter snoods and smaller hooks are used.

Each section has a marker buoy with flag. These buoys are 60 cm. square boxes and about 9 cm. high; they are constructed of marine plywood 1·5 cm. thick over a hardwood frame, copper nailed. They are made watertight by closing all joints with marine glue and several coats of good quality paint. In one corner a pole pot is built in to carry the marker flagpole. The flagpole is 1·60 cm. in length and carries a counterweight at the lower end. Each buoy has 2 lights during night, an oil lamp and an electric light fitted to the pole top. These buoys are very strong and can withstand the high pressure arising when the buoy is pulled under by large fish.

At each intersection of the branchlines with the mainline a small float is attached; these are made of solid wood of high buoyancy and have a truncated pyramidal shape, the base having about 13 cm. side and about 50 cm. long.

GENERAL INFORMATION

Off the Coast of Cuba the migration of White Marlin (*Makaira albida*, Poey) reaches its peak from April to July. In the case of Blue Marline (*Makaira ampla*, Poey)

Fig. 3. Method of attaching the bait.

Fig. 4. Salted bait hooked, ready for fishing.

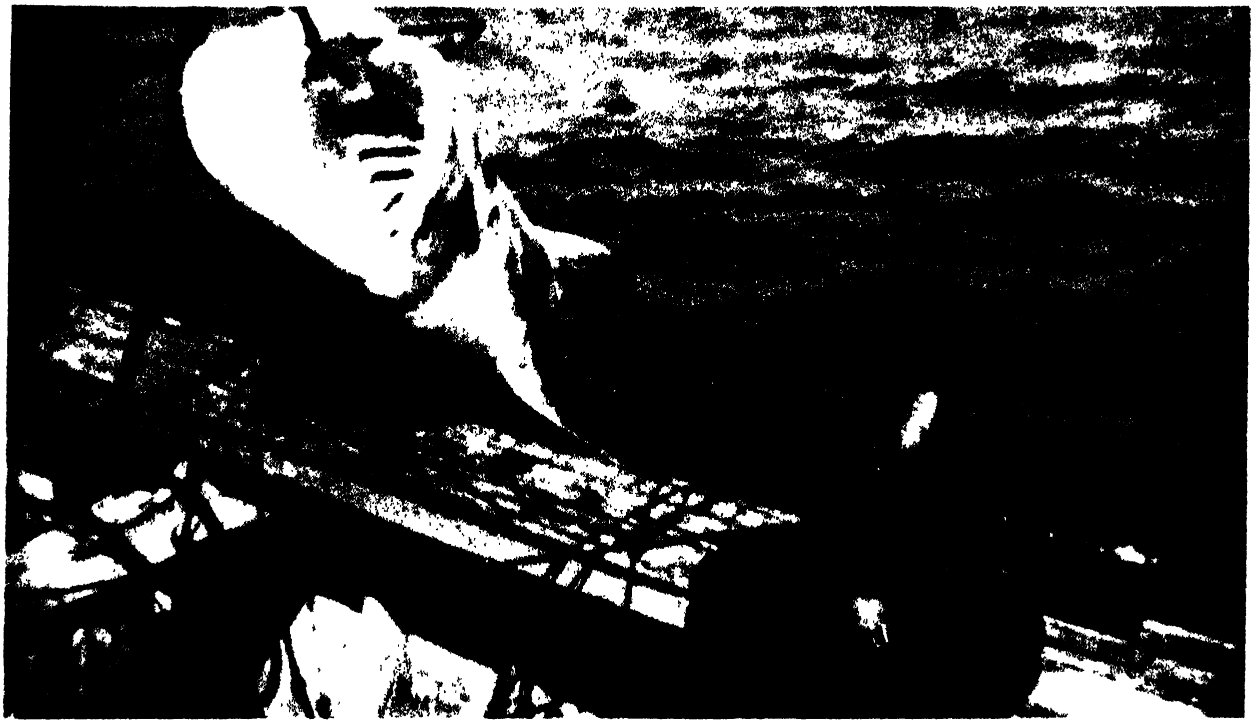
from July to October or November, but increase with the arrival of the first North winds. Swordfish is caught all the year around, at night, but mainly during the Winter months. The days when the catches are abundant depend upon the intensity of marine currents, which generally have a West to East direction and a rate of about 2½ knots. Best catches are made during strong tides due to the movement in the branch lines which tend to hang vertical during slack tides.

On clear nights, with intense moonlight, swordfish leave the surface layer and longer branch lines are used to fish deeper than on dark, moonless nights.

As bait any "white fish" of adequate size may be used. Among the appropriate species are: Spanish Mackerel (*Scomberomorus maculatus*, Mitchell), Bonefish (*Albula vulpes*, Linnaeus), Striped Mullet (*Mugil cephalus*) and other similar species such as the Barracuda (*Sphyraena guachancho*, Cuvier et Valenciennes). The bait should go over the hook so that it covers the shank; only whole fish are used and usually placed on the hook with the head down while the tail is tied to the wire to fix it in position (see fig. 3). Smaller bait such as sardine are baited through the body or through the eyes.

FISHING OPERATION

When a large fish strikes, it submerges pulling the buoy and rest of the line down with it. When this is observed from the boat the fishermen take up the gear and play the line until the fish can be brought to surface exhausted. The fish is then gaffed, stunned or killed and finally hauled aboard. The sections of line are set at 100 to 150 m. distance, so that a boat working 10 sections covers a distance of about a mile.



Shark longline being hauled mechanically on a 22 ft. open motor boat by a FAO expert off the Coromandel coast (India). Photo: FAO.

POWER HAULER FOR LONGLINES

by

IZUI IRON WORKS CO. LTD.

Tokyo, Japan

Abstract

The tuna longline fishery in Japan has been made much more effective since the first line hauler was made in 1923. The old method of hauling by hand was extremely slow and as much damage was done to the fishermen's hands, continuous working was impossible, and the fishery began to decline. After many trials and numerous failures, the hauler was perfected and there are now more than 8,000 in use in Japan, Brazil, Hawaii and the United States. The hauler is operated from a self-contained motor or an auxiliary engine through a counter-shaft. It takes 3 h.p. and hauls at a speed of 150 to 180 m. / min., and depending on the weather conditions and the construction of the gear and the vessel, it may take up to 12 hrs. to haul the 300 units of lines which constitute the usual fleet. Each unit consists of about 200 fm. of mainline so the total length of line used is about 60,000 fm. The line hauler consists of three parts, the lower one containing the motor and the gears, the middle one housing the speed governor which adjusts the tension on the line and prevents damage, and the upper part holding the set of three pulleys which wind in the line automatically.

Treuil à palangres Izui

Résumé

Le rendement de la pêche au thon à la palangre a considérablement augmenté au Japon depuis l'apparition du premier treuil à palangre en 1923. L'ancienne méthode de hâlage à la main était extrêmement lente, et comme elle blessait les mains des pêcheurs il était impossible d'assurer un travail continu et cette pêche s'était mise à décliner. Aprés un grand nombre d'essais infructueux, le treuil a été mis au point et il en existe actuellement plus de 8.000 en service au Japon, au Brésil, à Hawai et aux Etats Unis. Le treuil est actionné par un moteur électrique faisant corps avec l'appareil, ou par un moteur auxiliaire et un arbre de transmission. Il absorbe une puissance de 3 CV et vire la palangre à raison de 150 à 180 mètres-minute; suivant les conditions du temps et le type d'engin et de navire, il permet de rentrer à bord en 12 heures au maximum les 300 palangres qui constituent l'équipement normal d'un thonnier. Chaque palangre comporte environ 200 brasses de ligne principale en sorte que la longueur totale des lignes atteint 60,000 brasses environ. Le treuil à palangre se compose de trois éléments: l'élément inférieur qui renferme le moteur et les engrenages; l'élément central qui comporte le régulateur de vitresse qui règle la tension de la ligne et empêche qu'elle soit endommagée; et l'élément supérieur sur lequel sont montés les trois tambours qui récupèrent automatiquement la ligne.

Chigre para levantar palangres

Extracto

A partir de 1953 en que se fabricó el primer chigre para levantar palangres, la pesca de atún con este arte se hace en forma más efectiva. El antiguo método de izarlo a mano era extremadamente lento y dañaba considerablemente la mano de los pescadores imposibilitando el trabajo en forma continua, lo cual influyó en la decadencia de estas pesquerias.

Después de muchos ensayos y fracasos se logró perfeccionar un chigre con un motor acoplado directamente o uno auxiliar que se conectó mediante un contraeje. Este equipo permite recoger entre 150 y 180 metros de cuerda madre por minuto según el estado del tiempo, la construcción del arte y del barco, y en 12 horas podría izar a bordo un palangre corriente formado por 300 unidades o canastos de 200 brazas que, una vez unidos, dan una longitud de 60.000 brazas. El chigre consta de 3 partes: la inferior con el motor y engranajes, la del medio que encierra el regulador de velocidad para ajustar la tensión del arte e impedir que se dañe, y la superior que sostiene las 3 poleas destinadas a izar automáticamento la cuerda madre.

En la actualidad existen unos 8.000 aparatos como el descrito en Brasil, E.U.A., Hawaii y Japón.

GENERAL

TUNA fishing in Japan was quickly expanded with the introduction of hot bulb engines, but the method of operation remained old-fashioned and primitive. It took a very long time to haul the longlines, and the hands of fishermen were often lacerated. Continuous working was impossible and the fishing began to decline.

The first Izui line hauler was completed in Shikoku Island, one of the main bases for tuna fishing, in 1923. But the fishermen hesitated to adopt this new method before it had been successfully demonstrated by the inventor, who owned a fishing boat himself. At present some 8,230 Izui line haulers are used in Japan, Brazil, Hawaii, and the United States.

CONSTRUCTION

The body of the line hauler is made of cast steel and the pulleys of gunmetal and rubber to prevent wear on the lines. The middle and lower part of the hauler contain oil which is automatically fed to the working parts. The lower part contains the driving shaft, two gears to change the speed, and the stopping handle. A speed governor, installed in the middle part, compensates for excessive strain which may be caused by water resistance or a big catch, to prevent the wearing or cutting of the lines, and at the same time keeping the fish on the hooks.

The upper part of the hauler consists of three pulleys which wind the line automatically. The line is led

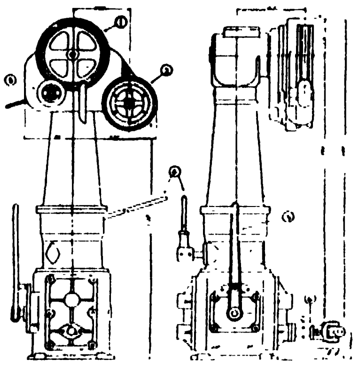


Fig. 1. Construction drawing of Izui line hauler for longlines. 1 = Rope winding pulley. 2 – Rope drive pulley. 3 – Rope push pulley. 4 – Stop handle. 5 – Clutch handle. 6 – Driving shaft.

to the hauler through fair-leads in the ship's side.

The qualities of the different models of Izui line haulers available are given below:

Model	*Height mm.*	*Weight kg.*	*r.p.m. of shaft*	*Hauling speed m./min.*	*Size of Boat tons*
Special Size	1,504	402	220 to 300	184 to 254	100
Large Size (Standard)	1,406	282	200 to 300	144 to 216	30
Large Size (Lower)	1,258	280	200 to 300	144 to 216	20
Medium Size	1,155	185	230 to 280	75 to 91	10
Small Size	849	119	170 to 200	68 to 80	10

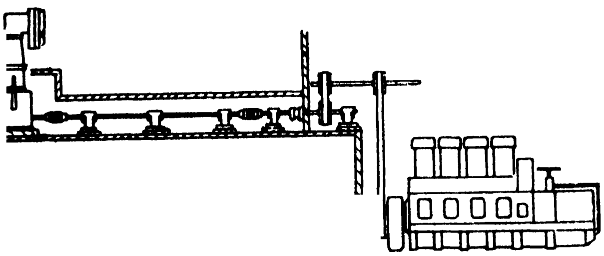


Fig. 2. Example of motor-winch arrangement when driven by the main engine.

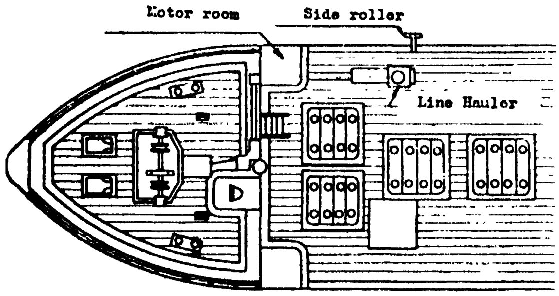


Fig. 3. Example of winch arrangement with auxiliary engine.

The power is either taken from a motor or from a main or auxiliary engine through an intermediate shaft. 2·5 to 10 h.p. are needed to drive the line hauler at 170 to 300 r.p.m. and a hauling speed of 68 to 254 m./min. It takes up to 12 hours to haul 300 units of lines, depending on the fishing vessel and gear, and the fishing conditions.

OPERATION

A Japanese tuna longline consists of the mainline to which the floatlines and the branchlines with hooks are attached. Usually 200 fm. mainline make one unit or basket. An ordinary vessel carries between 300 to 350 of such units, i.e. 60,000 to 70,000 fm. of longline.

The length and number of floatlines and branchlines per unit mainline depend on the kind of tuna to be caught and the fishing conditions. For *blue fin tuna* the floatlines are between 6 and 20 fm. long and for *albacore* even about 30 fm. long. For *blue fin tuna* one branchline with a big hook is attached between two floatlines which are 100 fm. apart. For *albacore* 12 to 13 branch lines with smaller hooks belong to each unit of mainline.

When a good fishing ground is found the lines are shot before sunrise. Since the lines are shot with considerable slack to bring the hooks into greater depth, about 100 units are shot per hour and the whole operation takes about 2 to 4 hrs. The vessel then usually returns and starts hauling the end of the line which was paid out first. Sometimes, however, depending on circumstances the lines are hauled in again immediately after shooting was finished.

AUTOMATIC STEERING SYSTEM FOR OCEAN-GOING FISHING BOATS

by

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Abstract

Automatic steering is usually associated with the use of the Gyro compass, but since 1946 some Japanese fishing vessels have been equipped with automatic steering which is used in conjunction with the magnetic compass. More than 100 vessels are equipped with "M.C.P." manufactured under licence from the Sperry Gyroscope Co., U.S.A. and their activities extend from the South Pacific to the Indian Ocean. The equipment operates by measuring the deflection from the plotted course by a controller fitted to the card-bowl of the magnetic compass, and, by fitting a portable remote controller, the ship can be steered by hand from any position on the ship outside the wheelhouse, a fact that will appeal to skippers supervising the shooting and hauling of their gear.

Système de pilotage automatique pour les bateaux de pêche de haute mer

Résumé

Le pilotage automatique est généralement associé à l'emploi du gyro-compas, mais depuis la dernière guerre, quelques bateaux de pêche japonais ont été équipés d'un système de pilotage automatique utilisé avec un compas magnétique. Cet appareil, connu sous le nom de "M.C.P." a été mis au point par la Sperry Gyroscope Co., Etats-Unis, et construit sous licence au Japon; il est considéré comme un élément indispensable pour tous les nouveaux navires de pêche de haute mer. Plus de 100 unités dont l'activité s'étend du Pacifique Sud à l'Océan indien sont équipées de cet appareil. Un appareil monté sur l'habitacle du compas magnétique permet de mesurer les écarts de route. Un dispositif portatif de commande à distance permet de gouverner le navire à la main de n'importe quel endroit du navire situé en dehors de la timonerie, ce qui intéresse particulièrement les patrons qui surveillent la mise à l'eau et la relevage des engins de pêche.

Sistema de gobierno automático para barcos pesqueros de alta mar

Extracto

El gobierno automático de las naves está generalmente asociado con el uso del compás giroscópico, pero desde la ultima guerra algunas embarcaciones pesqueras japonesas poseen un equipo de gobierno, también automático, que se utiliza junto con el compás magnético. Se considera que este equipo, conocido con el nombre de "M.C.P." y fabricado con licencia de la "Sperry Gyroscope Co.", de E.U.A., es indispensable para todos los barcos pesqueros de alta mar.

Más de 100 unidades que operan desde el Pacifico meridional al océano Indico cuentan con este equipo, cuyo funcionamiento se basa en la medida de la desviación de la ruta trazada mediante un regulador que se adapta a la cubeta del compás magnético. Con un dispositivo portátil de gobierno remoto, el cual seguramente atraerá a los patrones de barcos que supervisan las faenas del lance, es posible maniobrar el barco desde cualquier punto fuera de la caseta de gobierno.

GENERAL

A HUMAN helmsman, can for a short time steer as well as a machine, but he will quickly tire, lose attention and permit the vessel to wander off course. How long he can concentrate on his job depends on the manoeuvrability of the vessel and the state of the sea. An automatic pilot does not tire and will continue to steer with utmost precision, saving navigation time and fuel.

Automatic steering systems have been in use on large vessels for many years and have given excellent service. All these systems, however, rely for directional reference on the gyro compass which because of space and power supply limitations is difficult to install on small vessels. Since the Second World War automatic steering has become possible for small and medium sized vessels equipped only with a magnetic compass. Over one hundred fishing boats in Japan are today equipped with the Magnetic Compass Pilot and their activities extend from the South Pacific to the Indian Ocean.

The manufacture of the Sperry Magnetic Compass Pilot was started in Japan in 1953 under a licence agreement with the Sperry Gyroscope Co., U.S.A. It is known as "M.C.P.", and is now regarded as an indispensable instrument for ocean-going fishing vessels.

CHARACTERISTICS OF THE M.C.P.

The M.C.P. takes its directional reference from a steady dependable magnetic compass, which is compensated for deviation in the usual way. The controller fitted to the card-bowl measures the deflection from the plotted course and activates the steering engine through a power

Fig. 1. Magnetic compass and controller.

Fig. 2. Control panel and remote controller.

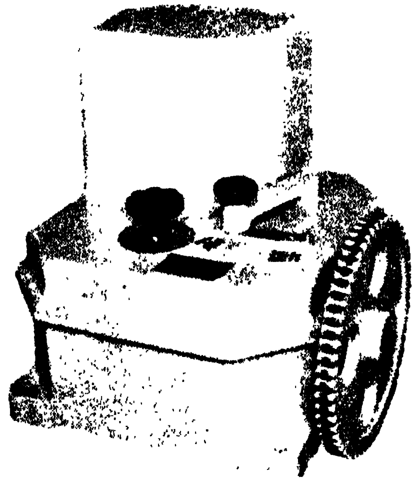


Fig. 3. Power-unit.

unit, to position the rudder with the exact amount required to bring the vessel on course again, as and when it diverges from the course to which the M.C.P. is set (fig. 1). While being sensitive to the slightest variation in course, the controller does not interfere with the movement and has no influence on the magnetic functions of the compass card. The same compass can therefore be used for handsteering in the usual way and the change-over from automatic pilot to hand steering and vice versa is done by an electric switch.

With the magnetic pilot it is not necessary to lay the vessel on course before setting to automatic steering; by setting the required course on the controller dial, the vessel will veer to the course set and be held there. The M.C.P. is fitted with remote control which makes it possible to steer the vessel by hand from any position on board. This allows the skipper to stand in the most suitable position to direct the fishing operations and at the same time have full control of his ship (fig. 2).

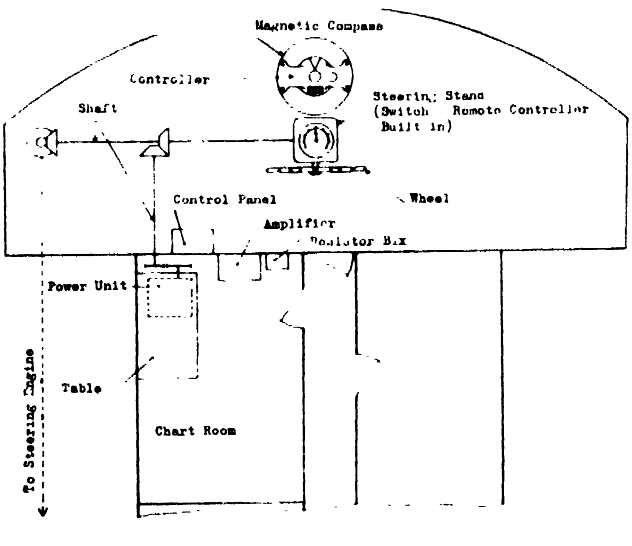


Fig. 4. General layout of installation.

INSTALLATION

The system requires 220 V or 110 V D.C. and consists of:
(a) Controller (c) Control panel (e) Power unit
(b) Amplifier (d) Switch box (f) Remote Controller

Being small and compact, it is suitable for fishing vessels. The controller is fitted to the compass which can stay in its normal position in the wheelhouse. Amplifier, control panel and switch box are mounted overhead in the chartroom where they are easily accessible for inspection. The power unit (fig. 3) is usually installed in the wheelhouse in a suitable place for connection to the steering gear. It should, however, be at least 5 ft. distant from the magnetic compass.

A plan showing the general disposition of the units in relation to the steering mechanism is shown in fig. 4.

DISCUSSION OF CHOICE OF FISHING GEAR AND SOME NEW METHODS

Mr. W. Dickson (U.K.) Rapporteur: In his gear classification Dr. von Brandt has listed most gears that have been used at one time or another so that you almost see history marching past. We come in at the tail end of this process, where mechanical, electrical and hydraulic power are firmly established. The tendency is to use more and more horse power per member of the crew with always new ways being introduced to eliminate hand labour. This process gives rise to a distinction between active and passive methods of fishing which was not so apparent in the past. In Northern Europe the two really important passive methods of fishing which remain are gillnetting and longlining. In Scotland and in Holland, too, I think, drift netting faces somewhat of a crisis, not unconnected, I believe, with the increasing use of mechanical power in competitive methods of catching. English, Russian and Polish dual purpose drifter trawlers are to be found drifting on the western edge of the Norway Deeps in the early part of the year. It is hardly likely that these boats would be drifting if they could do better by herring trawling, in that area, as herring trawlers are to be seen in quite closely neighbouring areas. There is a feeling of frustration about the passiveness of a drift net which is in the spirit of our modern times, but if you consider the water column filtered by a bottom or pelagic trawl and compare it with the probable water column fished by a drift net the advantages of the active gear are not quite so obvious. In more than one language there must be an equivalent of our English words "They also serve who only stand and wait". Perhaps we could discuss a more efficient way of handling drift nets and give an age-old method a new lease of life.

The demersal longline fishery extends to depths scarcely touched by trawls—down to 400 fathoms, and only scientists have fished deeper. At such depths the stress on the hemp line caused by its own weight and resistance through the water during hauling approaches its limits. However, it appears that the Australians have developed a method of longlining in very deep water using wire rope. Lead pellets are clamped on to the standing line at intervals, while the snoods with the baited hook at the end are clipped on to the main line as it is shot. It is my hope that something can also be made of this in the waters fished by our Scottish line men.

In my country other passive methods have declined in importance and are only used now for the catch of lobsters and salmon, and this by lack of choice in obtaining the product in any other way. Fukuhara, Rasalan and Kanamori all deal with types of gear used in the Far East which are more or less passive, involving the use of light attraction. There is an intriguing comparison or choice in the use of power, whether to use it to bring the fish to your gear as they do, or use it as we do to bring the gear to the fish. These attraction methods may be of interest primarily to the biologists to develop them fully and will need the cooperation of technologists

This brings us to the question of cooperation between biologists and technologists, on which we will hear more in a later section. There are a number of problems which the biologists could help to solve for the technologists, which would help in choosing the gear to use, or as basic data from which to start designing new gear. Such as for instance: at what speeds can different species and size of fish swim? Although something has been done in this respect, only little data of practical value is available.

At what distance and in which way are fish effected by vibrations of given strength and frequency?

Which senses of fish are affected by the approach of gear, at what distance and in which way? Would it not be possible to work a small trawl in a small area walled off by gillnets and by diving, observe the changed reactions of the fish.

The approach to such problems of an engineer, left to his own devices, often appears quite inadequate to the biologist and vice-versa. The first step in obtaining good answers is to formulate proper questions and to this end it seems to me that many of the questions are best tackled by a team of two on an equal footing—one biologist and one technologist. Often the physiological and technical problems are so intermixed that it is hard to say who is the better qualified.

How much further will we be when we have answers to questions such as those posed. Well, minimum towing speeds for minimum dimensions of mouth opening of pelagic trawls could be calculated. We would have more idea of how large it might be possible to make the mesh in the fore part of trawls. Optimum theoretical positions of kites and wires could be calculated. Parts of the gear could perhaps be eliminated altogether or altered to be more effective. All these things are design parameters for the designer which at the moment he just has to choose more or less by guess work, not daring to deviate very far from standard practice.

This leads us to standard practice in bottom trawl design. Binns describes how the lower selvedge of a net is made some 10 per cent. longer than the upper selvedge. True it is, but does anybody know what happens if it is not 10 per cent. longer? The Danish seine net and some herring trawls have no such provision for slack in the lower half and they work all right. From a study of models on the effect of the extra length in the lower wings and belly, if would seem that when taking a cross section through the body of the net, the tension is in the top half—the belly being made longer but in fact, constrained to the same length as the upper net, bulges out and the selvedges rise to well above the midway line. Mark that the belly lines as they run to the codend have to rise to that height and if an attempt is made to buoy up the headline with floats to an undue extent, the belly lines pinch the net like a string tightened across a cushion.

A net is like a jacket, you can have a big one or you can have a small one, but having picked your size you cannot have your cloth in breadth and length as well. You have to choose between spread and gape. Now to help me understand what was involved in this choice, I once made two separate nets that could be mounted one above the other so that the bottom one took fish between the bottom and two metres above it, and the top one took fish between two and four metres from the bottom. There were of course changes in the percentages of fish which appeared in the top codend—changes for the type of fish, by day and by night and from one ground to another where the net was tried. To cut a long story short these experiments showed not only that sometimes extra headline height would be well worthwhile, but that at others it would be better to have your cloth in breadth. So think twice before you load a trawl up with extra kites and floats.

An important point is to have the towing load on to the lastrich of a trawl. As long as the meshes are open this can only be done as Ben-Yami has already described by lashing along the lastrich a line which is somewhat shorter than the lastrich itself. If a lastrich as braided is 10 metres long it will shorten to say 9 metres as soon as the meshes open up, therefore unless a line of 9 metres or less is lashed along the lastrich it will remain slack and no towing load can be put on it. This however is not generally accepted by net designers and fishermen.

There are several papers covering midwater trawling. Barraclough and Needler describe the whole process of design, testing and development of a one-boat trawl. It describes its performance in midwater as well as on the bottom, successful for winter herring but somewhat less so for the same faster summer fish. The whole story is a model of what cooperation between fishermen, technologists and biologists ought to be. It includes a well illustrated and neat way of handling long double spreading wires from behind the trawl board. Noel describes pair trawling started by the Leggatt brothers for sprats in the Thames. Akyüz describes how even a Vinge trawl, hardly the best instrument for pelagic trawling, caught plenty of anchovy in the Black Sea; Grouselle describes a new type of floating trawl. Larsson, who has spoken to us already of his pioneering work on this type of fishing gear, describes Scandinavian experience with three different kinds of floating trawls. Parrish reviews almost all the pelagic trawls, the factors governing the choice and the successes and failures that have been met. There remains only the use of midwater nets close to the bottom for cod which should be given more attention.

Süberkrüb describes patent otterboards for use in pelagic trawling and I suspect many of us here would like some guidance on streamlined otter boards from the naval architects present. By increasing the ratio of height to length of the board, by decreasing its angle of attack and by shaping, the lift to drag ratio can be very markedly improved; I understand, however, that to keep the same value of absolute lift, the board would need to be slightly increased in size.

The paper, by Baird, I have deliberately kept until last. It deals with what most people would call a side line, namely escallop dredges. But on careful reading it shows how much local fishing knowledge goes into such a seemingly simple decision as to choose the length of tooth and the tooth angle of these dredges. It shows clearly, I believe, how detailed the knowledge of a gear technologist must be and that he should only be expected to advise on methods and fisheries which come within his direct experience.

Mr. L. Soublin (France) Chairman: I think Mr. Dickson has brought forward most of the points which should come under review so that we are well briefed for the discussion of these subjects. I hope that we will now hear the fishermen themselves tell us the results of their own experiments. I realize they are a silent breed who don't wish to talk of their setbacks and are not very anxious to boast of their successes to their colleagues, because these then become competitors, but nevertheless I feel it would be very interesting to have the professionals who have worked in the various fields covered by the papers, to come forward and tell us something of their problems, experiences and results. I have personally made numerous tests with midwater trawls but I have never had a complete success nor a complete failure.

Captain D. Roberts (U.K.): Although as the Chairman says, I do not want to give anything away, I agree that we should speak up here. In all experiments I have made I can honestly say I have not done myself any financial good.

I was very interested in the paper on inclination tests of trawl boards and things like that. If I could improve the efficiency of my trawl doors 5 per cent. or 10 per cent. everybody would agree that that would be very, very good indeed; yet, on the other hand, I would have to spend quite a lot of time fiddling about to do it actually at sea and lose fishing time. It is not our job only to catch fish, as I said previously we must catch fish that will sell.

The fishermen I have in my crew work long hours and want to see a catch as the result of their work. Fiddling about with experiments does not appeal to them. I have found that my men like best to get into a rhythm of work and they work best when they know what they are working for. I know what their thoughts are at the moment, knowing I have come to this Congress; it is a fact that they will be saying "What the Hell will the old man want us to do when he gets back". They know I am going to come with ideas and upset their rhythm of work.

So if after six months' experiments I get 10 per cent. more efficiency from my trawl boards, I have lost possibly 20 per cent. of cooperation. I am pointing this out to you because I want you to see how difficult it is for us to do experimental work in a commercial ship.

Mr. Phillips is a man who has ideas all the time and he comes along to me quite often and says: "will you try this" or "what do you think of that" and I do make some effort to assist him in his work.

Two years ago he was playing about with a practice golf ball and thought: "this is what we want on the bottom instead of a bobbin filled with air"—just an ordinary banded sphere with very little resistance, no weight at all, and he manufactured some of these and thought: "now, I will test them severely and then hand them to a fisherman to try". He got two cars and took his string of bobbins down on the beach at home to see if they would sink into the sand and he towed them along on the sand at 3 to 4 knots. They did not dig into the sand—they looked to be perfect—he then thought: "well, are these really strong enough"—will they stand up to the hard bottom on which he knows my trawler works—so he took this string of bobbins to the Ironworks at Scunthorpe near Grimsby, where there are slag heaps. A friend of his there had two railway lines running parallel in amongst the works and they got two railway engines, and they attached the arc of bobbins on the wires just exactly as it would run on the bottom of the sea and towed them up and down at three knots. The bobbins didn't break - they were hardly marked and they appeared to jump as they hit the different pieces of hard slag, they jumped up and over and gave us the impression they would do the same on the bottom and lift the belly over just as we wished. After watching that test for half an hour or so the speed was increased to 15 to 20 miles an hour, purposely to break these bobbins, but nothing happened.

Afterwards Mr. Phillips showed me a film of the test. He said, "I do not want you to try anything that is not good, look at this film, see what I have done, and then I want you to test my bobbins." After viewing the film I was convinced that I was on to something really good : I took the bobbins to sea and we tried them out first in rather muddy ground, but filled the trawl absolutely full of mud. My bosun who goes under the codend to release the catch— he does not think much of Mr. Phillips now! The next day I shot my gear on a hard bottom where I normally fish for flat fish. By engine pressures we noticed that the gear gave there more resistance so that while we thought those bobbins would give much less resistance, there was more. What is more, after three days we had broken half those bobbins.

We do not know what goes on down on the seabed, as one of the biologists pointed out to me. He also admitted that little is known about the pressure waves the trawl may cause as it is towed over the bottom, so there is an awful lot to learn as well. If, by using something new, we increase the efficiency of the gear by 10 per cent., but lose that amount in our crew's efficiency, there is no point in using the new gadget. When you consider the efficiency of gear you should bear in mind its effect on the crew; I mean our fellows work 18 hours a day and they have six hours of rest. By upsetting their rhythm of work and making them do work they are not used to—we are losing more than 10 per cent. in their efficiency and their cooperation and loyalty to the skipper.

Dr. A. W. H. Needler (Canada) : I was very much interested in what Mr. Roberts said because he is speaking about some very real difficulties. But the other aspect of the problem is that in order to test new kinds of gear we have to have fishermen and so the only solution that I know of is that after we have done what we can with research vessels and in laboratories and with models, we have to persuade experienced professional fishermen to test it under fishing condition before any piece of gear may be recommended to other fishermen to use in making their living.

I am being asked to say something more on the British Columbian midwater trawl. Well, I don't have anything particularly to add to the paper, except to say that although we do not claim that this is the best gear under all circumstances, it does work under certain conditions to catch slow moving schooled herring but less on fast moving herring.

At the moment we are unable to carry this experiment further for reasons of personnel and finance.

The scientists in catching plankton now use a high speed plankton net, which allows water to flow freely towards the centre of the net, but nevertheless collects small animals better than the net which has no hole through the middle. We made some preliminary experiments with this but the net that we constructed broke up—not being constructed strong enough. The idea may however well be worthwhile following up. The aim is to construct a net that could be towed faster and which would guide fish into the codend while relieving the hydrodynamic resistance of the net by allowing a free flow through the middle. The indications are that such a net can catch fish—we know that much—and I think ideas such as these will, in the long run, pay off. I may be pleading for a revolutionary idea, but very often it is the things that look a little bit silly at first that pay off later. The use of electricity, as we know it today, all came from an imaginative old bird who pushed magnets through loops of wire and wondered what would happen; he had no idea that this was going to be one of the principles most useful in industrial development.

Commander M. Melo de Carvalho (Portugal): I think that most of us at this session have read with interest Dr. Miyamoto's paper dealing with the relation between otter trawling gear and towing power. I think it would be very important to know from the technologists present and from fishermen what their points of view are in this matter.

The weight, the dimensions, the shape of the otter doors, the position of the brackets, the best working position for the towing point, the length and the size of the warps, are arrived at by hit and miss methods by the fishermen in my country. I would like to know from the technologists and the experienced fishermen present how they go about deciding on such measurements.

Mr. A. O'Grady (Australia): Those concerned with fisheries in Australia are particularly pleased that improvements in fishing gear and methods are being sought on an international basis. I say we are particularly pleased, because Australia is now at the commencement of a programme in fisheries development by way of improvements in the gear at present in use, and change over to new gear; also in the seeking of new fishing grounds following on the fisheries at present being conducted.

Our tuna fishermen use a lampara net for the capture of live bait at night, which is very light and comparatively cheap due mainly to the large meshes in the wings. It is very successful for the taking of live bait using light attraction at night, but unfortunately does not seem to give the same results during daylight. I have conducted experiments with a model and the results suggest that in daylight the net should be partly pursed. This will be tested under actual fishing conditions at the first available opportunity.

Mr. Dickson, Captain Ben-Yami and Captain Hodson have spoken already of their methods of allowing the headline to rise high by taking the strain off the head and placing it on the lastrich line. This is actually being done with one type of prawn trawl used in Australia for catching one particular species which apparently swim much higher than the bulk of the prawns which are caught in Australia. Some of our fishermen have actually measured the rise above the bottom and in some cases it has been 12 ft., which is quite an improvement on the height at which we fish normally.

I was surprised to learn from Mr. Dickson that in Great Britain the Danish seine net is hung so that the headline and footrope are of equal length. It has been our practice for many years now to have the headline shorter than the footrope, so that the footrope is allowed to work the bottom. Some years back when I was actually engaged in this fishery, we were hanging so that each wing of the footrope was one foot longer than its headline counterpart. Today that has been reduced to approximately five or six inches, the footrope therefore being 10 to 12 in. longer than the headline.

I have been asked to speak on advanced developments in fishing gear, and one has been suggested—the use of wire longlines. Wire longlines, made of ½ in. circumference steel wire rope have been used for the capture of shark for table food in in the Southern part of Australia. However, one operator—a very good and a very successful shark fisherman and owner of three vessels tested the steel longline gear, and found that he had to revert to the use of the gear in common use, that is natural fibre rope—manila or sisal—because of the heavy losses sustained by fouling up at the bottom, it was an uneconomic proposition. However, another method was actually introduced by Captain Ardiani, the master of a fisheries research vessel operated by the Division of Fisheries and Oceanography of the CSRIO. For this method a flexible galvanised steel wire rope approximately ½ in. circumference is operated from a hydraulic reel. A sinker, of course, is attached to the end of the line and several leads are stopped on, approximately one fathom apart where snoods and hooks are attached. This method has been used in depths of up to 300 fathoms. As in such depths it would be impossible to feel when the sinker and hooks had touched the bottom, it has to be used in conjunction with a depth recorder and a metre for measuring the length of wire rope which has been lowered into the water. Apparently this method is already successful, the particular Captain I have referred to who developed it is now launching his own vessel to engage in this fishery.

Mr. W. Dickson (U.K.): I just want to correct—I seem to have given the wrong impression to Mr. O'Grady, about the hanging of seine nets. Actually in Scotland, we do have the headline considerably shorter than the groundrope, for haddock and whiting fishing it is certainly as much as seven feet shorter than the groundrope. For plaice fishing, well the two have either the same length or the headline is only very little shorter than the groundrope. But that was not what I meant.

I meant that the hanging of the webbing is not more loose on the footrope than it is on the headline, whereas in trawl nets the netting on the headline is set more tightly to the ropes than it is along the footrope where more slack is set into it.

Mr. J. Jakobsson (Iceland): I am really talking here on behalf of the fishermen of Iceland, who are attending this Conference. They should themselves tell of their experiences, but I think they find the language difficulties rather too great to come up here.

As opposed to the experiences of Captain Roberts, some of our captains have had real success in experimenting with new gear. I am especially referring to Captain Ingimarsson, one of Iceland's crack skippers—as far as I know he still holds a sale record in Aberdeen where he sold the catch of a single trip for over £19,000 in 1948. Captain Ingimarsson realized very soon after the development of the echo sounders, there were sometimes, especially during April, very heavy concentrations of fish over a rough bottom off the south coast of Iceland. It had been tried to trawl there time and again and usually the nets got torn very badly. Not only were these heavy concentrations of fish over very rough bottom, but also they were quite often in midwater. The idea, therefore, occurred to him and many other people fishing on these grounds that midwater trawling was the answer and in 1952 the captains themselves for the part with some assistance from shore people, developed what is known as the Breidfjord trawl. It has been successful for cod fishing in late winter during the spawning season when there are very heavy concentrations of fish.

The special feature of this trawl which I think is rather unlike most of the midwater trawls I have seen drawings of, is that the headline legs are not connected to the otter doors but to the actual trawl warps far in front of the otter doors, which means that the vertical opening of the trawl is secured and no extra kites or other lifting devices are needed. This is actually drawn in Parrish's review of various midwater trawls. Parrish does suggest that kites are sometimes used but for cod fishing I do not know of any skipper who has used kites. The vertical opening is actually secured by the nature of the arrangement of wires.

Now, after this trawl had been used successfully for some years, we tried to fish herring as well as cod and I was lucky enough to be offered to work on this with Captain Ingimarsson last November. We had a fairly big nylon midwater trawl with a square mouth of 70 to 62 ft. and we tried this rope arrangement. Unfortunately, we were extremely unlucky with the weather—the Atlantic then was at its very worst. We had gale after gale for three weeks but we got the trawl into the sea several times and we were not successful using the customary arrangement of wires which is used for the cod trawl. There were quite heavy concentrations of herring, but we only caught very small amounts and we suspected, without knowing of course, that the wires going from the headline to the trawling wires were very much above and directly ahead of the mouth of the trawl; even if they did not scare or frighten cod, it might affect herring. So we tried to connect the headline legs to the otter boards and then, of course, the old question of vertical opening immediately became very acute. We therefore used kites and heavy weights at the ground rope and considering the echo recordings, I think that our catches were reasonable. But in actual fact this was an unfinished experiment because of the bad weather. We hope that we will be able to continue this very soon and experiment further with pelagic herring trawling in Icelandic waters.

The British Columbian trawl has been tried out to some extent in Icelandic waters by a relatively small boat, but it has not met with success so far.

I would also like to point out that Captain Ingimarsson and I were using a large trawler, a 180 footer with approximately 1,000 h.p.

Mr. B. Parrish (United Kingdom): We have heard many examples of the kind of problem which fishermen and technologists and those concerned with the effective operation of fishing gear are faced with in different situations, in different areas and at different times. All the problems appear to be a combination of two main factors; the technological efficiency of the gear and the biological characteristics of the species of fish which they are catching. The biological features of the fish one is trying to catch are important when making a choice of fishing gear. In areas where fishing is being introduced the first problem will be to decide what type of gear to use. There are two ways to tackle this problem, firstly, one can take all the existing types of gear and try them out, retaining the gear which proves successful. This would obviously be completely uneconomical. The second way would be to collect information on the biological characteristics of the fish in the region, and make the choice on the basis of such knowledge.

An example of this is the problem we are faced with in Northern Europe in relation to herring. Traditionally, the herring fisheries were drift net fisheries because of the particular biological characteristic of the herring to come to the surface layer at night. Then trawling was introduced in herring fishing in Northern Europe due to the other biological characteristic of herring, that during the daytime herring seeks the bottom layer near the seabed, and can then be caught in traditional trawl gear. Trawling for herring which was developed in the regions where distribution of the herring near the seabed was particularly suitable proved profitable. Since the last war, there has been a tremendous expenditure of effort in assessing whether herring trawling would be a suitable alternative to drift netting in different parts of the Northern European region.

Many of these experiments have been conducted wastefully because had the biological characteristics of the herring been studied in those regions before the experiments were carried out, it would have been quite clear that the herring trawling was not the practical alternative to drift netting, simply because this habit of herring seeking the lower water layers during the day time, is not a general characteristic and in fact in some regions, the herring distribute themselves in midwater.

Mr. K. H. Larsson (Sweden): It is a well known fact that the trawl takes almost everything that comes before its mouth -- big fish and small fish alike together with other sea animals -- and therefore, in the last years much concern has been felt regarding over-fishing for instance, in the North Sea. Many people are also worried about the damage wrought by the bobbins and footropes. The North Sea Convention has been established to preserve the fish stock and it must be kept in mind that trawling gear should be so arranged as to save the small fish if possible.

Trawl doors of the usual oblong shape make much damage to the sea bottom and the animals living on it, when they are ploughing through the mud. In designing the midwater trawl, I constructed trawl doors which can be towed along the ground a little, say 2 to 10 ft. above the seabed. The footrope of the trawl net then does not touch the bottom, but travels just above it. I think this would be a good idea to avoid damage to the bottom and, at the same time, save most of the small fish. Another point to be mentioned in connection with such a trawl, is that the resistance of the whole gear will decrease considerably.

Dr. J. Schärfe (FAO): First, I would like to underline what Captain Roberts said, that it cannot be expected of commercial fishermen to make experiments. Of course, this work has to be done by governmental institutes using research ships. Furthermore, it is not enough to prove the technical superiority of a certain design but it also has to be worked out until it is completely reliable for commercial use.

One example of this are hydrofoil otter boards. Such boards have been tested in Germany since about 30 years and most of the experiments were carried out in close collaboration with commercial fishermen and resulting increased efficiency of these boards was acknowledged also by those commercial fishermen involved. But nevertheless such boards have not been accepted by the fishery, presumably because of the unsolved preliminary difficulties in operation. We now hope that hydrofoil otter boards may be introduced in midwater trawling for which purpose they are very effective. I believe that also the commercial comparative fishing test, which has to follow the technical experiment to prove the efficiency of a new design, cannot be expected from commercial trawlers but has to be carried out by governmental research vessels.

I would like to give another example in answer to the remarks Mr. Parrish made to the part the biologist has to take in the development of gear. Several years ago experiments were carried out to catch the big herring schools approaching the Norwegian coast in the early spring by midwater trawling, because the depth in which they appear outside the national limits is too great for other methods.

It was well known that very thick schools were to be expected and we really saw them on the echo sounder. Furthermore, there was no doubt that the trawl worked in the right depth, but nevertheless we could not get them. The reason may be that the behaviour of this herring being on a migration to the coast is quite different from the behaviour of other herring schools, which had very successfully been caught by midwater trawling in other areas and at a different season. These herrings obviously were too alert and avoided the gear. Similar experiences were made with the well-known Larssen two-boat midwater trawl—which works very successfully, for instance in the Kattegat but gave poor results in the northern North Sea and in Icelandic waters, despite the strong concentrations of herring there.

In the last two years a successful herring trawl fishery, also in midwater, has been developed in the southern North Sea in winter time. This fishery is interesting in regard to one still pending question in midwater trawling—that is the frightening effect of the warps. It is commonly thought that with two boat midwater trawls, the frightening effect of the warps leading from the boats to the trawl improves the catching ability of the net. On the other hand with the one-boat trawl the warps lead from one point, the sliphook, to the two wings of the trawl and then the frightening effect might chase the herring away from the net opening. Now, the German cutters in the southern North Sea use not only the two-boat trawl but they tried also one-boat trawls. As they did not have sufficient experience in bringing and keeping them in the depth desired, they attached big floats to the otter boards with strops of such length that the gear fished at the desired depth and they also got the herring.

I myself made some observations on the behaviour of herring towards the warp by means of echo-sounding. The echograms obtained over the warps compared with those taken by the towing vessel indicate that there is a frightening effect, but not a very effective one.

The herring avoid the warp and keeps a distance of about 2 to 4 m., but after the warp has passed the school closes again.

Mr. S. Springer (U.S.A.): A very large part of the work that I have been associated with recently, has been in the Gulf of Mexico, where there is a well-established fishery for shrimp, for red snapper and for menhaden. The point that Mr. Parrish made about the importance of the cooperation of biologists, fishermen and technologists seems to me to be a very important one.

In the Gulf of Mexico very little is known either by the biologists, the fishermen or the technologists. In this case it will have to be the fisherman who attacks the problem first, because until the fish are caught the biologists have no data to work on.

We have at times, I think, used the wrong approach to some of our problems, as for example when we attempted to use the midwater trawl for catching menhaden. If we had realized before we started this work that the menhaden are extremely active and fast swimmers, we problaby would have saved ourselves quite a lot of extra work. By aerial observation we found that in using a midwater trawl or almost any kind of trawl, the fish could easily be got in the mouth of the trawl, but they could not be got into the codend. We operated with three fishing boats for nearly a month only to find out that we could not catch menhaden. However, this trial and error technique is sometimes necessary in fishing for species whose behaviour is insufficiently known.

There is now a small longline fishery for yellow fin tuna in the Gulf of Mexico. It was not until 1952, I think, that the first individual specimen of yellow fin tuna was taken. Fishermen travelling over the area, had not observed them, probably because they do not show on the surface. We tried to catch them by trolling and were phenomenally unsuccessful. Live bait fishing and purse seining operations also failed so that we wasted a whole year before trying longlining, which in this area is now modestly successful.

Captain A. Hodson (U.K.): I would just like to mention that we all know from practical experience that between ships of the same firms, the same horse power, using the same fishing gear as designed and adapted by the owners, the catches. can differ vastly and consistently. This can be due to more skilled fishing technique, but also to a difference in rigging-up of the gear, which was found by experimenting. Such experiments carried out by individual skippers are unluckily mostly held secret and should be made public.

With regard to the question of over-fishing I would like to say that I don't agree with Mr. Larsson that otter boards cause much damage to the bottom. Further that over-fishing should not be attributed so much to the method of trawling but to the use of small meshed nets, such as those used for catching sandeel. That old saying "we cannot take out more than we put in" holds true here. In my opinion unbridled catching of small runner fish food such as sandeel should be controlled because they are food for the large fish and without that, the stock of some other species will soon be depleted.

Mr. M. Svetina (Yugoslavia): I represent the fishermen from Yugoslavia. Much has been said about fishing gear, but unfortunately very little about fresh water fishing. I would like to say a few words about salmon fishing in fresh water, which is carried out in my country as well as other parts of the world. For some years now we have successfully used drift nets in our lakes. Very poor results had previously been obtained with cotton nets, but since we use monofilament nets which are hardly visible, we can produce rather important quantities of trout and other fish. We also use with great success monofilament nets to capture minnows for breeding purposes. I should like to obtain some information about lake fishing in other parts of the world.

Another question concerns the fishing in artificial lakes. During the construction of such lakes, usually for electricity, no steps are taken to clear trees and other obstructions from the bottom, which later present very serious obstacles to fishing. We find these obstacles are quite a problem and I would like to know what is done in other countries in this matter.

Mr. R. S. Rack (Northern Rhodesia): I would like to say a few words on the application of new fishing methods to areas where primitive fishery exists, with special reference to lake fishing.

When introducing new ways of fishing it is best to first study the indigenous methods of fishing. These methods may not be the best, but they are the result of a great deal of experimenting and practical experience by fishermen. Sometimes new methods fail when introduced in primitive areas, not on technical grounds, but because of the attitude of the natives towards it, who for various reasons may object to its use. It is best to start by introducing better material from which to construct one of the locally known gear.

In Northern Rhodesia the amount of fishing has increased 8- or 10-fold through the introduction of nylon.

The question of cooperation between the biologist and the technologist seems to be no problem in our lake fisheries —each has his well defined part to do. The technologist implements the result of the biologist's survey by testing appropriate methods and passes his own results on to the fishermen. In the lake fisheries we are particularly interested in gillnet fishing because it enables us to control the size and the amount of fish which is taken.

Mr. R. Ocran (Ghana): Most of our fishermen still fish from dug-out canoes, but during the last five years motor boats are being brought in and used very successfully, especially during the herring seasons.

We also have a good line fishing whereby dug-out canoes manned by 6 men go out 60 miles along the shore, sound the rocks and fish for snapper over them. Each line has five hooks and these dug-outs can hook up to one ton of snapper in two hours. We have also beach seine fishing, and gillnet fishing. We have experienced the advantage of nylon and this is being used in increasing quantities.

Our problem is, however, the choice between the different kinds of synthetics that are being offered, such as perlon, nylon, marlon and others.

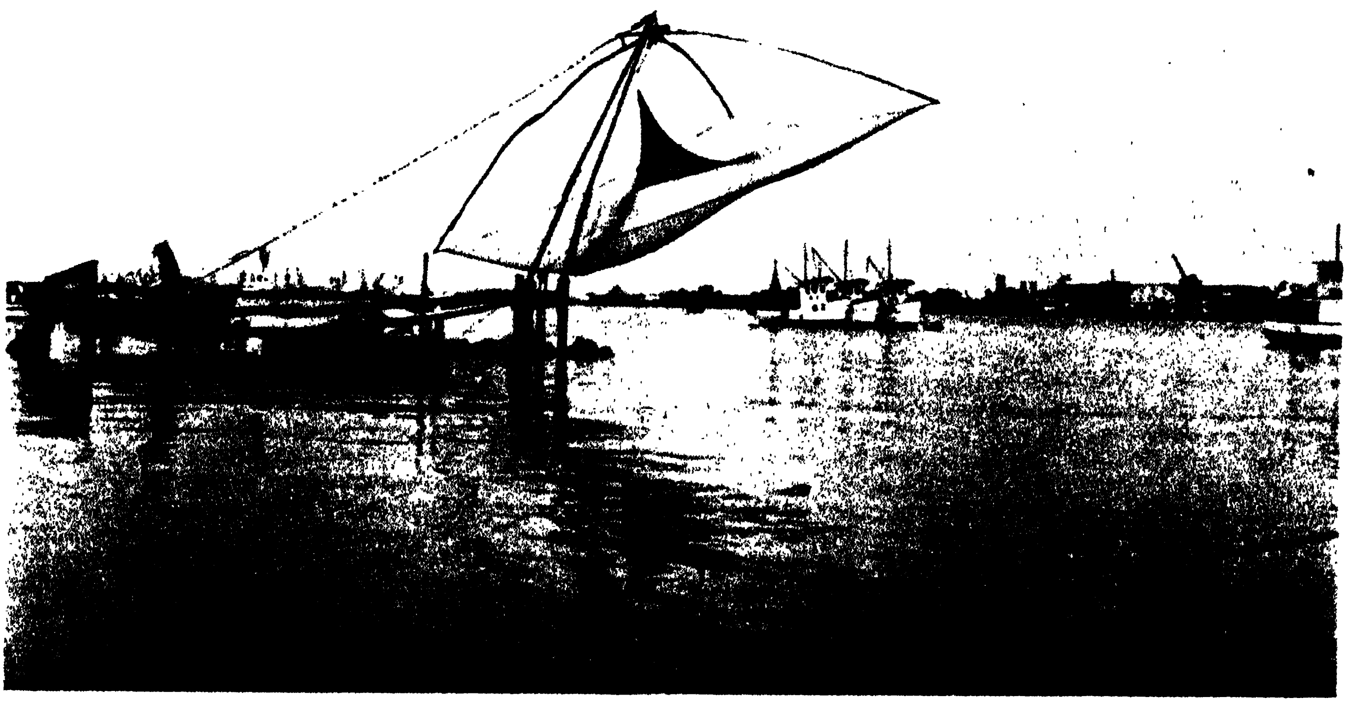
Mr. D. L. Alverson (United States): I would like to make a few comments at this time on some of the statements we have heard. With reference to earlier speakers on the effects of otter trawl doors on the bottom, I would like to state that I also don't think that they are detrimental to fish stocks.

Secondly on the problem of selecting a gear for a new area I agree that theoretically and possibly academically the biologist should first study the behaviour pattern to provide the gear technologist with data on which to base his choice of gear; but let us get down to reality. If we are in a new area or a new fishery is to be started where we know the fish exist, to begin with there is the difficulty of obtaining funds to study a fishery which does not exist. In the second place, the industry cannot afford to waste the time that is necessary to carry out such biological experiments which take considerable time. I have observed several fisheries evolve on the Pacific Coast of the United States and being a scientist I do appreciate the importance of experimentation. But to advise fishermen or to disseminate information on the selection of fishing gear for a new fishery, I believe the first step is to review the nature and methods that are in use and to discuss their efficiency with the local fishermen. Furthermore, the trial and error method, may not be the most thorough way of experimenting, but in the case of a new fishery, it is often the quickest way to obtain results. Where it concerns government research for the development of gear, I think it is important that the biologist, the gear technologist and the commercial fisherman work together. This is being done by the U.S. Fish and Wild Life Service; the crew for the research vessel *John N. Cobb* consists of top fishermen in trawl fishing, in gillnetting and seine fisheries and they are paid well.

The use of top notch fishermen working close together with the gear technologists on the spot has contributed largely to the success of the cruises undertaken.

Mr. I. Richardson (U.K.): Captain Hodson raised the matter of the type of vessel used for mid-water experimental trawling being not typical of the type of vessel that is commercially used. I may just very briefly outline the problems which have presented themselves to us during this work. Any gear of this square opening type of trawl is fairly easy to construct and observations show that this gear is opening and has roughly the right shape. The real problem is still to catch the fish and the only way to ascertain that, is by trying it out in your own particular locality. Because a gear works somewhere does not prove it will work in your area. It is the behaviour of the fish in a particular area that finally decides whether a gear is effective—not the mechanics of the gear, so that all such tests must finally be carried out for a particular fish in the particular area.

When we started experimenting on the midwater trawling in the southern North Sea for herring, we found that although we were sure of the mechanics of the gear, we still didn't catch them. Not knowing how the fish behaved towards the trawl we decided that towing faster we could neutralize whatever evading action the herring took, so a bigger vessel was used. This raised a new problem because immediately, the nets started splitting. The water resistance was too great for this type of net, made of the materials which we were using. This is where the technologists and the net makers could help us, to define the exact size and type of material to use. A new net of synthetic fibre was constructed and we began to catch a few fish but not enough. By then an instrument became available that told us something of the behaviour of the fish—the headline oscillator described by Woodgate. This instrument showed us that the fish were not going in to the mouth of the net, but passed just under the footrope all the time. Lowering the net didn't help, they were still going under the footrope. With the synthetic net made of thinner twine, we were getting a considerably higher speed. It was then observed that the fish were not escaping below the footrope any more, although the water was now clear instead of turbid as in the first trials. The net and the boat obviously had a scaring effect on the fish so that they took avoiding action. But to find this out some type of instrument was needed which indicates the fish distribution, the towing depth and shows how the fish behave. The echo sounder with headline oscillator provides these data and I think we can now go ahead with our experiments to find the optimum towing speed.



"Chinese" liftnet in Cochin, India.

DISCUSSION ON EFFICIENT HANDLING OF FISHING GEAR

Mr. H. Kristjonsson (FAO), Rapporteur: The handling of fishing gear and of the catch is closely connected with manpower, and the fishing industry in several countries is now facing grave difficulties in attracting men to the trade because of better opportunities offered by land based industries.

The only way of combatting this crisis is to improve the efficiency of fishing operations and to save manpower. This can be achieved in some cases by improving the method of operating the gear, in others by improving the work on board by better deck-layout and more use of mechanization. Line fishing is one of the fields where much effort has been made to improve the efficiency of gear operation. Yet it is surprising that such elementary and simple mechanical equipment, as the vertical line hauling gurdy, so very commonly used on all longline fishing boats in the Scandinavian countries during several decades, is still practically unknown in many other parts of the world. The Japanese tuna longline hauler described by the IZUI Iron Works is a more complex apparatus. The floating tuna longlines are extremely long, often 60 miles and more, and are hauled at a rate of 5 miles per hour as compared to cod lines in Northern European waters which are hauled at a speed of about 2 miles per hour.

Japanese haulers haul automatically, and by using line of appropriate stiffness, coil the line down, so that no handling of the lines is needed, only supervision. Such line haulers could perhaps be adapted to longlining for smaller fish, not so much to speed up hauling, but perhaps to reduce the number of crew needed at present and make work easier.

The exploratory fishing conducted in recent years has shown that productive tuna grounds extend really all round the world in a fairly broad belt in the tropics. Tuna longlining has therefore a much greater potential than ever before, but so far only Japanese vessels have been operating on a commercial scale, except for a few commercial boats which I understand, are working in the Gulf of Mexico. The Americans have tried out several modifications to streamline the operation and Mann describes such a new method of handling longline gear. The line is handled from a large, rotating tub, with a considerable saving in manpower. Instead of individual baskets of line which need joining and separation at each setting and hauling, a continuous mainline is set from and hauled into this tub.

The line is set at a speed of 9 knots running out over a setting trough or line shute. This is a simple device which has been used in Scandinavian countries for decades. It consists of a simple trough which pays out the line and allows the branch lines to swing out clear as the line is streamed out at full speed. The use of such a line shute is much more efficient than paying the lines out by hand at slow speed, getting things tangled up and the hands wounded. A step in the same direction is the steel wire line described this morning by Mr. O'Grady in which the line was wound on a hydraulically powered reel. A similar method was also tried for lingcod on the American West Coast some years ago. The idea was to have a system that would disconnect the branchlines from the mainline as it came aboard, stack them, bait the hooks mechanically and join them to the mainlines again as the line was paid out during setting.

This brings me to a question asked by Mr. Ocran from Ghana about synthetic materials for longlines. In Japan considerable use is being made now of Vinylon, under its different trade names, as a substitute for the previously used cotton lines. When I was in Tokyo last fall, Vinylon lines, which had been used for 4 years, were still as new. It appears that cotton lines of about 6 mm. diameter, when new, are thinned down to 5 mm. by stretching, having made about 100 sets during annual season. Although they still retain test strength, they have lost their elasticity and snap easily due to sudden jerks and are therefore unsuitable for the big tuna. This is pointed out as one of the advantages of synthetic line.

We now come to a more recent step forward in efficient handling of gear: the Puretic Power Block. On the Pacific Coast of America the generally high standard of living, and high income, has forced the fishermen to be more efficiency conscious than perhaps any other part of the world; in the handling of large nets, such as purse seiners, muscle power proved to be much too expensive. Already two or three decades ago, power driven rollers and later strapping of the nets from a high boom over the stern of the vessel, started the trend to mechanise the handling of these nets. Later drum seining was introduced, in which the entire net is wound on a large drum. This has found only limited application, mainly in salmon seining where you can use seines of a certain shape suitable to this application. The power block is an entirely new approach to the handling of such nets. It is claimed that at least two men can be cut from the traditional crew of herring and sardine boats on the Pacific coast. The blocks can be driven either mechanically, hydraulically or with a rope drive and are available in five different sizes to suit most sizes and types of nets. Apart from their now proved efficiency with purse seines, they can also be used with other nets.

Hauling of a purse seine with the power block is much quicker, particularly when there is no catch, taking only 8 to 10 minutes to haul. This greatly increases the chances the boats have of getting a school that was missed in the first try. It facilitates the work of the crew as no heavy weights need lifting by hand. We really need more fishermen like Puretic, who have a brain wave like this and the perseverance to see it through.

Saito in his paper points out the advantages of using the starboard side in operating a fishing net of the Danish seine type from a vessel with a righthanded propeller. Birkhoff's paper deals with operating the trawl over the stern as is used in some parts of the world and is in fact common practice in the Mediterranean and on the Pacific North West Coast. This method is better especially when using light gear with no heavy footropes and no bobbins. It simplifies manoeuvring and leads to a more rational handling of the gear on board. This method has lately been brought very much to everybody's attention in the Northern European countries because of the recent experiences with big stern trawlers, such as the *Fairtry* the Russian *Pushkin* class and the new German stern trawlers.

Birkhoff in his paper explains the various systems of handling the heavy trawl gear used in the North Atlantic over the stern shutes, and particularly the arrangement of the warps and the hanging of the trawl doors with and without gallows.

Although the systems described work quite well, experimentation is still going on to improve the efficiency and to speed up the operation. A particularly efficient solution appears to be that used on the German vessel *Heinrich Meins* which has a 50 m. long deck so that the net can be heaved aboard in one operation.

The Russians seem to have no special difficulties with their big stern trawlers except in handling very big catches, when it sometimes happens that the codend or the lengthening piece burst and the catch is lost. I understand they are seeking a solution to this problem in two different ways, first by strengthening the construction of the net and secondly by modifying the angle of hauling relative to the slope of the stern shute.

This brings up another related problem; that of shelter decks which can improve the working conditions on board and so the efficiency of the whole operation. A shelter deck such as built on the *Anton Dohrn* must make a tremendous difference to the fishermen who don't have to wear heavy, cumbersome seaclothes when gutting and otherwise handling the fish.

In another paper Birkhoff describes fleet operation of trawlers with a mothership but mainly in connection with the transfer of the catch from the catcher boats to the mothership. He mentions several methods used in such fleet operations and comes to the conclusion that one very efficient way is to detach the codend from the trawl and attach a buoy with radar reflector and light to it. The floating codend is then picked up by the mother ship and taken on board. Fleet operation is developing rapidly; the Russians now use hundreds of vessels in such operations and their factory ships are already operating in the North Atlantic, while others are being built. The Japanese have since long operated salmon and crab fishing with many catcher boats from motherships in the North West Pacific. Using advanced techniques of fish detection the "Admiral" in charge, sends out pilot boats in various directions to test the grounds. Their reports are interpreted on the main ship after which orders are sent to the catcher boats who are allocated certain fishing areas to operate in. By such methods it is possible to find where the concentration is heaviest and stay on the fish.

Closely connected to efficient handling of gear is the efficient handling of the vessel, and Suiyokai, a group of electronic manufacturers in Japan, describe magnetic compass automatic pilot which is used by several hundred boats in Japan. By using a portable remote controller, the boat can be steered from almost any point on deck which is, of course, a great advantage to the skipper during hauling and shooting of the gear.

In America thousands of large and small fishing boats are using similar equipment, which is found to save labour and fuel It would seem that the use of automatic and remote controls aboard fishing vessels has made less headway than could have been expected, considering their widespread use in industry on shore, and considering that fishing boats are in other respects often generously equipped with complex equipment. A point to keep in mind here, however, is that of watchkeeping.

Navigational aids are described by Alverson and the Decca Navigator Co.

Alverson says the skippers of trawl boats in the Pacific North West, which are commonly equipped with Loran, now even refer to trawl grounds and positions at sea, not by relation to headlands or to the marks on shore, but to the Loran microsecond reading. The value of navigation aids as a help to stay on the fish is quite obvious—for instance in covering a trawl ground systematically without using a dahn buoy or to back-track to the exact spot where fish has been indicated on the echo-sounder, or to avoid rough spots or obstructions which have been pinpointed previously and marked on the Decca chart. A further advantage lies in the use of the 'tracker', which gives a record of the track taken and facilitates the entry of harbours in poor visibility. The high cost of this equipment and the limited areas covered by the stations so far has limited the use of this equipment, to certain areas and to fairly large size trawlers. It will be to the manufacturer's advantage to bring this very useful equipment within the economic means of the smaller fishing boats, as there are several times more small boats in the world than big ones.

Creeelius stresses the importance of being able to match exactly the length of the two warps, especially during trawling in deep water. The meters described are fitted one on each warp near the winch and measure the amount of cable payed out. Although he does not mention it, I think such meters could be very useful in midwater trawling too where the amount of warp used is very important.

I would also like to draw your attention to the paper by Goodman and Lawton on the damage caused by fishermen to telegraph cables. Some six companies have shown very keen interest in bringing before this Congress this serious problem. Trawlers are seeking ever deeper grounds and intensifying the operations in areas not previously affected. The paper recounts the tragic story of the tremendous financial losses sustained when cables are cut and days are needed to splice together broken ends to replace missing sections. We should try to find the means of solving this problem very soon and one way is perhaps the use of streamlined doors, which are still in the experimental stage.

One example of this are the oval shaped doors used by the Russians now. Such boards would ride more easily over cables and cause less damage. Hydrodynamically shaped doors like the Larsson wingdoor, Süberkrüb boards and other similar rational and radical designs may also ride more easily over cables.

Eddie enlarges on the very interesting subject of power saving on trawlers. After discussing the power expended by trawlers of different sizes and basing on data obtained during both experimental and commercial use, he comes to the conclusion that very often the skippers are using much more engine power than necessary for the fishing operation. He explains that on reaching a certain towing speed, doubling or tripling the power expenditure results in only a very small increase in towing speed. It seems particularly important, then to develop some way of measuring the power developed by the engine at exactly measured trawling speeds, so that the economic towing speed can be determined. He is however convinced that much more research is really needed on this important subject.

That brings us to the matter of gear research and to the need for more rational methods of developing and testing gear which cannot, as Captain Roberts has already explained to us, be expected to be made by commercial vessels working under economic pressure. For several years now biological and processing laboratories have been in operation in practically every fishing country and in some cases doing some quite expensive research, which is accepted now by everybody and people are gradually realising that this money is well spent. That such research pays. The time has now come for us to show that research in the field of fishing gear technology also pays and to underscore its importance as it is quite obvious that government funds will have to sustain such research; not only must tests be carried out on materials ashore, but also with complete gears at sea. To guide the fishing industry, auxiliary equipment must be tested to ascertain that it suits the particular fishing conditions in different areas; also to guide the manufacturers into developing the right kind of equipment needed by the fishing industry. New ideas in gear development must be tested using both rational design and the time honoured "try, try and try again". The following message should quite clearly emerge from this Congress—that now that biological research is established and gathering way, the time has come to start and concentrate on the study of the efficient design, construction and operation of the gear that has to catch the fish. This is becoming more economically pressing every year.

Mr. P. G. Schmidt (U.S.A.): Until now most of the discussions were centred around trawling, which is certainly one of the most important fishing methods. But other methods are also very important and personally I am more interested in purse seining. Purse seining seems to have been neglected and the working method has not been improved in relation to its importance, when compared with trawling. One of the reasons for this is, that traditionally a large number of men were required to pull in the net, and therefore, we find that on the purse seine vessels many other operations are still done manually because this large man power was always available.

I am basically an engineer and a boat builder, but I have become thoroughly interested in the efficiency of fishing operations. In the course of my travels connected with the introduction of the Puretic Power Block in purse seine fishing, I have had an opportunity of visiting most of the important purse seine fisheries in the world. I have not been able to find out why the methods used in each area are so widely different. Why are they, for instance, in South Africa, using the Lampara purse seine with two tapered wings hauled on to one boat; why in Norway do they use two small seine boats working with a mother vessel; why do they use a similar system for catching menhaden off the U.S. Coast which is one of the world's largest fish producing areas; why in Iceland where originally a system similar to the Norwegians was used, are they now working with two or three different systems, including the use of one small seine boat carrying the net, with a mother vessel. Why is it that in Portugal they use a net which they call American style, with one boat and a small skiff, and why do Japanese have a method where two big tuna seiners carry each one half of a monstrous net and work together? I am sure that there are reasons for using such different methods. However, I believe that in most cases these reasons are historical and that with present-day techniques, simple machinery, fittings and devices available, many of these methods have become obsolete.

In Norway for instance, the very best fishing captains will tell you that they have refined their methods, have been working the method for years and years, catch more herring than any other country in the world, and that the method is therefore efficient. I wonder, if it is really the most efficient method. I wonder whether the reasons for using two small open boats are still valid, and if it is still necessary to have 18 to 30 men for handling nets which in comparison with those used in Japan and on the West Coast of the United States may be considered to be rather small nets.

The previous discussions were mainly concerned with the design of nets, the materials for making nets and so forth. I believe that in purse seine fishing, these things are not nearly as important as the operational method in connection with the economical use of manpower and the appropriate and effective use of equipment. Yet the power block is but one piece of the mechanical equipment. For instance, the Lampara seine fishery in South Africa is fairly new and I think most of our South African representatives can remember that about 10 years ago, maybe a little longer, it was a tremendous step forward to get the first purse winch introduced. We from U.S. could not possibly conceive of handling and pursing a large net without a purse winch, and yet this was a big step in an area which had not been using such nets before.

We have now found a new way to haul large nets on to the fishing vessel more efficiently, faster, with less men, with less wear on the nets than any historical hand hauling method.

When discussing purse seining with the local people, we always suggest that they should first attempt to increase the efficiency of the method used on the present boats. After all, they have large fleets of boats and it is impossible for them to dispose of these and build new boats, which is furthermore unnecessary as the method can be adapted to practically every boat. On trying to get them used to the idea of hauling the net by power, we immediately meet scepticism; what are we going to do with the purse rings; how are we going to get them off from the purse line, how will the catch be hardened in the bag, etc.? We know from experience that this hardening is not a problem, but in the minds of the local fishermen it is. The fact is that on the existing boats, booms and other equipment does not fit in with mechanical hauling and needs some changes.

Three years ago we thought that introducing more efficient methods to the menhaden industry on the East Coast of the U.S. would be easy. They have approximately 600 small seine boats operating as pairs with about 300 large vessels which they call steamers. Our problem was not operating the net, but in finding support for the power block on such small open seine boats and to find a system to handle the purse rings, the cork lines and some more details. After working with the industry now for two and a half years, most of these problems have been solved with the result that we have groups of boats which are now fishing with six men less per net.

In Iceland they are starting to develop methods of reducing crews, because in Iceland there is a great shortage of manpower and, of course, these are the areas where it is easiest to introduce mechanization.

I might just very briefly comment on some specific questions which were brought up by others concerning other fishing methods in the North West.

Mr. Kristjonsson mentioned the automatic pilot. On the Pacific Coast I would guess we have maybe 3,000 fishing boats of one type or other and I would say they are virtually 100 per cent. equipped with a very inexpensive automatic pilot, costing somewhere around U.S.$ 300 to 400.

Concerning longline hauling, there are two firms in the North West of the United States who have experimented with automatic longline haulers which are a bit different from what has been used elsewhere. They consist of a device which has drums on which the wire longline gear is reeled and which are driven mechanically and operated with clutches and brakes so that the branchlines can be attached as the gear is shot. This was, however, never generally adopted in the area, although it is felt in our area that this gear does have merits and it should be further developed.

Mr. E. R. Geroult (France): I would like to confirm what Mr. Eddie has stated in his very interesting paper. Each time when it has been possible to take measurements of power requirements of trawlers at sea, we have found that less power was actually used than is continually requested by the skippers. We think therefore that 500 to 1,000 h.p. is about what we need for a bigger trawler. About 500 h.p. are needed for trawling, and about 850 or even a little less for free running.

As regards stern trawling, there are in Portugal, in Spain and in Africa a certain number of boats who use this method. They allow for interesting comparisons with the new big stern trawlers recently developed in Northern Europe which have a stern shute. Most likely something useful could be learned from these techniques, particularly as regards the hauling operation. With the big stern trawlers there are problems concerning the handling of larger catches over the stern shute. There might be less danger of wearing or even bursting the codend and less damage to the fish with the Mediterranean method of hauling the catch on deck almost vertically and without a stern shute. For bigger boats and larger catches this would require some special crane arrangement.

Mr. A. I. Treschev (U.S.S.R.): According to our experience stern trawling is quite efficient in comparison with side trawling. The slightly longer time needed for operation in stern trawling is fully compensated by the possibility to continue fishing in bad weather conditions. In our opinion, stern trawling is more convenient from the point of ease of operation, in regard to the fishing operation itself and to provide the space needed for fish processing. There are some difficulties in hauling big catches, but we hope to overcome these pretty soon.

Mr. J. G. de Wit (Netherlands): I feel obliged to warn against automatic steering gear, particularly if it is of the type that can be operated by hand from any point outside the wheelhouse. According to my experience, fishermen are inclined to neglect watch keeping generally. I expect that automatic steering will aggravate this trend and will subsequently do more damage to fishing gears and lead to more collisions.

Particularly in trawl fishing there is a close relation between the ship and the gear. The ship has to tow the trawl gear at a certain speed for which a certain amount of towing power is needed which is supplied by the main engine through the propeller. The towing power requirement should be the starting point for the estimation of the main engine. As the towing resistance increases practically with the square of the speed, the fishermen should be careful in their power requirements because too big an engine means excessive initial and running costs. The risk of spoiling the economy of the vessel is not imaginary.

In the Netherlands also, many owners and skippers are inclined to increase the engine power of their trawlers. Recently some trawlers of 275 to 310 tons gross were put into service and they have main engine power of 1,000 h.p. at a speed of 11 knots. The length of these vessels is less than 140 feet between perpendiculars.

In this connection I also wish to underline the remarks Mr. Eddie made in his paper on the power measurements he carried out on three 180 ft. trawlers during trawling. From these valuable remarks it can be concluded that vessels of 132 ft. and 1,000 h.p. are over-powered.

The pull which the vessel has to exert on the warps consists of the net resistance and the resistance of otter boards and warps. Speaking of the resistance of bottom trawls, one has to take into account the fact that this consists of hydrodynamic resistance and bottom friction. Each of these factors follows its own laws. A recent research into the pull of a hydraulic trawl winch during the hauling operation showed that this pull was, at the beginning, about 10 to 11 per cent. higher than towards the end because the frictional resistance had disappeared and the hydrodynamic resistance of the warps had decreased.

Personally, I regret that so few papers are dealing with the resistance of the otter boards. The otter boards are supposed to provide shear. The drag has to be accepted as a necessary evil. The conventional flat otter boards are not the most suitable ones from a hydrodynamical point of view, as Schärfe states in his paper. But, perhaps the otter boards also have a function in ploughing the ground and stirring up the mud in front of the trawl net to camouflage it. It would be worth while to know whether this action is of real significance or not.

Decreasing the towing resistance means decreasing the fuel bill and raising the economy of the vessel. I cannot understand why otter boards like the Süberkrüb boards for instance, did not come into a more general use. The same applies to the warps. Adoption of warps of a smaller diameter and a higher tensile strength decreases the resistance of the warps in the water.

There seems to be a difference of opinion between Lewis and de Boer concerning the changes of the resistance of the fishing gear in relation to the amount of catch. Lewis mentions the closing of the trawl warps and the reduction in engine revolutions as an indication of an increasing amount of catch. Both factors point to an increase in the resistance of the fishing gear. De Boer, however, states that filling the codend results in a decrease of the pull.

The solution of this puzzle might be that both are right. The dynamometer in de Boer's case was arranged between the net and the otter board. The decrease of the net resistance meant a decrease of the pull of the net to the otter boards, resulting in an increase of the angle of attack of the otter boards and consequently an increase of the total drag. This increase of the total drag results in a closing of the trawl warps and a decrease in the number of revolutions. If this suggestion is right, it would underline the importance of the drag of the otter boards.

At a speed of about 5 knots something seems to happen with the trawl gear. Eddie refers to a slower increase of the drag. In one gear this seems to occur at a lower speed than in another gear. I should like to stress that the trawlers should be designed for optimal economic performance.

This involves careful consideration of problems such as what is the best towing speed? which pull must consequently be expected? and is it not possible to modify the trawl gear in order to reduce the drag without affecting the fishing efficiency?

These questions also apply to the auxiliary engines of diesel trawlers, particularly the winch drive. There is a trend to increase the hauling speed of the winches, but does the saving of a few minutes of the hauling time really justify the higher costs of the much more expensive winch installation? Such questions are particularly important for trawlers which are not designed for the high free running speeds of 13 knots and more. All such problems require a close cooperation between the fisherman who operates the boat and the trawl gear, the designer of the trawl gear, the scientist studying the behaviour of the trawl gear and the naval architect. I wish to express the hope and the expectation that this Congress and the Fishing Boat Congress may further this cooperation.

Mr. P. A. de Boer (Netherlands): In my opinion, with a certain amount of catch, the meshes of the net are stopped up and the water overflows. This results in a decrease of the net resistance. In the conventional otter board adjustment the pull of the net has a regulating effect. Lower pull allows an increase and higher pull forces a decrease of the angle of attack. If, due to low net resistance, the angle of attack exceeds a certain limit, not only the drag goes up considerably but also the shear goes down. This effect might be responsible for both the increase in total resistance at decreased net resistance and the closing of the warps. As the decrease of the net resistance seems to be more significant than the increase in the resistance of the boards which is partly camouflaged by the former, I suggest that for determining the amount of catch by changes in the towing resistance, the pull measurements should be made behind the otter boards. Suitable equipment for such underwater measurements is available and, with a cable connection as described in McNeely's paper, an indication or even recording could easily be arranged in the wheelhouse.

Mr. A. O'Grady (Australia): The trap fishery in Australia is rather an important fishery for snapper and other bottom fish. The type of trap used is a wooden framed rectangular shaped trap, sometimes 5 to 6 ft. in length, 2½ to 3 ft. in height and a similar width. It is completely covered with 2½ in. diameter galvanised wire netting. These traps are baited and lowered to the bottom and are secured with a buoy rope of 1 to 1½ in. sisal or manila rope, and the buoy line is held up by 6 in. glass floats. Now, we have quite a problem with this fishery. The traps are set in waters up to about 50 fms. in depth, where normally a strong current is running, but slackens from time to time. We find that the current assists the fishing, for when the current is slack very few fish enter the traps. However, when the traps are lowered to the bottom during strong current, it is not long before the glass floats submerge and disappear. These traps may stay submerged, including the buoy line and the floats for sometimes up to 7 or 8 days. So that when the fishermen go out to pick up their traps they often cannot find them. It is thought that the traps continue to fish until the bait is all eaten. Furthermore, when the fish are left unnecessarily long in the trap they are frequently mutilated by colliding with the wire netting.

Possibly the use of a fine galvanised wire, instead of the thicker buoy lines may be the answer to this problem. I understand from Mr. Ocran of Ghana that they are engaged there in a hand-line fishery for snapper (the same kind of fish we trap for) and that they propose to engage a trap fishery similar to that used in Australia. Perhaps this current problem in trap fishing has been solved somewhere else and I would be glad if I could get some advice.

Mr. H. Kristjonsson (FAO): I think Mr. O'Grady's problem of submerging floats is much more widespread than just trap gear. It also concerns set longlines and in fact any gear that employs anchored marker floats or buoys. Light wires are in fact used by trawlers for these marker buoys when set in deep water. Light wire has also been used for many years in France and other countries for traps set in deep water and small hand reels are then used to haul the pots. To avoid the traps being carried away by the tide in such strong currents, most fishermen use small grapnels instead of the traditional heavy stones.

The submerging of the floats can be partly avoided to some extent by the use of several floats spaced along the end of the buoy rope, but is not altogether satisfactory. Such floats as designed by Larsson which combine static and hydrodynamic buoyancy may be the answer to this problem.

Dr. Ch. Hennings (Germany): I am concerned with handling and processing of fish rather than catching it and, therefore, mainly interested in quality problems. It is well known that the quality of fish depends very much on how it was caught and how it was treated on board the fishing vessel.

It is for instance, known that fish caught with gillnets or longlines is often more palatable and more valuable food than trawler fish. We also know that fish which is maltreated or is not adequately stored on board, consequently loses in nutritive and market value and may be unsuitable for any further processing for human consumption. I am aware that such problems are not exactly within the scope of this Congress and therefore would not go into further details. But, I think it might be useful just to mention that when considering fishing gear design and operation the problem of fish quality must be kept in mind too.

Captain I. R. Finlayson (U.K.): I command a cable ship and I am speaking on behalf of operators of submarine cables, who own thousands of miles of telegraph and telephone cable lying on the seabed in fishing areas throughout the world. We have a problem which has been mentioned in the paper by Goodman and Lawton which was so ably amplified by the Rapporteur. We feel that this problem is not generally known in the fishing industry.

Submarine cables are armoured with steel wires, they vary in diameter from 1 to 3 in. They are sometimes fouled by trawling gear, particularly by otter boards when these have defective shoes or protruding bolts.

Sometimes the otter boards skid along the cable for hundreds of fathoms damaging the cable before it frees itself and other times the cable is torn in two by the fishing vessel. Occasionally the cable is even hauled up to the surface together with the fouled gear and then cut away. This can be highly dangerous to the fisherman, as some of these cables now carry up to 3,000 volts.

This damage and the consequent interruption of international communication is a very serious matter for everyone and the cost of repairing is high. During the last year, there have been more than one hundred interruptions throughout the world due to trawlers and other fishing vessels. The cost of repairing these runs into millions of pounds, and the loss of revenue while the cables are broken, cannot be estimated.

I ask designers and manufacturers of trawl gear and other fishing equipment, to bear the cables in mind and ensure that there are no projections on otter boards or fittings. The gear should be designed to avoid fouling submarine cables and so reduce the risk of damage to both the fishing gear and the cables.

I would also like to remind owners and skippers of fishing vessels that under Article 7 of the International Convention for the Protection of Submarine Cables, 1884, when they sacrifice gear to avoid damaging submarine cables they shall and I repeat they shall, receive compensation from the cable owner.

Mr. J. R. Lénier (France): I should like to reply to the question raised by the Rapporteur; on why the Decca system is not used on small boats. The existing Decca chains would allow for that, at least in the North Sea and considerable parts of the Atlantic and most of the big trawlers use this simple and reliable method for spot plotting their position. I think that this navigational aid would be even more valuable for the smaller boats, the skippers of which usually do not have the same navigational training.

Now, in France, and I do not know whether this goes for other countries, the small fishing boats of 16 to 20 m. in length simply do not have the space for the installation of the rather bulky equipment. They therefore have to use simpler equipment like radio direction finders. I think it is mainly up to the boat designers to provide the space needed for the equipment and the special maps and then Decca could also be used by small boats.

Prof. E. Halme (Finland): In 1948 the Fisheries Foundation in Finland announced a prize competition for fishermen's accounts of their experiences and discoveries concerning the habits of fish and special methods or devices of fisheries techniques. The primary purpose was to collect such material for scientific purposes. It was left to the fishermen themselves to decide what kind of things they considered important. To this prize competition answers were received from 365 different persons from the whole coastal area of Finland and from the inland waters. The majority of the accounts covered the life and spawning habits of the different species of fish but all kinds of small devices concerning gear and fishing methods were also given. These replies formed a pile of about half a metre thick and study, screening and indexing will take quite a considerable time.

This is the guide to fishermen's lore. It is intended to have this material compiled and printed in form of a book. Most of the devices described concern our specific problems of how to get fish from our Baltic area and from our 7,000 lakes. But I think that in spite of this and eventual language difficulties, from the many pictures in this book you would understand how much information you could get in this way from the fishermen of your own countries.

Mr. Z. Zebrowski (Poland): This time I am talking to you as a manager of a fishing company. As such I am responsible not only for the efficiency of gear and the speed of work, but also for the safety on board. You may remember that not very long ago, one new British trawler capsized because his gear was caught and the crew lost their lives. In my company we fortunately have not had such a serious accident. But I am sorry to say that we have had accidents, when the gear was caught, and either the wires broke and then slashed across the deck, or the bollards were torn away. In both cases the people working on deck are in serious danger of being hurt by the warps.

I want to ask how such accidents could be avoided. Is it not possible to have a trawl winch, the brakes of which give way when the gear is caught and the tension on the warps exceeds a certain value well below their breaking strength? Or could not each gallows be provided with a separate winch, operated, for instance, by a synchronic arrangement from the bridge? In the latter case the warps would not run across the deck where the people are gutting fish. I think this is a problem of utmost importance because it is concerned with the safety of human life.

Mr. L. Soublin (Chairman): I am very grateful to Mr. Zebrowski for having closed the discussion with this humane matter. I am glad to say that in France this problem is already solved. As far as I know, on the latest French trawlers there is a system which allows the warp to slip when the resistance becomes too great.

In closing this meeting, I should like to refer to what was said by Mr. De Wit, who pointed out that automatic piloting did not just point to the need for careful watch by the skipper. I would like to go even a little further—nothing, of course, can act as a substitute for the intelligence of man. All the technical improvements which are made for the boats are an aid to this intelligence but nothing replaces intelligence. Nothing can be a substitute for the personal qualities of the captain and nothing can act as a substitute for the capacities of energy, endurance and intelligence of the crew.

LOCATING FISH CONCENTRATIONS BY THERMOMETRIC METHODS

by

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Abstract

A correlation exists between the distribution of water temperature and the concentration of some species of commercial fishes, sometimes for the whole year, but mainly only during special seasons. In those areas where there are temperature differences during the year or season, the correlations are useful for defining the distribution of the fish concentrations. Temperature differences can be caused by convergence or divergence of water movements and also by vertical turbulence of the tidal stream and examples are given of cod, haddock, yellowfin tuna and herring in relation to these differences. Temperature may not be the only influencing factor, but it is the easiest to observe and the authors feel that the results of their work could well be augmented by further surveys by specially equipped vessels.

Localisation des concentrations de poissons par les méthodes thermométriques

Résumé

Il existe une corrélation entre la distribution de la température des eaux et la façon dont les concentrations de certaines espèces commerciales de poisson sont réparties, parfois toute l'année mais principalement pendant certaines saisons. Dans les régions où la température varie au cours de l'année ou de la saison, la connaissance de cette corrélation est précieuse pour la localisation des concentrations de poisson. Les différences de température peuvent être provoquées par des déplacements de masses d'eau convergentes ou divergentes ainsi que par la turbulence verticale des courants de marée. Les auteurs donnent des exemples de la répartition des bancs de morues, de haddocks, de thons et de harengs en fonction de ces différences. La température peut ne pas être le seul facteur en cause, mais il est le plus facile à observer, et les auteurs estiment que les résultats de leurs travaux pourraient être enrichis par d'autres campagnes d'observation exécutées par des navires dotés d'un équipement approprié.

Localización de concentraciones de peces mediante métodos termométricos

Extracto

A veces durante todo el año y, de preferencia, durante ciertas temporadas existe una correlación entre la temperatura del agua y la concentración de algunas especies de peces de importancia comercial. En aquellas zonas donde hay diferencias térmicas anuales o estacionales, esta correlación es útil para precisar la distribución de las concentraciones de peces. Las variaciones de temperatura pueden deberse a la convergencia o divergencia de los movimientos del agua y también a la turbulencia de las corrientes de mareas. Para ilustrar estas diferencias, en el trabajo original se dan ejemplos relativos a las siguientes especies: bacalao, eglefino, atún de aleta amarilla y arenque. Probablemente la temperatura no es el único factor que ejerce influencia, pero se observa con mayor facilidad que otros, y los autores creen que los resultados de su trabajo podrían aumentarse con nuevos estudios mediante barcos equipados especialmente para tal objeto.

GENERAL BASIS FOR FISH FINDING BY THERMOMETRIC METHODS

INVESTIGATIONS have established beyond doubt some general facts which can be summarized as follows:

1. The stocks of commercial fish are intimates of ecological systems in which interrelated physical and chemical conditions of great complexity operate and fluctuate from year to year. These systems exercise a decisive influence on reproduction, growth and mortality of the organisms, and no rational study of food fish can be undertaken without exhaustive inquiry into the physico-chemical conditions.
2. Among the different factors of the ecological systems such as temperature of the sea water, salinity, depth, pressure, currents, content of nutrients, oxygen, intensity of light, osmotic pressure, hydrogen-ion concentration, food, etc., temperature and food are the most outstanding. Food, however, consists either of other animals, which are subject to similar physico-chemical influences in general and the temperature in particular, or of marine plants depending entirely upon certain elements dissolved in sea water, and certain intensity of light and temperature. Therefore the temperature may be used as the most practicable indicator of ecological conditions.
3. (a) In many cases the hatching of fish eggs is to a high degree dependent on just the right temperature of the surrounding water.

   (b) In their growth and ripening from the larval to mature stages fish continue to be influenced directly by temperature.

(c) At the spawning time many species of fish have to find just the right temperature of water in which to deposit their spawn,

4. In addition to these general findings, the special temperature range, which some species of commercial fish prefer, is known. This is especially true for the spawning conditions, and partly for other periods of their life.

This relation existing between the concentration of certain commercial fish and the water temperature can be utilized in practical fishing. Since measurement of the temperature is easy, it should facilitate location of fish. But one cannot expect completely correct conclusions by thermometric methods, as temperature is only one factor influencing fish concentration.

Thermometric methods for locating fish have been applied for a long time with varying success. The prediction of the size of the stocks in different seas based on analogies in temperature data may be called fishery strategy. Here we deal with the task of fishery hydrography in the form of tactical information for fishermen with regard to the special fishing ground based on the water temperature. For such tactical information:

(1) The distribution of temperature must be known.

(2) The differences in temperature must reach several degrees centigrade.

(3) The correlation between temperature and concentration of fish must be known.

So far, information on the two first items can be given only with the aid of direct observations of temperature. Data with reference to item 3 are available only for limited areas and for some commercial species of fish.

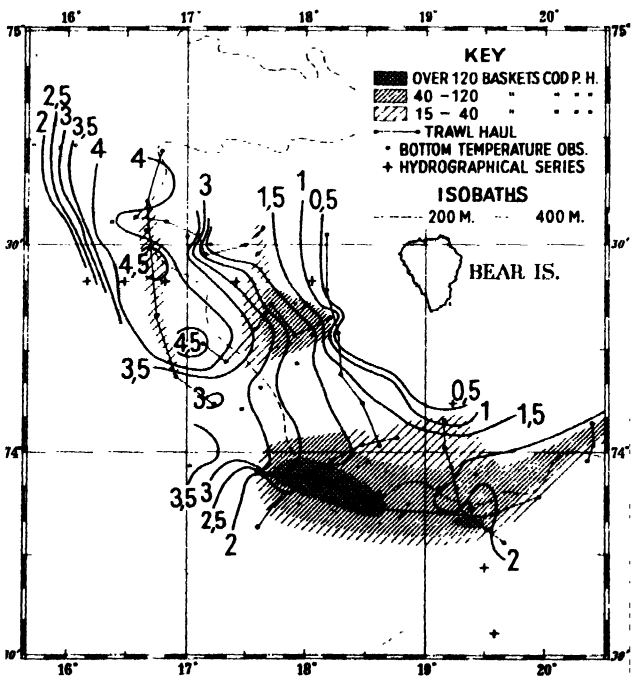

Fig. 1. Distribution of bottom temperature and cod in the Bear Island area, 20 to 28 November 1949 (After 6).

A general application of thermometric methods for locating fish cannot be expected, but its use in selected regions and for certain species of fish demonstrates the line to be followed to achieve success.

RESULTS OF FISH FINDING BY THERMOMETRIC METHODS IN SELECTED HYDROGRAPHICAL REGIONS

Differences in temperature within narrow strips in the sea result from these three different processes, namely the convergence of water masses of different origin, the divergence in thermally stratified water whereby colder water gets to higher levels, and vertical turbulence and its local differences. This turbulence, which can be generated either by wind or tidal stream, contributes to the formation of the thermocline and its local differences.

Zones of Convergence

The most conspicuous example of convergence is the Polar Front in the northern and southern hemisphere. Here cold polar and sub-polar water masses meet the warmer water of the temperate latitudes. The concentration of food fish at this Front has long been made use of by fishermen. An example of relationship between temperature and fish distribution is that of the Bear Island region. Westward and southward of Bear Island there is a convergence between cold arctic water and warmer Atlantic water.

The investigations made from the English research vessel *Ernest Holt* since 1949 into the relationship between bottom temperature and cod distribution have yielded some remarkable results. They show that the thermal structure seems to assist a concentration of cod in a narrow strip at certain times. The best yields were obtained in winter on grounds with bottom temperatures between 1·75 degrees C. and 3 degrees C.

But it is supposed that such thermoclines do not provide a universal indicator of where to fish successfully, but only that there is a greater probability of finding remunerative quantities of fish.

The temperature distribution at the Polar Front shown in fig. 1 changes in the course of time. There

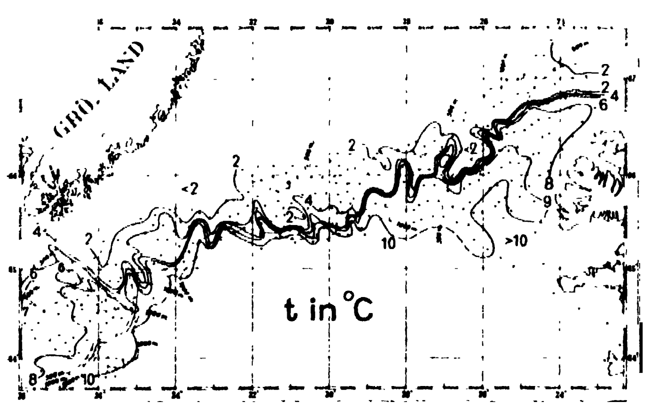

Fig. 2. Distribution of surface temperature in the Greenlandic-Icelandic Waters in August 1956 (After 5).

is no published data to give more information about these changes. Observations have been made in a similar region, namely the Greenland-Iceland-Ridge, where polar water of the East Greenland Current and Atlantic water of the Irminger Current meet. From the temperature distribution at the surface, determined by the German R. V. *Gauss* in August 1956, it is obvious that the Polar Front meanders along an axis which follows the edge of the shelf, approximately the 500 m. depth line (fig. 2).

Probably these meanderings are in the direction of the axis, which is also the prevailing direction of the East Greenland Current. These variations also influence the temperature distribution on the bottom, so the information given to fishermen should take into account not only the observed distribution of temperature but also the variations in the course of time. As the fishermen will have neither the time nor be equipped to gather information about the thermal conditions existing in the fishing ground, the locating of fish concentrations by thermometric methods would very soon become discredited. The work should therefore be carried out by systematic fishery biological and hydrographical investigations on the main fishing grounds and the results distributed to the fishermen.

Zones of Divergence

Zones of divergence are the upwelling zones at the west coasts of the continents in the temperate latitudes and the upwelling at the equator, where fishermen find paying quantities of fish. These zones can be found by thermometric methods. The impressive results of the Pacific Oceanic Fishery Investigations (POFI) of the U.S. Fish and Wildlife Service in investigating the fishery potential of the tropical mid-Pacific waters, show that yellowfin tuna, *Neothunnus macropterus*, and skipjack, *Katsuwonus pelamis*, are concentrated in the upwelling zone at the equator and in the narrow strip south of the Equatorial Counter Current [2,7,11 and others].

Fig. 3 shows an example of the results along 150 degrees W between 5 degrees S and 15 degrees N, i.e. south of the Hawaiian Islands. Other investigations by POFI prove that the tuna larvae are also concentrated in great numbers in the same zone.

Further observations, discussed by G. J. Murphy and R. S. Shomura[7], show that the quantities of fish caught and the positions of the zones vary considerably in the north-south direction, probably in response to the value of the upwelling and meandering of the current system.

It may be mentioned that the divergence of the northern frontier of the Equatorial Counter Current, recognizable in fig. 3 at about 9 degrees N, brings about no enrichment either in zooplankton or in yellowfin tuna. The stability of the surface layer is very high and therefore the upwelling of water, rich in nutrients which exist in this zone, does not reach the surface layer.

When one realizes the full potentials of this equatorial

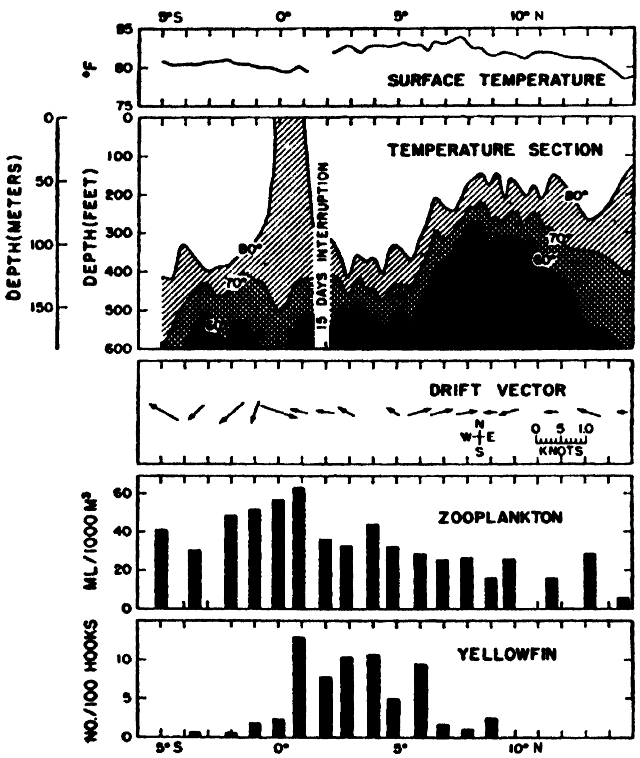

Fig. 3. Surface temperature, vertical temperature field, long-line drift, zooplankton abundance in the upper 200 m., and the yellowfin tuna catch along long. 150 degrees W. August 22 to September 25, 1952 (After 11).

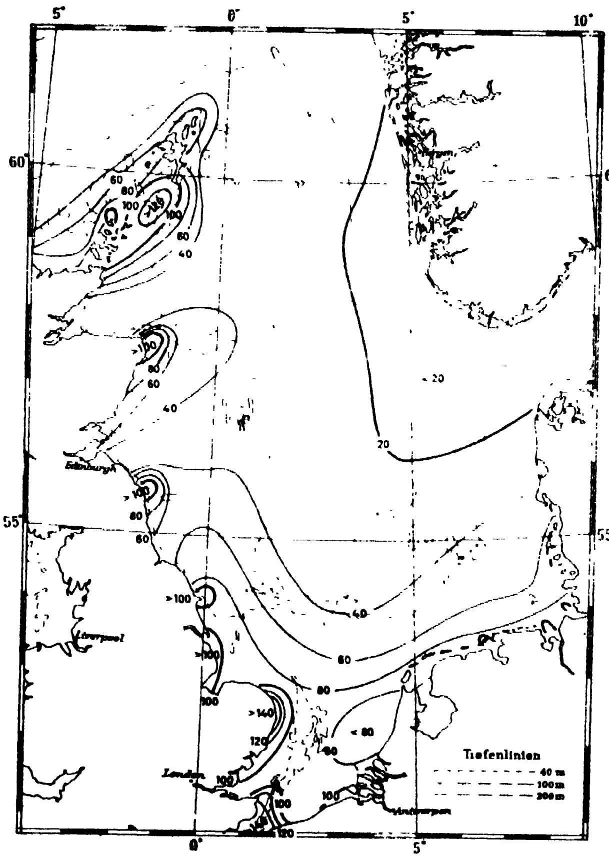

Fig. 4. Distribution of maximum velocities (cm/sec.) of tidal streams in the North Sea at springtide (After 3).

area the enormous resources available for a high seas fishery are evident. Informing fishermen of possible fish concentrations by research ships becomes possible when thermometric methods are applied to determine the variations in the current system. This could be applied also in other regions with divergent water movements.

Zones of Local Differences in Vertical Turbulence

Local differences of vertical turbulence, observed frequently in shelf waters, cause and maintain local differences in temperature in stratified waters. The differences of turbulence increase with the maximum velocity of the tidal stream which stretches from the surface to the bottom. The temperature distribution in stratified waters is influenced, especially during summer, in those seas in which great local differences in tidal streams exist. An interesting example is the North Sea. Here the distribution of maximum velocity of tidal streams as well as the temperature distribution are known, and some relations between them and the concentration of fish are worth using for tactical information for fishermen.

The southern and the western areas of the North Sea are comparatively rich in tidal streams. When the thermocline begins to develop in spring it is influenced by the tidal stream turbulence. Observations have shown that the central and north-east is less affected than the southern and western areas. The resulting character of the summer thermoclines can be seen in fig. 5, from the hydrographic sections through the North Sea made in August 1955, while the courses of these sections are shown in fig. 6.

1. The intensity of the thermocline, i.e. the vertical gradient of temperature in the discontinuity layer, is as small in the northern North Sea as in the neighbouring ocean.
2. In the central North Sea the thermocline is narrower, therefore the gradient is bigger.
3. South of the *Dogger Bank* an extraordinarily large temperature change of about 9 degrees C. in 2 or 3 m. vertical distance (sometimes in less than 1 m.), can be observed.
4. The thermocline disappears totally as soon as the tidal turbulence is strong enough to prevent a permanent existence of temperature in vertical direction. That is the case in most parts of the southern and western North Sea.

The distribution of temperature is such that in some areas the thermocline preserves the cool winter water, but in the southern and western North Sea summer heating reaches the bottom because of the turbulence of strong tidal streams. Great horizontal differences in bottom temperature result (fig. 6). The temperature is less than 6 degrees C. in areas with small mixing and more than 11 degrees C. in regions with high mixing. In the north-east, the cool bottom water is delimited by warmer Atlantic water entering the *Norwegian Deep* in the north. Taking into account the great counter clockwise swirl on the *Fladen Ground* in the northern North Sea, it is clear that bottom water east of Scotland, comparatively warm by great tidal mixing, flows to the east and divides the cool winter water into two cool water masses. Separated by the shallow *Dogger Bank*, there is a third core of cold bottom water in the south-eastern North Sea in summer, which has been observed repeatedly in the summers of different years.

Fluctuations from year to year influence three points:

1. The position of the three cores of cold winter water.
2. The temperature of these cores.
3. The structure of the thermocline.

The positions of the cores are influenced to a certain degree by the current system, which changes with the

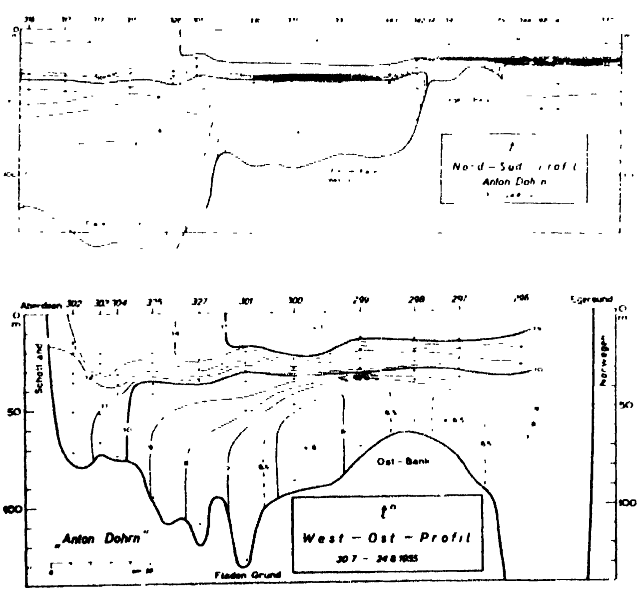

Fig. 5. Vertical distribution of temperature in a north-south and in a west-east section through the North Sea in August 1955, for course of the sections, see fig. 6.

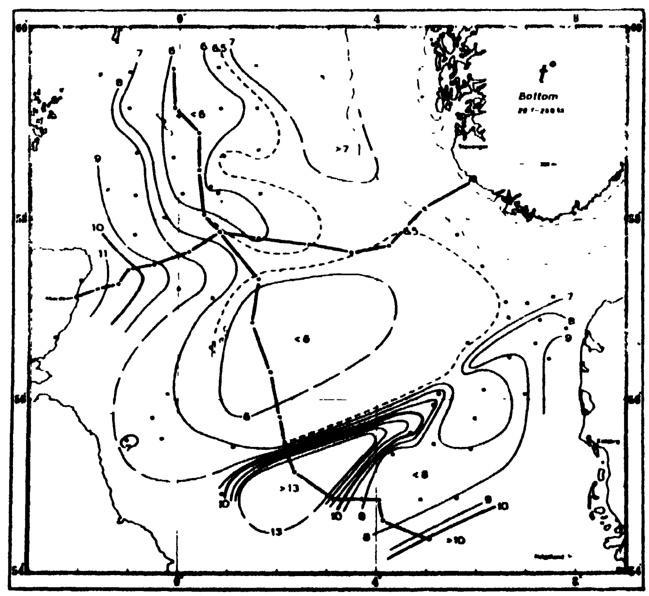

Fig. 6. Bottom temperature of the northern and central North Sea in August 1955, the broken line shows the course of the sections represented in fig. 5.

wind conditions. The temperature of the cores, for the last 50 years, investigated by G. Prahm[8], seems to be determined by the severity of the preceding winter. The structure of the thermocline is influenced by the wind conditions, and the heat exchange between the sea and the atmosphere during late spring and early summer. This points to the fact that temperature distribution, determined by the local difference in vertical turbulence, is complicated by weather conditions.

Some information on the relationship between distribution of temperature and concentration of fish, i.e. haddock and herring, based on recent investigations by the German F.R.S. *Anton Dohrn* in the North Sea is given below.

CONCENTRATION OF HADDOCK IN RELATION TO BOTTOM TEMPERATURE IN THE DOGGER BANK AREA

During two cruises in September and October 1956, experimental trawling, combined with hydrographical investigations, was carried out in the Dogger Bank area and the southern North Sea[9]. In figs. 7 and 8, the number of haddock caught per haul of half an hour's duration are marked for all trawl stations. As shown in fig. 7, the haddock seems to avoid areas of bottom temperature below 5 degrees C. and also water masses of more than 13·5 degrees C., the biggest yield of this species of fish being in areas of 5 to 8 degrees C. This can be seen clearly from the course of the interpolated isoplath for a catch of 500 haddock per ½ hr. trawling. It delimits the areas of higher haddock concentration from those of lower concentration in the cold water masses north of the Dogger Bank, and in the warmer waters of the southern and south-eastern regions of the North Sea.

One isolated exceptionally good haddock catch in waters of nearly 14 degrees C. (2,124 haddock per ½ hr. trawling) was made south of the Dogger Bank. Presumably this accumulation of fish may be connected with the current that flows around the south-western edge of the Dogger Bank in an easterly direction. This current is indicated by a strongly marked strip of water with comparatively high salinity (34·6 per mille.), in which the station mentioned above is situated, and also by the course of the isotherms.

One month later, in October 1956, similar investigations also seemed to prove a relationship between haddock distribution and temperatures (fig. 8). Only in the area of colder bottom temperatures (below 11 degrees C.) northwest of the Dogger Bank were sizeable catches of haddock obtained, while the amount caught in the region of warmer waters was very small or absolutely nil.

The correlation between the concentration of haddock (as measured in catch per unit effort) and the temperature,

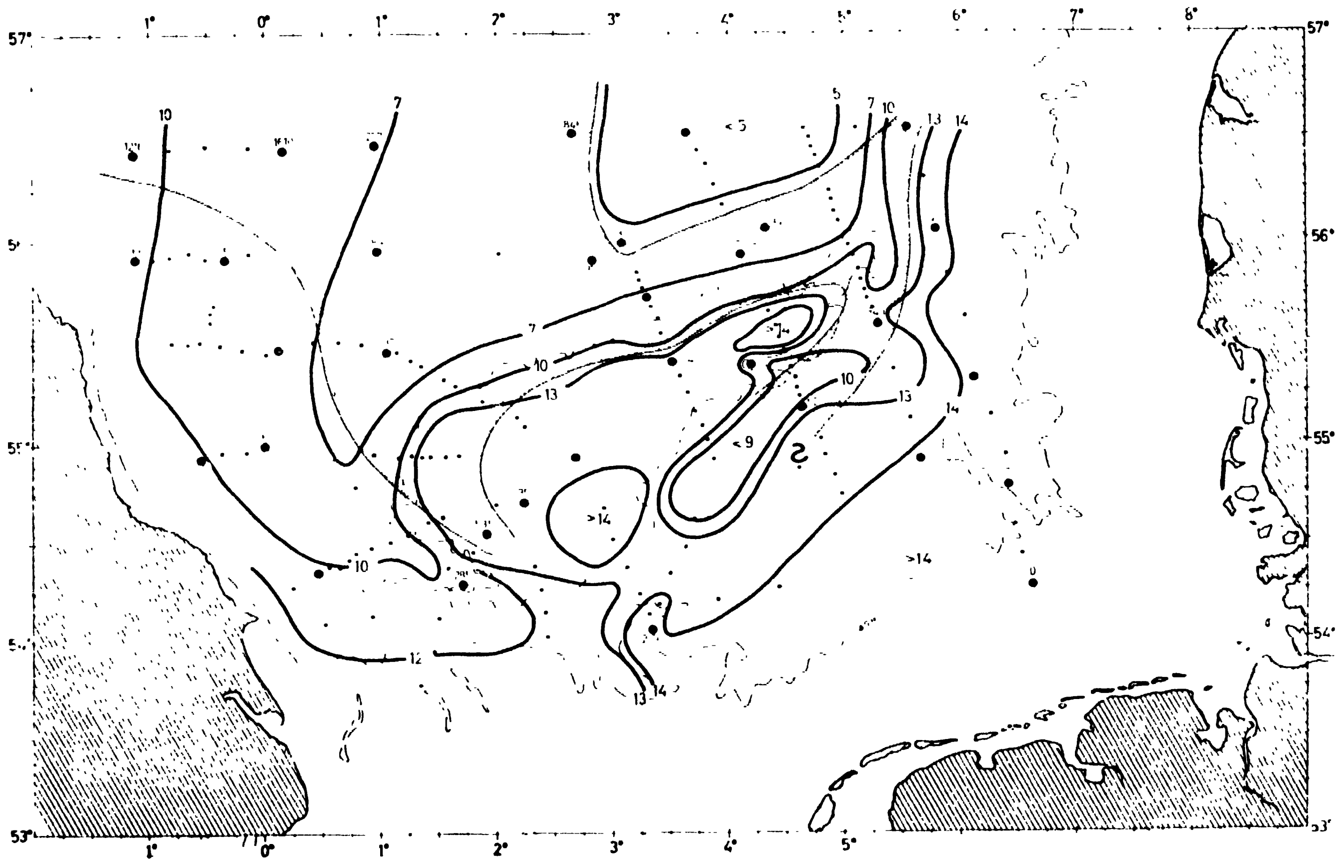

Fig. 7. Catches of haddock per half-hour trawling (●) in the North Sea made by F. R. S. Anton Dohrn *in September 1956 and isotherms for bottom temperatures stated simultaneously (Temperature observations [·]; Isoplath for 500 haddocks per half-hour trawling drawn in).*

Fig. 8. Catches of haddock per half-hour trawling (●) in the North Sea made by F. R. S. Anton Dohrn *in October 1956 and corresponding isotherms for surface temperatures (uninterrupted lines). In the area of thermal stratification also bottom temperatures are given (dotted lines). (Temperature observations [·]).*

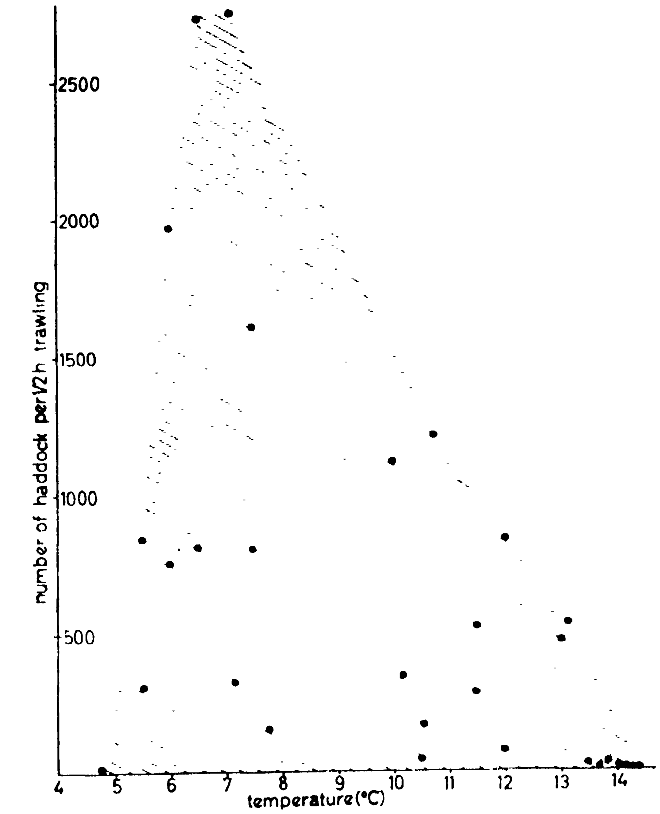

Fig. 9. Correlation between catch per unit effort of haddock in the Dogger Bank area, September 1956, and corresponding water temperatures on the bottom (according to data of fig. 7).

is not always very close. It may be influenced and veiled not only by other environmental factors such as hydrographical conditions, food supply, depth, etc., but also by factors based on the fish stock itself, e.g. the stock density and migrations. Thus, influenced by the very high density of the haddock stock in 1956 (on the basis of numerous year-class 1955), the correlation becomes evident, whereas observations made in the same area the year before showed no results, because the haddock stock was comparatively poor.

In fig. 9 the number of haddock caught per ½ hour trawling (fig. 7) is plotted against the corresponding bottom temperature in order to show the temperature-haddock-density correlation in greater detail. On the whole, there is a wide range of variation. The correlation, however, becomes more evident by hatching the whole area in which all points are situated. As shown by the contour of this hatched region, the optimum temperature for haddock lies between 6 to 8 degrees C. whereas minimum conditions are found to be below 5 degrees C. and above 14 degrees C. respectively, the latter with the one exception mentioned above.

Summing up, we may conclude that a correlation between the concentration of haddock and temperature exists in the region of the Dogger Bank as soon as the total number of fish in this area and the differences in temperature reach a sufficient level.

Bottom temperature, however, changes in space and time. Profitable locating of haddock concentrations by thermometric methods may be possible in this area only by systematic hydrographical observations conducted by a research vessel. Thermometric observations made by fishermen are considered helpful only in special cases.

CONCENTRATION OF HERRING IN RELATION TO TEMPERATURE DISTRIBUTION IN THE NORTHERN NORTH SEA

Four interrelations seem to exist between the concentration of herring and the distribution of temperature in the northern North Sea:

1. In summer and autumn the herrings are concentrated in the core of the cold bottom water.
2. The lower the temperature of this cold water, the longer is the duration of the concentration.
3. The geographical position of this concentration fluctuates with the dislocation of the centre of the cold water.
4. The daily vertical movements of the herring schools are influenced by the structure of the thermocline.

Recent observations prove these statements[10].

During a cruise from 6th to 20th August 1955 the F.R.S. *Anton Dohrn* investigated the relation between the distribution of the herring stocks, the activity of the trawlers, and the hydrographical conditions in the northern North Sea (fig. 10). The Atlas "Fischfinder"

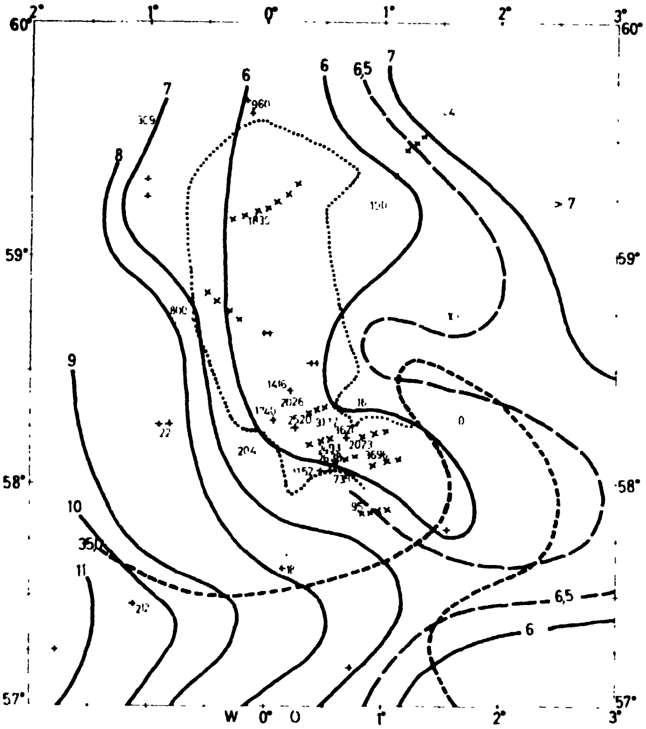

Fig. 10. Distribution of herring in the Fladen Ground area (catch per half-hour trawling, dotted line: Isoplath for 1,000 herrings); Records by echo sounding of herring (× × × Frequent, + + + Moderate, ::::. Rare); and hydrographical conditions (temperature and salinity) based on the investigations with F. R. S. Anton Dohrn *in August 1955.*

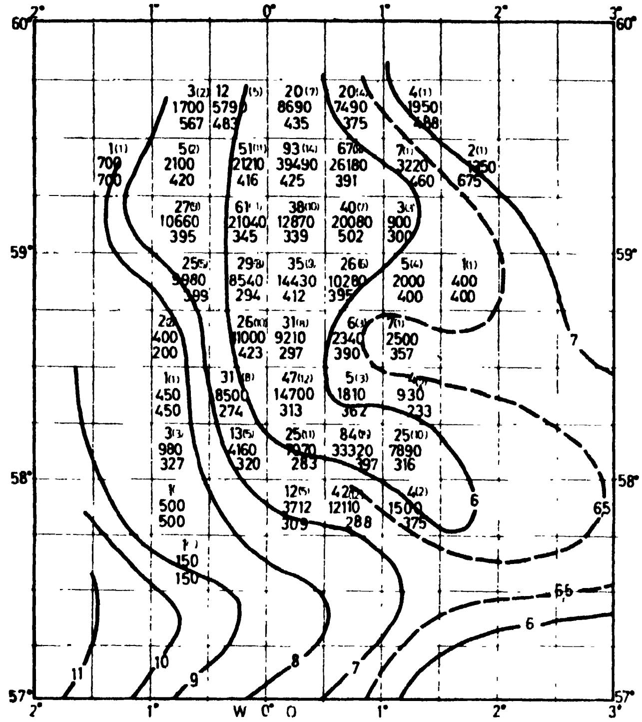

Fig. 11. Activity of the German trawlers from 1 to 20 August 1955 [Number of trawlers, fishing days (in brackets), total yields and average yield in baskets] and distribution of bottom temperature in August 1955.

was running throughout the cruise. The greatest concentration of herring was observed in the small area on the Fladen Ground and Bressay Shoal. The isoplath for 1,000 herrings per ½ hour trawling corresponds well with the cold centre of the bottom water, which covers this area in summer-time. This area also corresponds with the activity of the fishing fleet, and fig. 11 shows the number of trawlers, the fishing days, the total yields and the average catch per vessel for the period 1st to 20th August 1955.

The figures show that most fishing days and most of the fleet, which takes the major part of the catch, are

TABLE I

The Water Temperatures (Degree C.) and the Number of Fishing Days on the Fladen Ground in different Years

		1935	*1936*	*1937*	*1938*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*
May	surface .	8·0	7·5	?	8·1	6·2	8·1	7·8	8·1	?	?	9·5	8·0	8·0	7·5
	bottom .	?	6·2	5·9	7·1	5·9	8·0	7·2	7·2	?	?	6·7	6·7	?	?
June	surface .	?	11·3	11·1	?	?	11·6	10·5	10·4	?	?	11·2	11·0	11·0	10·0
	bottom .	?	6·1	5·5	7·0	5·8	7·4	7·4	7·3	6·1	6·4	6·7	7·0	6·0	5·8
July	surface .	14·4	?	14·1	13·5	15·0	12·1	12·0	13·6	?	?	14·5	11·5	12·5	12·0
	bottom .	6·8	?	5·6	6·9	5·5	7·0	6·3	7·2	?	?	6·7	7·0	?	?
August	surface .	12·5	14·1	14·1	?	16·4	13·3	14·3	14·1	?	?	14·4	14·1	14·2	13·0
	bottom .	6·8	6·3	5·6	?	6·0	7·6	7·1	7·3	6·0	7·0	7·2	6·9	5·8	5·7
September	surface .	11·8	?	?	13·4	16·5	13·0	14·2	?	?	?	12·0	12·5	14·0	12·5
	bottom .	6·9	?	?	7·5	5·5	7·1	7·6	?	?	?	?	?	?	?
Fishing	start . .	28.6.	28.6.	27.6.	24.6.	18.7.	14.7.	10.7.	25.7.	25.7.	5.7.	4.7.	24.6.	16.6.	10.6.
	termination .	6.9.	17.9.	25.9.	5.9.	28.10.	18.9.	21.9.	21.9.	25.9.	10.9.	23.9.	15.9.	23.9.	19.9.
Fishing	days . .	71	82	*91*	74	*103*	67	73	59	58	67	82	84	*100*	*102*
Air temperature in February/March (+rel. warm) (—rel. cold)		+	+	—	+	—	+	+	+	?	?	+	+	—	—

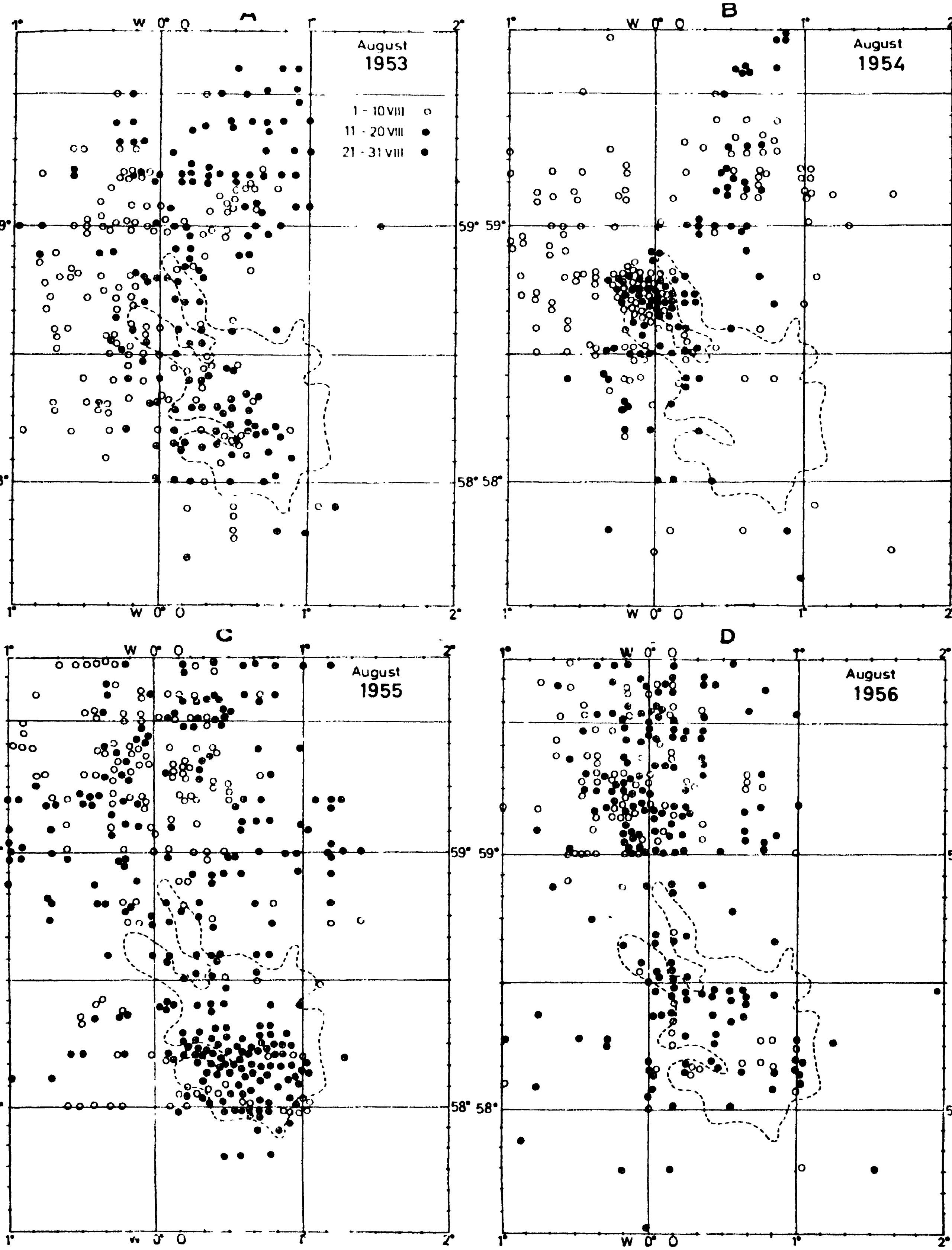

Fig. 12. A-D Distribution of the fishing fleet in August 1953 to 1956 according to weather reports.

TABLE II

The German Herring Trawl Fishery in August 1953-1956 on the Fladen Ground

	MIDDLE			*NORTH*			*EAST*			*SOUTH*			*WEST*			*NW/N from FLADEN GROUND*		
	no. of traw-lers	*aver. no. of baskets*	*fish-ing days*	*no. of traw-lers*	*aver. no. of baskets*	*fish-ing days*	*no. of traw-lers*	*aver. no. of baskets*	*fish-ing days*	*no. of traw-lers*	*aver. no. of baskets*	*fish-ing days*	*no. of traw-lers*	*aver. no. of baskets*	*fish-ing days*	*no. of traw-lers*	*aver. no. of baskets*	*fish-ing days*
1953	47	1507	18	218	1358	22	3	350	3	59	984	17	225	1526	22	72	1408	14
1954	7	962	5	82	1466	15	3	225	3	7	536	4	167	1590	21	236	1819	24
1955	165	2262	23	205	1845	24	0	0	0	438	2332	31	3	150	1	922	2407	31
1956	66	1838	20	246	1416	28	45	1057	11	123	930	22	108	1567	22	1127	1622	31

to be found in the area with bottom temperature below 6 degrees C. Unfortunately, no hydrographical survey of the whole area was made in 1953, 1954 and 1956. We know, however, by chance observations that the greatest accumulation of trawlers and the highest yields were also found in the cooler part of this area.

As shown in Table I, the period for the summer trawl fishery in several years (1935 to 1938 and 1947 to 1956) ranges from 58 to 103 days.

In years of cooler bottom temperatures (5 to 6 degrees C.), the fishing period is longer (91 to 103 days) than in years with higher bottom temperature, which indicates that the length of the fishing period is dependent on the temperature of the bottom water. The bottom temperature itself obviously depends on the weather conditions in spring. The relation between fishing time and bottom temperature may be explained by the fact that the development of the grounds depends on the temperature of the surrounding water, and consequently the herrings seem to stay longer in cold areas before they are able to spawn.

From Table II it is evident that the catches in the different areas of the Fladen Ground fluctuate from year to year. In 1953, 1955 and 1956, the catches in the area "middle" were good, whereas in 1954 they were a failure. In the area "east", the fishing activity was always poor. The area "south" shows a decline in 1954, but good fishing in 1955 and 1956. In the area "west", the fishing was a failure in 1953. It is remarkable that, since 1953, the more north-western and northern areas of the Fladen Ground have shown an increase in the fishing activity. Fig. 12 a to d shows the distribution of the fleet in August from 1953-56 according to the daily weather reports, which corresponds well with the results from Table II.

It can be concluded that the movement of the fishing fleet reflects the accumulation of herring, which is directed by the dislocation of cold water masses in connection with the variation of the current system.

The daily vertical movements of herring to the surface are limited by the thermocline in summer time. The herrings rise during the night from the bottom up to the thermocline and descend down to the bottom again in the morning. A concentration of herring food is to be found in the thermocline as soon as it develops. The herrings seem to feed at night on the plankton concentration in the thermocline and do not go up to the surface as they do when the thermocline is missing or poorly developed, in which case the drifters generally have good catches. The catches of the drifters in the central area decline quickly from May to August because the vertical movements of the herring are restricted and they no longer come within the range of the drift nets. On the other hand, successful trawl fishing begins every year between the middle of June and the middle of July, as soon as the surface temperature rises above 12 degrees C. The phenomena 1, 2 and 4 given above may be considered as safely established by observations and can therefore be used as a source of tactical information for fishermen. In addition, phenomenon 2 can be used in making strategical predictions as early as March and April, when the cold winter bottom water is formed, concerning the probable duration of the fishing in the following summer and autumn in the northern North Sea. The location of herring concentrations by thermometric methods, therefore, is possible but presumes that a research vessel will carry out systematic hydrographical and fishery biological observations.

REFERENCES

[1] Carruthers, J. N. Some inter-relationships of oceanography and fisheries. Arch. Meteorol. Geophys. Bioklimat., Ser. B, *6*. 1955.

[2] Cromwell, T. Circulation in a meridional plane in the central equatorial Pacific. J. Mar. Res. *12*, 196-213. 1953.

[3] Dietrich, G. Die natürlichen Regionen von Nord-und Ostsee auf hydrographischer Grundlage. Kieler Meeresforsch. 7. 1950.

[4] Dietrich, G., Wyrtki, K., Carruthers, J. N., Lawford, A.L., Parmenter, H. C. Windverhältnisse über den Meeren um die britischen Inseln im Zeitraum 1900-1949. Dtsch. Hydr. Inst. Hamburg. 1952.

[5] Dietrich G. Ozeanographische Probleme der deutschen, Forschungsfahrten im Internationalen Geophysikalischen Jahr 1957/58. Dtsch. Hydr. Z. *10*. 1957.

[6] Lee, A. J. The influence of hydrography on the Bear Island cod fishery. Rapp. Proc.-Verb. des Réunions. Vol. CXXXI. Kopenhagen. 1952.

[7] Murphy, G. J. and Shomura, R. S. Longline fishing for deep-swimming tunas in the central Pacific, January to June, 1952. Spec. Sci. Rep. U.S. Fish Wildlife Serv., Fish No. 108. 1 to 32. 1953.

[8] Prahm, G. Summerly bottom temperature in two selected areas of the Central North Sea in the years 1900 to 1956. Ann. Biol. (1956) *13*. 1958.

[9] Sahrhage, D. Haddock of the North Sea. German investigations. Ann. Biol. (1956) *13*. 1958.

[10] Schubert, K. The conditions of the Herring Fishery in the Northern North Sea during August 1955. Ann. Biol. (1955) *12*. 1957.

[11] Sette, O. E. Consideration of mid-ocean fish production as related to oceanic circulatory systems. Jour. Mar. Res. *14*, 398-414. 1955.

RADIO DIRECTION FINDERS AND RADAR USED BY JAPANESE FISHING VESSELS

by

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Abstract

In addition to echo sounders and a comprehensive range of radio, the Japanese fishing fleet is being equipped with many modern devices which help in both navigation and fishing. The modern radio direction finder uses a Cathode Ray Tube which instantly gives the correct bearing of the transmitting station. New radars have been produced for use in small fishing craft. In conjunction with these, radar-reflecting buoys are used to enable the fisherman to keep in touch with his nets at all times.

Equipement électronique utilisé à bord des bateaux de pêche japonais

Résumé

Outre les écho sondeurs et une gamme très complète d'appareils de radio, la flotte de pêche japonaise est dotée d'un grand nombre de dispositifs modernes qui facilitent aussi bien la navigation que la pêche. Le radiogoniomètre est équipé d'une lampe à rayons cathodiques qui donne instantanément la direction exacte de la station émettrice. Il existe également un radiotélémétre à longueur d'onde unique permettant de déterminer avec une grande précision la distance d'une station fixe ou flottante, et de nouveaux radars ont été mis au point à l'intention des petits bateaux de pêche, qui utilisent avec ces appareils des bouées munies d'un réflecteur de radar pour repérer à tout moment leurs filets.

El equipo electrónico usado en los barcos pesqueros japoneses

Extracto

Además de las ecosondas y una gran colección de equipo de radio, la flota pesquera japonesa cuenta con varios inventos modernos que sirven como ayudas para la navegación y la pesca.

El radiogoniómetro usa un tubo de rayos catódicos que da instantáneamente la posición correcta de la estación transmisora. También hay un equipo de radiotelemetria—que usa un sistema de onda única mediante el cual puede determinarse con gran exactitud la distancia a que se encuentra una estación fija o flotante—y nuevos aparatos de radar para uso en embarcaciones pesqueras pequeñas. Con este equipo se usan boyas provistas de radar para que el pescador se mantenga en contacto continuo con sus redes.

RADIO DIRECTION FINDING

WITH the hand operated direction finder originally used on fishing vessels, the bearing of the radio station was found by rotating the loop antenna until a minimum of signal was heard.

This system is now replaced by the goniometer system using two fixed loop antennas adjusted at right angles to each other and mounted in a suitable position on the superstructure of the vessel. The minimum of reception is found by turning a goniometer coil which can be hand operated or automatically revolved. The indication of the reception is no longer acoustical but is effected by means of a Cathode Ray Tube (C.R.T.). With the hand operated equipment, the bearing of the radio station is given by the angle of the goniometer coil at the point of minimum reception which is determined from the size of the amplitude indicated on the C.R.T. With the automatic system, the goniometer is revolved at a high speed and the bearing of the radio station can be determined continuously from the shape of the amplitude configuration on the C.R.T. screen.

The automatic system is easy to handle and gives quick and accurate measurements under the stringent conditions as are common in fishery. Because of this superiority, it is gradually replacing the hand operated system.

The set consists of a goniometer, rectifier, loop antennas, speaker, inverter and the direction indicating C.R.T. which are contained in one housing. After switching on the instrument, the dial is turned to the frequency of the radio station of which a bearing is to be taken. A propeller shaped image then appears on the C.R.T. When the receiver is not properly tuned only a round shaped image will appear on the screen.

The angle at which this propeller is tipped indicates the direction from which the radio beam is coming. When the sense button is pressed, the image tilts to the right or left of the direction line, thus indicating the bearing by means of a 360 degree scale.

The frequencies used in direction finding have been between 200 kc. and 500 kc., but higher frequencies of

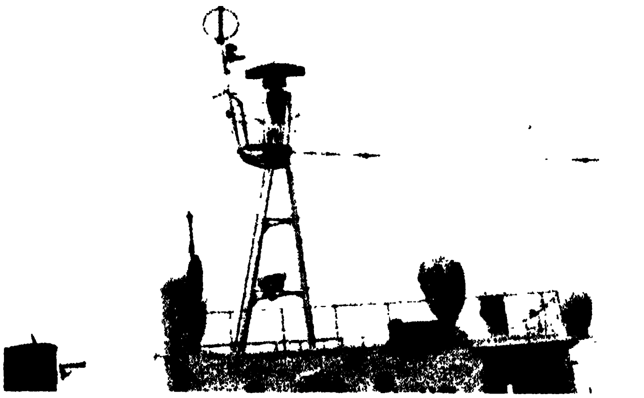

Fig. 1. Typical installation of a double loop antenna on top of a radar mast.

1·7 mc. to 4 mc. or more are now being used by fishing vessels too.

The main and at present unavoidable causes of errors in radio direction finding are:

1. Distortion of signals by the ship and its superstructure (mast, funnel, and antenna)
2. Reflection of signals from the Heaviside layer
3. Terrestrial conditions

Since the causes given under 2 and 3 do not occur in the open sea, they constitute no serious problem, but the errors arising from the ship's hull and superstructure increase with the frequency and in extreme cases, they may even cause resonance with the radio signals. Therefore when using high frequencies on comparatively large vessels, the antenna must be installed as far away from the hull as possible. In Japan, good results are obtained by mounting the antennas on the top of masts or radar towers (fig. 1).

It is now possible for 300 ton fishing vessels to use frequencies up to 3,500 kc. and even 10,000 ton whalers can use up to 3,000 kc.

SMALL MARINE RADARS

In 1951 several manufacturers started or resumed their study and production of marine radars, and at present at least ten companies are manufacturing different kinds of radars and more than 800 Japanese ships are equipped with these instruments.

Marine radars can be classified into three size groups according to the size of the ships they are used for.

As examples for the models designed for fishing purposes, the following are some of the special features of the BR-10 and AR-25 type marine radars.

(a) Current consumption less than 550 W.
(b) Weight less than 160 kg.
(c) Easy maintenance
(d) Low price
(e) Sturdy manufacture to withstand the rough working conditions.

The technical details of these two models are given in Table I and the indicator unit of model BR-10 is shown in fig. 2.

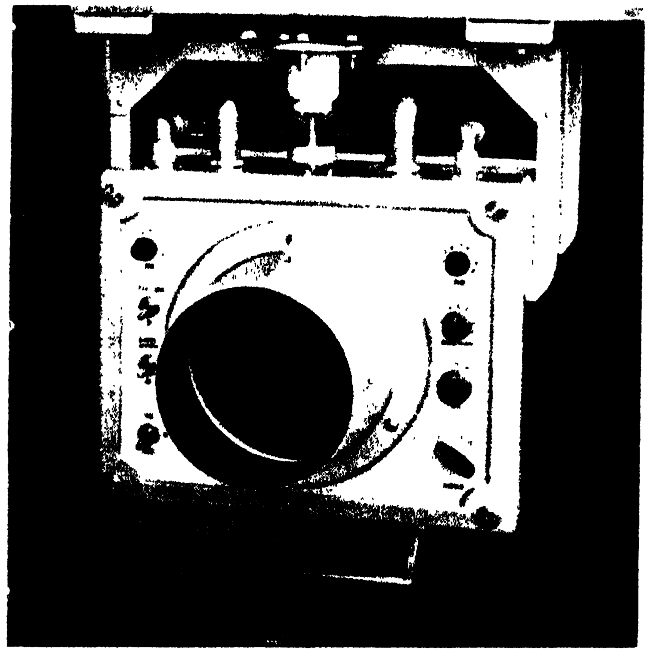

Fig. 2. Indicator unit of the model BR-10 radar.

APPLICATION TO FISHING OPERATIONS

The small marine radar plays an important role in the operation of fishing boats, especially in combination with a corner-reflector. Extensive studies and experiments in the use of these aids are being made in the salmon and trout fisheries in the Northern Pacific.

TABLE I

Item	*AR-25*	*BR-10*
Frequency Band	9345–9405 MC	9320–9430
Output	10 kW.	10 kW.
Pulse Width	0·27–0·33 μ sec.	0·35 μ sec.
Pulse Repeating Frequency	1000 c./sec.	800 c./sec.
Type of Antenna System	Double Cheese type	Reflector and Horn type
Width of Scanner	3 ft.	4 ft.
Revolution of Antenna	15 r.p.m.	15 r.p.m.
Bearing Resolution	3 degrees	2 degrees
Range Resolution	60 m.	70 m.
Minimum Range	70 m.	70 m.
Diameter of Scope	7 in.	7 in.
Range	1, 3, 10, 25 mile	1, 5, 4, 10, 20 mile
Range Accuracy	± 2 per cent.	± 2 per cent.
Power	550 W. D.C. 24 V., 100 V., 220 V. A.C. optional	Antenna D.C. 100 V. or A.C. 100 V., 150 W. Others D.C.24 V. or 100 V., 350 W. or A.C. 100 V., 50c./sec. 200 W.
Weight		
Scanner	45 kg.	60 kg.
Mast		35 kg.
Indicator	18 kg.	35 kg.
Modulator	18 kg.	
Rotary Converter	15 kg.	15 kg.
Automatic Voltage-Regulator	35 kg.	10 kg.
Position of Installation	Optional	Indicator must be directly beneath the antenna mast.

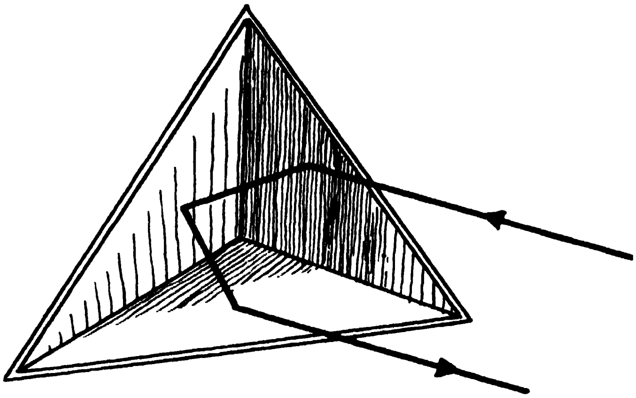

Fig. 3. Triple reflection at a corner reflector.

Corner reflectors are frequently used in order to increase the range of radar with respect to small objects such as fishing boats and buoys. A corner reflector consists of three metal plates adjusted normal to each other. This adjustment results in all incoming waves being reflected to the point of origin (fig. 3). A corner reflector, therefore, provides optical reflection independent of its actual position to the direction of the radar beam. The maximum allowance for the right angle adjustment is ± ½ degree. The construction must be rigid enough not to be deformed by waves and wind pressures, which usually means a rather heavy weight.

When used for marking the position of fishing nets, the reflectors have to be attached to rafts or other floats for which purpose their heaviness makes them very inconvenient. The buoy-type corner reflector was designed to overcome these difficulties (fig. 4). The reflecting plates are made of thin aluminium plate, which is filled in with polystyrene foam, through which micro waves pass without loss. As illustrated in fig. 5 its exterior is a ball which maintains high mechanical accuracy and strength. The specific gravity of the foam polystyrene being approximately 0·03, the ball can float on the water surface.

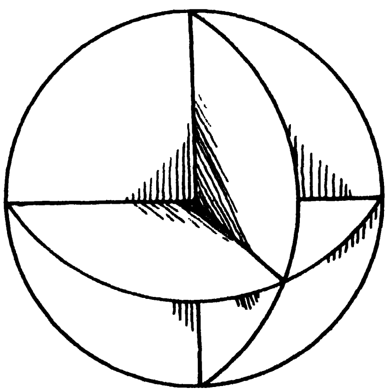

Fig. 4. Shape and adjustment of the reflecting plates of a buoy type corner reflector.

TABLE II

Diameter	*35 cm.*	*70 cm.*
Weight	Approx. 400 g.	Approx. 1,200 g.
Maximum Range (by Radar)	A. approx. 2·2 naut. miles (when floating by itself) B. approx. 4·2 naut. miles (when attached at 1·0 m. above the surface)	A. approx. 3·4 naut. miles (when floating by itself) B. approx. 5·8 naut. miles (when attached at 1·0 m. above the surface).

Two models of different size are available at present, the main features of which are given in Table II.

Fishing in the Northern Pacific Ocean is governed by the Japan-U.S.S.R. Fishing Treaty, which strictly limits the length of the nets and the space between the nets of neighbouring boats. Hence it is very important to keep the relative position between the nets of different ships as specified which may be difficult in rough seas where visibility may be reduced to zero. The small marine radar solves this problem. Corner reflectors are attached to the nets at several points to make their position visible on the radar screen. This enables a skipper to determine his own position in relation to the others and their nets and shoot his own nets at the specified distance.

Radar can also be used as a very effective aid in crab fishing. The crab nets are usually set parallel to the coast and at intervals of 200 to 300 m. The total length of one series of nets is approximately 4 nautical miles. By watching the radar traces of the corner reflectors attached to the net buoy, the skipper can shoot his nets even in fog at the proper distance from the gear of other boats making allowance for tide and current. Formerly, the whole operation had to be suspended in dense fog. In this fishery the radar must be very accurate within the range of 100 to 300 m.

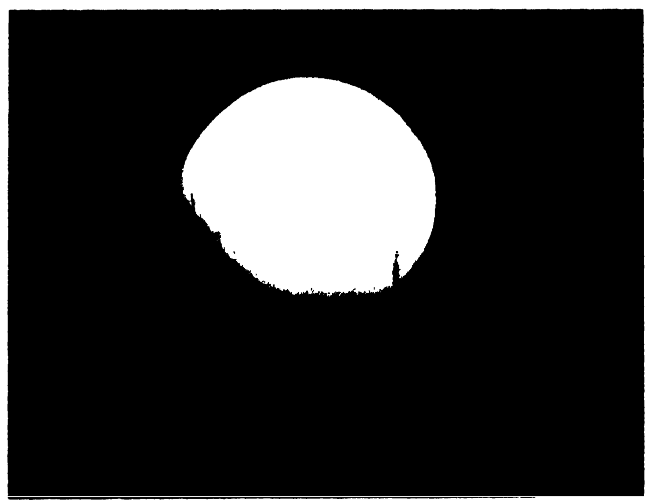

Fig. 5. Complete buoy-type corner reflector.

RADIO COMMUNICATION APPARATUS FOR FISHING BOATS IN JAPAN

by

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Abstract

The author gives a general survey of the radio equipment used at present in Japanese fishing vessels; the frequency bands used and the intercommunication facilities. He deals further with the Radio Rotary Beacons, whose signals can be picked up with an ordinary receiver and the use of automatic radio-buoys to mark nets and captured whales, using low powered transmitting sets.

The author stresses the great need for improved radio transmission and reception to avoid interference and disturbance during communication.

Les appareils de radio communication pour les bateaux de pêche au Japon

Résumé

L'auteur donne une vue d'ensemble de l'équipement radio utilisé actuellement à bord des bateaux de pêche japonais, des bandes de fréquence utilisées et des installations d'intercommunication. Il traite en outre des radiophares tournants dont les signaux peuvent être reçus par un récepteur ordinaire et de l'emploi de bouées radio automatiques pour marquer les filets et les baleines capturées en utilisant des émetteurs à faible consommation d'énergie électrique.

L'auteur souligne le grand besoin d'une meilleure émission et réception radio pour éviter les interférences et les brouillages pendant les communications.

Los aparatos de radio comunicación de los barcos de pesca del Japón

Extracto

El autor hace une exposición general del equipo de radio empleado actualmente a bordo de los barcos de pesca japoneses, de las bandas de frecuencia usadas y de los medios de intercomunicación. Pasa a ocuparse de los radiofaros giratorios, cuyas señales las puede recoger un receptor corriente y del empleo de radiobalizas automàticas, para marcar artes de pesca y ballenas capturadas, empleando emisores de poco consumo de energía eléctrica.

El autor subraya la gran necesidad que existe de mejorar la emisión y recepción de radio para evitar las interferencias y perturbaciones durante la comunicación.

RADIO FACILITIES ON BOARD THE VESSELS

ALL Japanese fishing boats over 100 tons are obliged to carry radio transceivers, the effective range of which is shown in the table below. They, therefore, are equipped with MHF (medium/high frequency) transceivers, with frequencies between 410 kc. and 4,000 kc. In addition, some have HF (high frequency) transceivers between 4 Mc. and 23 Mc. (Megacycles) for long distance communication and eventually also telephony transceivers for the 150 Mc. or 27 Mc. band, for short distance communication. Most boats of under 100 tons also have MHF trans. ceivers; boats which communicate only over shor-distances use 27 Mc. or 150 Mc. band radio transceiverst

Tonnage of boats	Effective distance of communication at A2, 500 kc. daytime	
	Main Equipment	Emergency Equipment
1,600 tons and over	More than 280 km.	More than 190 km.
500 to 1,600 tons	,, ,, 190 ,,	,, , 140 ,,
300 to 500 tons	,, ,, 100 ,,	,, ,, 95 ,,
100 to 300 tons	,, ,, 100 ,,	— — —

The number of fishing boats fitted with radio equipment is given below:—

Equipment	Number of boats
Telegraphy	1,262
Telephony	3,928
Both telephony and telephony .	957
VHF (very high frequency) . .	280

FREQUENCY BANDS

Besides the MF and HF bands generally assigned to marine mobile stations, some frequency bands are allotted exclusively for fishery. The frequency bands commonly used are:

Frequency Range	Number
MHF band (410 to 4,000 kc.)	49
27 Mc. band	9
150 Mc. band . . .	10
MHF band for radio buoys .	13

COAST STATIONS

Communication for fishing boats is two-fold, between boats, and between boats and special fishery coast stations. Communication with coast or harbour stations for general shipping traffic is exceptional. The fishery coast stations, which are located at all the main fishing ports, are founded by prefectures or fishing guilds and communicate with the guild members' boats. The number of stations is given below:

Coast stations for fishing boats		*Number of stations*
Communicating mainly by	telegraphy	48 (HF Stations 13)
	telephony	35
	VHF band	27
	27 Mc. band	109

EQUIPMENT

Radio Telegraphy

For boats over 100 tons, MF transmitters (410 kc. to 535 kc.) are obligatory, but MHF (1605 kc. to 4000 kc.), which is the main frequency band of fishery communication, may also be used: since HF for long-distance communication is also utilized, there are three bands with 10 to 11 channels. The antenna power of the transmitters lies between 50 W. and 500 W. When the power is less than 150 W., radio telephony is generally confined to the MHF band. Big fishing vessels have three transmitters, MF, MHF and HF, and an emergency set. The usual power of the emergency set is 25 W. or 50 W.

The high frequency bands mainly used have been 4 Mc., 6 Mc. and 8 Mc., but recently 12 Mc., 16 Mc. and 22 Mc. bands have become popular because of congested communication. Consequently, increasing use of the HF bands is evident even in middle class and smaller boats. All transmitters have the quartz crystal controlled power amplification system, the break-in communication system, and the one switch channel change system, except in the HF band.

MHF Radio Telephony

Most of the bigger fishing vessels have MHF radio equipment which can be used for both telegraphy and telephony. The equipment of the small boats is suitable for MHF telephony only, has an antenna power of about 50 W. and mostly 6 channels. All these telephony sets have also the quartz crystal controlled power amplification system, the press-talk system and the one switch channel change system.

HF Radio Telephony

The 27 Mc. band has been adopted by the fishing industry since 1955 to make up for the shortage in the MHF bands. It is used for short distance communication only. The transceivers which work with A.M. (amplitude modulation), have an antenna power of 10 W. and 2 to 3 channels.

Recently the 150 Mc. band has come increasingly into use for short distance communication. Most of the equipment works with F.M. (frequency modulation) and only some with A.M. The antenna power is 10 W., with one to two channels.

Radio Receivers

Usually, large fishing boats have three receivers, one for all-wave, one for HF, and one for emergency; middle class boats have two all-wave, and smaller boats one all-wave receiver.

Ships without radio direction finders can make use of the Radio Rotary Beacon station if they have beacon band receivers. Radio Rotary Beacon receivers which can receive the beacon band (285 to 325 kc.), the MF broadcast band (535 to 1605 kc.) and the MHF band (1605 to 7000 kc.), have come increasingly into use for small fishing boats which have no other radio equipment.

At present there are 15 Radio Rotary Beacon stations, but at least 30 more stations are to be built.

Radio Buoys

Such buoys are fixed to captured whales, fishing nets, etc. The small-sized transmitter, which is installed in the buoy, transmits signals automatically at regular intervals, which enable its position to be spotted by means of radio direction finding. The most common type uses a MHF band and has an antenna power of 2 to 3 W. They are now so common in sea fisheries that the problem of interference has arisen. A device to overcome the difficulty is being studied. This will have a receiver which starts transmission only after selective receipt of a special signal from the respective fishing vessel.

General tendencies of improvement

The adaptation of electronics to fishing boats is increasing and many new devices are being developed. The future trend will be substantially as follows: –

(1) *More use of radio equipment in small fishing boats.* Many small fishing boats (up to 20 tons), which at present have no radio equipment or only radio receivers, are likely to adopt radio telephony transceivers of small power.

(2) *Improvement of the performance of radio transceivers.* Interference and disturbance have increased with the growing number of users, and less time is permitted for communication. Improvement in the quality of transmission is urgently needed, such as by diminution of the frequency band width of transmission, checking the radiation of spurious frequencies, etc. Receivers of increased stability and selectivity are needed.

(3) *Speeding-up of communication.* A simple, small high-speed transceiver is being developed to relieve the congestion and speed up communication. This will replace the conventional hand-operated telegraphy.

(4) *Adoption of SSB system in radio telephony.* At present DSB (double sideband transmission) is used exclusively in radio telephony on the HF band. But, as the allotment of band width is now very difficult, the adoption of the SSB (single sideband transmission) system for radio telephony of small power is being studied. The quality of communication is thereby improved and because of the narrower band width needed, the channels assigned to telephony could be doubled. A SSB radio telephony transceiver recently manufactured was successfully tested, and appears to be suitable for replacing the present DSB equipment.

THE DECCA NAVIGATOR SYSTEM AND ITS APPLICATION TO FISHING

by

THE DECCA NAVIGATOR CO. LTD.

Marine Sales Department, London, S.W.9

Abstract

This system consists of several chains of land-based transmitting stations and an appropriate set of meters (the decometers) and receiver installed on board ship. It enables skippers to navigate with extreme accuracy up to 240 miles from a master station and some 1,400 fishing vessels of all classes, both in the U.K. and in other countries, are now fitted with the equipment. Pin-pointing of trawling grounds is accomplished with ease and a skipper can cover an area without going over the same ground twice and without the use of a dan buoy. The use of the Marine Automatic Plotter for fishing is also described. This instrument removes the need for manually transferring the Decca readings to the chart by making a continuous plot of the ship's track, and by its aid a course can be retraced with precision. Its value in fishing is obvious.

Le système Decca Navigateur et des applications à la pêche

Résumé

Ce système comporte d'une part plusieurs chaînes de postes émetteurs terrestres et, de l'autre, des appareils de mesure appropriés (décomètres) et un récepteur montés sur le navire. Il permet aux patrons de pêche de naviguer avec une très grande précision jusqu'à 240 milles d'une station maîtresse, et quelque 1 400 bateaux de pêche de tous types appartenant au Royaume-Uni et à d'autres pays sont maintenant équipés de cet appareil. Le repérage exact des lieux de chalutage s'opère facilement et un patron de pêche peut chaluter une zone sans repasser deux fois sur le même endroit ni avoir recours à des bouées de repere. L'auteur décrit également l'emploi du Marine Automatic Plotter (traceur de route automatique) pour le pêche. Cet appareil qui donne un trace continu du parcours du navire évite ainsi de repo ter sur la carte les indications du Decca et permet de retracer une route avec précision. L'intérêt qu'il présante pour la pêche est évident.

El sistema "Decca Navigator" y su aplicación en la pesca

Extracto

Este sistema está formado por varias cadenas de estaciones trasmisoras terrestres y aparatos de medida ("decometros") adecuados que se conectan con un receptor a bordo del barco, los cuales permiten a los patrones de barcos navegar con gran precisión hasta 240 millas de distancia de la estación maestra. Unas 1.400 embarcaciones pesqueras de todas clases, tanto en el Reino Unido como en otros paises, poseen en la actualidad dicho equipo que ayuda a determinar, en forma precisa y con facilidad, la posición de los bancos donde se practica la pesca de arrastre, pudiendo el patrón cubrir una zona sin pasar por ella dos veces ni usar boyas. En el articulo también se describe el empleo del "Marine Automatic Plotter" en la pesca, que elimina la necesidad de transportar manualmente las lecturas obtenidas con el "Decca" a la carta de navegación, traza en forma continua el rumbo del barco y mediante su ayuda permite reproducirlo con precisión. Por las razones mencionadas, el valor de este instrumento en la pesca es evidente.

GENERAL

THE most successful and accurate aids to navigation which have been developed over the past 50 years are those based on radio technique. They involve the use of electromagnetic waves, which usually enable a fix to be obtained in all types of weather conditions.

The first stage in the use of radio waves was radio direction-finding, enabling the mariner to find the direction from which the radio waves originate, i.e. the bearing of the transmitting station. A second stage was the discovery of a means for determining the distance, by measuring the time taken by a radio wave to travel from the transmitting station. Radar and Shoran are examples of this development.

The third stage marks the development of hyperbolic systems, where, instead of the distance to a fixed station, the difference in the distances to two fixed stations is measured, resulting in hyperbolae as position lines. This can be done either by measuring the difference in time that it takes the radio waves from the two stations to reach the observer, or by measuring the difference in phase between the two radio waves at the point of observation. The Decca Navigator System uses the latter method.

DESCRIPTION OF OPERATION

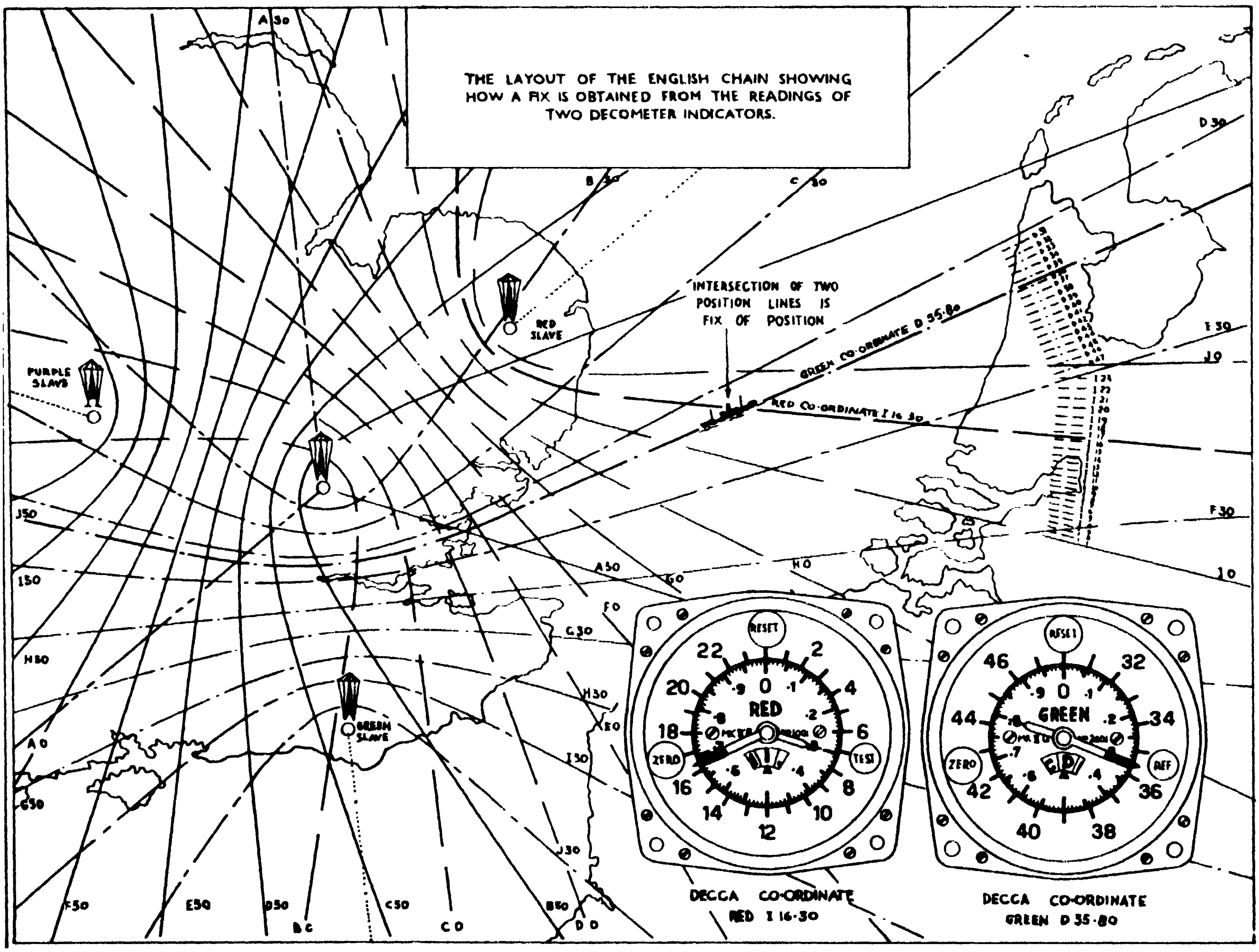
The system consists of several chains of land-based transmitting stations and a set of meters (the decometers) and receiver (the Decca Navigator) installed on board the ship. A set of specially overprinted charts is used to plot the information from the decometers.

Each chain comprises four stations (a master and three slave stations) which transmit continuous radio waves. The receiver which picks up these transmissions, actuates three decometers, designated, Red, Green, and Purple. Each compares the transmission from the master and Red slave, Green slave and Purple slave station respectively, and is based upon phase-comparison of the incoming signals. As the phase condition of a radio wave in a certain place at any given moment depends upon the wave-length and the actual distance from the transmitter, phase-comparison is closely related to a measurement of the difference in distance from the master and respective slave stations. A position line indicating a fixed phase difference between, say, master and red slave station and therefore defining a fixed difference in distance to the master and the red slave, is by definition a hyperbola, and a lattice of hyperbolic red position lines is therefore set up between these two stations. A similar lattice of green and purple position lines exist between the master and the green and purple slave stations respectively. The patterns intersect in such a way that at any place two of them will yield a pair of position lines by which the ship's position may be fixed.

The hyperbolic position lines on the chart are numbered and the readings on the three decometers correspond with these numbers. At the start of a voyage or on entering the Decca coverage, the decometers are set up manually to the numbers indicated on a fourth dial, the Lane Identification meter. Thereafter, the decometer pointers, rotating automatically as the ship proceeds, will give readings corresponding to the ship's position. Lane Identification readings continue to be given three times every minute, thus providing a valuable independent cross-check in addition to enabling ocean-going vessels to set their decometers on first entering the area covered by the System.

To fix his position, the mariner reads two of the decometers and finds on his chart the intersection point of the two position lines bearing the numbers indicated. Readings from only two decometers are sufficient; the two corresponding to the patterns giving the best angle of cut in the particular area (fig. 1).

The space bounded by two adjacent 'in-phase' hyperbolic position lines is called a Decca lane, and the pattern produced by one pair of stations may contain 200 or more of these lanes. Measured along the inter station base line, the lane width is some 500 yards. Each



PURPLE ——————·—————— GREEN —————— —————— RED

Fig. 1. Illustration of how the Decca Navigator System functions.

decometer is capable of measuring 0·01 of a lane, representing about 5 yards.

The charts used in conjunction with the System are normal navigational charts over-printed by the Hydrographer of the Navy with the Decca hyperbolic position lines (fig. 2). In addition, special fishing charts are being issued which are similarly latticed. As these are normally of a small scale, we are now preparing special plotting sheets of a much larger scale, say, 1 : 200,000, which give only the Decca lattice lines for a particular area plus a geographical reference in the form of one parallel and one meridian. The fishing grounds can be drawn in by the skipper himself, with the positions of various wrecks known to him.

COVERAGE AND RANGE

Due to the frequencies used, which are in the area of 100 kcs., the operational range is about 300 to 500 miles. As a rule, the normal transmissions of a Decca Chain may be used as a general navigational aid up to 240 miles from the master stations in areas covered by Decca charts. Eight chains of Decca stations cover North-West Europe from Cape Finisterre to the Gulf of Bothnia and the Faroe Islands (fig. 2). In North America three chains have been recently established in Newfoundland and Nova Scotia, which also cover the rich fishing grounds in that area.

APPLICATION TO FISHING

The accuracy with which the Decca Navigator fixes a ship's position makes the System particularly valuable to fishing. Some 3,200 fishing vessels of all classes, such as trawlers, seine netters and drifters, in the U.K. and abroad are already fitted with this type of equipment. The advantages may be listed as follows:

1. Pin-point positions save much wasted steaming time in reaching the fishing grounds and the subsequent return with the catches. Exact courses can be steered and accurate landfalls made by means of a regular check of the decometer readings. This simple operation will also enable the skipper to cover the fishing grounds very thoroughly, not leaving any spot untouched or going over the same place twice. Any specially profitable area can be plotted with extreme accuracy and the vessel can be taken back to the same locality again and again with great precision, without even the use of a dan buoy and regardless of visibility.

   A common practice of many fishermen is to trawl along a certain Decca position line thus keeping one of the decometers, say, the red one, at a stable reading. When the trawl is put out, the reading of the other, say, the green decometer, is also noted, and this procedure repeated at the end of the track after about three or four hours. If the catch is good and of the right quality fish, then the skipper will endeavour to retrace his course by following the same Decca lattice line on the red decometer until he has arrived at the original point where he obtained his first reading on the green decometer. All the time his red reading will tell him whether his vessel is making leeway or drifting and to what extent.
2. A noticeable reduction in losses of nets has been experienced on board the ships fitted with the Decca Navigator. The presence of wrecks with which the trawl net and gear may become entangled can cause the complete loss of a trawl or at least some considerable damage plus loss of time involved in disentangling the gear. Often, however, fish abound close to wrecks and rocks.

The Decca Navigator enables every movement of the vessel to be immediately shown on the decometers, and these dangerous grounds can be passed at very close proximity once the Decca position is known.

This is of even more importance with seine net fishing. Seine fishermen use very light fishing gear and a great deal of damage can be done to a net and the ropes by rocks and wrecks. They are, therefore, very particular in finding clear ground before shooting their net.

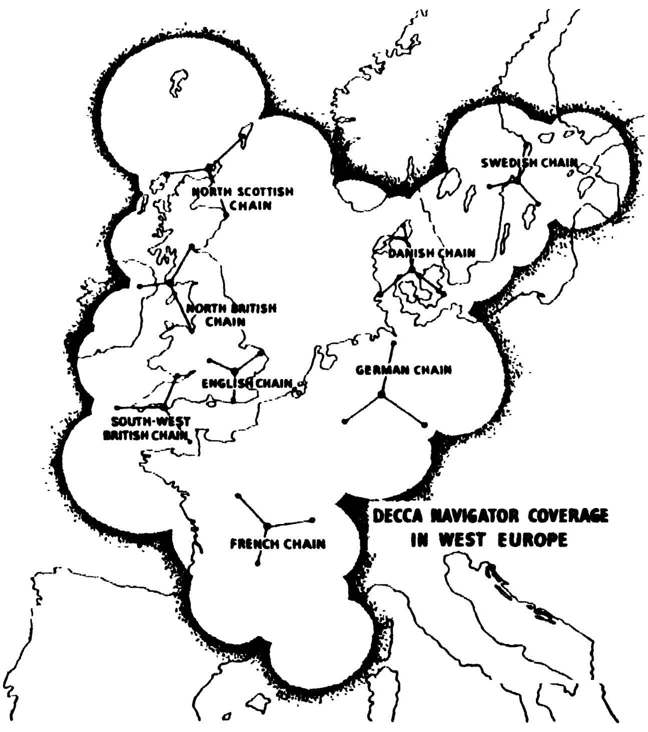


Fig. 2. Decca Navigator coverage in West Europe.

THE AUTOMATIC PLOTTER

This recently developed instrument has been in use for several years for other purposes, such as mine-sweeping, hydrographic survey and submarine oil-exploration. It is a device similar to the Flight Log used in aircraft, and produces a continuous record of the ship's position on a roller-mounted chart by means of a plotting pen. The Decca information, which is normally taken from the decometers and plotted by hand on a Decca lattice chart, is fed into a servo amplifier and translated into a pen and paper movement, horizontally and vertically, respectively. In this way, a continuous plot is produced of the track made good. Various scales are provided,. giving a movement of $\frac{1}{4}$ in. to 4 in. per Decca lane, whilst

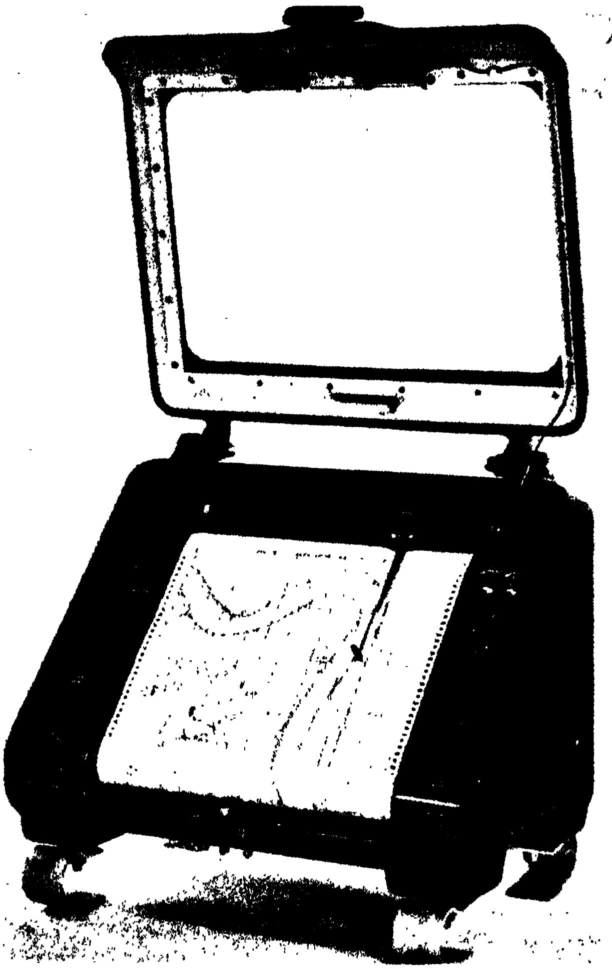


Fig. 3. Decca Marina Automatic Plotter.

the Display Unit shows a chart area of 10 in. by 10 in. As the plotting pen and the chart move at right-angles to each other, the hyperbolic Decca position line patterns are presented upon the chart in a rectilinear lattice form (fig. 3).

This brings about a certain amount of chart distortion which will vary according to the position of the ship in relation to the Decca Chains in use. However, compass roses can easily be computed and drawn, informing the user of the amount of distortion. In practice, no distortion has proved to be of inconvenience within 150 miles from the master stations.

The Marine Automatic Plotter has proved of great value to trawling. The Decca Navigator enables the fisherman to plot any specially profitable area and return to it again and again with precision in all visibilities. To accomplish this, it was hitherto necessary to follow a certain Decca lattice line, i.e. to keep one of the decometers at a stationary reading. This restricts the user to certain courses, depending also upon which chain of stations he has selected. For instance, many fishermen operating in the German Bight make use of the German Chain, because its lattice lines run in a more suitable direction over the fishing grounds, rather than the Danish Chain, although the characteristics of the latter for that area provide better means for accurate position fixing. With the aid of the Marine Automatic Plotter, it is no longer necessary to follow a certain lattice line, as it enables the user to check his positions at a glance with reference to his point of origin, and steer the vessel back to this point along a straight course. Thus the Plotter makes the Skipper independent of the chain pattern. Moreover, by using the largest scale in the appropriate areas, i.e. 4 in. to 1 lane representing approximately $1\frac{1}{4}$ miles at 150 miles from the master stations, the instrument provides detailed and continuous information of the track made good, whilst at the same time the position of wrecks and details of the fishing grounds can be marked.

Another feature is the safe and quick piloting of vessels over tracks previously made. When leaving harbour under good weather conditions, the Marine Automatic Plotter will draw a track which can be used when returning. If, then, visibility should be bad, the helmsman can steer the ship in the opposite direction along the track recorded on the way out.

This method has been adopted with success on various trawlers in Great Britain, Germany, Belgium and France.

DISCUSSION ON FISH LOCATION

Dr. A. W. H. Needler (Canada), Chairman: The general strategy of fishing covers a broad subject concerned with how to find more fish as food for our growing population, and how to better the lot of the people who produce the food. This means a much broader examination of the problem. Three phases to be considered are: location of fish; detection of fish; and attraction of fish. These overlap to a considerable degree. The first item concerns the problem of where to find fish.

Mr. S. Holt (FAO), Rapporteur: Detection is a matter of communication between fish and man, and a communication system consists of a transmitter which produces signals to a receiver. The source of the signal is the fish and the signal may be, for instance, a sound or a movement made by the fish. The signal channel is usually some characteristic of the water itself, its conductivity for sound, pressure waves, or light. The receiver can be the human eye or the ear or, more likely, an instrument to amplify the signal.

Attraction covers also repulsion and any other stimulating effect. While the transmitter in this communication system may be a man's voice, a board he bangs on the water, a light, or an ultrasonic oscillator, the channel is again provided by one or other properties of the water, and the receiver is one or more of the sense organs of the fish. Fish react by becoming excited, turning, swimming towards or away f.om the source of the signal, i.e. being directed, attracted or repelled. For attraction and detection the relevant properties of the water act as a signal channel: ability to conduct heat or electricity, to flow, to propagate mechanical or electro magnetic waves, the physical chemical property of diffusing dissolved chemicals. Almost all these properties have been used by fishermen and scientists to direct or detect fish. The instruments used may also be the same in both cases. In detection, the fish may produce a signal spontaneously, but we can also induce the fish to give signals, as for instance, by making a sound which disturbs the fish, which can then be seen by its movement. An electric pulse may induce the fish to make a sound, which we in turn hear. In detection methods using echoes, a signal received back is usually of the same kind as that originally sent out. But the fish is not just a passive reflector. The character of the echo from the fish depends as much on the behaviour of the fish as it does on its anatomy.

Usually a variety of signals arrives at the receiver. Not all of them will be from the original transmitter and carry a message. There are others which come from outside sources. They are a disturbance for the communication system and the elimination or reduction of this "noise" is one of the main problems in communications engineering.

However, what is noise to one man may be a message to another. If we are trying to detect fish by echo-sounding, an echo from the seabed, or from a patch of plankton, or from a water layer where the temperature is changing rapidly, may be a nuisance in detecting, but any one of them may lead to a way of improving location methods.

Location and detection differ only in that for location, we may find fish indirectly by detecting not the fish themselves, but something else, the distribution of which is closely related to that of the fish, as, for example, the type of bottom or the temperature distribution in the water which often is associated with plankton concentrations which are the food of pelagic fish. Furthermore some fish are restricted to a certain temperature range. If, for example, a certain kind of fish is never found in water of less than 5 degrees C. or more than 7 degrees C., then a signal from the thermometer that the temperature is 3 degrees C., is a definite message: no fish of that certain kind can be expected. A temperature of 6 degrees C. would not mean that there is fish, but only that fish may be present.

Science can help by inventing instruments to receive signals man cannot himself receive, such as ultra sound or infra red light. Science can also improve methods of interpreting such signals, resulting in more reliable messages. Organising the collection of data is another means for improving location methods. Here, the fishermen, the special research ships, and science have to collaborate closely. Dietrich *et al.* conclude in their paper on the relation of fish to temperature that only fully synoptic observations, made as a special research project, can lead to satisfactory results. In many cases, however, a fisherman himself can use instruments to help him locate good fishing grounds.

If fish can be expected to stay where they have been found before, the only location problem would be to find one's way back to the same place. If they are spread about very unevenly, it may be necessary to get back rather precisely to the same position, even within a few metres. Kodaira, the Suiyokai and the Decca Navigator Company describe modern equipment for such spot plotting.

Other than navigational factors will be important if we want to search areas previously unexploited; or if the fish move about much. In the first case, we can make fishing trials, and cruise about with detecting instruments. But the oceans are so vast that an indication as to when and where to look would be helpful. We now know a little about the parts of the ocean where fish are likely to be found, but not enough to advise confidently on the success of a new fishing enterprise. We also know a little about the kinds of fish to expect in certain areas.

A knowledge of the kind of relation between the fish and its environment not only reduces the work of searching, but also helps in deciphering the detective signal. The instruments being developed now for navigation and for detection, can help to improve location methods. They allow to identify for instance concentration of fish foods, bottom types and so on, and find the correlation between fish distribution and such factors more quickly by measuring fish abundance without having to catch them.

Schaefers and Powell, and Vestnes show how systematic detection of fish, and plotting migration rules, can help predict the future position of the schools. Echo sounding can be used for mapping the distribution of fish in relation to environmental factors.

Fish movement, local or within the general fishing area, may be determined by some unchanging feature of the seabed or the water, and a simple fishing chart based on an analysis of past catches can be very useful. Fish may only live in certain places at certain times of their life, or at particular seasons or times of day. A useful chart must take such changes into account and relate them, if possible, to other changes in the environment, such as the food supply. Atlases to help the fishermen work fresh grounds would need to show the expected location of each species, their abundance, and quality of the fish, whether expressed by size, or age, fatness or some other measure. They should also show the vulnerability of fish to different gears.

Other factors ruling fish migrations are variable as for instance light, temperature, chemical composition of the water, water movement, food and enemies. Some of these affect the fish food, others work both directly and indirectly. The practical use that could be made of such relations depends on how close they are and how easily they can be observed. Dietrich *et al.* point out that temperature may only be correlated with fish indirectly, being an indicator of "something else" which is difficult to determine. But a relation to fish exists and temperature is easy to measure. The abundance or lack of food for example may be indicated by the turbidity or the chemical composition of the water. Plankton animals have been used to identify water masses. The presence of sharks or birds may indicate the presence of commercial fishes. There can be positive correlation, i.e. a lot of fish where there is a lot of food or negative correlation, fish avoiding areas that have certain chemical composition or where there are enemies or obnoxious plankton. The correlation can, however, reverse itself, starting as positive, ending as negative; at one time there may be many fish where there are few food animals, most of them having been eaten. Whether any of these relations are useful depends on whether they are consistent, easily observable and can be clearly interpreted.

I would emphasise the importance of the exact way we look at each factor. We may be concerned not only with the actual fish abundance, or the actual temperature, but also the way these things are changing, geographically or in time. Dietrich *et al.* show how a temperature gradient or a rate of change of salinity may be much more significant as an indicator of fish distribution than a simple measure of these factors.

Matters are complicated by the interference of different factors. In fish attraction, the fish may react to light in different ways at different times and under different conditions. In detection, the signal sent by the fish may vary. In detection and location, the fisherman must react on the same message in different ways at different times, depending on other messages relating to weather conditions and so on.

In the fishery strategy of nations and governments, the broader aspects of location play a very important part—to know whether new fish stocks may be found and to determine the size of known stocks.

To summarize the present, and, particularly, the future of fish location methods: firstly, we know something about the general distribution of fish, but we are still constantly being surprised at the rapid development of new and unsuspected fisheries. Secondly, we know much less about the factors determining occurrence of fish within a particular area. Research is needed. Scattered information in scientific literature needs to be collected. There is a great deal of experience in the heads of the fishermen, which needs to be extracted, and tested by exact observation and experiment.

We need more statistics of catches, including location, time and the conditions under which the catches have been taken. We need more research on the fundamentals of fish physiology and behaviour, especially in relation to fishing gear. Next to putting promising methods into practice, we need the technical means of good navigation, communication and observation at sea and fishermen to use these instruments. Synoptic data are needed to which the fishermen can contribute.

Mr. J. Jakobsson (Iceland): During the herring fishery in Iceland, a research vessel continuously cruises on the herring grounds, using Asdic (echo-ranging) for detection. For location, we are chiefly interested in the distribution of certain plankton animals, i.e. *Calanus finmarchicus*, which is the main herring food in these areas. A very close correlation has been ascertained between the quantitative distribution of these animals. In recent years, especially this summer, a very interesting phenomenon has been observed in the distribution and age composition of this plankton. When the season started there was very little plankton on the main fishing grounds, except at the extreme end of the western area. By making a detailed analysis at the beginning of the season, we were able to observe that the western area plankton was composed almost entirely of mature animals. In the extreme eastern area there was a very strong concentration of newly hatched plankton. In the middle area, little plankton was found except in a curved section where the main fishing takes place. During the beginning of this season it was quite obvious that there would be very little food in the main area because of the adverse current. Everything pointed to the fact that the newly hatched plankton would later in the season provide very rich herring food off the east coast. So I tentatively made the suggestion that, because of this food distribution, herring would gradually disappear from the main area and move east. This prediction turned out to be right.

This shows that the quantitative distribution of the plankton is not only important for the actual distribution of the herring, but that a study of plankton distribution sometimes makes it possible to indicate future movements of the fish.

Plankton in these waters practically rules the schooling behaviour on which, as in most fisheries, the Icelandic herring fishery depends. For purse seining, the schools must rise very near to the surface and they must be compact. Where there is little plankton, the schools come to the surface and spread, consequently the fishing is poor even though herring are present. Where plankton patches are heavy, the schools actually break surface and stay in catchable quantities. When using Asdic, the fisherman can sometimes set his purse seine according to the Asdic records, without waiting for the fish to break the surface.

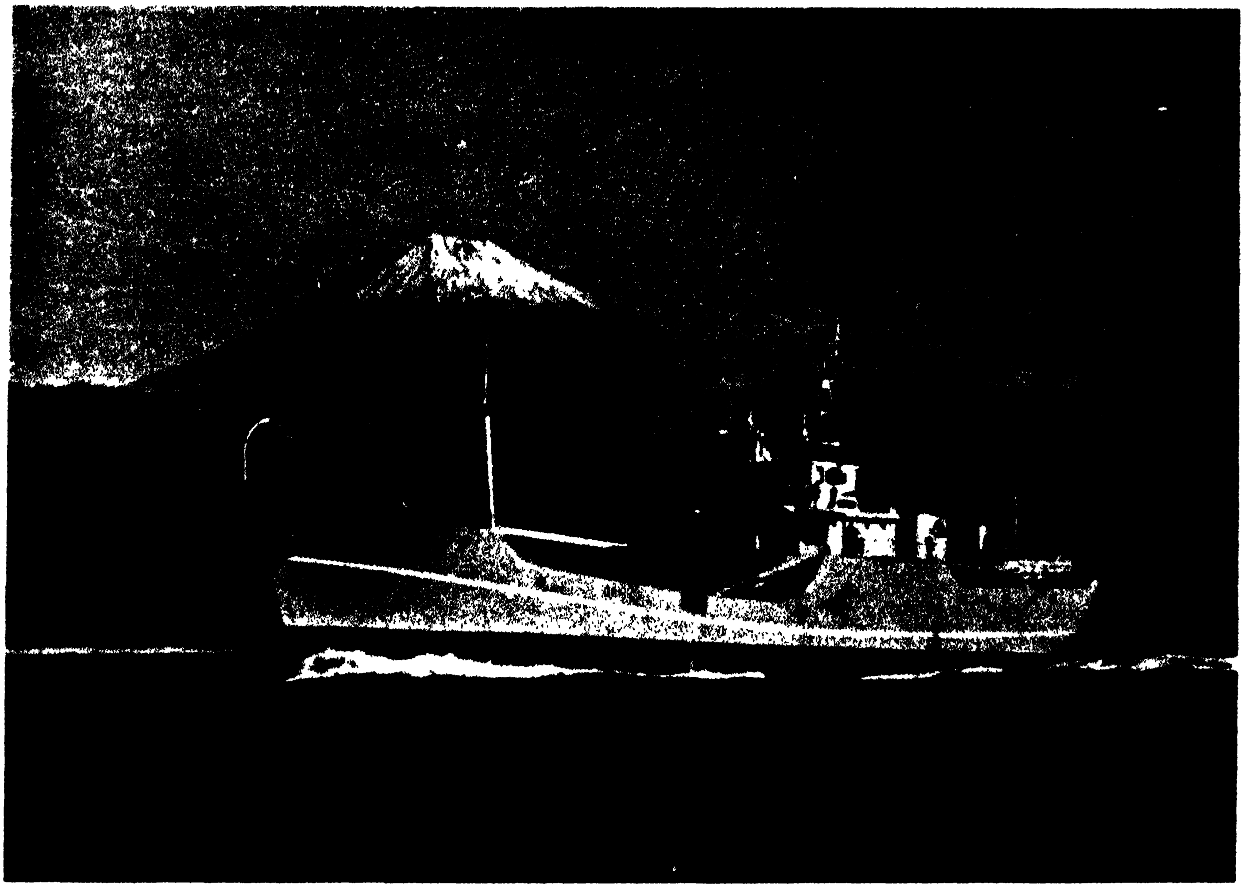
Dr. D. Sahrhage (Germany): Since 1955, when the Research Vessel *Anton Dohrn* was put in service, six trips have been made to the North Sea to carry out hydrographical studies. The results have strengthened our opinion that we shall finally be able to predict the distribution of fish. But to establish this method of fish location, a regular survey of the temperature distribution in the particular area has to be organized, and our knowledge of the relation between temperature and fish distribution has to be improved.

Each area must be dealt with separately. In particular, hydrographical observations of the herring grounds in the North Sea would be advisable and should be made annually, i.e. each spring. In many cases, temperature measurements made by the skippers of fishing boats are valuable, but they cannot, of course, replace surveys by research vessel. In 1954, we initiated studies of the area around the Dogger Bank, and have repeated them every year in spring and later. Restricting the survey to a limited area will, it is hoped, lead to quicker results. We hope, for instance, that these regular surveys in the Dogger Bank area will soon enable us to predict how long the herring season will last and what the catch will be.

Dr. M. Ruivo (Portugal): I would like to draw your attention particularly to the stage when data concerning fish location become transferred to fishing maps and information is given to the fishermen. We need to be very critical at this stage to ensure that the fishermen are not given out-dated maps.

While it may be theoretically easy to deal with fish which are easy to locate, the problem becomes much more complicated in dealing with pelagic fish, which tend to move over vast areas, with variations in the migratory pattern from season to season and year to year.

It would be useful if, with these maps, practical information could be given to fishermen on fish location. We could, for example, tell the fishermen about the relation of sardine schools to varying mineral contents of the water. This is the type of information which they might be able to put to practical use.



Modern Japanese tuna longline vessels like this one which operate on the high seas depend extensively on hydrographic data and observations for locating fish concentrations. Note inclined belt conveyor for taking the longline from the foredeck to the stern. Fujiyama in the background.

ECHO SOUNDING AND FISH DETECTION

by

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Abstract

The tendency of echo sounder manufacturers has been to work on a frequency of about 30 kc. for fish detection but for fishing, there is no such thing as the ideal type. For example, for locating fish a fairly narrow sound beam, without side-lobes, is needed, but if fishermen want to study the nature of the seabed a wide beam and frequencies somewhat lower than 30 kc. have certain advantages. A narrow beam used from small ships may be neutralized by aeration and the motion of the ship, and some sort of stabilization, such as mounting the oscillator in gimbals, is called for. In searching for fish, though not for use during fishing, the oscillator could be mounted in a streamlined housing (which the author calls a *shark*) and towed at a suitable depth. This would provide a stable sound beam and would eliminate or reduce aeration. For studying the seabed, frequencies in the lower range, 10-15 kc. give a clearer picture than the more usual higher range. The future trends in the science of echo sounding are discussed, and it is suggested that the recording of signals as presented on a Cathode Ray Tube might be done photographically although notwithstanding certain limitations, the recorder is likely to remain an essential feature of echo sounders of the future.

Sondage à écho et détection du poisson

Résumé

Les constructeurs de sondeurs à écho ont eu tendance à choisir une fréquence voisine de 30 kc. pour la détection du poisson, mais il n'existe pas, pour la pêche, un type d'appareil idéal. Par exemple il faut pour localiser le poisson un faisceau sonore étroit, sans lobes latéraux, mais si les pêcheurs veulent connaître la nature du fond, un faisceau large et des fréquences un peu inférieures à 30 kc. présentent certains avantages. Sur les petits bateaux, un faisceau étroit peut être neutralisé par l'aération et le mouvement de la coque, et il faut avoir recours à un système stabilisateur, tel que celui qui consiste à monter l'oscillateur à la cardan. On peut monter l'oscillateur dans une boite profilée (que l'auteur appelle "requin") que l'on remorque à une profondeur appropriée pour détecter le poisson mais que l'on n'utilise pas pendant les opérations de pêche proprement dites. Ce système permettrait d'obtenir un faisceau sonore stable et d'éliminer ou de réduire l'aération. Pour l'étude des fonds de la mer, des fréquences inférieures, de l'ordre de 10 à 15 kc. donnent une image plus claire que les fréquences habituelles plus élevées. L'auteur examine les perspectives de la science du sondage à écho et suggère que l'enregistrement des signaux reproduits par le tube à rayons cathodiques pourrait s'effectuer photographiquement, mais en dèpit de certaines limitations, l'enregistreur demeurera probablement un des éléments essentiels des écho-sondeurs de l'avenir.

El sondeo a eco y la localización de peces

Extracto

Los fabricantes de ecosondas tienden a usar frecuencias de aproximadamente 30 Kc. por segundo en la localización de peces, pero esto no significa que sean las mejores. Por ejemplo, para este objeto se necesita un haz de ondas sonoras bastante estrecho, sin lóbulos laterales, pero cuando el pescador desea estudiar la naturaleza del fondo marino, el uso de un haz ancho y frecuencias inferiores a 30 Kc. por segundo presenta ciertas ventajas. El haz estrecho que utilizan las embarcaciones pesqueras pequeñas puede ser neutralizado por la aeración y los movimientos del barco, necesitàndose cierto tipo de estabilización como el montaje de los osciladores en aros de suspensión de brújulas. En la búsqueda de peces—aunque no se usa durante las faenas de pesca—el oscilador puede montarse dentro de una caja hidrodinámica que el observador llama "shark" (tiburón) y remolca a una profundidad adecuada. Este equipo proporcionaría un haz de ondas sonoras estable, a la vez que eliminaría o reduciría la aeración. En el estudio del fondo del mar se ha obtenido una imagen más clara al reemplazar frecuencias altas por otras más bajas de 10 a 15 Kc. por segundo.

En el trabajo también se analizan las futuras tendencias en la ciencia del sondeo a eco, sugiriéndose que las imágenes captadas por un tubo de rayos catódicos podrian registrarse fotográficamente. No obstante ciertas limitaciones, el mecanismo registrador parece que continuará siendo la característica esencial de las ecosondas del futuro.

INTRODUCTION

SINCE publication of a wide summary of knowledge of echo sounding in fisheries, prepared by a Committee of the International Council for the Exploration of the Sea[1], the attention of manufacturers has been directed to improving the performance of echo sounders. The tendency has been to settle on a frequency of around 30 kc. for fish detection, and to use oscillators, of rectangular form, in direct contact with the sea. Horizontal ranging equipments (referred to hereafter as sonar) have been developed and marketed in America, Norway, Germany and Great Britain.

A DILEMMA IN ECHO SOUNDING

For fish detection, a fairly narrow sound beam, without side lobes, is desirable and modern magneto-striction oscillators are well adapted to produce such a beam. Fishermen also use their echo sounders to tell them the nature of the seabed. For this purpose a wide sound beam, and rather lower frequencies than 30 kc. offer advantages. Thus it seems that there is no one *best* type of machine for all purposes.

FISH DETECTION—DEMERSAL FISH

The detection of fish either as schools or individuals at depths of up to about 150 m. is possible with any efficient modern machine, provided that the fish are in midwater or distinctly above the seabed. Thus, in 20 m. depth, fish ½ m. from the seabed can readily be detected, while in 200 m. of water, it is not easy to detect fish unless they are 3 or 4 m. from the seabed. This arises partly from

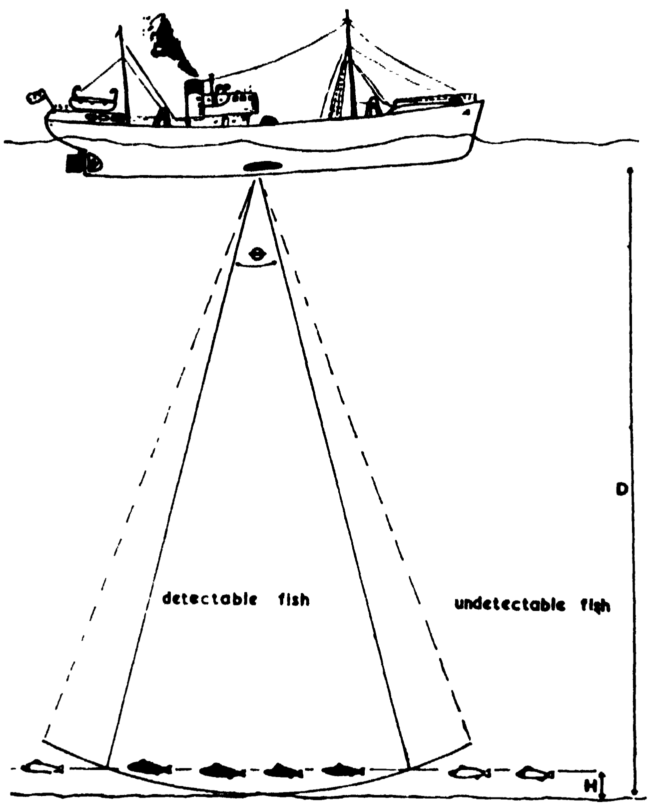


Fig. 1. Schematic representation of the limits in displaying bottom fish by means of echo sounding.

the difficulty of finding a distinctive way of presenting echo information on paper, but more fundamentally from the limitations of the wide acoustic beam (see fig. 1). Only a fraction of the sound beam is usefully employed for the detection of demersal fish, and this fraction becomes less as the fish go closer to the seabed.

If, in fact, the fish are at a distance H above the seabed and the depth of water is D, then the area A in which the fish can be detected is given by $A = 2\pi$ DH i.e. it is proportional to H. The traces of fish outside this area would disappear in the bottom record. Also the maximum useful beam angle (θ) is given by $\sin\theta/2 = \sqrt{2H/D}$. thus in 200 m. depth, the maximum useful beam width is achieved at a beam angle $\theta = 12°$ for fish 1 m. above the seabed, and by $\theta = 6°$ for fish ¼ m. above the seabed. These are absolute maxima.

A narrow beam will also give greater discrimination and detail of the form of fish schools. The use of a sound beam of greater width will decrease the signal-to-noise ratio and reduce efficiency.

FISH DETECTION—PELAGIC FISH

Most modern echo sounders are suitable for the detection of pelagic fish. The most immediate requirement is for greater discrimination between types of fish and types of school. It is possible that comparison of echoes on two or more frequencies will prove to be helpful in this case. It is likely that here, again, reduction in width of the sound beam may be helpful. A narrow beam gives a greater chance of counting individual fish, and even where this is not possible, gives more precise information about the details of school pattern.

STABILIZING THE BEAM

A narrow beam can be provided by increasing the oscillator dimensions or increasing the frequency. However, particularly in the case of small vessels, considerable motion is normally to be expected. This introduces problems of aeration; bubbles of air are carried under the oscillators and performance is impaired, often to a degree that makes the echo-sounder useful only in moderate to fine weather. Motion can be expected also to neutralize the benefit of a narrow sound beam.

It seems desirable, therefore, that the oscillator should be stabilised to keep the sound beam vertical. There are three obvious possibilities:

(a) To hang the oscillator in gimbals in the same way as a compass. This would necessitate a fairly large housing, with a covering diaphragm of some material with good sound transmission qualities.

(b) To maintain the oscillator position by servo-motors controlled by a damped pendulum. While this would seem technically feasible, it is too elaborate for early application in fishing.

(c) To place the oscillator on a streamlined housing or *shark* which can be towed behind the ship at a suitable depth. This method can eliminate or reduce aeration, as well as provide a stable beam. It is unsuitable for use during some fishing operations, but could be employed during a search for fish.

Method (c) is the only one likely to be applied to small vessels, while (a) or (b) might find application in large trawlers in which motion and aeration are less serious. Other applications are suggested by Lochridge[3].

ASSESSMENT OF THE SEABED

When a recording echo sounder with a fairly wide beam is used, a distinction can be made between the recording of a smooth seabed, and one of irregular character due to rocks or stones. In the case of the first, the fringe of the sound beam is largely reflected upwards and outwards and is therefore not picked up by the receiving oscillator. In the case of the second, a part of this fringe is reflected upwards and inwards by irregularities and is picked up and recorded. As a result, the echo trace of a rough seabed is very much thicker than that of a smooth one.

Another feature, that is sometimes useful as a guide to fishing, is the recording of hard ground lying below a layer of mud or sand. In such cases, the limits of hard and soft ground can sometimes be observed with great accuracy. This information is of value, for instance, in seining, finding suitable ground for shooting, and sometimes is helpful as an indication of the kind of fish likely to be caught. The requirement for observing such patterns is that the pulse, though partially reflected at the surface of the seabed, should be able to penetrate the mud and be reflected with sufficient intensity from the rock below. It is known that absorption of high frequen-

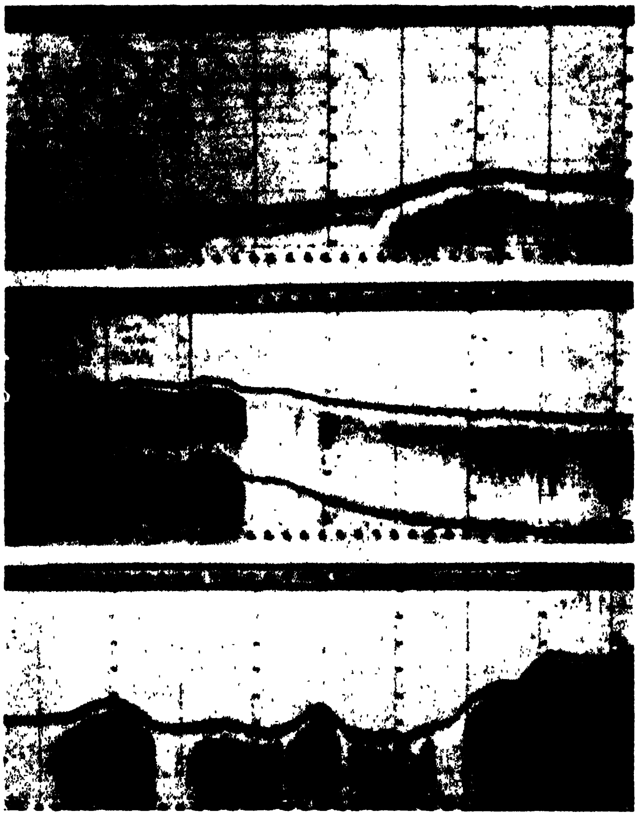


Fig. 2. Differences in character of seabed echo. Marconi Graphette echo sounder, ship's speed 8 knots. The upper echogram shows mud or sand overlying solid rock which outcrops on the right. The lower record shows differences between rough and smooth ground echoes, the extended echo-length *being due to reflection from a bigger area in case of rough bottom.*

cies is much greater than that of low frequencies. In fact the pattern of soft over hard bottom is more clearly detectable by sounders in the 10 to 15 kc. range than by those in the higher frequency 30 to 50 kc. range.

These two effects produce the differences in appearance of the bottom echo which many fishermen have come to recognize and use as an aid in fishing. Some examples are given in fig. 2. It is perhaps worth noting that an indication of the surface shape of the bottom can be obtained equally well, perhaps better, with a narrow beam machine, if an inclined auxiliary beam is provided that can be brought into use as required. In fact, if this auxiliary beam is directed forwards at a suitable angle, it should assist in the prior detection of rough ground.

If knowledge of the composition of the bottom is considered to be essential for some types of fishing then it would appear best to equip the vessel with a low frequency machine, even if a specialist machine is used for fish detection. If, however, this is not required, it seems possible to visualise the following equipment being used by fishing vessels in the near future (fig. 3): Echo sounders, in the frequency range 30 to 50 kc. using:

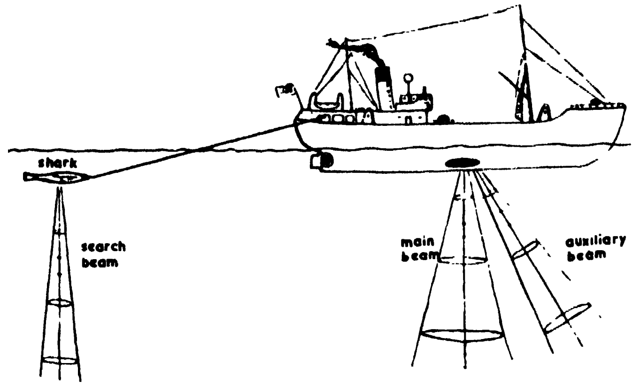


Fig. 3. Possible arrangement of oscillators for fishing purposes. Main beam for general use, the auxiliary beam for determining the character of the bottom surface, shark *oscillator for searching for fish.*

(a) A fixed single oscillator in a limpet fitting with a beam angle (θ) to half power point of about 30° in the athwartships direction and 10° in the fore and aft direction;

(b) an auxiliary fixed oscillator inclined forward by about 20° in the fore end of the limpet, which can be switched in to give an index of seabed character;

(c) very narrow beam oscillator with a symmetrical beam angle of 8° or less, which can be used from a *shark* when searching for fish.

THE PROBLEM OF PRESENTATION

The simplest method of presenting echoes is to use a Cathode Ray Tube and display the echoes on a suitable time base. This calls for continuous attention on the part of the operator and requires him to act as a kind of integrating machine, comparing the complex of echo frequency and character from area to area, making due allowance for changes in depth. Such comparisons can perhaps be better made automatically by electronic means.

The traditional recorder remains one of the neatest and most ingenious methods of presentation, but it has two serious limitations. These are:

(a) it is a poor device for the estimation of echo *amplitude*, as this can be gauged only by the intensity of the markings on the paper;

(b) since the mechanical system has considerable inertia, its timing cannot be conveniently altered to allow for vertical movements of the ship. If these are of the same order as the height of fish above the bottom, detection of fish on the chart may become very difficult.

Two great merits of the recorder are that its indications of fish have a great deal of character—it is possible to recognize large or small schools, or individual fish, with some confidence—and its integrating properties provide an impression of the form of the seabed, which is of great value to fishing and navigation.

For this reason recording is likely to remain an essential feature of future echo-sounders for general purposes, and the techniques remain worthy of further development. The recorder is, however, likely to continue to be supplemented by other more discriminating equipment for the detection of demersal fish. The problem of ship movement can undoubtedly be overcome and the recording principle retained, provided the recording is done photographically. (A continuous recording camera would be required, the signal being applied to vary spot brilliance on a Cathode Ray Tube.) However, this is a solution only for research purposes. If this problem can be overcome, the recorder in some specialised form may continue to be a basic equipment even for demersal fishing.

SONAR

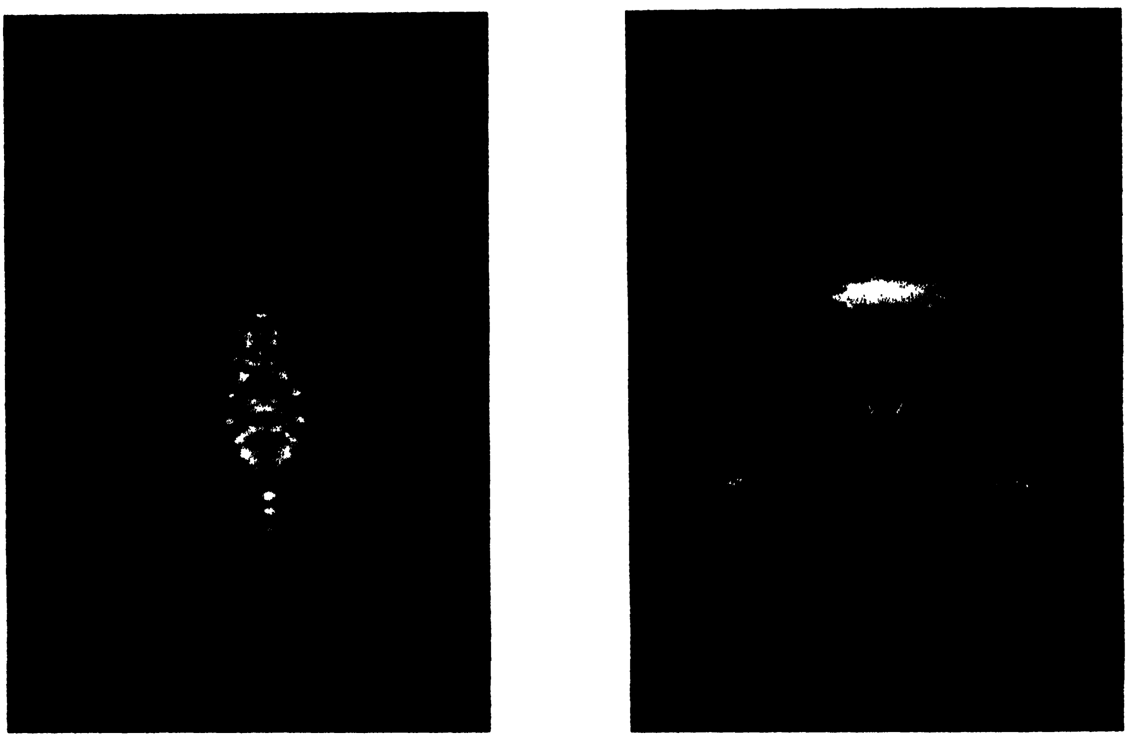
Most fishing vessels are comparatively small, and so the greatest problem in the application of Sonar techniques is the motion of the vessel and the associated aeration. A useful discussion is given by Good[2]. To achieve a satisfactory range, which should be at least half a mile for practical fishing, the searching beam has to be narrow. Thus the method presents problems similar to narrow beam echo sounding, but in more acute form. The same kind of solutions as have been suggested for deep-sea echo sounding may well find adoption for Sonar search.

REFERENCES

1 Hodgson and Fridriksson (eds.) Report on echo-sounding and asdic for fishing purposes. Rapp. Cons. Explor. Mer. 139. Sept. 1955.

2 Good, C. M. Asdic in the Fishing Industry, World Fishing, March, April 1956.

3 Lochridge. Developments in Midwater Trawling. World Fishing, September 1956.



Cathode Ray Tube echo display of Herring in 100 m. depth (left) and of Redfish in 300 m. depth (right), both near the bottom.
Photo: Elac, Kiel

STUDIES ON THE BEHAVIOUR OF ULTRASOUND IN SEA WATER

by

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Abstract

The propagation characteristics of ultrasound in sea water and its reflection loss on the sea-bottom or on fish-schools must be studied for both the design and the practical operation of echo sounders, fish finders and Sonars. This paper shows a practical method for the above-mentioned study, together with the results of measured propagation characteristics in both vertical and horizonta directions, as well as the reflection loss on the sea-bottom and on fish-schools, using 28, 50, 200, 300, and 400 kc.

The propagation attenuation is due mainly to spherical divergence, but also to absorption. This absorption becomes larger at higher frequencies; in fact, the results of experiments show that the absorption is 10-20 db./*km. at 28 kc., 37-50 db./km. at 200 kc., and about 120 db./km. at 400 kc. The reflection loss of the ultrasound at a fish-school decreases as frequency increases. On the other hand, the reflection loss of the sea-bottom increases as frequency increases. At 200 kc., therefore, the echoes from ground-fishes sometimes become stronger than those from the sea-bottom.

* db. — decibel.

Mesure de la propagation dans l'eau de mer des ultrasons jusqu'à 400 kilocycles

Résumé

Il faut étudier les caractéristiques de la propagation des ultrasons dans l'eaudemer et les pertespar réflexion sur le fond ousur les bancs de poisson en vue de la construction et de l'utilisation pratique des sondeurs à écho, des détecteurs de poissons et des Sonars. Cet article décrit une méthode pratique pour l'étude en question et indique les résultats des mesures des caractéristiques de la propagation dans le sens vertical et dans le sens horizontal, ainsi que la perte d'ultrasons par réflexion sur le fond de la mer et sur les bancs de poisson, avec des fréquences de 28, 50, 200, 300 et 400 kilocycles.

L'atténuation de la propagation dans une direction perpendiculaire à la surface de la mer est due surtout à une divergence sphérique mais l'atténuation en direction horizontale est due aussi en partie à un phénomène d'absorption qui devient plus prononcé aux fréquences supérieures. En fait, les expériences montrent que l'absorption est de 10-20 db*/km. à 28 kilocycles, de 37-50 db/km. à 200 kilocycles et d'environ 120 db/km. à 400 kilocycles. La peite par réflexion des ultrasons au niveau d'un banc de poisson varie en raison inverse de leur fréquence. Au contraire, la perte par réflexion sur le fond de la mer augmente dans le même sens que la fréquence. Il en résulte que, pour une fréquence de 200 kilocycles, les échos des poissons de fond deviennent parfois plus marqués que les échos donnés par le fond de la mer.

Medida de la propagación de las ondas ultrasonoras en agua de mar usando frecuencias hasta de 400 kc.

Extracto

La propagación de las ondas ultrasonoras en agua salada y su pérdida por reflexión en el fondo del mar o cardúmenes deben ser estudiadas tanto por las personas que proyectan ecosondas, localizadores de peces y equipo de "sonar" como por las prácticas en su funcionamiento. En este trabajo se dan a conocer: un método práctico para efectuar el estudio antes mencionado, los resultados de las características de propagación medidas tanto en sentido vertical como horizontal, así como las pérdidas por reflexión ultrasonora sobre el fondo del mar y cardúmenes usando frecuencias de 28, 40, 200, 300 y 400 Kc.

La propagación en el sentido vertical es atenuada principalmente por las divergencias esféricas, pero la disminución en el sentido horizontal se debe, en parte, a la absorción que aumenta con frecuencias más altas. En efecto, los resultados de diversos experimentos demuestran que la absorción es igual a 10—20 db.* por Km. a 28 Kc. 37—50 db. per Km. a 200 Kc. y unos 120 db. por Km. a 400 Kc. Las pérdidas por reflexión de las ondas ultrasonoras en el cardumen y en el fondo del mar disminuyen y aumentan, respectivamente, al elevarse la frecuencia. Por esto, a 200 Kc. los ecos de las ondas que se reflejan en los peces de fondo son a veces más intensos que los producidos contra el mismo fondo marino.

* db. = decibel.

SINCE high frequency ultrasonic waves have greater attenuation during their propagation in water, lower frequencies are generally used for echo sounders or fish finders. However, for sharp directivity, higher frequencies are more convenient because they allow smaller transducers to be used. This is especially true in the case of the Plan-Position-Indication for which sharp directivity is indispensable. For the rational design of sounding and ranging equipment, comprehensive knowledge of the propagation characteristics, particularly of high-frequency ultrasound, is needed, which has to be collected by quantitative measurements.

The measurements of wave-propagations recorded in this paper were investigated in sea water with frequencies of 100 kc., 200 kc., and 400 kc., and simultaneously with 28 kc., allowing for a comparison between the higher and lower frequency range.

CHARACTERISTICS OF HORIZONTAL PROPAGATION

Two vessels (fig. 1) with equipment as arranged in fig. 2, are needed for this investigation.

An ordinary echo sounder is used for reception, the transmission contact of which is connected to a radio

Fig. 1. The boats equipped for horizontal attenuation measurements.

transmitter, so that instead of an ultrasonic impulse a radio impulse is transmitted when the recording stylus passes the zero-depth mark. When this radio impulse is received by the second ship, it initiates the transmission of an ultrasonic impulse in horizontal direction to the first ship.

This ultrasonic impulse travels to the receiving ship in three different ways: (1) directly, (2) with one reflection to the sea-bottom, or (3) with two or more reflections to the sea-bottom. Each of these parts of the impulse, on reaching the receiving transducer, causes its own mark on the recording paper.

At a short distance between the two ships the recorder first indicates the direct part only. With increasing distance, the reflected parts appear slightly below the trace of the direct part (fig. 3).

The intensity of the received impulse can be measured at any time and at any distance by reading the attenuator which is inserted between the receiving transducer and the amplifier. This attenuator is adjusted so that the trace on the recorder disappears whilst the sound-pressure is measured. This method, started in Japan in 1943, is called *Margin Test*, the attenuated amount being

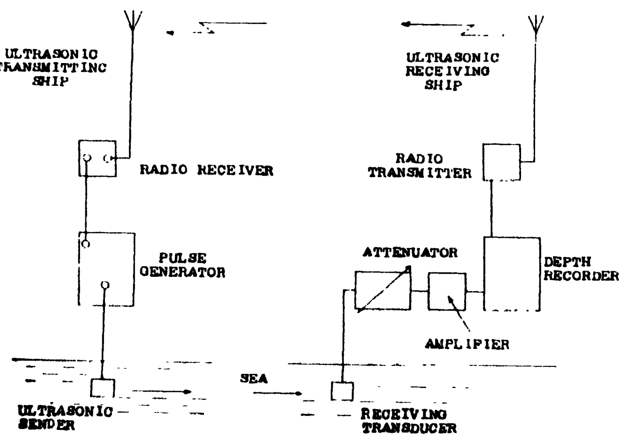


Fig. 2. Principle of measuring apparatus for horizontal attenuation.

Fig. 3. Echograms of horizontal attenuation.

the *Margin* of the equipment under test. The depth scale of the ordinary echo sounder, of course, has to be doubled when measuring the propagation speed in the way described.

In figs. 4 and 5 the results given, show the relation between *Margin* and the distance for the different frequencies in question for the directly travelling part of the sound impulse.

Since the temperature gradient near the surface was small during the measuring experiments, a bending of the sound direction can be practically excluded.

By comparing the measured curves with the theoretical

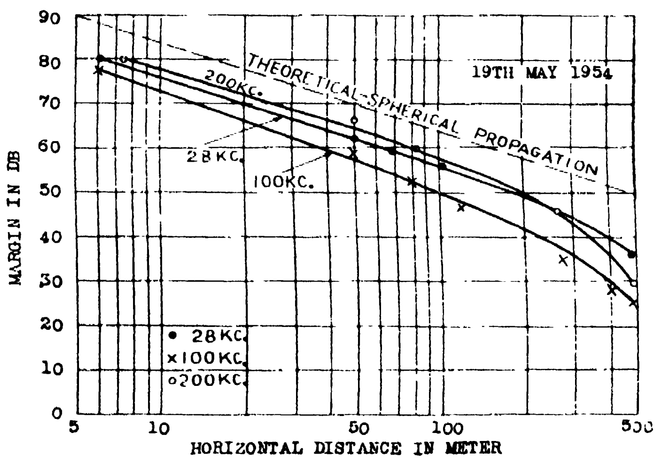


Fig. 4. Curves of horizontal attenuation. (In May 1954)

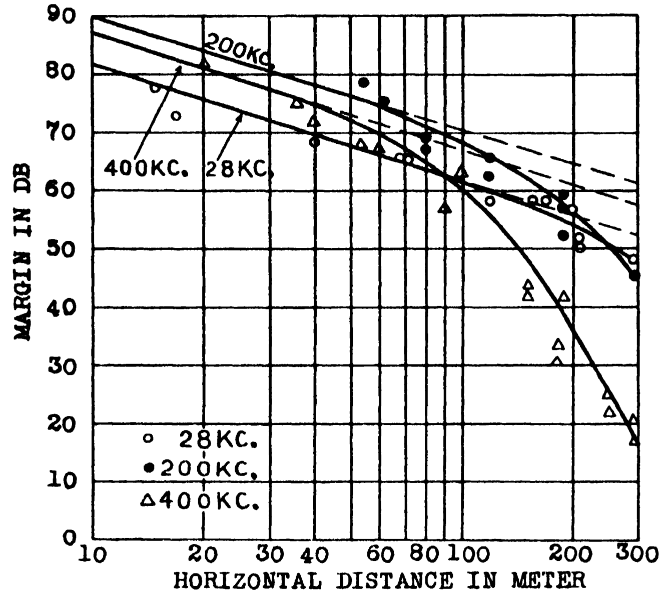


Fig. 5. Curves of horizontal attenuation. (In December 1954)

curve for the propagation of spherical waves, the absorption constants can be obtained for each frequency, as shown in Table I.

The variations in attenuation are due to different water conditions at the different seasons at which the measurements took place. At present no general conclusions can be drawn in this regard because our experience is still too limited. The absorption constants obtained are in average for 100 kc. about 30 db./km., for 200 kc. about 43 db./km., and for 400 kc. about 120 db./km.

CHARACTERISTICS OF VERTICAL PROPAGATION

The absorption constant of vertical propagation was measured in a certain area with flat bottoms of equal consistency (mud) in different depths so that the reflection loss was kept equal. Thus, by measuring the echo intensities at various depths, the absorption constant of vertical propagation was obtained.

The results are shown in figs. 6 and 7 where the echo intensities for the different frequencies are plotted against the depth.

The absorption constants are shown in Table II. The values are much lower than those for horizontal propagation.

REFLECTION LOSS AT THE SEA-BOTTOM

The reflection loss at the sea-bottom can be directly measured by the "Sliding Method"[1]. The principle consists in finding the value of the discontinuity between

TABLE I

Absorption Constant (db./km.) for horizontal propagation

Frequency (kc.)	*April*		*May In shallow water (15 m.)*		*In deep water (50 m.)*		*December In shallow water (10 m.)*
28	18	16	20	—	20	—	10
100	25	33	29	33	30	—	—
200	47	49	37	50	37	37	43
400	—	—	—	—	—	—	120

TABLE II

Absorption Constant for vertical propagation.

Frequency (kc.)	*Absorption Constant (db./km.)*
100	about 10
200	about 10
300	25
400	50

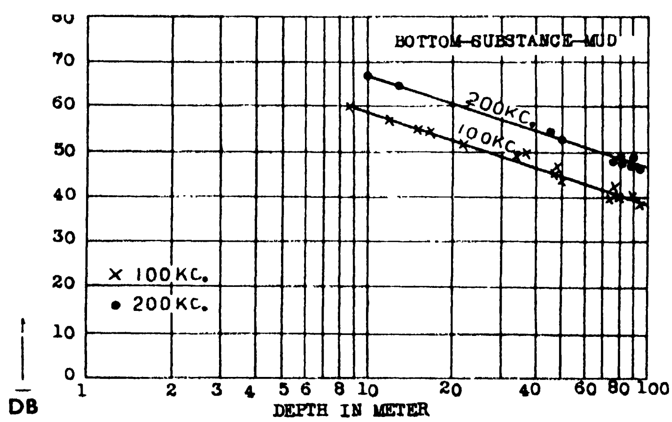


Fig. 6. Curves of vertical attenuation. (In May 1954)

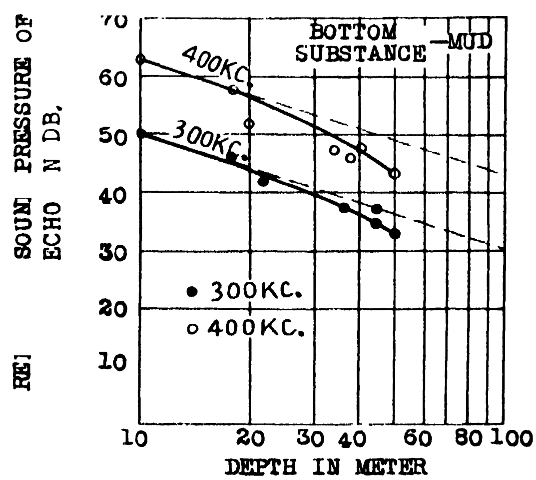


Fig. 7. Curves of vertical attenuation. (In December 1954)

TABLE III

Reflection Loss of Ultrasound at the Sea-bottom

Sea-bottom Substance	*Frequency (kc.)*	*Reflection loss (db.)*	*Reflection loss in Lower Frequency Range (10-50 kc.) (db.)*
Mud	200	24	11
Mud	400	26	11
Sand	300	17	7-8

the extrapolated intensity-distance curves of the incident wave and the reflected wave.

The data obtained in Tokyo Bay area on mud or sand bottom are shown in Table III. It was found that the reflection losses of high frequencies are 10 to 14 db. greater than those previously obtained for lower frequencies.

REFLECTION LOSS AT THE FISH BODY

Our definition of the reflection loss at the fish is the ratio of P_O to P, where P_O is the sound pressure of the plane wave inciting on the body of a fish, and P is that of the reflected spherical wave, measured at a distance of 1 m. from the fish.

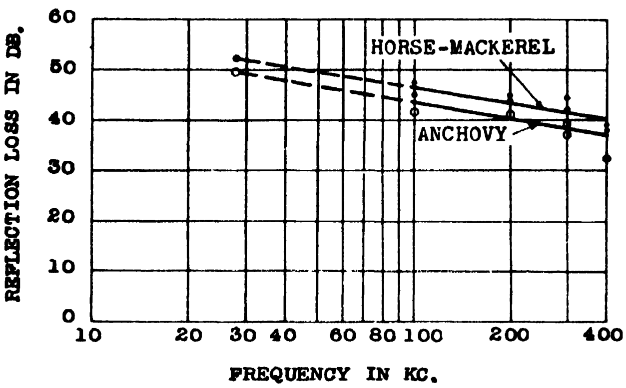
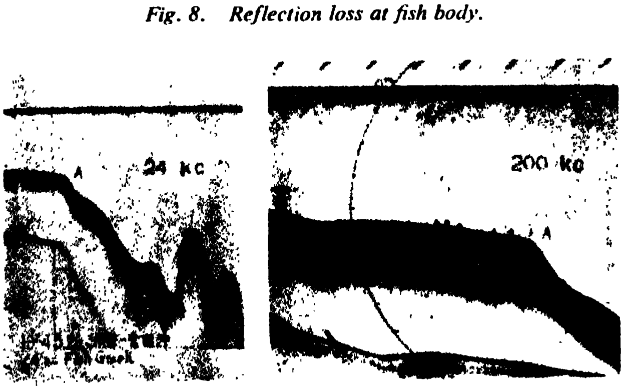


Fig. 8. Reflection loss at fish body.



(a) 24 kc. (b) 200 kc.

Fig. 9. Simultaneous records of bottom fish obtained by 24 kc. and 200 kc.

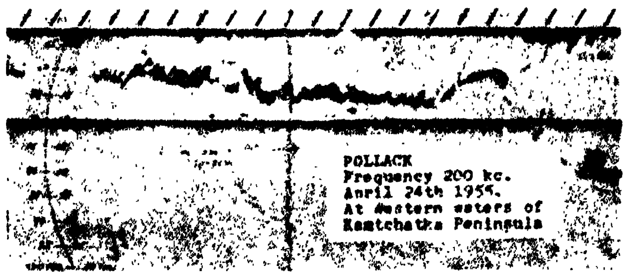


Fig. 10. Echogram of 200 kc. obtained in actual fishing—Alaska Pollack

A *Sliding Method* is used in making measurements similar to that used for bottom reflection. The data indicate that the higher the frequency, the better the reflection (fig. 9). This suggests that the higher attenuation of higher frequencies might be compensated by lower reflection loss at the fish. This statement is almost proved by several experiments with PPI type equipment, using 200 kc.

EXPERIMENTS ON FISH DETECTION WITH HIGH FREQUENCIES

High frequencies favour the resolving power due to the shorter wave-length, which comes into the order of millimeters. Furthermore, there is the increase of the reflection loss on the sea-bottom, which may help especially in locating bottom fish by improving the possibility for discriminating between the fish and the seabed.

Sounding with 200 kc.

Simultaneous experiments were carried out with recorder-type fish finders using 200 kc. and 24 kc. respectively in order to compare the traces of bottom fish. The position A indicated on both echograms in fig. 9 correspond to each other.

By inspecting the record of bottom fish traces it can be stated that the resolving power of 200 kc. is better than that of 24 kc.

More examples of high frequency records are shown in figs. 10 and 11, the former from a school of Alaska pollack (200 kc.) and the latter from schools of anchovy (400 kc.).

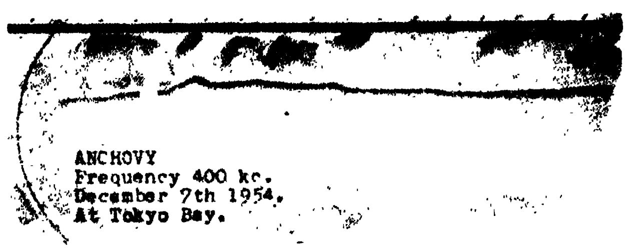


Fig. 11. Echogram of 400 kc. obtained in actual fishing—Anchovy

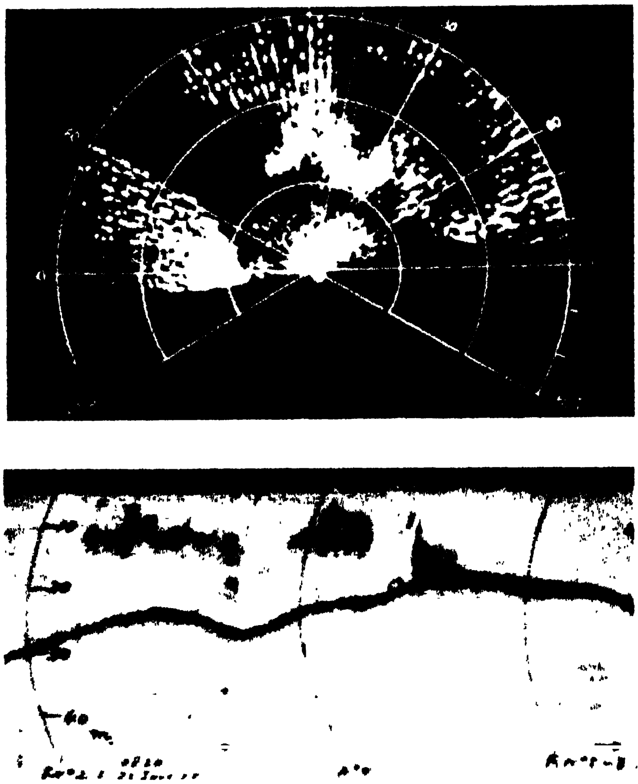


Fig. 12. Example of PPI-Sonar and recorder-type fishfinder traces obtained simultaneously from a school of Anchovy

Horizontal ranging with PPI Sonar

Another application of high frequency ultrasound is the Plan-Position-Indication (PPI), using 200 kc. Fig. 12(a) gives a photograph of the successive records obtained from a school of anchovy which was caught almost entirely by the operation of a pair of fishing boats.

Fig. 12 (b) shows the echogram of vertical soundings carried out simultaneously, of the same anchovy school.

EFFECT OF AIR BUBBLES ON ULTRASOUND OF DIFFERENT FREQUENCIES

Laboratory Experiment

The data obtained from experimental studies and theoretical work carried out in the laboratory on the absorbing effect of dense bubbles in water are shown in fig. 13. Numerous fine bubbles were generated, intersecting the path of ultrasound. The ordinate of the graph corresponds to the increase of attenuation when the bubbles were suddenly generated, and the abcissa corresponds to the sound frequencies. It can be clearly noted that the effect of the air bubbles decreases with increasing sound frequency.

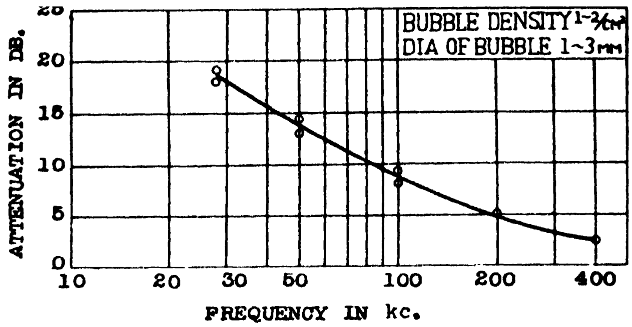


Fig. 13. Absorption due to bubbles.—Laboratory measurement

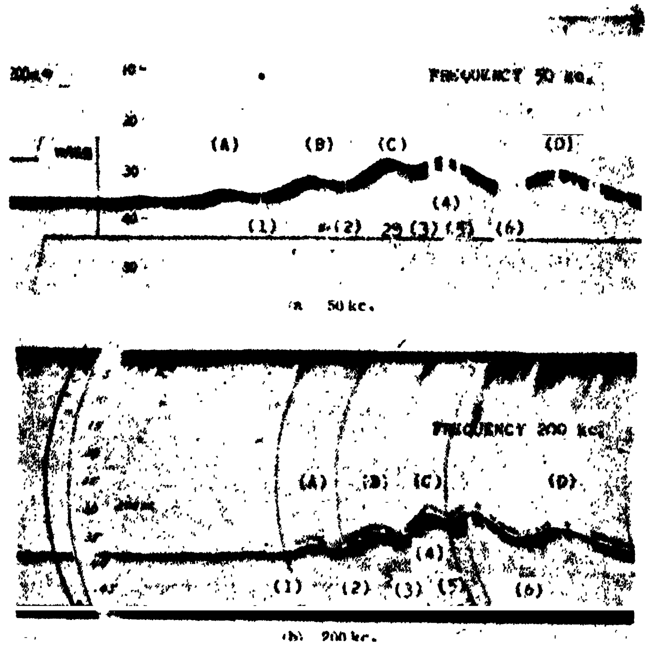


Fig. 14. Absorption due to wake—simultaneous records of 50 kc. and 200 kc.

Propeller Wake

The effect of the propeller wake of a 1·5 ton fishing boat driven by a 4 h.p. diesel engine at 750 r.p.m. full speed is shown in fig. 14. The measuring boat sailed slowly across the wake six times. The present echograms were obtained simultaneously and the figures 1 to 6 on both records correspond to each other. It can be noted that the bottom traces disappear on the 50 kc. records at every instant of crossing, whilst the records of 200 kc. show no interruption. This observation, which may be of some practical value, is in accordance with the laboratory experiments mentioned above.

REFERENCE:

[1] T. Hashimoto, Report of Fishing Boat Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, Japan, No. 1, p. 13, Dec. 1953.

RELIABILITY OF BOTTOM TOPOGRAPHY OBTAINED BY ULTRASONIC ECHO SOUNDING*

by

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Fishing Boat Laboratory, Fisheries Agency, Japanese Government

Abstract

In this paper the authors show a comparison between an echo-survey of the topography of an artificial lake with visual and high frequency and an actual survey by triangulation made before the valley was filled with water. Accurate results were obtained using high frequency and a narrow beam angle.

L'exactitude de la topographie du fond obtenue par les sondeurs à écho ultrasoniques

Résumé

Dans cette communication les auteurs montrent la comparaison entre une exploration ultrasonique de la topographie d'un lac artificiel et un relevé reel par triangulation effectué avant mise en eau de la vallée. On a obtenu des resultats précis en utilisant une fréquence élevée et un faisceau de faible ouverture.

Precisión de la topografía del fondo mediante sondeos ultrasonoros

Extracto

En este trabajo los autores comparan un levantamiento topográfico de un lago artificial mediante el empleo de sondas ultrasonoras con el obtenido por triangulación antes de llenar el valle de agua. Se obtuvieron resultados precisos usando un estrecho haz de ondas sonoras de alta frecuencia en ángulo agudo.

GENERAL

WHEN investigating the boundary conditions of an artificial fish shelter by echo sounding, special precautions have to be taken to obtain sufficient accuracy.

When using an echo sounder with a wide sound beam, it is very difficult to obtain the true shape of a sloping or undulating sea bottom[1]. With the common 15 to 3 cm. sound waves, the necessary focusing of the sound beam is possible only with rather big and heavy transducers which are not suitable for installation in a small craft used for survey in shallow water. Consequently, high frequency ultrasound such as 200 kc. is needed to obtain the sharp directivity needed with small transducers which can be used in small craft.

While constructing an artificial lake along the Saikawa river (Nagano Prefecture), the cross section was surveyed by triangulation before the lake was filled with water and by echo sounding afterwards. This paper contains the results of this experiment.

*** This experiment was carried out in cooperation with the Tokyo Electric Power Co. Inc. in September 1954 at a power plant at the Saikawa River.**

EFFECT OF WIDE BEAM

A measurement with wide beam angle was carried out in November 1953 in an artificial lake of the Yanaizu power plant (Tadami river)[1]. The echo sounder worked

Fig. 1. Echogram showing the accuracy of reproduction of a bottom profile with different slope. Frequency 50 kc., half power beam angle 22 degrees.

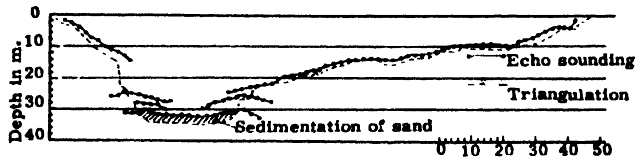


Fig. 2. Comparison of bottom profiles obtained by echo sounding (see fig. 1) and triangulation.

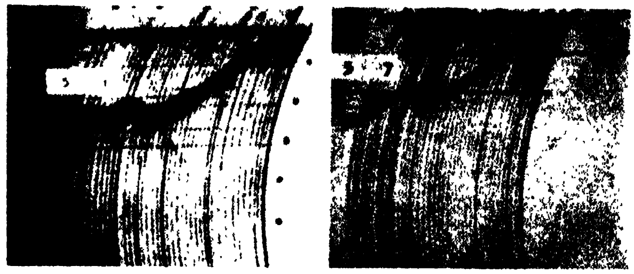


Fig. 4. Echograms obtained with the experimental sounder. Left: frequency 100 kc.; half power beam angle 16 degrees. Right: frequency 200 kc.; half power beam angle 3·3 degrees.

at a frequency of 50 kc. and a half power beam angle of 22 degrees. Fig. 1 shows the cross section of the valley obtained by echo sounding and fig. 2 gives a comparison between the shapes obtained by triangulation and echo sounding.

It can be seen that where the slope is not too steep, the shape obtained by echo sounding is comparable to that obtained by triangulation (figs. 1 and 2, right). But, as soon as the slope becomes steeper or steplike, the two shapes diverge and the conformity between echo sounding and triangulation is lost (figs. 1 and 2, left).

Method and Apparatus

For this experiment, first a triangulation was made at a cross section of the under-water valley of Saikawa river. The slope of both banks of the valley is steep. The experiment was mainly made around masonry revetment intended to separate the water flow and situated at the right hand of the valley 10 m. below the water line. This revetment was 6·2 m. wide and 2·8 m. high. It was found by lead-sounding that, after the valley was filled with water, the shape of the bottom was deformed a little by sand sedimentation on the right side of the revetment.

In order to keep exactly the same cross section, a steel wire covered with plastic with marks every metre was extended between the two marks which had been used for triangulation. The echo sounding measurement

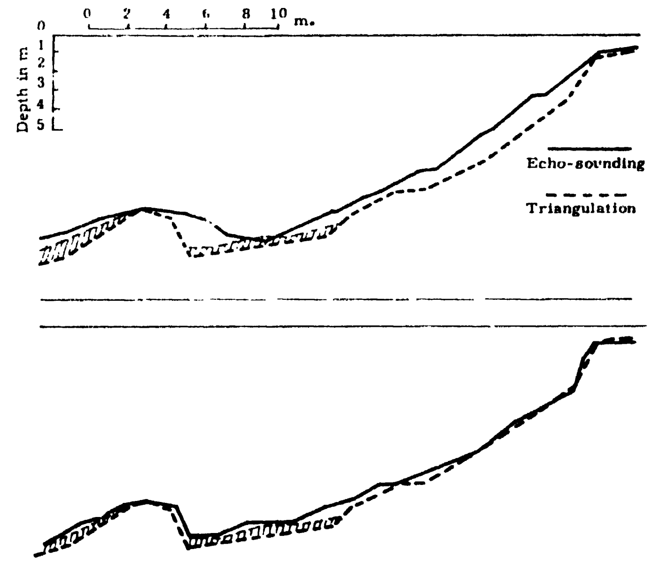


Fig. 5. Comparison of bottom profiles obtained by echo sounding (see fig. 4) and triangulation (see fig. 3). Top: frequency 100 kc.; half power beam angle 16 degrees. Bottom: frequency 200 kc.; half power beam angle 3·3 degrees.

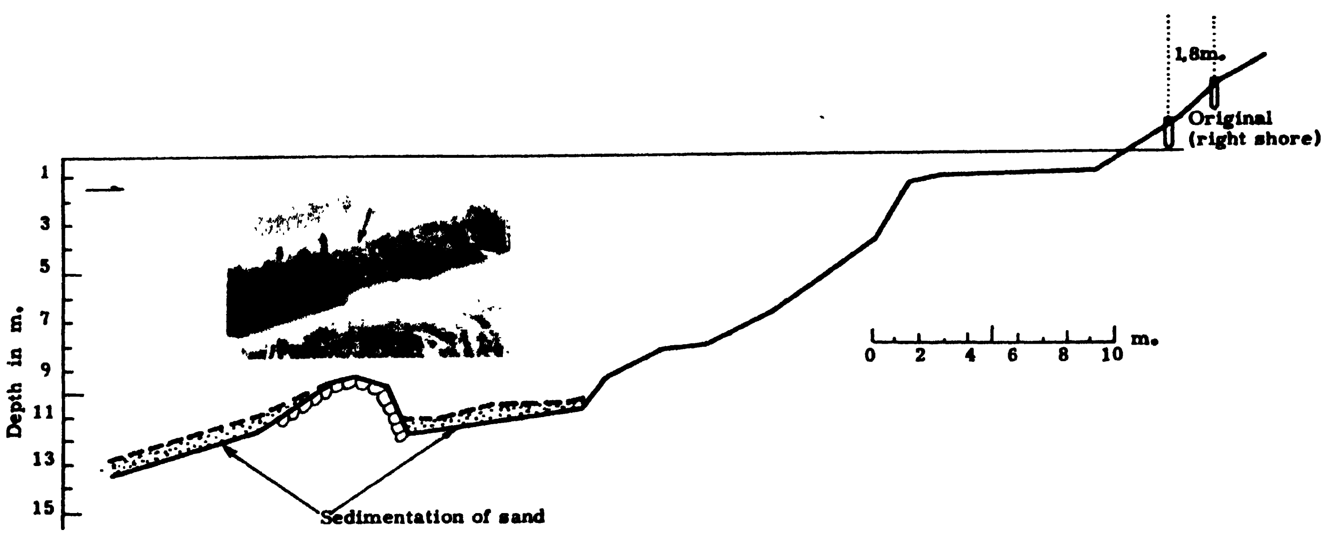


Fig. 3. Triangulated shape and photo of revetment of the profile used for the experiments

was made while travelling along this wire, marking 1 m. intervals on the recording paper.

The echo sounder used in this experiment is of experimental design, fitted for transmitting and receiving 100 or 200 kc. by changing the transducers, and has a measuring range of 50 m. The recording system is of the rotating type, with wet recording paper. The half power beam angles of the transducers are 16 degrees and 3·3 degrees respectively.

Results

With a half power beam angle of 16 degrees (100 kc.), the shape of the revetment is deformed considerably and it is difficult to obtain the true shape from the echogram (fig. 4, left; fig. 5, top). The narrower beam angle of 3·3 degrees gives much better results, i.e. the recorded width of the revetment is only 20 cm. longer than the true width fig. 4, right; fig. 5, bottom.

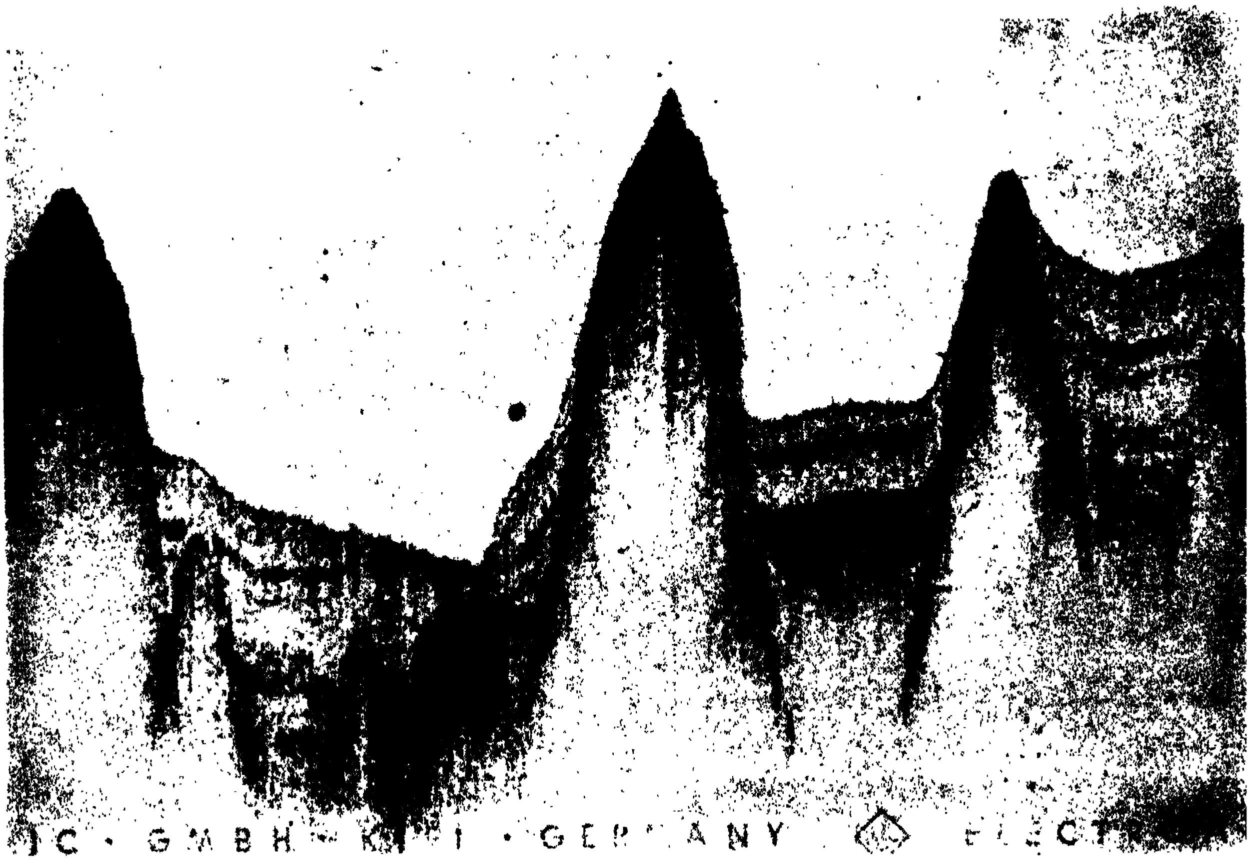
CONCLUSIONS

From the results of these experiments, the following conclusions can be drawn:

1. For a sharp beam angle, high frequency ultrasonic waves of, for instance, 200 kc. are favourable as the transducers can be small and compact, allowing installation in small boats as needed for echo sounding in the shallow waters of lakes or swamps.
2. With a sharp beam angle, such as 3·3 degrees, it is possible not only to obtain high accuracy in the reproduction of the shape of the bottom but also to detect fish schools swimming quite near a wall, as, for instance, an artificial fish shelter.

REFERENCE

[1] Hashimoto, T. and Nishimura M.: Tech. Rep. of Fishing Boat Laboratory No. 5, p. 155, 1954.



Echogram of a stratified bottom with soft layers over harder ones. Photo: Elac, Kiel

ON THE DIFFERENCE BETWEEN 24 kc. AND 200 kc. ULTRASOUND FOR FISH-FINDING

by

T. HASHIMOTO and Y. MANIWA

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Abstract

The authors have produced an experimental echo sounder using 200 kc. with a barium titanate transducer, and they consider that this machine gives a better picture quality than the standard model using 24 kc. They illustrate this claim by photographs of traces of fish and of the Deep Scattering Layer (DSL), but point out that the 200 kc. instrument has a different depth scale and a higher paper speed than the standard model. It is considered that the higher frequency has the better reflection coefficient which compensates for some increase in attenuation.

Différence entre les écho-sondeurs de 200 kc. et de 24 kc.

Résumé

Les auteurs ont mis au point un écho-sondeur expérimental fonctionnant sur 200 kc. avec un émetteur en titanate de barium; ils estiment que les images de cet appareil sont d'une qualité supérieure à celles du modèle standard fonctionnant sur 24 kc. Ils montrent, a l'appui de leur théorie, des photographies de traces de poisson ainsi que de la couche dispersante profonde (DSL), mais font observer que l'échelle des profondeurs de leur appareil est différente de celle du modèle standard et que la vitesse de déroulement de la bande est plus élevée. On considére que la fréquence plus élevée permet d'obtenir un meilleur coefficient de réflexion qui compense une atténuation un peu plus importante.

Diferencia entre las ecosondas que usan frecuencias de 24 y 200 kc.

Extracto

Los autores han construído una ecosonda experimental, provista de un transductor de titanato de bario, que funciona con frecuencias de 200 kc. y, según ellos, produce una imagen más clara que el modelo corriente de 24 kc. Ilustran esta aserción con fotografías de ecogramas producidos por peces y la capa profunda de dispersion ("DSL" en inglés) del sonido haciendo notar, al mismo tiempo, que el instrumento de 200 kc. posee una escala de profundidad diferente y una banda registradora más veloz que el modelo corriente. El uso de frecuencias más altas tiene un mejor coeficiente de reflección que compensa parte de las pérdidas causadas por la atenuación.

EXPERIMENTAL ARRANGEMENT

AFTER having experimented with 100 kc. to 400 kc. ultrasound for fish detection[1, 2] an experimental 200 kc. echo sounder was designed to compare its performance with the 24 kc. model which is in common use.

The experimental model is shown in fig. 1. The transducer is a circular disc of barium titanate of 100 mm. in diameter. Its transmitting surface is covered with a plate of synthetic rubber 5 mm. thick and the container is filled with castor-oil. The beam-angle used is 5 degrees and the peak power of transmission lies between 320 and 480 W.

The amplifier is a double heterodyne type (200 kc. to 452 kc. to 12 kc.), converted to direct current for the recorder. The synthetic gain is 155 db. The recorder is of instantaneous return type with 180 mm. paper width and 50 m. and 300 m. measuring range.

RESULTS

We equalised the second echoes of both the 24 kc. and 200 kc. echo sounders to regulate the gains of both instruments. Their transmitting powers, of course, are not strictly equal but this gives at least a general comparison The reproduction scale and the paper speed unfortunately are not equal for the two echo sounders to be compared. (The same most probably is true for the impulse period and the beam angles—Editor.) Both echo sounders were operated simultaneously. Respective sections of both records are indicated by equal numbers at the lower edge.

Bottom-fish not recognizable in the 24 kc. record can be distinguished in the 200 kc. record (fig. 2(a) and (b)). Even fish schools as near as 20 cm. above the bottom are recorded separately from the sea bottom by the 200 kc. experimental sounder (figs. 2(a); 3(a) and (b)).

Surface and midwater fish are represented more

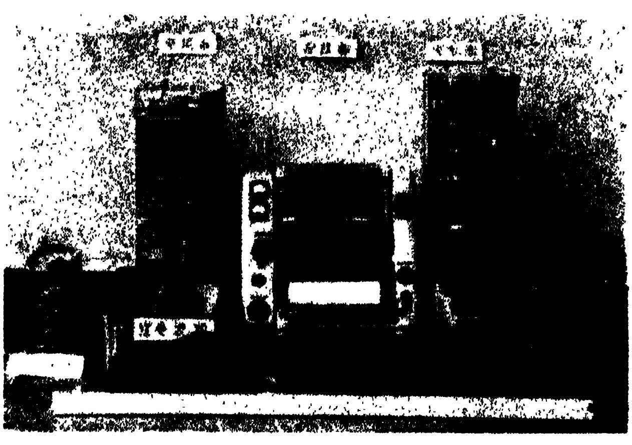

Fig. 1. The experimental 200 kc. echo sounder

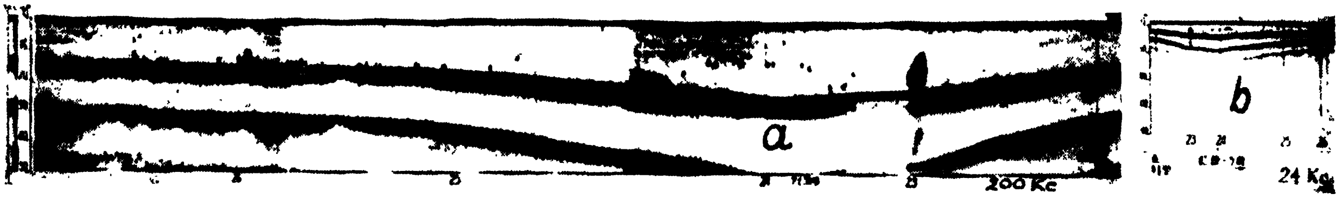

Fig. 2. Comparison of fish records obtained with the experimental sounder (a) and a common 24 kc. model (b).

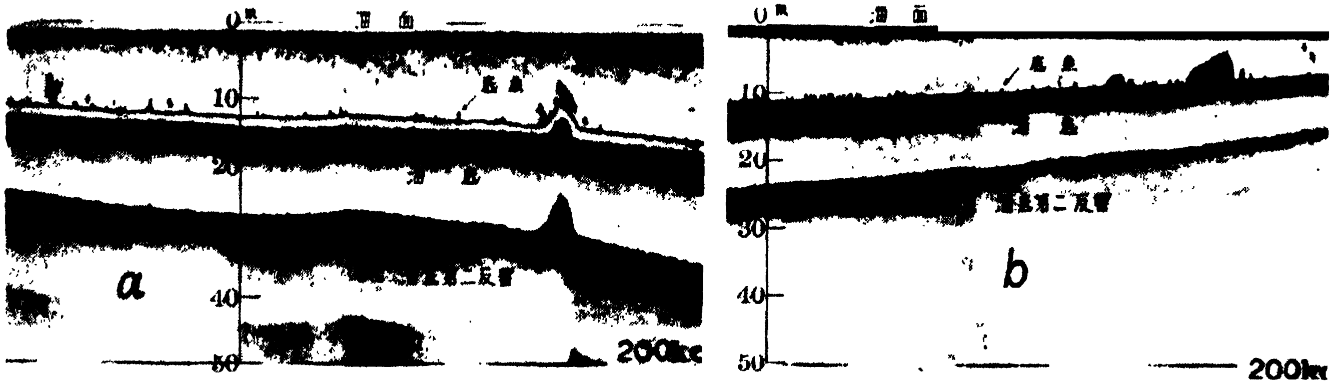

Fig. 3. Comparison of bottom fish traces with (a) and without (b) suppressor circuit.

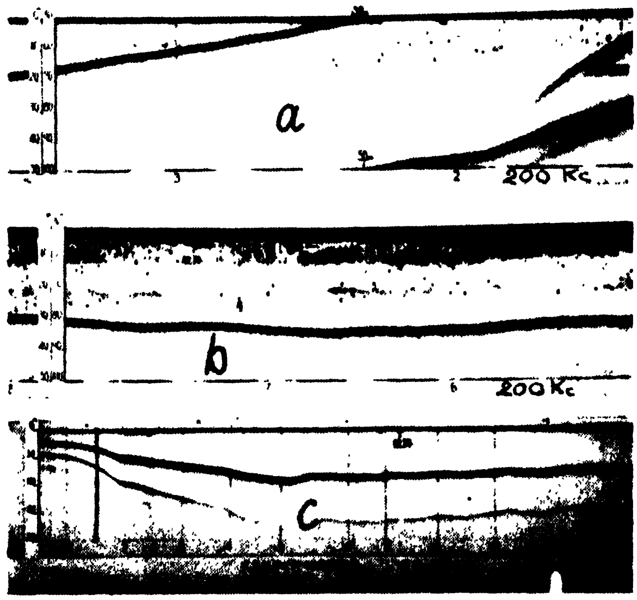

Fig. 4. Comparison of fish and deep scattering layer *traces obtained with the experimental sounder (a) and (b) and the common 24 kc. model (c).*

Fig. 5. Example of the higher resolving power of the experimental echo sounder (a) compared with a 50 kc. model (b).

clearly by the 200 kc. model (fig. 4(a), (b) and (c)). These are not distinguished from the background noise by the 24 kc. model, even if the amplification is increased as at '2' in fig. 4(c), probably because the reflection coefficient for fish is less for 24 kc. than it is for 200 kc.

The Deep Scattering Layer is not clearly recorded by the 24 kc. model, as it is by the 200 kc. model (fig. 4 (c) and (b)).

The superior resolving power of the 200 kc. experimental sounder is clearly proved by the records shown in fig. 5, (a) and (b). This 200 kc. echogram (fig. 5 (a)) is considered to be the first to provide the detailed construction of a fish school.

The use of a suppressor circuit for depressing the peak of the bottom echo (*white line*) improves the representation of bottom fish considerably also for 200 kc. (fig. 3 (a)).

The superiority of the 200 kc. experimental sounder compared with the common 24 kc. model in resolving power and performance in recording single fish and the deep scattering layer are considered to be due to the higher reflection coefficient for 200 kc. of small reflectors such as small single fish and plankton concentrations.

REFERENCES

[1] T. Hashimoto, Y. Maniwa and M. Nishimura; Propagation Characteristics of 100 kc. to 400 kc. Ultrasound in Sea Water, Technical Report of Fishing Boat No. 8, March 1956.
[2] T. Hashimoto and Y. Maniwa; Study on Reflection Loss of Ultrasound of Millimeter Wave on Fish-body, Technical Report of Fishing Boat No. 8 and No. 9, March and September, 1956.
[3] T. Hashimoto and Y. Maniwa; Technical Examination and Experiment on Fish-finder for Bottom-fish, Technical Report of Fishing Boat No. 9, September, 1956.

RECENT TRENDS AND DEVELOPMENT IN ECHO FISHING

by

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Abstract

This paper describes briefly the electronic Pye Marine Fish-Finder, and then goes on to discuss in detail the three attachments which have been designed to operate from it.

First attachment is a horizontal searching transducer designed to be fitted on fishing vessels, and suitable for shallow waters such as are found in the North Sea, as well as deep water. This equipment is as simple as is compatible with efficient operation, and can be easily removed from the vessel when required without slipping.

The second attachment consists of a transducer for fitting to a midwater trawl, so that soundings can be made from the net or the ship at will. In this way the depth of the net, and the opening of the net mouth can be easily measured.

The third attachment is an attempt to overcome the need to watch the Cathode-Ray-Tube of the Fish-Finder when searching for bottom fish. This "Fish-Counter" acts as an electronic observer, and using the sea bed echo as a datum, looks back to see if any echoes appeared in the two fathoms immediately above the sea bed. If there is an echo a click is produced in a loud-speaker. Alternatively for research work, the instrument will operate a counter, and so give a record of the number of fish-echoes seen.

L'utilisation du sondeur à écho pour la pêche. Perspectives et progrès récents

Résumé

Ce document donne une description rapide de l'appareil électronique Pye Marine Fish Finder et étudie en détail les trois appareils complémentaires qu'il doit faire fonctionner.

Le premier est un émetteur de recherche horizontal, pouvant être montré sur bateaux de pêche et convenant pour les eaux peu profondes comme celles de la mer du Nord, ainsi, que pour les eaux profondes. La simplicité de ce matériel est égale à l'efficacité de son fonctionnement et il peut être facilement démonté du bateau en cas de besoin.

Le deuxième se compose d'un émetteur à adapter à un chalut flottant de sorte que les sondages peuvent être effectués à volonté à partir du filet ou à partir du bateau. De cette manière, on peut facilement obtenir la mesure de la profondeur du filet et la mesure de son ouverture.

Le troisième représente une tentative pour remédier à la nécessité de surveiller le tube à rayons cathodiques du détecteur de poisson quand on recherche les poissons de fond. Cet "enregistreur de poisson" se comporte comme un observateur électronique et, utilisant comme donnée l'écho renvoyé par le fond de la mer, recherche s'il ne s'est pas produit d'echo dans les deux brasses situées immédiatement au-dessus du fond de la mer. Dans le cas d'un écho, un haut-parleur fait entendre un signal. Lorsqu'il est employé pour la recherche, l'instrument fait fonctionner un compteur et donnera ainsi le nombre global des échos donnés par les poissons.

Tendencias recientes y perfeccionamiento de la pesca con ecosonda

Extracto

En este trabajo se describe brevemente el localizador electrónico de peces "Pye Marino" ("Pye Marino Fish-Finder") y analizan, en detalle, los tres accesorios que se proyectaron para su funcionamiento en diversas condiciones.

El primer accesorio es un transductor para la localización horizontal destinado a embarcaciones pesqueras, que se presta para trabajar en aguas someras como las del mar del Norte y también en zonas profundas. Este equipo es tan sencillo como su funcionamiento eficaz lo permite y puede retirarse ràpidamente del barco cuando las circunstancias lo requieren, sin necesidad de proceder a la varadura.

El segundo accesorio es un transductor que puede adaptarse a una red de arrastre para la pesca entre aguas, el cual permite efectuar sondeos desde el arte o el barco, según lo exijan las necesidades de trabajo. En esta forma puede determinarse fácilmente la profundidad a que se encuentra la red y la altura de su boca.

El tercer accesorio evita la necesidad de observar el tubo de rayos catódicos del localizador cuando se buscan especies de fondo. Este "registrador de peces" actúa como un observador electrónico y, usando el fondo marino como plano de referencia, verifica si aparecen nuevos ecos en las dos brazas immediatas al fondo. En caso de producirse un eco, el alto parlante emite un ruido agudo. Cuando el instrumento se usa para investigaciones científicas, puede hacer funcionar un contador que determina el número de ecos producidos por los peces que "vió" el aparato.

GENERAL COMPARISON OF PAPER-RECORDER AND CATHODE RAY TUBE DISPLAY

By the early 1940's the use of the paper-recorder in searching for herring schools was quite common, and most of the English East Coast Fleet was fitted with such echo sounders. The results, however, were not consistent. Often herring echoes would appear suddenly and just as mysteriously disappear, and catches did not always correspond to the distribution of echoes.

This effect became even more noticeable when the paper-recorder was used by the Arctic trawlers. Either echoes were seen and no fish caught, or good catches were obtained when the paper was clear. This immediately gave a clue to the problem as the trawler, of course, only catches fish very close to the seabed. It seemed reasonable to suppose that the paper-recorder was unable to show fish near the seabed as separate markings, and that when echoes were seen the fish were too high to be caught in the bottom trawl.

This theory was proved when the Cathode Ray Tube (C.R.T.) display for fish searching was brought on to the market. The normal paper-recorder does not show demersal fish in such a manner as makes them easily recognizable. Firstly, the scale length of most recorders

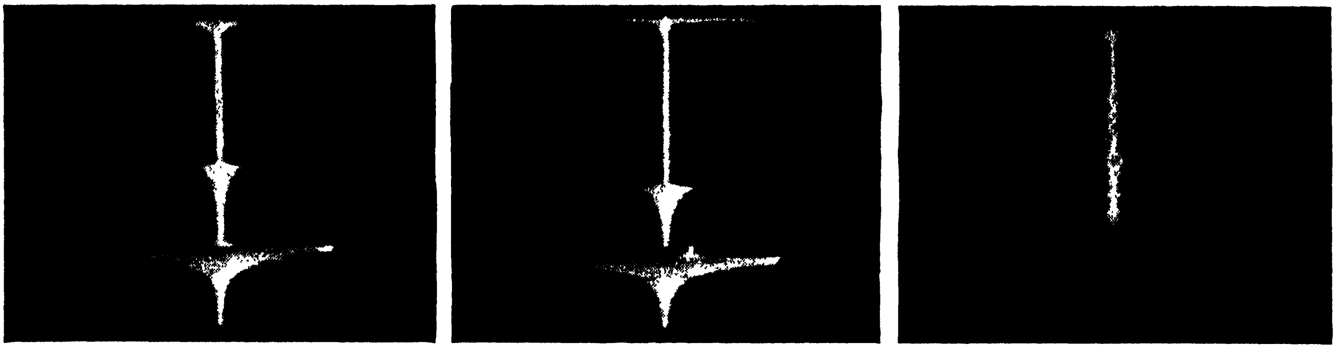

Fig. 1. The operation of the Fish-Finder when searching for bottom fish. Left: C.R.T. reproducing the full range. On top the transmitter pulse, in the middle a secondary echo and below the echo of the seabed with a small fish echo on top of it. Middle: As above with the 7 fm. marker placed over the fish echo. Right: The 7 fm. section expanded over the whole screen. The fish echoes are now seen to extend 3 fm. up from the seabed.

is in the order of 40 fm. on a paper 6 in. wide, and on this scale a fish school 2 ft. in depth would make a line of about 1/20 in. if shown as a separate mark. This would be fairly easily seen, but, unfortunately, owing to the pulse length of the transmission, any echo near enough to the seabed is joined to the seabed echo. When fish markings are seen as separate echoes clear of the seabed they are approximately 1 fm. above the bottom, and the trawl may pass under the fish.

The Cathode Ray Tube has no such limitation of scale, and no mechanical moving parts to limit the sensitivity or speed of display. It has one more very great advantage in that it is possible to compare the strength of the echoes received. It is chiefly this which makes it possible to see fish close to the seabed on the C.R.T. display. The fish echo is always smaller than the seabed echo, and is usually very much smaller. If the fish are near the seabed, their echo appears as an extension of the seabed echo, which is easily visible on the C.R.T. The smaller fish echo appears much brighter, which helps to make even the smallest easily identifiable. There is no doubt that the C.R.T. display is more difficult to interpret, and requires considerable skill and experience on the part of the operator. If, however, the operator approaches this problem with confidence he can quickly attain the necessary skill to decide whether the fish are present, and to estimate his catch with considerable accuracy.

THE PYE FISH-FINDER

The Pye Fish-Finder is an electronic echo sounder solely designed for locating fish under the conditions found in deep-water trawling, and seine net fishing. The following facts were considered when planning the design:

1. Fishing is carried out at all depths down to 300 fm., but chiefly around 80 to 150 fm.
2. Using present fishing techniques, it is only possible to catch fish within 3 or 4 ft. of the seabed, whereas the fish may only be a few inches from the bottom.
3. As the equipment is usually operated by the skipper, who is often alone on the bridge while fishing, the information must be presented simply and clearly.
4. The equipment is operated continuously while fishing and may be required to run for 14 or 15 days at a time.
5. It is difficult to service electronic equipment at sea, and there may be no skilled personnel on board.

When using a C.R.T. display, it is inconvenient to watch a slow flashing trace, as is required for a measuring range of 300 fm. Since most fishing is carried out at

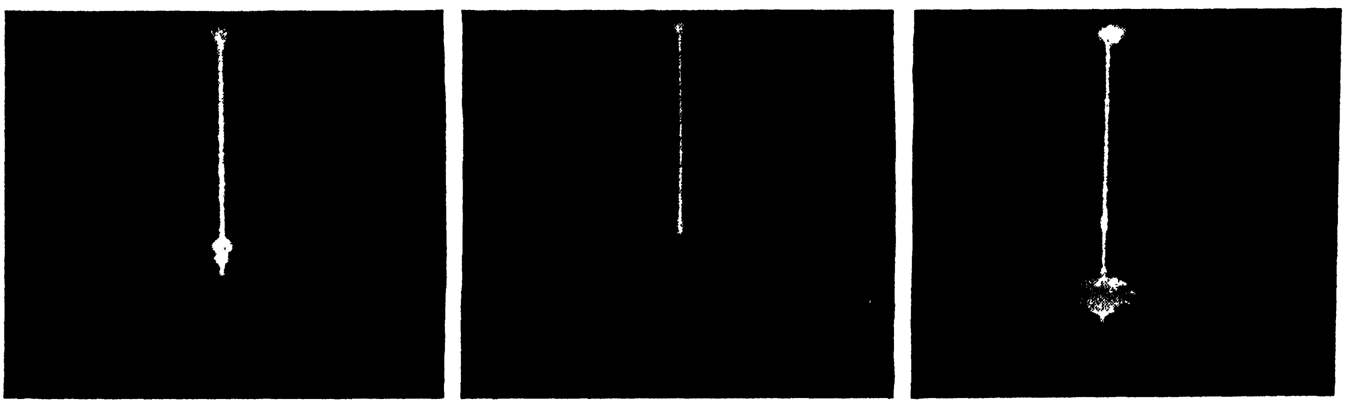

Fig. 2. Different kinds of fish echoes near the seabed. Left and middle: Cod in deeper water in the Arctic fishery. Right: Small quantity of immature herring in 35 fm. in the North Sea.

lesser depths the transmission rate can be speeded up for sounding in this shallower water and a steadier picture obtained.

Therefore an impulse rate control is installed which may be set to transmit pulses at the maximum rate according to the actual depth. Consequently the display is as steady as possible, and is much easier to watch than the flash of a fixed pulse rate machine. We have also fitted a long persistence C.R.T. with a suitable colour filter, and the set is remarkably easy to watch under all conditions.

It is necessary to examine the fish echoes closely, and determine their distance from the seabed. To do this we have used the old Radar trick of an expanded time-base (fig. 1). A marker pulse 7 fm. in width is placed on the time-base, and, by means of a variable delay circuit, moved up or down. On pressing a key switch, the 7 fm. enclosed by the marker can be expanded to the full tube width and any portion of the main trace closely examined. The delay control or 7 fm. marker control is also calibrated in depth, as the delay circuit is started at the same time as the transmission. When using the expanded time-base, it is not necessary to switch back to the main time-base to read off depths; also the marker can be used to measure the depths of midwater schools while the main time-base is used to measure the depth of the seabed.

The sensitivity of the equipment is limited by the water noise picked up. Since the received echo must be of greater amplitude than this noise, the transmission must be strong enough to produce an echo of sufficient amplitude even from the smallest fish school at the greatest depth at which fishing takes place. The Pye Fish-Finder produces a transmitted pulse power which is capable of giving echoes from concentrations of fish too small to be worth trawling (fig. 2).

The controls are largely self explanatory; and, while fishing, it is virtually a *one-knob* instrument. Once the gain and sounded depth controls are correctly adjusted, the fish echoes can be watched with only an occasional touch of the 7 fm. marker depth control to keep them on the tube. The gain control has a calibrated scale, and both this and the sounded depth and 7 fm. marker depth scales are edge-lit in orange light and provided with a dimmer to avoid upsetting the operator's vision when fishing at night.

The equipment is housed in two cases—the pedestal which carries the transmitter and power unit, and the display head which houses the receiver, the C.R.T. and all the control and pulse circuits (fig. 3). Normally these units are mounted together as a single console, but in small craft the pedestal can be sited in the engine room and the display head in the wheel-house.

The oscillators are of the bar type and are either mounted through the hull or on the keel. In wooden vessels, the transducer housings are small enough to be fitted without cutting into the frames. Corrosion is avoided by isolating the transducer electrically from the ship's earthing system.

The results obtained from the Fish-Finder depend almost entirely on the proficiency of the operator; it has been found absolutely essential to send a skilled man to sea with each new installation.

Results have proved that once the skipper is able to make full use of the set, fishing efficiency improves and he will never shoot his gear until fish echoes are recorded on the instrument.

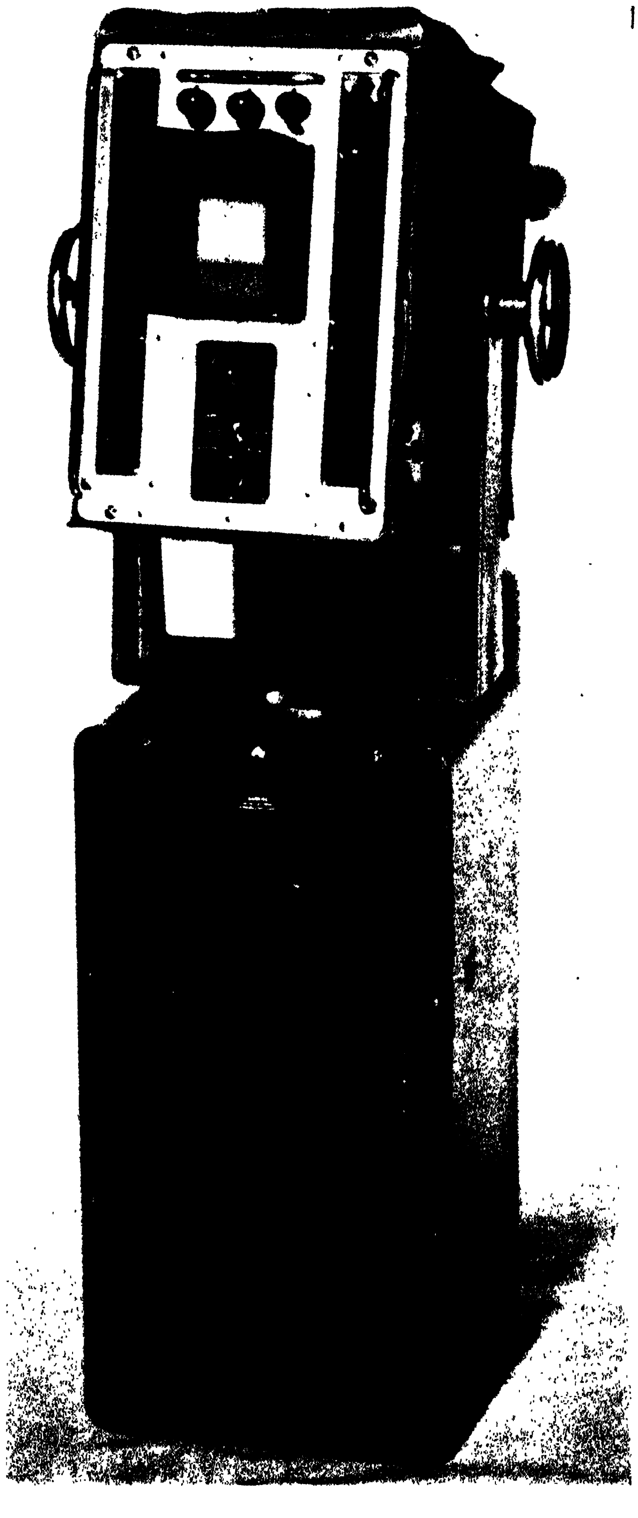

Fig. 3. Pye Fish-Finder in single console installation.

Fig. 4. Depth gauge for midwater trawling. Left: Hand-winch with cable. Right: Transducer float attached to the headline.

DEPTH GAUGE FOR MIDWATER TRAWLS

In designing the Fish-Finder we kept in mind that we were using a valve transmitter and able to transmit over long lengths of cable, a fact used to provide the Fish-Finder with an attachment for measuring the depth of any midwater trawl. The system comprises a float attached to the headline of this trawl and containing a transducer, which combines the duties of transmitting and receiving (fig. 4); a length of high tensile cable to connect the float to the ship, and a small relay panel in the pedestal, so that the switch on the display head enables the operator to use either the ship's transducer or the headline transducer. For all North Sea work, and any depths up to 50 fm., a simple hand-winch is quite suitable for handling the cable, and no difficulty has been found in using the gear after the first few hauls (fig. 4.) Fish are usually found with the normal ship-transducers, the trawl is shot and towed back through the school, adjusted in the depth to that of the fish.

On the C.R.T. the transmitted pulse now indicates the trawl headline instead of the sea-surface and below it will be seen the echo from the footrope, the seabed, and any fish present. Therefore it is possible to tell the height of the trawl above the seabed, the mouth opening of the trawl, and the relative position of the trawl in relation to the fish school. It is possible to know immediately if the gear is fishing properly, and if the fish are entering the net.

This equipment has proved both reliable and easy to handle, and has given us a great deal of information on the behaviour of both the gear and the fish. Incidentally, when using this equipment, we found that the *angle of warp* measuring method for estimating the trawl depth is very inaccurate, and that paying out a fixed amount of warp, and trawling at a fixed speed, does not always put the trawl at the depth indicated by the tables.

We are also hoping to make this equipment suitable for deep-sea work, using up to 500 fm. of cable down to the transducer. For this purpose we have designed a special electric winch, which handles the cable automatically. When paying out, the winch holds a steady 100 lb. pull on the cable, and prevents it running free or tangling up. While fishing, the winch is held by a disc brake which slips at 200 lb. and prevents sudden surges breaking the cable. On heaving, the winch maintains a pull of up to 280 lb. It thus follows the trawl winch, and takes up the slack as the gear comes to the ship. No extra manpower is required to handle the cable. The operator has a three position switch, *shoot, fish, heave*, and he follows the skipper's orders to the trawl-winch man.

HORIZONTAL RANGER

Our second attachment is a simple device for finding midwater schools, which could well be used in conjunction with the trawl depth gauge. We have a particular problem in the East Anglian herring fishery in that the boats are used part of the year as drifters, and part of the year as trawlers. The device is therefore designed so that it can be quickly taken out of the ship without slipping or dry docking.

In the shallow waters of the North Sea, bottom and surface echoes can be a problem with horizontal echo ranging and for this reason we have reduced the vertical beam angle to 8 degrees and put up the search speed to 1·6 r.p.m. Although interfering echoes are still picked up when the ship rolls and pitches, the high sweep speed does enable the operator to distinguish the genuine fish echoes as they are visible during the whole period of the roll while the interfering echoes appear and disappear. To achieve this high sweep speed, we have made the horizontal beam angle 30 degrees and the maximum range just over 400 fm. In spite of this wide horizontal beam, there is no difficulty in obtaining a bearing on the schools, and it does make it easier to maintain contact with the target when the ship is manoeuvring. The transducer is raised, lowered, and rotated electrically, and is controlled from a small box mounted on the Fish-Finder display head. This box also contains the indicator which shows the heading of the transducer and consequently the bearing at which the echoes are picked up. The signals are displayed on the C.R.T. and they also produce an audible signal, which is used when searching. Only when it is necessary to *home* on to the fish school, or find its range, is the C.R.T. brought into use.

FISH-COUNTER

We have recently been working on a new device, the Fish-Counter, which may lead to the end of the supremacy of the C.R.T. in this type of echo sounding.

We were asked by the Ministry of Agriculture, Fisheries and Food if we could devise a system for surveying bottom fish without having to watch the C.R.T. and time the echoes. We eventually designed an equipment which acts as an electronic observer. Our fish counter acts in the same way as the human eye. Using the sea-bed echo as a reference level, it looks back, and if there is a small echo within a pre-set distance of the sea bed, it produces a count. If there is no bottom echo, it ceases to operate until the echo returns. The results are displayed on 4 Dekatron counters, 3 for counting the fish echoes of differing amplitudes, and the fourth for counting the number of transmissions sent out.

During trials, the counts were found to be remarkably accurate. It was more accurate in good weather than a human observer, although the accuracy fell off slightly under conditions of bad aeration, so we designed a simplified version for the commercial fisherman. This is a small box which can be attached to the Fish Finder and has two pre-set controls and an external loud-speaker. When set up, the counter watches the echoes on the 7 fm. expanded time-base, and produces a click in the loud-speaker each time a fish echo comes from within 2 fm. of the sea bed. Three counters were fitted on commercial ships, two trawlers and one seine netter, and the skippers were enthusiastic over their performance. The counters are now standard equipment in our range of optional fittings to the Fish-Finder (fig. 5).

OUTLOOK

The success of this device gives a clue to future developments in this field. Already the C.R.T is being used as an auxiliary to the counter, simply to check the amplitude and shape of the echoes. We foresee the day when we come again to the recorder, with an electronic device watching the echoes as they are received at the ship, and after sorting them out, printing the results on a paper tape. When this can be made a reliable and practical system, we shall see the end of the C.R.T. in fish-finding echo sounders.

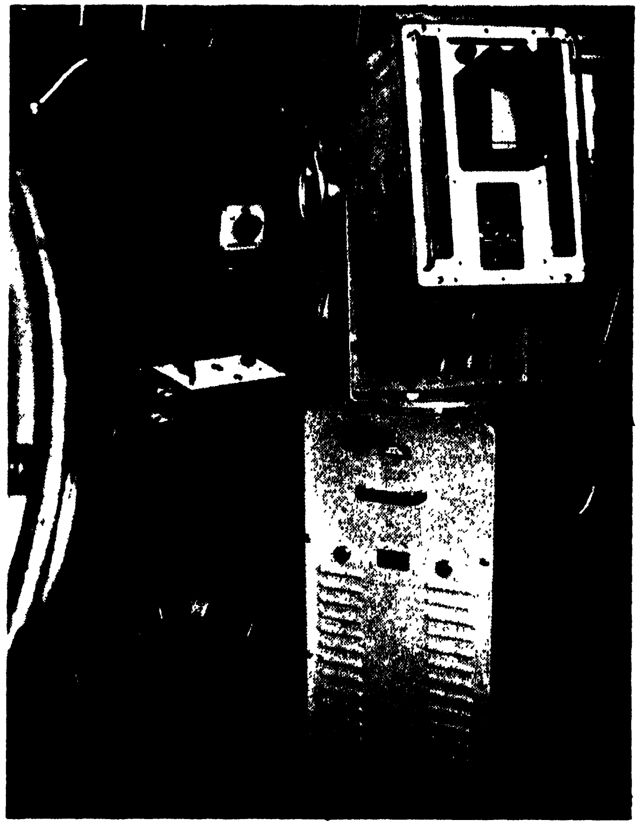

Fig. 5. The complete installation of Fish-Finder and Fish-Counter as fitted in the Grimsby trawler Boston Fury.

THE DEVELOPMENT OF ECHO SOUNDING AND ECHO RANGING

by

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Abstract

One of the most exacting problems facing the designer of echo-sounding equipment is the detection of fish within a few feet of the seabed. The use of the *scale expander* which enlarges the picture as presented on the Cathode Ray Tube, has helped to clarify the situation, for by this means, fish very close to the bottom are presented as having a brighter trace than the seabed itself. The C.R.T., unfortunately, lacks a memory which the recorder has. In order to get the best of both worlds the manufacturer must produce, in a single display, an instrument having both qualities. Owing to the limited number of gradations or "tones" that can be produced on the recording paper, fish on the bottom may pass unnoticed because their echo merges with that of the bottom and to overcome this limitation, an ingenious and simple gating circuit has been devised. This operates only on receipt of the bottom echo and has the effect of cutting out the amplifier for about 1/100 sec., thus producing a white line which follows the bottom contour on the paper, dividing the fish echoes from the bottom echoes. The author deals with the problems and limitations of echo-ranging and stresses the need for the training of fishermen by experts in the use of modern electronic equipment, for only by the correct use of the instruments can complete liaison be maintained between the fishermen and the manufacturer.

Perfectionnement de l'écho-sondeur et du télémètre a écho

Résumé

Un des problèmes les plus délicats qui se posent au technicien des appareils de sondage à écho est la détection des poissons situés très près du fond. L'emploi d'un "agrandisseur d'échelle" qui agrandit l' "image" donnée sur le tube à rayons cathodiques, a permis de réaliser certains progrés car il permet de reproduire le poisson situé très près du fond sous forme d'une trace plus brilliante que celle du fond. Malheureusement, le tube à rayons cathodiques est dépourvu de la mémoire que possède l'enregistreur, en sorte que pour obtenir les avantages des deux systèmes le fabricant doit mettre au point un appareil permettant de combiner ces deux qualités dans la même image. En raison du nombre limité de gradations ou de "nuances" que peut reproduire la bande enregistreuse, les poissons du fond peuvent passer inaperçus car leur écho se confond avec celui du fond; pour résoudre cette difficulté, on a mis au point un système simple et ingénieux appelé "circuit à déclanchement" (gating circuit). Ce circuit ne fonctionne qu'à la réception de l'echo du fond et a pour effet de couper l'amplificateur pendant 1/100 de seconde environ en produisant une ligne blanche qui suit le contour du fond sur la bande et sépare ainsi les échos du poissons de ceux du fond. L'auteur examine les problèmes et limitations du télémètre à écho et souligne la nécessité de confier à des experts la tâche d'enseigner aux pêcheurs l'emploi des appareils électroniques modernes, car la collaboration entre les fabricants et les pêcheurs ne sera complète que si ces derniers savont se servir correctement des appareils.

Evolución del sondeo y telemetría ultrasonoros

Extracto

Uno de los problemas más dificiles que debe resolver el proyectista de equipo para sondeo ultrasonoro es la localización de peces a pocos pies del fondo del mar. El uso del "Scale expander", que amplia la imagen producida en el tubo de rayos catódicos, ha ayudado a esclarecer la situación, ya que permite representar a los peces que se encuentran muy cerca del fondo por un trazo más brillante que el mismo lecho marino. Desgraciademente, como el tubo de rayos catódicos carece de la memoria que posee la ecosonda registradora, para obtener lo mejor de ambos instrumentos el fabricante debe producir un aparato con ambas cualidades. A causa del limitado número de gradaciones o "tonos" que se observan en el ecograma, los peces sobre el fondo pueden pasar desapercibidos cuando los ecos resultantes de su presencia se mezclan o fusionan con los del fondo. Para evitar este inconveniente se ha ideado un sencillo circuito "de rejilla" que funciona únicamente al recibir el eco del fondo y tiene el efecto de interrumpir el funcionamiento del amplificador durante aproximadamente 1/100 segundo, produciendo sobre el papel una línea blanca que sigue el relieve del fondo del mar.

El autor analiza los problemas y limitaciones de la telemetría ultrasonora y pone de relieve la necesidad de que expertos adiestren a los pescadores a manejar equipo electrónico moderno, ya que solamente el uso correcto de estos instrumentos puede coordinar la relación que debe existir entre el pescador y el fabricante de estos aparatos.

THE development of echo sounding and echo ranging techniques as applied to fish detection has made rapid strides since the war. For these instruments to be used efficiently and for the new developments and refinements of technique that are continually being introduced to be mastered by the user, the fisherman, there should be the closest possible association and interchange of ideas between manufacturer and fisherman.

BOTTOM FISH

The most exacting problem facing the designer of echo sounding equipment today is the detection of bottom fish, such as cod, when they are on or within 1 or 2 fm. of the bottom. The introduction of a Cathode Ray Tube (C.R.T.), or *Scale Expander*, as a complementary device to the moist or dry paper recorder, made considerable progress towards solving the problem. But there is a tendency to look upon the C.R.T. as an alternative to the recorder chart instead of as an additional aid, to be used in conjunction with it.

When actually trawling, the skipper needs to assess the density of fish lying within, say, 2 fm. of the bottom; he is only indirectly interested in anything above this. Consequently, it is this layer of water which must be spread out for display across the chart or the face of the *Scale Expander* tube. To do this, a very short time base is required, the *echo time* equivalent to 2 fm. being just under 5/1,000 sec.

Comparison of C.R.T. and paper recording

The pen of a recorder would have to travel at a speed of a 100 ft./sec. to cross a 6 in. chart in this time—a speed which, from the designer's point of view, is uncomfortably fast. On the other hand, a spot can be made to move over the screen of a C.R.T. at this speed with no trouble at all. But perhaps the chief advantage of the C.R.T. presentation is that the available *dynamic range* is greater than with intensity modulation.

The *Scale Expander* is also well suited for the separation of the comparatively weak fish echo just clear of the bottom from the much stronger bottom echo which immediately follows it, particularly because the weaker fish echo shows up more clearly (fig. 1). The deflection of the spot on the C.R.T. is proportional to the strength of the signal being recorded; consequently the spot moves more slowly in response to a weak echo than to a strong one and therefore leaves a brighter trace.

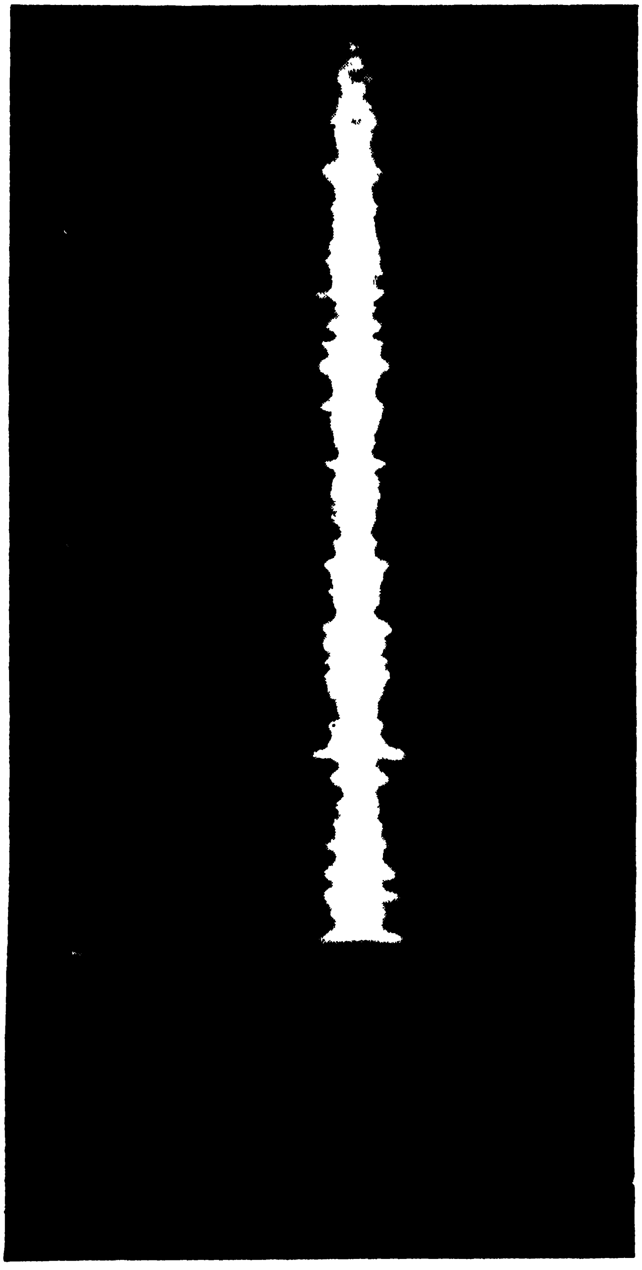

Fig. 1. Example of the C.R.T. display of the bottom echo and fish echoes.

However, the C.R.T. has certain fundamental limitations as a fish indicator. It gives only the instantaneous picture—it has, in fact, no *memory*. A trawler skipper using a *Scale Expander* to assess the density of fish sufficiently close to the bottom to be below the headline of the trawl, and so help him to decide how long to continue the tow, has to add up the fish signals in his head. Once he has seen them, the successive pictures are lost for ever—he cannot refer back to them. The recorder chart, on the other hand, builds up a trace which can be examined at leisure in one piece, and, what is perhaps not so well known, the fact of placing successive echoes side by side, as on the chart, does actually make them more visible.

Here, then, is a problem for the manufacturer: to produce, in a single display, the scale expansion and good echo discrimination of the C.R.T. together with the *memory* of the recorder and the advantage it has of placing successive echoes alongside each other. To achieve this would be to get the best of both worlds.

The limitations of the *Scale Expander* appear to be the more fundamental, so it seems more fruitful to improve the recorder.

Increasing the speed of the pen is largely a matter of engineering and I do not propose to deal with that aspect except to mention, in passing, that the rotating pen, giving a curved recorder trace, which is still preferred by my Company on the grounds of simplicity, may prove to be the only feasible way of achieving the very high pen speeds now required. The other weakness of the recorder is its relatively limited *dynamic range*, that is to say, the comparatively small number of separately discernible steps between the unmarked paper at one extreme and the saturation echo at the other. The number of *just noticeable differences* between black and white has been found to be about 50 for wet paper, and slightly less, about 30, for dry. These figures compare with about 100 for the *Scale Expander*.

Now, the limits between which the strength of bottom fish echoes can vary—depending on the depth of water and the size and density of the fish—is greater than the *dynamic range* of the recorder paper. To put it another way: with the sensitivity set to maximum so that the faintest detectable fish echo will just mark the chart, the strongest group-fish echo likely to be received will saturate the paper; no other echo, whatever its strength, can give a darker echo mark than this.

It is for this reason that group-fish traces can sometimes merge into the bottom echo trace, despite the latter being much stronger, and whenever the bottom trace is serrated due to the vertical movement of the ship in a sea-way, it may be impossible to recognise the fish traces at all. There is no immediate prospect of achieving a fundamental improvement in the *dynamic range* of the recorder paper; after all, there are only so many gradations between black and white.

White line recording

However, my Company has just introduced a device for circumventing the limitation in this particular application. Like so many clever ideas, it is extremely simple and will prove, it is thought, to be equally effective in practice.

A *gating* circuit is introduced into the amplifier which operates only in response to signals above a certain amplitude, this being set at a value in excess of that of the strongest fish echo that can be received, but below that of the bottom echo. The operation of the circuit, which only occurs on receipt of the bottom echo, has the effect of cutting out the amplifier altogether for about 1/100 sec., so that the bottom echo is immediately followed by a white gap, whereas the fish echo is not.

These white gaps build up into a white line which follows exactly the apparent contours of the bottom. The effect is quite dramatic. Group-fish echoes on the bottom which would otherwise have been undistinguishable from it now stand out clearly and can be recognised at once for what they are (fig. 2).

This new refinement is one of several developments on the way.

Relation between quantity of fish echoes and amount of catch

Now for something much more fundamental. How closely does the quantity of fish echoes seen on the C.R.T. and/or recorder compare with the quantity of fish actually caught in the trawl? And the answer is—one may as well be candid about it—not very well.

It can happen that after seeing a good concentration of fish within 1 or 2 fm. of the bottom throughout the period of trawling, the catch is disappointing. Fifty baskets, perhaps, instead of the 5 or 6 bags that might have been expected. Less frequently, the opposite is experienced: no fish on the echo sounder and a good haul.

The explanation seems to be an ambiguity in the recorded depth of the fish echoes. Only when the fish are directly below the ship will their depth, as recorded on the chart or C.R.T., be correct. However, as the sound beam has a certain width—it may be likened to a searchlight beam—it will *illuminate* an area on the bottom, rather than a single point. Fish may therefore return echoes before the ship gets up to them and after the ship has passed over them; and those which lie slightly to one side of the ship may also be detected. Now, the depth of any echo as shown on the chart is the distance between the transducer and the object giving the echo. If a fish, for example, is not vertically below the ship at the time then the recorded depth will be slightly greater than the true depth, consequently—and this is what matters—it will appear to be nearer the bottom than it really is. This is why the echo trace returned by a single fish—or any other small object in the water—takes the form of a crescent as the ship passes over it. If the ship passes exactly over it, then the centre of the trace, that is to say, its highest point above the seabed, will be the measure of its true position in relation to the bottom, but there is no way of telling whether the ship did, in fact, pass exactly over the top or slightly to one side. If the latter is the case, a fish will be shown as being nearer the bottom than it really is.

Moreover, when the fish are densely concentrated, the echoes received are from groups of fish; the crescent shapes of each fish are superimposed on one another and the result is a blob on the bottom. In such conditions, the position of the top of the layer of fish in relation to the seabed can be read off the chart but the bottom of the layer is obscured. So, in a typical case, the chart may show plenty of fish in the layer from, say 3 fm. off the bottom down to the bottom itself. Assuming the headline of the trawl to be about 1½ fm. clear of the bottom, only the lower half of this layer will be caught. But, as I have explained, the trouble is that most of the fish may really be in the upper half of the layer—a fact which will only become apparent when the trawl is hauled.

This may explain the reason for apparent over-logging of fish at trawl depth. Under-logging, when it occurs, must presumably be due to the fact that fish on the bottom are not always recorded.

A lot of thought has been given to developments which may help overcome, or at any rate reduce, these limitations in the performance of echo-sounders. The problem is not an easy one, and, of course, the designer must bear in mind that what is required is not a theoretically ideal solution so much as a practical one—practical from the point of view of the maximum size, complexity and cost that can be tolerated or accepted by the fishing industry.

Clearly, what is needed is even better resolution, both in depth and angle. How can this be achieved? A more directional beam can be obtained by using a higher frequency, but this must be at the expense of greater attenuation and consequently reduced performance at maximum depth.

The effect of the rolling and pitching of the ship would have to be carefully considered and a means of stabilizing the transducer might have to be incorporated in the design. A transducer housed in a streamlined body and towed at a substantial depth below the keel might be the answer, but, here again, there are obvious difficulties which would have to be mastered before a really practical device of this kind could be produced.

HORIZONTAL FISH DETECTION

By far the most important step forward in recent years regarding midwater fishing is the development of the technique which is often referred to as echo ranging as opposed to echo sounding. The principles involved are the same as those of the Asdic used during the war for submarine detection, but whereas the trend of Asdic development for Naval warfare has been in the direction of greater complexity, that for fish detection is towards greater simplicity, without loss of efficiency.

The advantage of an echo ranging system for searching fish is obvious enough. It is the ability to look all round you instead of only at your feet.

A vessel looking for herring schools can, with the aid of an Asdic, search out a lane of water about 2 miles in width—one mile on either side of the ship's course. The advantages of this can be dramatically illustrated by comparing the coverage of an Asdic-fitted fishing vessel with that of, say, a helicopter towing the transducer of an echo sounder through the water at 50 knots—a proposal that is made from time to time. It might be supposed that the much higher towing speed of the helicopter would have the advantage. In fact, about 20 helicopters operated in this way, would be needed to cover the same amount of water in a given space of time as a single fishing vessel steaming at 10 knots, and using Asdic.

Limitations of echo ranging

However, the use of the Asdic for fish detection is not all plain sailing. It can provide, at best, only a partial aid to fishing, and is still in an early stage of development. Further research may show the way to improved performance but the limitations of such horizontal detection

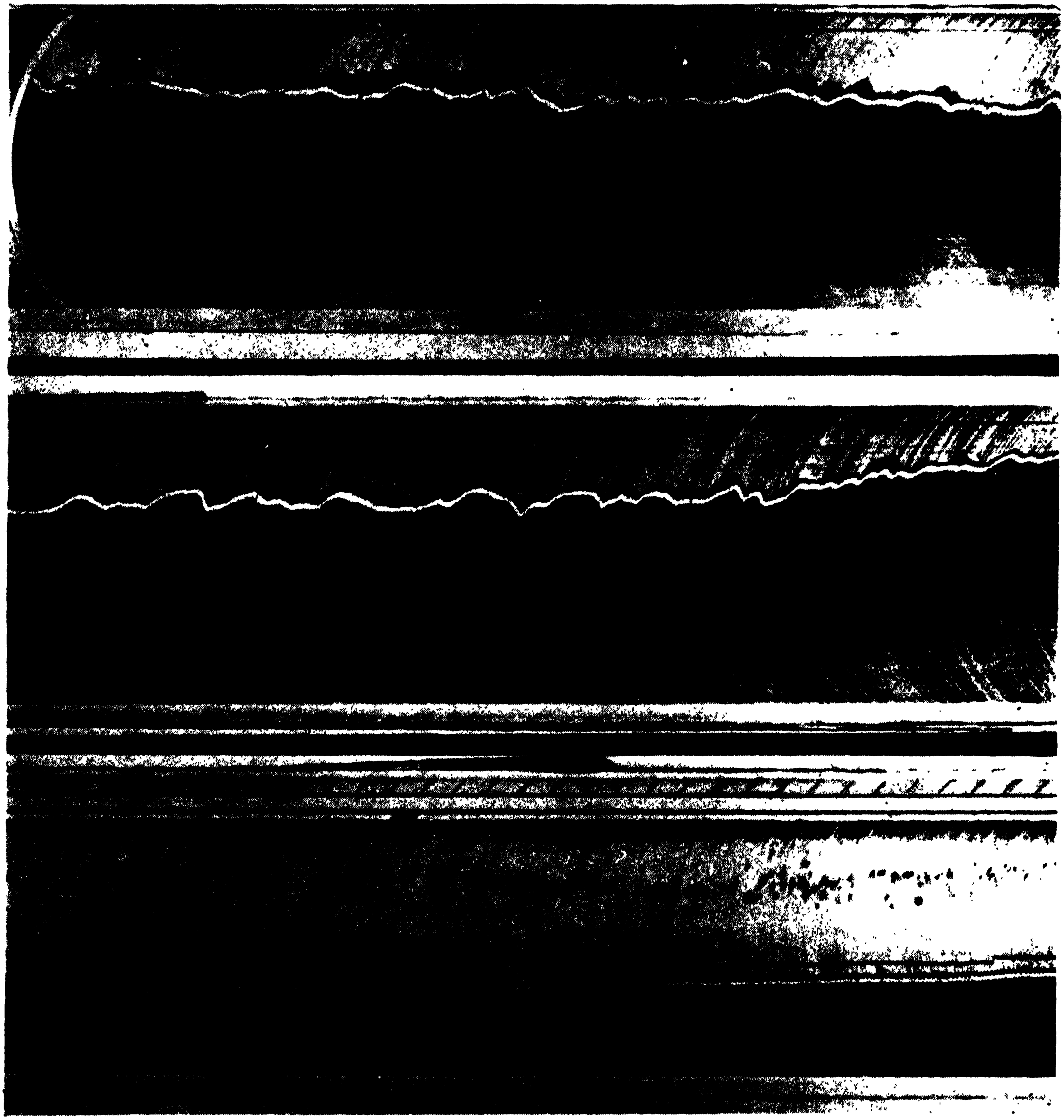

Fig. 2. White line *recordings of bottom fish.*

are as much as anything due to the physical laws governing the propagation of sound in water and, as such, cannot be altered.

For example, as is generally known, a sound beam transmitted horizontally through the water is liable to be bent, either up or down, depending on the change of water temperature with depth. This can have the effect of limiting the maximum range of detection of schools in midwater and may sometimes mean that, whereas echoes from objects near the surface can be picked up at considerable ranges, those in deeper water may only be detectable at a few hundred yards. But a more serious limitation to Asdic performance is due to reflections from the bottom. In depths of water less than 20 to 30 fm. these bottom echoes can be very troublesome.

If the seabed reflected sound as a mirror does light, all would be well, but the surface of the seabed is too rough for this, and the sort of reflection you get is more akin to that from a *rough-cast* wall than from a mirror. The sound is, in fact, scattered in all directions, and so some of the energy of the transmitted beam finds its way back to the ship. These scattered echoes from the bottom are, of course, amplified along with the wanted echoes from fish schools and, unless the latter are of greater amplitude, they will be lost in the background.

A lot of these background echoes are returned from the side lobes of the sound beam, or *secondaries*, rather than from the main beam itself, and so an improvement in the performance can be achieved by designing a transducer in which the energy transmitted is, as far as possible, all concentrated in the main beam. The performance of a conventional transducer can, in fact, be substantially improved by the use of a *tapered array* —my Company has done this in their Fisherman's Asdic —but it would be going beyond the scope of this paper to describe the technique.

There is another aspect to be borne in mind: the actual business of operating the set at a maximum level of efficiency. The main problem is a matter of understanding the Asdic chart, of recognizing the various clues which help to determine the source of any echo trace, and of discarding, by a process of elimination, those which emanate from objects other than fish, such as wrecks on the seabed, wakes of other vessels, and so on.

The operating problem differs from the comparable one of echo sounding in two ways. First, the direction in which the transducer is pointed can be varied at will by the operator, instead of remaining always fixed in one direction. For searching, the transducer bearing is changed by a small step angle before each sound pulse is transmitted. This is normally done automatically to cover progressively the whole area of search, and so presents no problem to the operator. But when an echo is heard on any particular bearing which has the general characteristics of a fish school echo, the operator must himself take over the directional control, and the information which is subsequently displayed on the chart will depend upon his handling of the transducer. What he should do is to train the transducer in steps back and forth across the target, only reversing the direction of training after he has lost the echo on one side or the other. He has to remember that the movement of the vessel will cause the target bearing to draw aft; he must decide at what point to turn towards the bearing of the target in order to have a closer look. Obviously, much time would be wasted if he were to do this every time anything showed on the chart. All this calls for a certain amount of judgment and discrimination which comes more easily, of course, with experience.

The second point is this: fish echoes recorded on an echo sounder come in the clear space on the chart before the bottom echo, but those recorded when echo ranging are mixed up with the returns from the seabed and the surface and have to be sorted from them. This means that the fish school echo cannot be identified as such by its position on the chart in relation to the bottom echo trace, but must be recognized by its appearance—width, regularity, sharpness of edges and so on.

The wakes of the vessels in the vicinity can undoubtedly confuse the Asdic chart, and if there are many of them it may become difficult, and eventually impossible, to pick out the fish school trace from amongst them.

This is important in cases which involve the use of ancillary craft, as, for example, the Norwegian purse seine fishing in which a small boat is used to locate the exact position of the school and direct the shooting of the net. Unless this boat is homed on to the school by the parent ship and finds it almost at once, there is a danger that a series of wakes will be laid between ship and school and so considerably complicate the Asdic operator's problem. No doubt, as Asdics become more generally used, a method of putting the boat over the shoal will be developed and perfected by the fishermen themselves. While the manufacturer can suggest ways of doing it, this particular problem is really a matter of seamanship and therefore one that the seaman knows best how to solve.

It is clear, then, that the Asdic can be of relatively little help when extensive herring schools close inshore are being fished by a large number of boats at the same time, and it is more a question of finding clear water to shoot the nets than of finding the fish. On the other hand, it has tremendous advantages in searching areas further offshore where the schools are more widely scattered. In these circumstances, too, the operating conditions favour the use of Asdics: deeper water, fewer vessels in the vicinity, etc.

Training of operators

There is a very natural tendency, when marketing this new device, for the manufacturer to under-emphasize the operating difficulties. He does not want to give the impression that the user must have great skill and experience if he is to obtain useful results and, indeed, to suggest this would be to exaggerate the problem very considerably.

Nevertheless, it is no good denying that there are rather more difficulties involved in successful echo ranging of fish than in echo sounding.

It is therefore incumbent on the manufacturer to supply not only the equipment, but also guidance and, perhaps, actual training in its use. It is also in his best interests to do so. The skipper setting out to sea for the first time with an Asdic will then know what to expect— and what not to expect—and how to use it. He will,

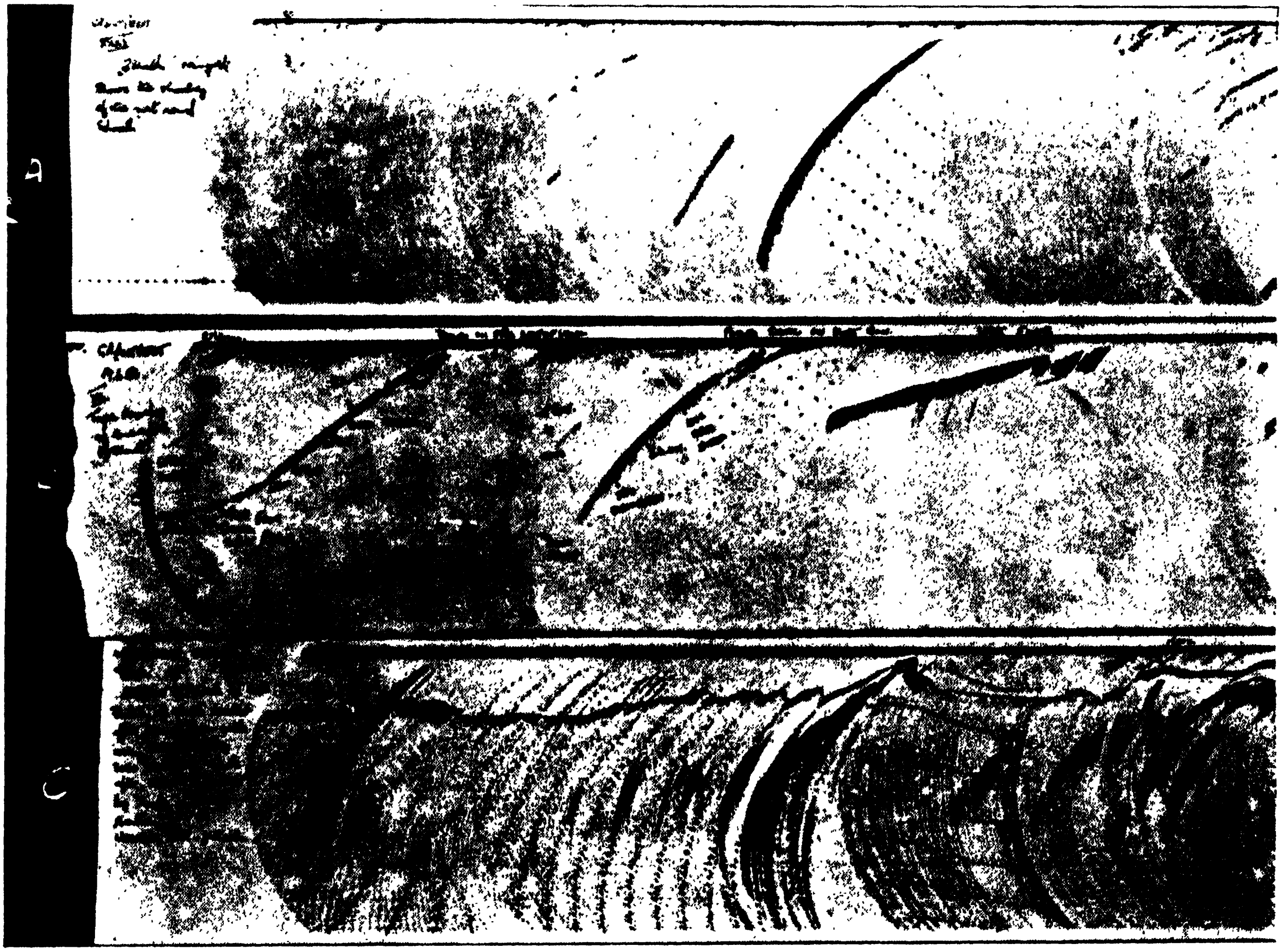

Fig. 3. Some examples of recordings obtained with the Fisherman's Asdic *in the Norwegian purse seine fishery.*

of course, learn from experience and, with other members of his crew, become more proficient as time goes on, but he should not have to find everything out for himself the hard way. Written instructions are all very well so far as they go but they are useless if they are not read, learnt and inwardly digested! And perhaps it is rather too much to expect the fisherman to do this.

The subject is a technical one and if it is to be treated at all adequately some technical language is unavoidable which is certain to discourage the reader who has no previous training in acoustics, electronics and so on. An alternative is to take people to sea and give them first-hand instruction on actual schools, but this is always difficult to arrange in practice and is both costly and time-consuming.

To some extent, of course, the real thing can be simulated ashore by means of specially designed training apparatus. An example of this is the Echo Whale Finder Simulator designed by my Company for the sole purpose of training operators in the use of the Echo Whale Finder, a type of Asdic designed specially to assist the gunner in quickly putting the ship within harpoon-firing range of the whale he is chasing. This simulator has been successfully used for several years and there is no doubt that the training it has made possible has done much to ensure that the Whaling Asdic is put to effective use at sea.

The operating skill involved in this case differs considerably from the skills I have been discussing and it does not follow that a simulator for shore training would necessarily be the right answer for horizontal fish detection.

The way in which instruction and advice are given must depend on the particular problem but the important thing is that the customers do get it. If not, both producer and customer will suffer in the long run.

Until quite recently the evolution of fishing has been essentially local, in response to local conditions. As a result of the introduction of modern aids, such as echo detection, industries far removed from the background and traditions of the fishing ports have been brought in to play a part in this evolution. If they are to play an effective part there must be a real understanding by the engineer of the problems of the fisherman and vice-versa, and so, as I said at the beginning, good lines of communication are essential in both directions.

FISH-FINDER FOR BOTTOM FISH

by

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Abstract

Experiments have been carried out to assess the resolving power of different echo sounders when used for fish-finding close to the seabed. Using a recording type with a frequency of 10 to 50 kc. and a depth scale of 50 m. it was difficult to distinguish fish less than 50 cm. above the bottom, but with 200 kc. it was possible to resolve fish at a distance of 30 cm. from the bottom.

With C.R.T. presentation and an expanded scale the resolving power could be 10 cm.

Interesting results were obtained when using a suppressor circuit by which the bottom echo on the trace could be reduced without affecting the fish trace. Tank tests using 200 kc. showed that the echo from a brass disc 40 mm. in diameter could be distinguished from that of an iron plate when the two were 20 cm. apart.

Détecteur de poisson pour espèces de fond

Résumé

On a cherché à déterminer expérimentalement le pouvoir de résolution de différents sondeurs à écho lorsqu'on les utilise à la détection du poisson au voisinage du fond de la mer. Avec un appareil enregistreur d'une fréquence de 10 à 50 kilo-cycles et une gamme de profondeur 50 m. il était difficile de distinguer des poissons se trouvant à moins de 50 cm du fond mais, avec une frequence de 200 kilo-cycles, il a été possible de distinguer des poissons se trouvant à 30 cm du fond.

Avec un tube à rayons cathodiques et une échelle plus grande, le pouvoir de résolution a pu atteindre 10 cm.

On a obtenu des résultats intéressants au moyen d'un circuit d'arrêt permettant d'affailir du tracé l'echo donné par le fond sans modifier l'indication relative au poisson, et des essais en bassin avec des fréquences de 200 kilo-cycles ont montré que l'on pouvait distinguer l'echo donné par un disque de laiton de 40 mm de diamètre de celui donné par une plaque de fer, lorsque ces deux objets se trouvaient à 20 cms l'un de l'autre.

Ecosonda para peces de fondo

Extracto

Se han hecho experimentos para evaluar el poder de resolución de los diferentes tipos de ecosondas al determinar la presencia de peces cerca del fondo del mar. Cuando se utilizó una ecosonda registradora con una frecuencia de 10—15 kc. y una escala para profundidades hasta de 50 m. fué difícil distinguir los peces que se hallaban a menos de 50 cm. del fondo, pero con 200 kc., ha sido posible su localización a 30 cm. del lecho oceánico. Al usar un tubo de rayos catódicos y una escala mayor, el poder de resolución llega a 10 cm.

También se obtuvieron resultados interesantes utilizando un circuito supresor que permitió reducir el trazo del eco producido por a onda cuando se refleja en el fondo sin afectar el trazo correspondiente al pez. Las pruebas en estanques con frecuencias de 200 kc., demostraron que el eco obtenido al utilizar un disco de latón de 40 mm. de diámetro puede distinguirse del logrado con una placa de hierro cuando estos dos objetos se hallan separados por una distancia de 20 cm.

FISH schools in the range of 2 m. above the sea bottom play an important part both in trawling operations and in the crab fisheries. Four echo recordings are needed to confirm the presence of a fish school. With normal equipment when the speed of the ship is 10 knots (300 m./min.), the sounding impulses are transmitted at intervals of about 3 to 15 m. For accurate identification on the echogram the length of the school must therefore be at least 12 to 60 m.^{2}. In order to spot small schools, sounding impulses should be transmitted at intervals of about 30 cm., and consequently the speed of the recording paper should be high.

RESOLVING POWER OF COMMON ECHO-RECORDING AND CATHODE RAY TUBE (C.R.T) DISPLAY FOR BOTTOM FISH

A fish school, less than 50 cm. above the sea bottom, is already difficult to distinguish by means of a common 10 to 50 kc. recording type echo sounder with a 50 m. depth scale. Tank and field experiments show that the resolving power can be increased to 30 cm. when a 200 kc. set is used.

The C.R.T. type fish-finder with 15 m. depth range has a resolving power of 10 cm. and bottom fish are distinguished by single transmissions. Fig. 1 shows the C.R.T. display of 50 flat fish on a net of 4 sq. m. (fig. 2) placed on the sea bottom at a depth of 10 m., with the boat passing over at a speed of about 2 knots.

A glass ball of 15 cm. diameter was indicated by the C.R.T. type fish-finder even when it just touched the sea bottom (fig. 3).

This superiority of the C.R.T. results from the considerable *magnification* of the image as compared with common recorder type echo sounders.

When using both systems simultaneously, a bottom fish echo is normally seen on the C.R.T. screen, but can also be identified on the echogram. If a differential suppressor circuit is used for depressing the peak of the bottom echo, the bottom echo trace may take the form of a bottom fish trace when the sea bottom is

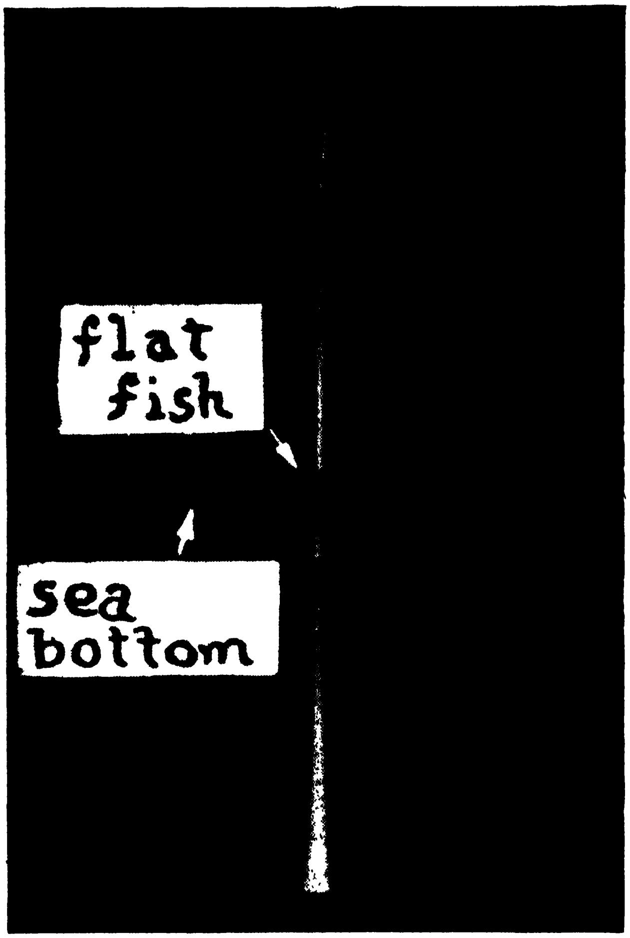

Fig. 1. C.R.T. display of an artificial flat fish school in 10 m. depth.

Fig. 3. C.R.T. display of a glass ball of 15 cm. diameter lying on the bottom in 10 m. depth.

Fig. 2. The artificial flat fish school being submersed.

sloping or uneven, particularly when the ship is rolling.

COMPARISON OF 200 kc. RECORDER AND 50 kc. RECORDER WITH SUPPRESSOR CIRCUIT

Fig. 4 shows that, by suppressing the peak of the bottom echo, identification of bottom fish can also be greatly improved with the use of 50 kc. The simultaneous record obtained with 200 kc. proves the higher resolving power.

REFERENCES

[1] T. Hashimoto and M. Nishimura: Study on Application of Echo-sounder for Fishing-ground of Crab at the Okhotsk Sea, Waters of Kamtchatka Peninsula, Technical Report of Fishing Boat No. 8, 1956.

[2] T. Hashimoto: Technical Examination on Fish-finder. Fisheries Agency, Nov. 1955.

[3] T. Hashimoto: Study on Ultrasonic Wave Soundings and Fish-finding, Society of Fisheries Research, February, 1951.

Fig. 4. Simultaneous records of bottom fish with 200 kc. conventional recording (top) and 50 kc. with suppressor circuit.

IMPROVED ECHO SOUNDING EQUIPMENT FOR THE DETECTION OF SHOALS OF BOTTOM FISH

by

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Abstract

In the trawl fishery, the fish are usually caught within a few feet of the seabed, so that it is most important that recording echo-sounders should be able to discriminate between these bottom fish and the sea bottom itself. The resolving power (picture quality) of a conventional echo sounder allows a fish to be recorded just clear of the seabed, if it is at least 75 cm. above the bottom. As it is not practical to increase this resolving power, a special receiving amplifier has been made which records the strong bottom echoes in a black tone, and the weaker fish echoes in a grey tone, thus making the discrimination between fish and seabed possible. This "Grey-Black Amplifier" should be of great help in the trawl fisheries.

Matérial perfectionné d'écho-sondage pour la repérage des bancs de poissons situés près du fond

Résumé

Dans la pêche au chalut, le poisson est capturé généralement à quelques pieds du fond en sorte qu'il est extrêmement important d'avoir des écho-sondeurs enregistreurs qui permettent de donner des échos de ces poissons que soient distincts de ceux du fond. Le pouvoir séparateur (c'est-à-dire la qualité de l'image) d'un écho sondeur conventionnel permet de repérer distinctement un poisson à plus de 75 cm. du fond. Comme on ne peut, dans la pratique, augmenter ce pouvoir séparateur, on a construit un amplificateur spécial de réception qui enregistre noir les échos puissants du fond, et en gris ceux, plus faibles, des poissons, ce qui permet de distinguer les échos du fond de ceux des poissons. Cet "amplificateur gris-noir" pourrait rendre de grands services dans la pêche au chalut.

Equipo de sondeo ultrasonoro mejorado para la localización de cardúmenes que nadan cerca del fondo

Extracto

Como en la pesca con red de arrastre los peces se capturan generalmente a pocos pies del fondo del mar, es de suma importancia que las ecosondas registradoras establezcan una diferencia entre ellos y el lecho marino. El poder de resolución (i.e. calidad de la imagen) de una ecosonda convencional permite registrar con claridad peces que se hallan a 75 cm. de distancia del fondo. Como no es práctico aumentar el poder de resolución del instrumento, ha sido necesario construir un amplificador de recepción especial que registra, en colores negro y gris, los ecos fuertes y débiles producidos por las ondas sonoras al reflejarse sobre el fondo y los peces, respectivamente, haciendo de esta manera posible la diferenciación entre ambos. A causa de esta caracteristica, el amplificador "gris-negro" podría ser una gran ayuda para las pesquerias de arrastre.

GENERAL

WITH bottom trawling only fish close to the seabed can be caught; with certain trawls, fish may be caught in a range up to 10 m. above the bottom, but the average height is under 5 m. Although modern echo sounders make it possible to record fish echoes from any fishable depth of water, there is some difficulty in clearly recording fish which are slightly above the sea-bed. Although such fish are most important for bottom trawling, it would be wrong to confine the recording only to this small zone. The skipper of a fishing craft should always be able to get evidence about the conditions in the whole area between the surface and the sea-bed, for this can often give valuable information.

For optimal detection of bottom fish a favourable solution is, no doubt, the combination of a recording type echo sounder with the visual indication of the echoes by means of Cathode Ray Tube (C.R.T.) (fig. 1). While for instance the whole range between 0 and 200 m.

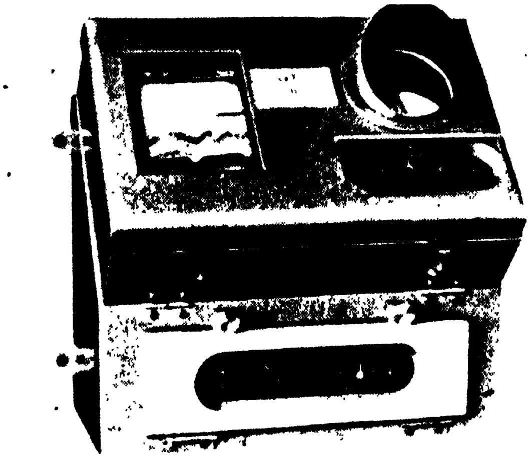

Fig. 1. A combination echo sounder consisting of a recorder and C.R.T. presentation.

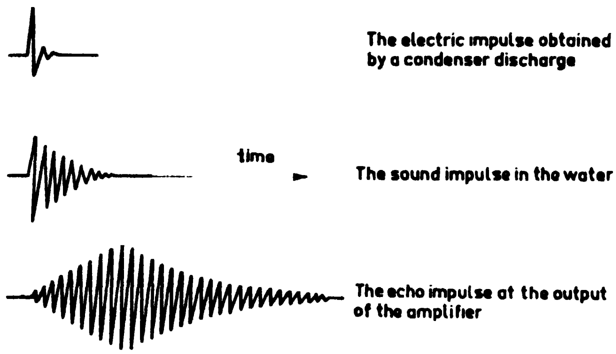

Fig. 2. The result of a condenser discharge into a transmitter oscillator is an electric and strongly damped wave train (top). The transmitter is shock-excited and dies out (centre). The receiving system transforms the impulse as shown in the lower diagram.

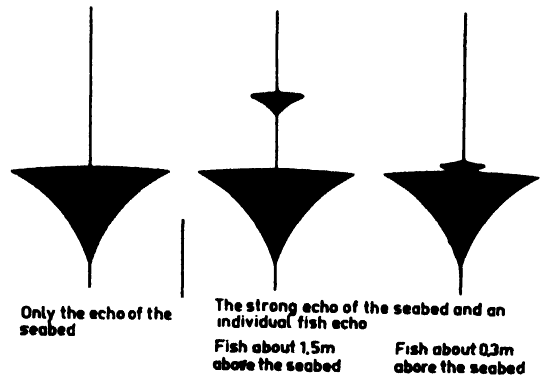

Fig. 3. The echo of the seabed is generally so strong that it passes beyond the screen of the C.R.T. The fish echo is much smaller.

depth is recorded, a magnified image of a small area close to the seabed is displayed on the screen of the C.R.T. giving all details of bottom fish echoes.

However it is still desirable to have an echo recorder in which the feeble echoes of bottom fish can be clearly distinguished from the much stronger echo of the seabed. The echoes of the fish schools arrive earlier than the bottom echo, so they are alone for a short time, before being masked by the stronger echo of the seabed.

SIGNIFICANCE OF LENGTH, SHAPE AND FREQUENCY OF THE SOUND PULSE

Generally the shorter the echoes the greater the possibility of distinguishing between fish and bottom echo. A shorter sound pulse results in a shorter echo. The length and the shape of the echo depend on the electric pulse exciting the sound transducer, on the sound frequency used, on the sharpness of resonance of the sound transducer, and on the selectivity of the receiving system. The shortest possible electric exciting pulse is obtained by the condenser discharge method. Fig. 2 shows what pulse shape can be expected at the output of the receiving amplifier.

As a general rule, when using shock excitation of the sound transducer by a condenser discharge, the amplitude of the echo pulse at the receiving amplifier builds up for 10 cycles and dies out in 20 cycles. To visualise the appearance of the pulse, as recorded or as shown on the screen of a C.R.T., the following assumptions are made:

Sound frequency, 30 kc.; recording range of 0 to 200 m.; paper width of 18 cm.; partial observation range of 25 m. above the seabed is presented on the screen of a C.R.T. for a length of 13 cm.

The pulse length of the echo of an individual fish at the output of the amplifier (see fig. 2, bottom) is about 30 cycles i.e. $\frac{30}{30{,}000} = \frac{1}{1{,}000}$ sec. Considering the velocity of sound in water, this time corresponds to a depth of 75 cm. so that on the recording paper of the echo sounder the echo of an individual fish would produce a black mark of 0·7 mm. length and, on the screen of the assumed C.R.T., an echo image of about 4 mm. length.

If the echo of a single fish has a recorded length equivalent to a depth measure of 75 cm., it is possible, with conventional recording echo sounders, to recognise that fish echo clearly separated from the echo of the seabed only if they are at least 75 cm. above the seabed.

If fish are closer to the seabed, their echoes will merge into the strong echo of the bottom and thus become difficult to distinguish from an echogram. This can subsequently be observed on the screen of the C.R.T. (fig. 3).

The pulse length of about 75 cm. limits the resolving power of most of the currently used recording type echo sounder and, generally, this resolving power is sufficient for bottom trawling. When using a *keyed tube oscillator*, instead of a condenser discharge, for exciting the transducer, the pulse length will become longer and the resolving power inferior. The resolving power can be improved in two ways, either by increasing the sound frequency, for instance, from 30 to 80 kc., or by keeping the building-up and dying-out time of the pulse as short as possible. This can be effected by shock-exciting a sound transducer mechanically tuned to a frequency of 25 kc. with a condenser discharge and by receiving the echoes through a frequency-selective amplifier tuned to 30 kc. By such measures, the resolving power can easily be improved from 75 cm. to about 10 to 20 cm., so that echoes of fish only this distance above the seabed can be clearly distinguished from the bottom echo. These measures have, however, the disadvantage of increasing susceptibility to interference and for this reason a resolving power of 75 cm. has to be accepted for practical fishing.

INFLUENCE OF SHIP MOVEMENTS

A high resolving power can only be fully used if the sea is calm and the seabed level. Irregularities in the contours of the bottom, small rocks, and movements of the vessel in a rough sea, make it more difficult to recognise bottom fish echoes in the echogram.

It is assumed that the transmitter-transducer is displaced periodically by 2 m. in a vertical direction for a

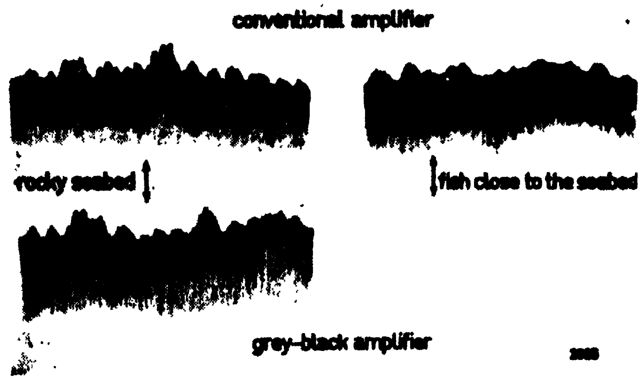

Fig. 4. Diagrams showing the effect of the Grey-black *amplifier.*

period of 6 sec. owing to the motion of the vessel, and the paper speed of the recording echo sounders, having the same reproduction scale as that given above, is 60 cm./hr. corresponding to 1 mm. in 6 sec. Even if the seabed is level, the echo trace of the bottom would appear serrated with an amplitude of about 1·5 mm. in height and a distance of 1 mm. between the individual wave crests. As the bottom echo is generally very strong, and the echo recording consequently rather broad, echo traces originating from bottom fish cannot be recognised in the troughs between the wave crests.

With the C.R.T., the echoes of each individual sounding are displayed and completely disappear afterwards. For this reason, the echoes from consecutive soundings do not overlap as described above for the recording-type echo sounder. Thus, the echoes of bottom fish can also clearly be seen despite the ship's movements in a rough sea.

The echoes of fish schools which form a flat layer close to the bottom are of particular interest to fishermen. In calm weather, the presence of such schools may be recognizable in the echogram by a certain roughness of the bottom contour.

Fig. 5. Large schools of fish recorded by a Grey-black *amplifier.*

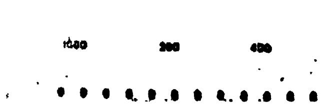

Fig. 6. An extended school of fish just above the seabed recorded by a Grey-black *amplifier.*

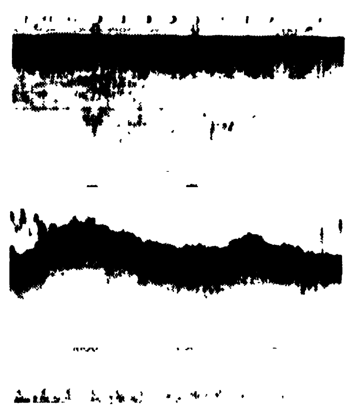

Fig. 7. Fish just above the seabed recorded by a conventional amplifier. It is not clear if schools of fish or the roughness of the seabed are indicated.

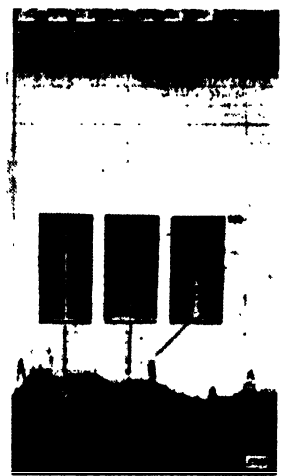

Fig. 8. Comparison between echogram and C.R.T. display.

However, even under such favourable conditions, it is not easy to distinguish in echograms of conventional machines, between a rough seabed and a school of bottom fish.

GREY-BLACK RECORDING

The difference in the amplitude of fish and bottom echoes can be used for an improved recording. The echoes from the bottom large stones, etc., are almost always much stronger than fish echoes. By using a special recording amplifier to record the weaker fish echoes in a grey tone and the strong bottom echoes in a deep black tone, it is possible to differentiate clearly between them.

Examples (drawn by hand for the sake of clearness) of the comparative performance of a conventional and of an amplitude-discriminatory amplifier, are shown in fig. 4. The recordings shown in the top row are made by a conventional amplifier and those at the bottom by a special amplifier, the *grey-black* recording amplifier. The recordings on the left correspond to a rocky seabed. Those on the right are from fish dispersed in several schools close to the seabed.

In actual recordings obtained by a *grey-black* amplifier aboard a trawler fishing on the Fladen Ground in the North Sea (figs. 5 and 6), the fish can be clearly recognized as grey shadows above the contour line of the seabed. In an echogram from a conventional type amplifier, however, it cannot be said whether the irregularities of the depth line have been caused by fish close to the seabed or by the roughness of the seabed (fig. 7).

In fig. 8 an echogram from a *grey-black* amplifier installed in an Atlas Fischfinder is compared with photos of C.R.T. displays obtained simultaneously. In the magnified, C.R.T. display the particular shape and quality of the fish echoes can be more clearly recognized than is possible in the echogram.

SOME ELECTRO-TECHNICAL IMPROVEMENTS IN ECHO-SOUNDERS

by

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Abstract

Echo-sounders for locating fish close to the seabed have been improved by a "distinctive recorder" on which the fish echos are made to stand out clearly from the seabed, being marked by a sharp black line. Thus it is possible to discriminate between the bottom fish and the sea bottom itself.

A so-called "tele-indicator", using two simultaneously working cathode ray tubes, is described. The first tube gives the whole measuring range (i.e. 240 m.) in four vertical parallel lines, each representing ¼ of the whole range. A particular feature of this set is that the sounding rate can be adapted to the specific measuring range needed. By this means, the highest possible sounding rate can always be used in favour of an optimal indication. The second cathode ray tube gives an enlarged representation of 15 m. range which can be adjusted to any depth wanted within the main measuring range (i.e. 240 m.).

A simple, inexpensive oscillator installation is available for horizontal location of fish at a short range. This makes it possible to sound in horizontal direction with vertical echo-sounders. With additional equipment, four principal directions may be chosen, so that the fisherman can, with some practice, recognize in which direction he must steer his craft in order to obtain good catches.

Quelques perfectionnements électro-techniques des sondeurs à écho

Résumé

Les sondeurs à écho pour le repérage des poissons près du fond de la mer ont été perfectionnés par un "enregistreur séparateur" dans lequel les poissons se détachent nettement du fond, lequel est figuré par une ligne noire très précise. Ainsi, il est possible de faire la distinction entre les poissons de fond et le fond de la mer lui-même.

L'auteur décrit un appareil appelé "télé-indicateur", qui utilise simultanément deux tubes à rayons cathodiques. Le premier tube donne toute la portée du sondage (soit 240 m.) en 4 lignes verticales parallèles, chacune représentant ¼ de la portée totale. Une caractéristique particulière de cet appareil est que la fréquence des sondages peut être adaptée à la portée spécifique de sondage désirée. De cette façon, on peut toujours utiliser la fréquence de sondages la plus élevés ce qui favorise une indication optimum. Le second tube cathodique donne l'agrandissement d'une tranche de 15 m. que l'on peut déplacer à n'importe quelle profondeur désirée dans la portée totale de sondage (soit 240 m.).

L'installation simple et bon marché d'un oscillateur est possible pour le repérage horizontal du poisson à une courte distance. Cela permet la télémétrie horizontale avec des sondeurs à écho. Avec l'équipement supplémentaire on peut choisir quatre directions principales et, avec de la pratique, le pêcheur peut reconnaître dans quelle direction il doit diriger son bateau afin de faire une bonne pêche.

Mejoras electrotécnicas en las ecosondas

Extracto

El "registrador diferencial" ha permitido mejorar la eficacia de las ecosondas para localizar peces cerca del fondo destacándolas claramente por una línea bien marcada. De este modo es imposible confundir los peces que se hallan cerca del lecho del mar con éste.

En el trabajo también se describe el "teleindicador" provisto de tubos catódicos que funcionan simultáneamente. El primero da el alcance total del aparato (240 m.) en cuatro líneas verticales y paralelas, cada una de las quales representa ¼ de toda la gama. Una característica especial del equipo lo constituye la adaptación de la cadencia de sondeo a la gama de medición más conveniente. Por este medio siempre es posible utilizar la mayor cadencia posible en favor de sondeos más precisos. El segundo tubo de rayos catódicos permi obtener una ampliación de la gama de 15 m. que puede ajustarse a cualquier profundidad deseada dentro del alcance (240 m.) del aparato.te

Para la localización horizontal de los peces a corta distancia, se usa un oscilador sencillo y barato que deja a las ecosondas verticales en condiciones de hacer sondeos en sentido horizontal. Con un equipo adicional es posible elegir cuatro direcciones principales, de manera que el pescador pueda, con algo de prática, reconocer en qué sentido debe dirigir su embarcación para obtener buenas redadas.

IMPROVEMENT OF BOTTOM FISH REPRESENTATION

To be suitable for bottom trawling fishfinder echo sounders should have a representation system which allows for easy discrimination between the traces of bottom fish and the bottom trace itself. As a result of extensive work carried out for many years in the author's laboratory, a design has been developed which meets this request in the form of an additional installation which can be combined with any existing model of "Fahrentholz Echographs".

For this purpose output of the last valve of the amplifier is throttled so that, also with highest amplification, all echoes are recorded in dark grey only. There is also an additional circuit to the amplifier which operates only in response to signals above a certain amplitude which is beyond the strongest fish echo and can only be reached by the very strong echo of the seabed. This is effected by an additional thyraton or another valve, with a high negative voltage on its grid, and which consequently responds only to an echo which causes a higher voltage than this negative potential. This high echo strength is only produced by the peak of the

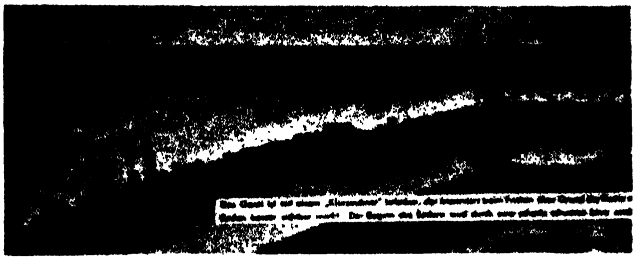


Fig. 1. Echogram showing "black band" recording for better discrimination of bottom fish traces.

oscillations of the bottom echo. Consequently the valve responds only for a very short part near the peak of the bottom echo which hereby is recorded in deep black. This results in a deep black band indicating the shape of the bottom profile, which in a measuring range up to 200 m. is about 1 mm. wide. The traces of bottom fish recorded in grey now appear easily recognizable on top of the deep black bottom profile band (fig. 1).

This valuable improvement is particularly prominent in the echo sounder models which record small sounding ranges on the whole width of the recording paper.

CATHODE RAY TUBE REPRESENTATION

Recently a cathode ray tube set has been successfully used in addition to an ordinary recording echo sounder to magnify a small part of the sounding range and at the same time represent the strength configuration of the echoes, making it possible to distinguish easily between fish and bottom traces. In combination with ordinary echo sounders the pulse rate of the cathode ray tube is necessarily the same as that of the main unit, which usually means that for the cathode ray tube it is lower than desirable for a quick decision about the quality of fish shoals.

The Fahrentholz fish-tele-indicator has been developed to overcome this drawback (fig. 2). It can be used in combination with recording or other echo sounders, but is a complete fish-finding equipment itself. The "tele-indicator" has two cathode ray tubes of equal size side by side, one to represent the entire sounding range and the other for magnifying a small part of it

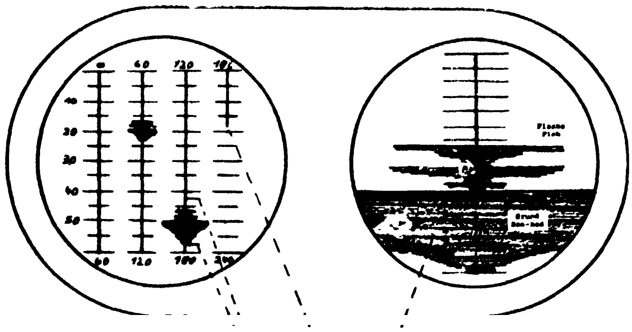


Fig. 3. Sketch showing the echo representation on the whole scale (left) and magnifying tube (right).

which can be chosen at will. The whole range on the left screen is usually divided into four vertical parallel lines, e.g. a sounding range of 240 m., consisting of four parts of 60 m. each using the whole diameter of the screen. Formerly these four lines were created by vertical and horizontal multivibrators and were consequently inclined. The new "tele-indicator" uses electronic switches, which bring the lines to exact vertical position. The echoes appear as horizontal light flashes normal to these "time lines". The depth reading is done by means of a scale (fig. 3, left).

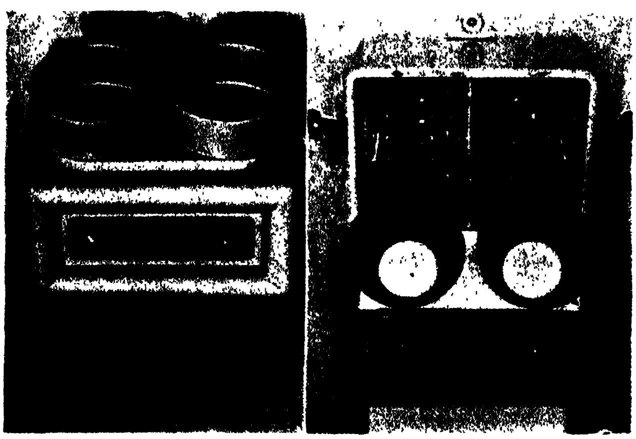


Fig. 2. Fish-tele-indicator set.

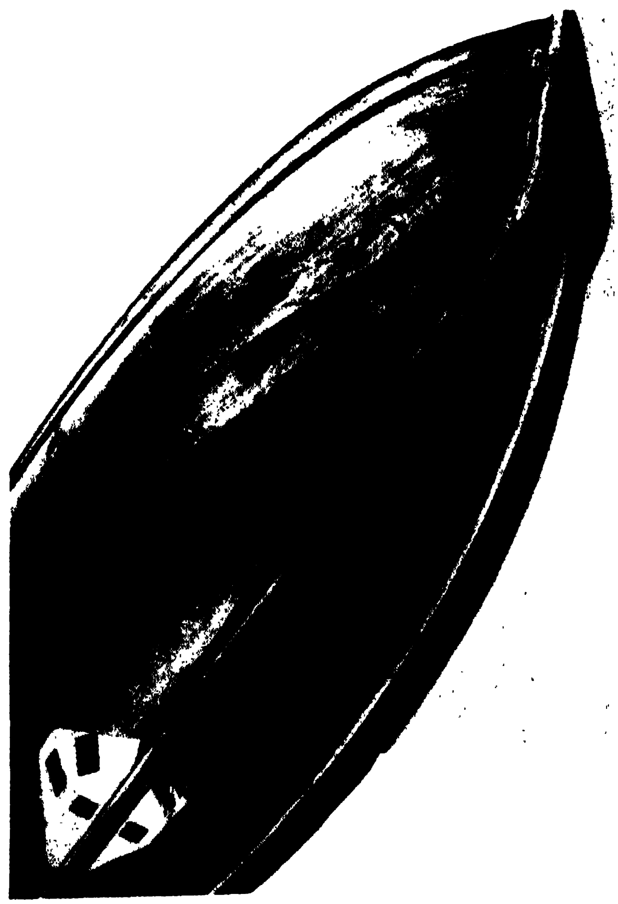


Fig. 4. Transducer arrangement for alternative horizontal ranging and vertical sounding.

The moveable, magnified range covers 15 m. (fig. 3, left). A mark on the whole range tube, which is operated by turning a knob marks the place on the scale to which the magnifying tube is adjusted. Both tubes work simultaneously.

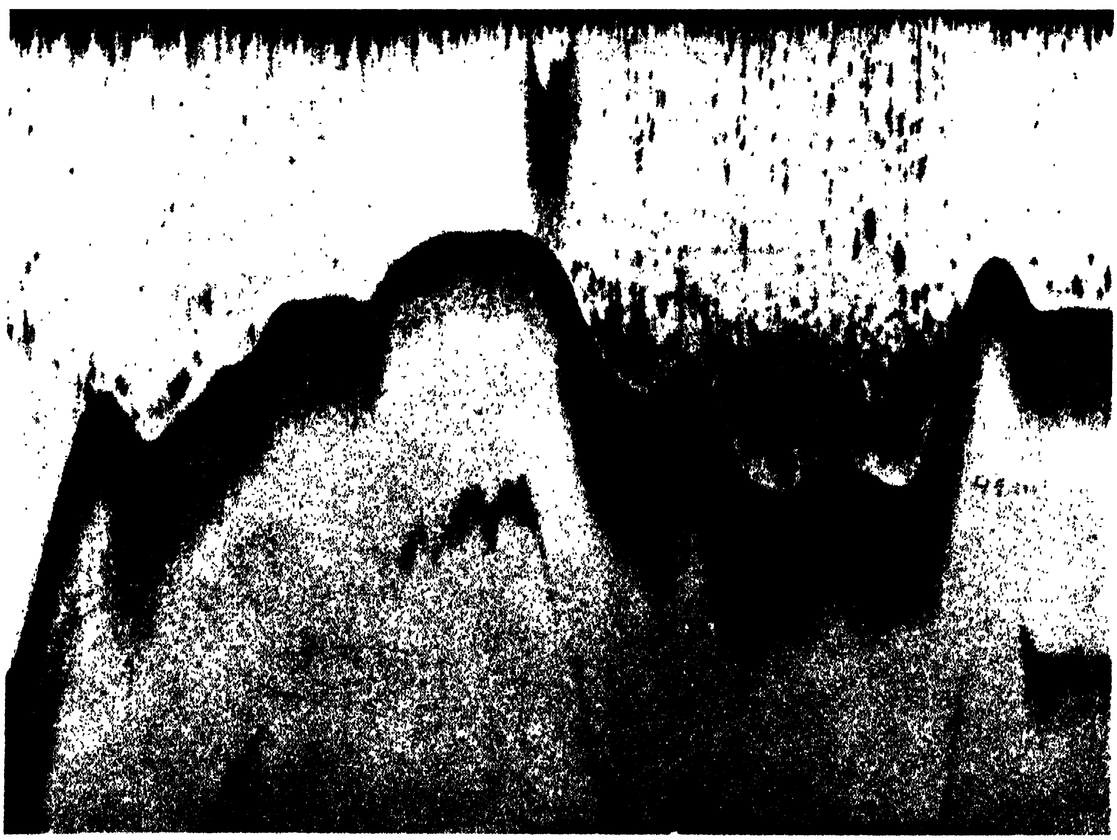
Another knob is provided to set the impulse rate of the whole set. This is effected by an electronic switching-device which assigns the length of the scale of the whole range tube. For example, if the equipment has a total measuring range of 240 m. with four time lines it is possible to cut the range gradually down to 60 m. leaving only one time line. Thus the measuring range can be adjusted to the actual depth and immediately after the bottom echo has been received a new sounding impulse can be sent resulting in the highest possible impulse rate, favouring the visual image of the echo indications. The magnification on the right screen is achieved in a different way. A continually working electronic circuit creates alternating current of 50 cycles, which, fed to the vertical plates of the cathode ray tube, synchronizes another frequency of 12·5 cycles by means of a counter, thus activating the top to bottom movement of the electronic ray. The four vertical time lines on the whole range screen are produced by another counter which creates a frequency of 3·125 cycles and actuates an electronic switch.

Summarized, it may be said that the new set which is called "fish-tele-indicator" has two essential advantages:

1. Simultaneous indication of the echo on the whole range screen and on the magnified screen.
2. The highest possible impulse rate for locating fish.

SIMPLE DEVICE FOR HORIZONTAL RANGING

In order to increase the range at which fish can be located a simple arrangement of oscillators has been designed for alternative vertical sounding or horizontal ranging (fig. 4). Four ultrasonic transducers with about 10 degrees beam angle and tilted 10 degrees down are fitted to the keel, in forward and sideways direction, two to starboard and two to port. A switch box is used to connect the echograph to each of these transducers and thus to the ranging direction required or to an additional pair of vertical transducers. Under favourable conditions and with some practice, this equipment can be used to recognize the position of fish schools in a radius of several 100 m.



Echogram showing fish concentrations in a bottom depression. Photo: Fahrentholz

FISH DETECTION BY ASDIC AND ECHO-SOUNDER

by

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Abstract

The success of initial trials with Asdic for fish detection immediately after the war led to the installation of the apparatus in the research vessel *G. O. Sars* in 1950. Since then, regular surveys have been made in winter and summer, the former to locate the herring shoals when they were about 120 miles from the coastal spawning grounds, and the latter to help in establishing a pelagic herring fishery in the open Norwegian Sea. The progress made in echo sounding is also described, one of the most important advances being the introduction of the *bottom blocking* device by which fish echoes can be separated from bottom echoes. Echo-surveys for *skrei* in northern Norway and in the Barents Sea are also mentioned.

Le repérage du poisson par l'asdic et le sondeur à écho

Résumé

Le succès des premières sorties d'un bateau muni de l'asdic immédiatement après la guerre, a conduit, à l'installation de l'appareil à bord du navire de recherches *G. O. Sars* en 1950. Depuis lors, on effectue des explorations régulières en hiver et en été, les premiéres pour localiser les bancs de harengs quand ils se trouvent à 120 milles environ des lieux de ponte côtiers, et les secondes pour aider à l'etablissement d'une pêche pélagique de harengs dans la haute mer de Norvège. L'auteur décrit aussi les progrés réalisés dans l'emploi du sondeur à écho, un des plus importants progrès etant l'introduction du *blocage du fond*, dispositif au moyen duquel les échos de poissons peuvent etre séparés des échos du fond. Il est aussi fait mention des recherches des *skrei* (morues à maturité sexuelle) avec le sondeur à écho dans la Norvège septentrionale et dans la mer de Barentz.

Localización de peces con "asdic" y ecosondas

Extracto

El éxito que se obtuvo después de la guerra con una embarcación provista de "asdic" indujo, en 1950, a instalar este aparato en el barco de investigaciones pesqueras *G. O. Sars*. Desde entonces regularmente se han hecho reconocimientos en invierno para localizar cardúmenes de arenque que se hallaban a unas 120 millas de los bancos de desove costeros, y, en verano, para ayudar el cominezo de las pesquerías pelágicas en el mar abierto de Noruega. También se describen los progresos alcanzados con las ecosondas, uno de cuyos adelantos más importantes es el dispositivo *bottom blocking* para separar los ecos producidos al reflejarse las ondas en los peces y en el fondo del mar. También se mencionan los reconocimientos hechos por *skrei* en Noruega septentrional y en el mar de Barents mediante el empleo de ecosondas.

GENERAL

DURING the winter of 1945/46 the Norwegian corvette *Eglantine* was put at the disposal of the Institute of Marine Research, Bergen, to investigate the possibilities for locating herring shoals by means of Asdic. After the promising results of these trials[2, 3] it was decided that the research vessel, *G.O. Sars*, should be equipped with an Asdic set.

Since the vessel was commissioned in 1950 the Asdic equipment has been in use for more than 25,000 hrs. on various cruises in the Norwegian Sea. In winter seasons, from November to February, the task has mainly been to trace and follow the herring shoals on their spawning migration to the Norwegian coast. Part of the work during the summer, from June to September, has been to locate the herring in the Norwegian Sea.

The Asdic has, however, given satisfactory results only in locating concentrated herring shoals. In recent years, therefore, we have tried to improve the echo sounding equipment especially with the object of obtaining reliable registration of cod and haddock.

DETECTION OF HERRING BY ASDIC

Winter Season

In November/December, herring normally concentrate in large shoals in the open sea, when the temperature gradients are small and no considerable bending of the horizontal sound beam occurs. Under these favourable circumstances Asdic ranges of 2,000 to 2,500 m. can normally be obtained in reasonable weather conditions.

Twenty-four hours' Asdic watches are kept on the cruises. The normal operating procedure is to train the oscillator stepwise from port to starboard at a rate of 1 transmission every 4 sec.

When an echo is heard or recorded, the target has to be identified. Since echoes may be obtained from

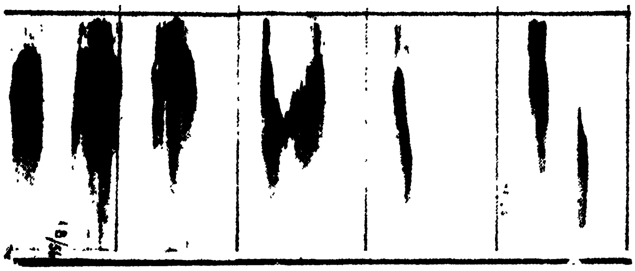


Fig. 1. Echogram of typical winter herring shoals in the Norwegian Sea (Migratory Shoals). Distance between vertical lines is 1 nautical mile. Depth scale 0-200 m. R.V. G.O. Sars, *January 1955.*

aerated water, crest of waves, shoals of squids, whales, etc., the question of identification is an important one because much valuable time may be lost by investigating *false* echoes. Experience has shown that a well trained operator can, to a certain extent, distinguish between echoes from herring shoals and echoes from other sources by analyzing the sound quality of the echoes. This procedure, however, is not infallible and it has been found advantageous to identify the Asdic target by the vertical echo sounder. To do this, the ship's course is altered to the bearing of the echo. By training the transmitter and noting the range and the angle of reception an estimate of the width of the shoal at 90 deg. to the ship's course can be obtained. When passing over the shoal, the second horizontal dimenions can be measured by the vertical echo sounder. The vertical extension of the shoal is rather difficult to measure, since the length and intensity of the marking on the recording paper also depend on the density of the shoal and several technical features of the echo sounder being used. It has been our experience that the echo markings obtained give only a rough estimate of the vertical dimension of the shoal.

The winter herring shoals on migration to the spawning grounds usually appear as vertical *comets* with a width of 50 m. to about 2 km. and with an apparent vertical extension of 10 to 200 m. (fig. 1).

When the herring appear at the coastal banks (depth less than 200 m.), the efficiency of the Asdic is reduced because of less favourable water condition and frequent occurrence of echoes from the rough bottom. These are difficult to distinguish from the echoes from a herring shoal. In the coastal waters, all Asdic targets must, therefore, be classified by means of a vertical echo sounder.

To show the migration route of the herring, all Asdic records are plotted on a chart. Our fishing authority is daily informed of the position of the herring shoals and, when the shoals are about 120 nautical miles from the coast, the fishermen receive information several times a day by radio from the research vessel. In some years the first catch has been taken more than 100 nautical miles from the coast[1].

Summer Season

It is well known that the range of the Asdic shows a large variation due to changes in water condition

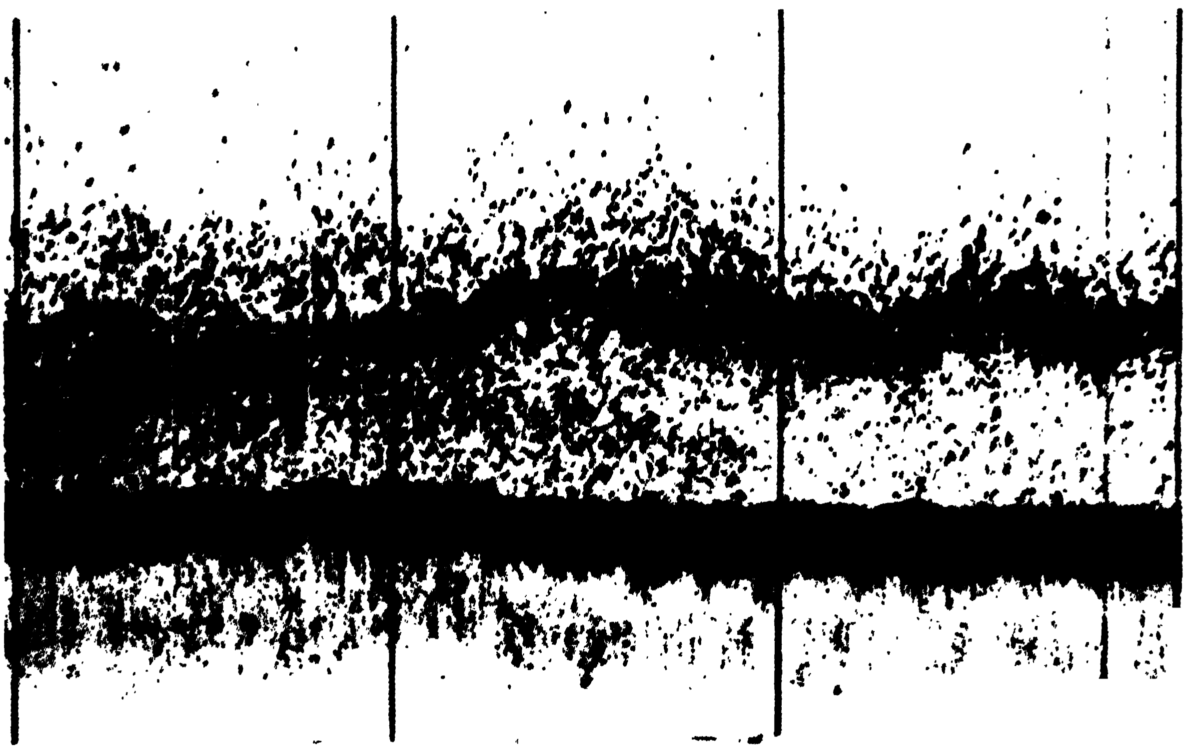


Fig. 2. Echogram of a pelagic shoal of cod/haddock. Barents Sea, March 1956. Distance between vertical lines is 1 nautical mile. Depth scale 100-300 m.

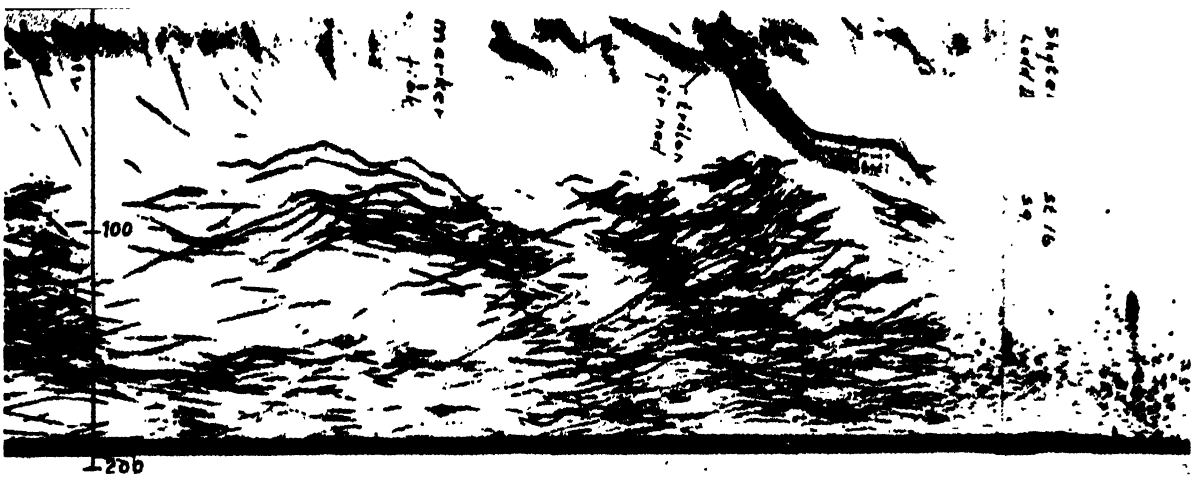


Fig. 3. Echogram taken while releasing marked fish from the R.V. G.O. Sars *and shooting the trawl. Barents Sea, March 1956.*

The distribution of salinity and temperature in the summer season, is such that the effective working range is reduced and ranges of more than 1,000 m. should not be expected.

The much greater horizontal range of the Asdic as compared with an echo sounder has opened new possibilities of catching herring in the open sea and consequently a pelagic herring fishery in the Norwegian Sea is now a reality. Asdic sets are already used by several Norwegian fishing vessels.

EXPERIMENTS WITH ECHO SOUNDERS

Trials in 1954 to locate shoals of cod and haddock in the deeper waters of the Barents Sea by means of echo sounding proved that ordinary types of commercial echo sounders were not well suited for this purpose. In 1955, therefore, a working programme was established in cooperation with *Simonsen Radio A/S*, Oslo, to develop an improved model suitable for recording fish in deeper water (200 to 400 m.) and particularly close to the bottom.

Improvement of Sensitivity

An increase of the amplification of the received signal above the maximum of a normal *Simrad* echo sounder was first tried. The result was a considerable improvement of the sensitivity: echos of single cod/haddock could now be clearly obtained down to 200 m. depth.

Secondly, various types of oscillators were tried. Normally this make of echo sounder is equipped with an oscillator which gives a half value angle of 13 deg. alongship and 22 deg. abeam. Great improvements in results were obtained with an oscillator which pro-

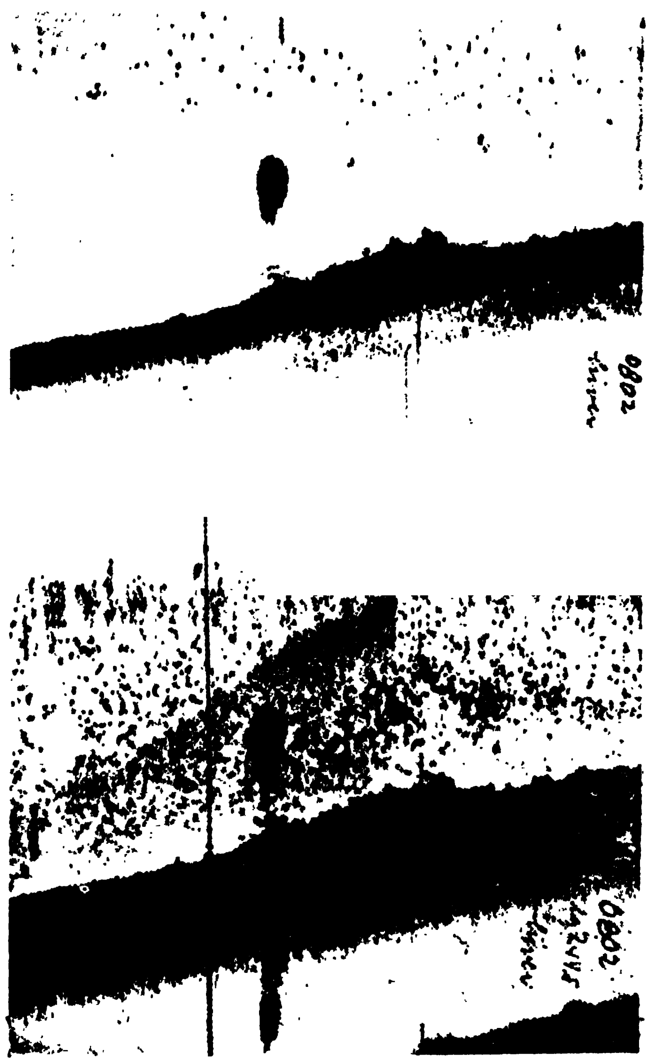


Fig. 4. Echograms from normal echo sounder (top) and from echo sounder equipped with bottom blocking device (lower), showing concentration of cod/haddock close to the bottom. Ship's speed 4 knots. Barents Sea, April 1957. (from Fiskets Gang, *No. 2230. May, 1957).*

Fig. 5. Echogram showing mainly pelagic occurrence of cod with local bottom concentration. Bottom depth 210-200 m. Ship's speed 10 knots. East Skolpen Bank, *Barents Sea, November, 1956.*

duced a beam of 6·5 deg. alongship and 22 deg. abeam. With this, the number of echoes from deeper water (200 to 400 m.) increased markedly.

Identification of bottom fish

This equipment has now been used on a number of cruises of the R.V. *G.O. Sars* to the coastal waters of North Norway and the Barents Sea, and some experience has been gained in its application. Several characteristic types of midwater echoes are regularly obtained in these areas. Although some of them have not been identified yet, we believe we are able to recognize the traces given by individual cod or haddock of marketable size. Apparently these fish often live in pelagic shoals, usually of low density, which makes it possible to discern the echoes of single fish (fig. 2).

Echograms taken while releasing marked fish over the side of the vessel have been of great help in the identification of the traces of single fish (fig. 3). Experiments have also been made in comparing echoes fish of of different sizes, and the echoes of live and dead fish by lowering the targets attached to a line. On this occasion the vessel lay to during the fish marking. The nearly vertical lines (fig. 3, top left) are echoes of single fish going down. At a depth of approximately 100 m. the fish seem to stop, perhaps in order to adapt themselves to the increasing hydrostatic pressure. The echo of the trawl gear whilst shooting is shown further to the right of the echogram. As soon as the vessel takes up speed to shoot the trawl, the long horizontal traces of single fish are changed into the dotted form characteristic of records taken during steaming (fig. 3, right and fig. 2).

Bottom blocking

Greater difficulties were encountered in our attempts to obtain a quantitative measure of bottom fish concentrations. One step forward was achieved in 1956 when a technical improvement was made which enabled us to distinguish between the traces of bottom fish and the bottom trace itself. Fig. 4 shows echograms taken simultaneously with a normal echo sounder (top) and with an echo sounder equipped with this *bottom blocking* device (bottom) during a haul in the Barents Sea in April 1957. By this new method the upper part of the bottom trace is presented as a thin line only while the echoes fron fish shoals close to the bottom are shown as usual.

It seems probable that *bottom blocking* will prove of great practical value to fishermen. Its application may also include means to a rough estimate by the density of pelagic shoals of, for example, herring.

Fish Surveys

This echo sounder equipment is being used in the Barents Sea for surveying large areas to study the relation between the distribution of the fish and the environmental factors. We are not yet, however, entirely satisfied with our instruments and methods.

A simpler and more practical application of the high sensitive echo sounder is as follows. In the Barents Sea shoals of cod and haddock have often a largely pelagic character, but with a local concentration closer to the bottom. After detailed echo surveys of such shoals we have repeatedly been able to find the best *bottom concentrations*, so increasing our trawl catches from insignificant to paying amounts. Fig. 5 is a part of an echo-

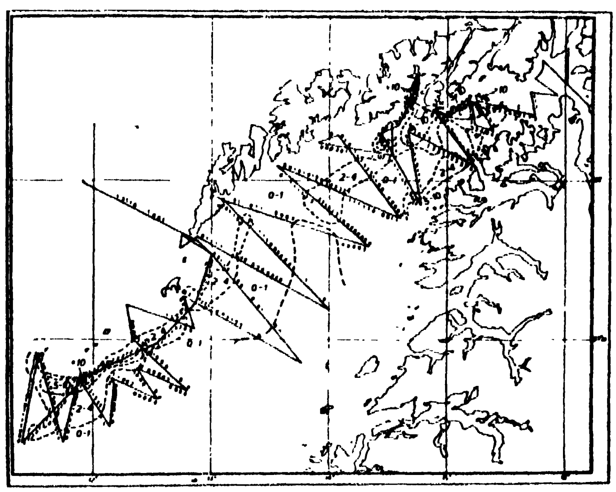


Fig. 6. Distribution of skrei *in* Lofoten *at the beginning of March 1957 according to echo survey by the* R.V. G.O. Sars.

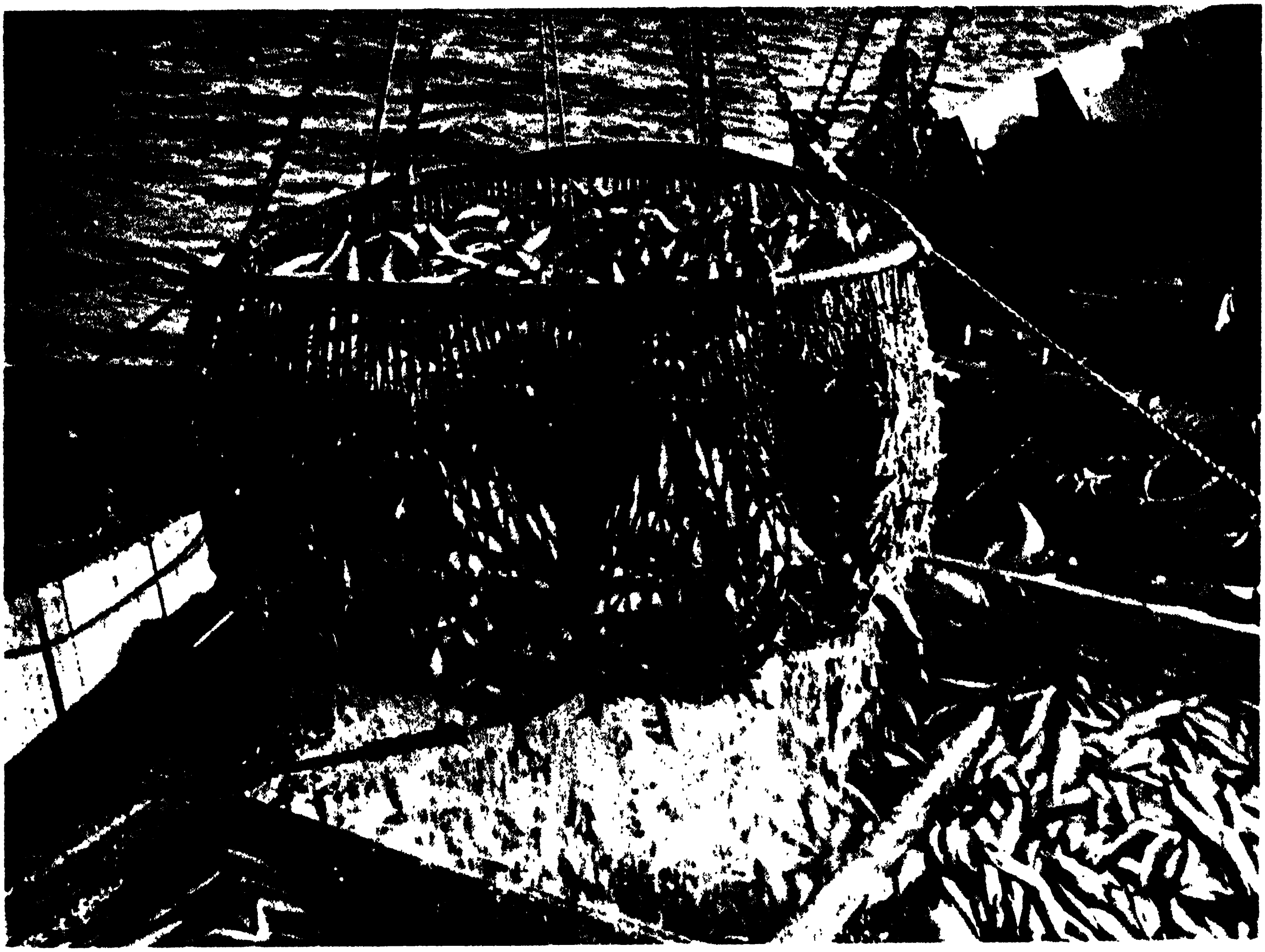
gram of such a search showing a local *bottom concentration* in a largely pelagic shoal of cod.

Local echo surveys were also carried out in the *skrei* district of North Norway during the season 1957 with this equipment (*skrei* is large mature cod).

Fig. 6 shows the distribution of *skrei* in the *Lofoten* area at the beginning of March, according to an echo survey by *G. O. Sars*. The straight lines are the course of the ship. The figures along these lines denote the tens of the average number of single fish traces per nautical mile. The yields of the *skrei* fishery in the various localities in the first part of March showed a convincing correspondence with the quantitative distribution indicated on this chart. Thus, in the *skrei* district, it seems possible to obtain a fairly reliable picture of the distribution of the fish by means of echo sounding.

REFERENCES

Devold, F. På jakt etter storsilden i Norskehavet. *Fiskets Gang*, 20 : 217-222. 1951.
[2] Gerhardsen, T. Sildeleting ved hjelp av Asdic og ekkolodd. *Teknisk Ukeblad*, 51 : 3-7. 1946.
[3] Lea, E. Asdic i fiskeritjenesten. *Fiskets Gang*, 4 : 41. 1946.



Brailing herring from a purse seine during the Norwegian winter herring fishing which relies heavily on echo sounding and echo ranging for detecting the schools which normally are submerged.

HORIZONTAL ECHO RANGING

by

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Abstract

Two dual purpose echo sounding/ranging units have been produced for fishing; one, the *Miniature Lodar*, for installation in small fishing vessels and the other, the *Lodar*, for use in medium and large ships. In the former, the aim has been to produce a simple unit that can be used by fishermen. It consists of an indicating unit and a hoist/sweep gear with a transducer, and has 8 ranges, covering 0-1,000 m. It uses 150 W. and operates on a frequency of 30 kc. The transducer can be trained from 135 degrees to port to 135 degrees to starboard. This combined horizontal and vertical sounder can be used at a speed of 10 knots and has proved in practice to be an essential aid for fishing. The *Lodar*, i.e. the larger equipment, is a more highly developed instrument and operates with two separate transducers, one for sounding and the other, fitted in the hoist/sweep gear, for horizontal ranging. This unit is also equipped with loudspeaker reproduction of the echo which enables the operator, with experience, to discriminate between echoes from different sources.

Télémetrie horizontale á écho

Résumé

Deux sondeurs-télémétres à double effet ont été mis au point pour la pêche; l'un, appelé *Miniatur Lodar* pour les petits bateaux de pêche, et l'autre, appelé *Lodar* pour les navires de moyen et gros tonnage. En réalisant le premier, les constructeurs ont cherché à produire un appareil simple susceptible d'être utilisé par les pêcheurs. Il comporte un écran et un dispositif de belayage vertical et horizontal, avec émetteur; il a 8 portées couvrant de 0 à 1,000 mètres. Sa consommation est de 150 W. et il fonctionne sur 30 kc.; l'emetteur peut pivoter de 135 degrees tribord à 135 degrees babord. Cet appareil à effet combiné vertical et horizontal peut être utilisé à une vitesse de 10 noeuds et s'est avéré d'une grande importance pratique pour la pêche. Le *Lodar*, c'est-à-dire l'appareil de plus grandes dimensions, est plus perfectionné et fonctionne avec deux émetteurs distincts, l'un pour le sondage et l'autre, monté dans le dispositif de balayage, pour la télémétrie horizontale. L'appareil est aussi muni d'un système de reproduction de l'echo par haut-parleur qui permet à l'opérateur expérimenté de distinguer les échos provenant de sources différentes.

Telemetría mediante ondas ultrasonoras

Extracto

Se han construído dos ecotelémetros para pesca: el *Miniature Lodar* destinado a embarcaciones pequeñas y el *Lodar* que se usa en barcos medianos y grandes. En el primer caso se tuvo por finalidad producir un equipo sencillo para uso de los pescadores, que consiste en una unidad indicadora con un transductor de 150 vatios, 8 gamas de sondeo que abarcan profundidades de 0-1,000 m., una frecuencia de onda de 30 Kc. por segundo y un mecanismo de elevación y exploración o "barrido" que permite dirigir el transductor desde 135 degrees a babor hasta 135 degrees a estribor. Este ecotelémetro mixto para mediciones verticales y horizontales puede usarse a velocidades de 10 nudos, demostrando en la pràctica ser una ayuda esencial para la pesca. El equipo de *Lodar* es un instrumento mucho màs perfeccionado para medir distancias, que funciona con dos transductores independientes: uno vertical y otro horizontal, instalados en el mecanismo de elevación y exploración. Este instrumento también cuenta con un altavoz para reproducir los ecos permitiendo a una persona con experiencia diferenciarlos según las diversas fuentes de donde provienen.

GENERAL

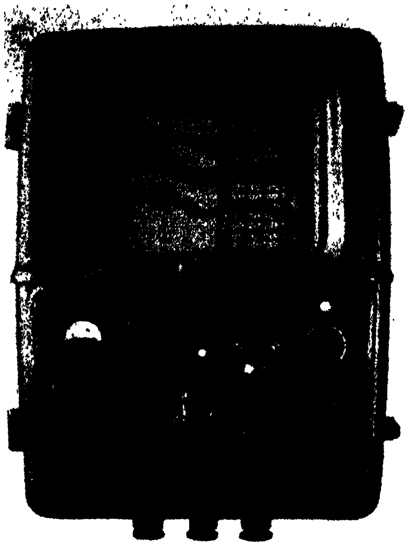
RECENT publications have dealt in detail with horizontal ranging for fishing, and have considered both the theoretical principles and the practical viewpoints[1,2,3].

From a technical point of view, horizontal ranging is a more pretentious procedure than conventional vertical sounding; the operators must therefore be better informed and more experienced regarding the characteristics of the apparatus and the properties of the sea water as a medium for the propagation of sound. Horizontal ranging offers a considerable extension of the searching range and direct hunting for distant fish.

The horizontal ranging equipments, of course, must meet the requirements of the customers regarding technique and cost. Small craft, for instance, which hunt for fish in the immediate neighbourhood can only use small equipment because of economic and space-saving reasons. It must be designed so that the weight is low and the ship's electrical supply is not overloaded.

Large and medium fishing craft, however, can use more powerful equipment by means of which normal fish targets can be located even under adverse propagation conditions.

The Electroacoustic G.m.b.H., Kiel, have tried to



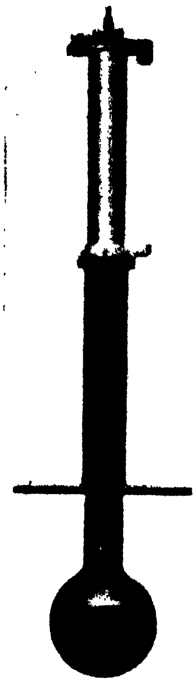


Fig. 1. Recording unit of the Miniature Lodar.
Fig. 2. Hoist/sweep gear of the Miniature Lodar.

solve the technical and cost problems by designing two types of horizontal rangers, which are discussed below.

MINIATURE LODAR

This equipment is a small combined horizontal and vertical ranger/sounder, with a minimum of technical complexity and size. The equipment consists of two parts:

1. Recording unit, with electronic groups and power supply (fig. 1).
2. Hoist/sweep gear with transducer (fig. 2).

The recording unit, which is housed in a strong light-metal casing, consists of the following components:

(a) The recording mechanism, with 8 sounding ranges, the smallest coverage ranging between 0 and 75 m., the largest between 400 and 1,000 m. The pulse rate is arranged to match the respective working range. The recording paper is 180 mm. wide and can be adjusted to advance at a speed between 0 and a maximum of 160 mm./min., according to the engaged range.

(b) The electronic unit consists of a generator of 30 kc. and of a highly sensitive, selective echo amplifier, which is tuned for 30 kc. Besides the continuous gain control, the amplifier contains an automatic device for suppressing the near echoes.

(c) The power supply unit, which delivers the 95 W. (approximately) consumed by the equipment.

The hoist sweep gear of the Miniature Lodar (fig. 2) is arranged for manual operation or, in a second type, may be operated by a motor. It permits the transducer to be moved in three directions.

(a) The transducer is housed in a ball and is located at the lower end of the hoisting shaft, which has an elliptical cross-section and is made of non-corrosive chrome-nickel steel. The hoisting length of the shaft is approximately 80 cm.

(b) The transducer is arranged so that it can be tilted continuously from the horizontal to the vertical position. It is thus able to carry out horizontal ranging as well as vertical soundings with only one transducer, and to sound in a slant downward direction from 0 degrees to 90 degrees.

(c) The transducer can also be trained in the horizontal plane from 135 degrees port to 135 degrees starboard.

With medium and large ships, the hoist/sweep gear is installed in the hull. This has the advantage that the ball is in a completely protected position when the unit is hoisted. For small craft, the hoist/sweep gear can also be used as an outboard installation. The three possible movements of the hoist/sweep gear, i.e. hoisting and lowering, and setting tne vertical or horizontal angle, can be controlled directly from the unit by means of handwheels or by actuating a remote control from the operator's stand or the wheelhouse.

The transducer is of the magnetostrictive type and is used for transmission as well as reception of sound pulses. The beam angle of the transducer for half power is approximately ± 6 degrees in the horizontal and ± 10 degrees in the vertical plane. The ball-shaped housing, made of sound transmissive material, is meant to avoid

Fig. 3. Horizontal ranging with Miniature Lodar Recording range 0 to 600 m.

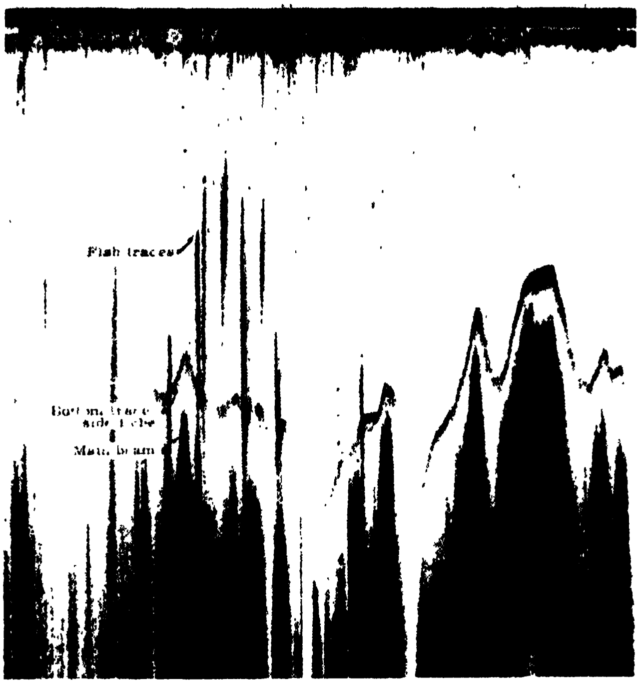


Fig. 4. Horizontal ranging with Miniature Lodar, showing bottom and fish traces. Recording range 0 to 150 m.

interfering noises from eddying when the ship travels at a high speed. The ball is filled with water when submerged. The speed at which the transducer is trained during horizontal ranging should be adjusted to the range for which the Echograph has been set. If, for instance, the 0 to 75 m. range is engaged, the pulse rate is still 158/min., since the echoes from the reflecting objects will return to the transducer shortly after the pulses have been emitted. In this case, the transducer can be trained at a relatively high speed. On the larger ranges (0 to 600 m. and 400 to 1,000 m.), however, the pulse rate is reduced (19·75/min.), since the echoes

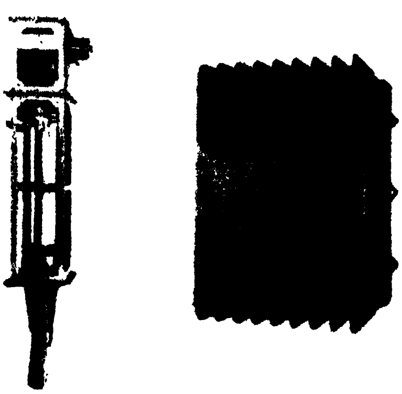


Fig. 5. Hoist/sweep gear and valve generator of the big Lodar equipment.

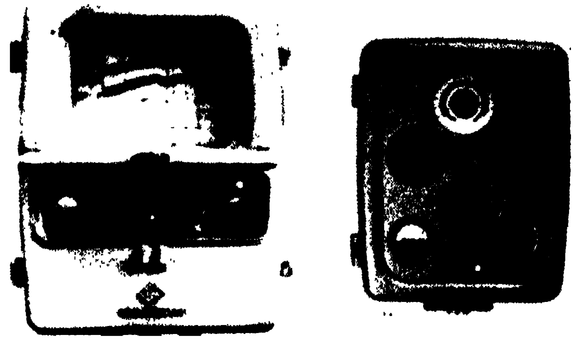


Fig. 6. Recorder and operating unit of the big Lodar.

from a greater distance take longer to reach the receiver. The transducer must, therefore, be trained at a lower speed when working large ranges. If this is not observed, targets may easily be lost from the sound beam.

Miniature Lodar offers the possibility of tracking a located fish target by means of horizontal ranging and then to approach the target and measure its depth by means of slowly tilting the transducer in the vertical plane from 0 degree to 90 degrees.

The horizontal effective range of the unit naturally depends on the propagation conditions, and on the kind and size of the target. In fig. 3, which shows a recording in deep water, horizontally located fish are indicated as slanted lines. The distance corresponds to the vertical distance of the echo-trace from the zero line at the upper margin of the illustration. The paper move was set at low speed. Range 0 to 600 m. Fig. 4 shows horizontal echo indications in relatively shallow water. The transducer was inclined to about 40 degrees below the horizontal line. Measuring range was 150 m. Fish being located horizontally appear as almost vertical stripes because of the low paper speed. Also one can see a weak contour of the vertical bottom echo which is caused by a minor side lobe of the transducer beam and thus permits a simultaneous observation of the bottom. Below the bottom echo appears a wide bottom echo caused by the main beam hitting the ground.

LODAR EQUIPMENT

This very efficient equipment is designed for use on medium and large ships and is also a combination ranger/sounder. Unlike the Miniature Lodar, the Lodar equipment operates with two identical transducers. One is permanently installed in the ship's hull and is exclusively used for vertical soundings, while the other is installed in a hoist/sweep gear and is only used for horizontal ranging. The transition from horizontal to vertical is effected by means of electrically switching from one transducer to the other.

The equipment consists of the following units.

1. The high frequency valve generator (fig. 5), which has a pulse output of 1·5 kw., and a transmitting

frequency of 20 kc. The length of the transmission pulse is automatically increased in the generator when switching from vertical to horizontal.

2. The operating unit (fig. 6), which contains all operating components for switching on the equipment, training the transducer, and hoisting and lowering the transducer. It is, therefore, arranged in the wheelhouse, near the recording unit. The hoisted and lowered position of the transducer as well as the training angle are indicated on the operating unit by means of pilot lamps or synchro-repeaters.

3. The recording unit (fig. 6), which is housed in a cast light-metal casing, exactly like the operating unit, consists of the following components:

   (a) The recording mechanism, with 8 ranges, the smallest extending from 0 to 300 m., and the largest from 1,600 to 4,000 m. The echoes are registered on dry paper of 204 mm. width, the speed of which can be manually adjusted to a maximum of 40 mm./min., according to the working range. The respective paper speed is marked on the recording paper by means of a time marker.

   (b) The highly sensitive, selective amplifier, which contains an automatic device for the suppression of near echoes. A supplementary unit provides the facility of simultaneously observing the targets acoustically, which is an important aid in identifying the targets.

4. The hoist/sweep gear, with the horizontal transducer (fig. 5) is permanently installed in the ship's bottom. The transducer can be trained horizontally, at a maximum from 150 degrees starboard to 150 degrees port, by means of an electro-motor remotely controlled from the operator's stand. The automatic control can be carried out at 0·7 degrees/sec. in a search sector of maximal 90 degrees, which can be selected as required. The sea area is usually searched automatically. On locating a school of fish, the manual control is switched on to track the target. The maximum training speed for manual control is 20 degrees/sec. Hoisting and lowering the transducer is also remotely controlled and the limit positions are indicated by means of pilot lamps.

5. The transducers are of magnetostrictive type and are suitable for transmission as well as for reception. The beam angle of the transducers is ± 9 degrees in the horizontal plane, and ± 6 degrees in the vertical plane. The resonance frequency of the transducers is tuned for 20 kc. transmission. The output is 1·5 kw.

The main reason for supplying the Lodar with a transmission output of 1·5 kw. was to achieve a working range for fish of 2,000 m. under normal sounding conditions, and to have a certain power reserve for adverse conditions. Trials have shown that under good conditions ships and fish were clearly indicated at great distances, e.g. up to 4,000 m. In the Bay of Biscay, vertical soundings with Lodar could be taken down to depths of more than 4,000 m. The power reserve of the Lodar guarantees that a range of 1,000 m. is obtained even under adverse conditions.

The vertical beam angle of the transducer must not be too narrow for the detection of fish schools at a slant distance in depths. Narrow beam angles are of advantage only in calm sea. In rough sea, however, the over-emphasised directional characteristics would render it difficult to focus the objects while the ship is rolling and pitching. Therefore, beam angles of ± 6 degrees in the vertical plane and ± 9 degrees in the horizontal plane are considered to be optimal.

If a fish school is spotted near the surface, it can be closely approached by the ranging ship, which will receive the echoes even at a very short distance. The

Fig. 7. Fish recordings obtained with Lodar in the Kattegat. Horizontal range 1,000 to 2,000 m. and 0 to 1,000 m. Vertical range 0 to 200 m.

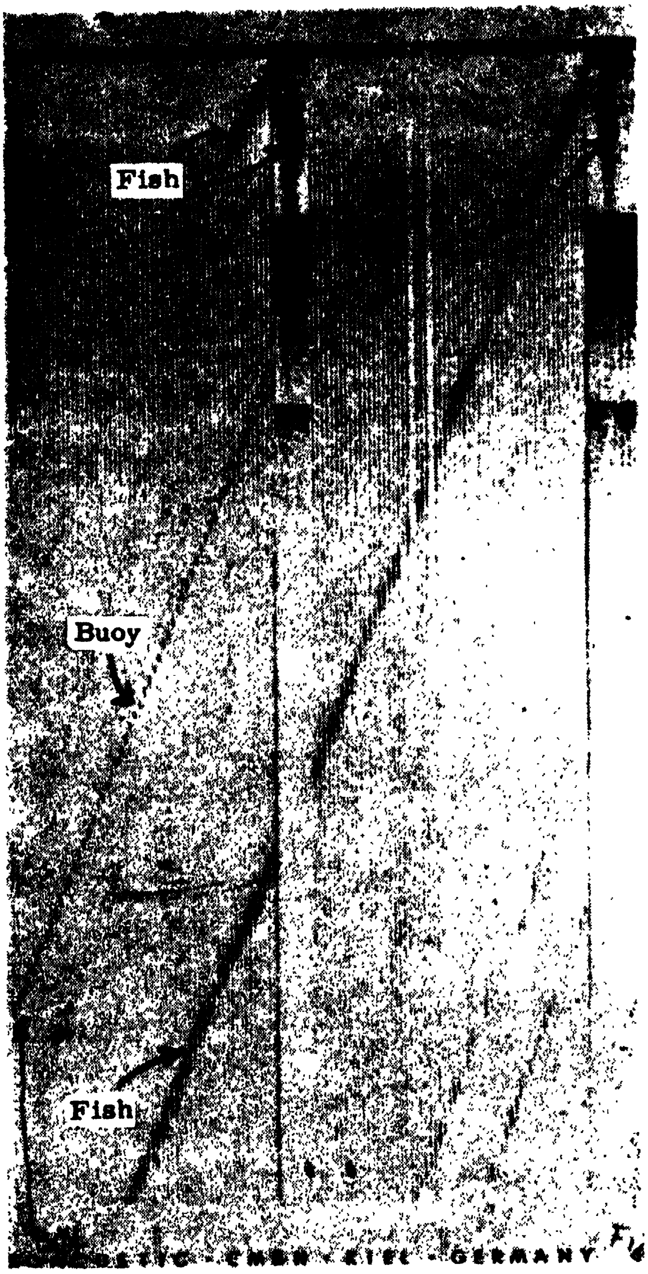


Fig. 8. Traces of fish schools and a buoy obtained with Lodar. Horizontal range 0 to 1,000 m., vertical range 0 to 200 m.

greater the depth of a school, however, the earlier it will move out of the sound beam. When nearing a target, the echo recordings will steadily approach the zero line until a certain distance has been reached when they will be completely skipped. This is the moment to switch the equipment from horizontal ranging to vertical sounding, in order to determine the depth of the school.

The supplementary acoustic unit makes the transmitted pulses and the echo signals audible by means of a loud-speaker, which is arranged in the wheelhouse. These audible signals give the experienced operator valuable indications on the nature and the character of the targets. The echo from a vertical wall of rocks, for instance, is usually clear-cut, distinct tone, while the echo of a scattered fish school consists of a multitude of short tones, as each fish produces an individual echo. The echo from the sandy seabed, however, resembles an elongated background noise because each unevenness of the seabed reflects a portion of the transmitted energy back to the receiver. A trace of a fish school is shown in fig. 7. This was picked up acoustically beyond the 2,000 m. range of the recorder. As the ship was headed for this target and approached it at a constant speed, the trace is a straight band ascending from the left hand bottom to the right hand top. The upper edge of the paper shows where the working range was switched to 0 to 1,000 range. At the distance of approximately 100 m., the school leaves the sound beam. After having switched to vertical sounding (0 to 200 m. range) and still following the same course, the depth of the fish school was measured to be between 8 and 15 m. approximately.

Fig. 8 shows the records of a fish school and of a buoy. The buoy was registered and tracked from a distance of 800 m. The fish school was simultaneously focused at a distance of 1,000 m. The fish trace is wider than that of the buoy. It was horizontally tracked up to a distance of approximately 30 m. and then identified by vertical sounding. A second fish school was simultaneously focused and recorded during horizontal operation (see left-hand top of the echogram). This school was vertically sounded at a depth between 10 and 20 m.

REFERENCES

[1] Ahrens, E. Die Horizontallotung in der Hochseefischerei. Bücherei der Funkortung, IV, 1954, Teil IV, p.35. 1954.

[2] Ahrens, E. Horizontallotung im Fishfang. Archiv f. Fischereiw. 6, 1955, Heft 3/4. 1955.

[3] Ahrens, E. Anwendung des Horizontallotes bei der Wrackortung, Bücherei der Funkortung, 1957.

CORRELATION OF MIDWATER TRAWL CATCHES WITH ECHO RECORDINGS FROM THE NORTHEASTERN PACIFIC

by

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Abstract

Midwater trawling experiments, utilizing a Sea Scanar equipped with a prototype recorder, were conducted during the spring of 1956 off the coasts of Washington and British Columbia. Catches of fish and other marine organisms were identified from 66 midwater tows made from the U.S. Fish and Wildlife Service's exploratory fishing vessel *John N. Cobb*. Trawl fishing depth ranged from 10 to 213 fm. over bottom depths of 15 to 950 fm. Catches varied widely, from no fish for a 60-min. tow to 5,500 lb., mostly hake, in a 20-min. tow. Examples of Sea Scanar recordings made during the tows show different types of traces for the various species caught, but with no fully consistent pattern. Traces of dense schools of hake are compared with others showing scattered patches of rockfish. Plankton forms, particularly euphausiids, were abundant and caused traces on the recorder which at first were mistaken for fish. With experience a fair degree of success was attained in identifying echoes and predicting species in the catch.

Corrélation entre les quantités pêchées au chalut flottant dans le Nord-est Pacifique, et les enregistrements du sondeur à écho

Résumé

Des essais de chalut flottant ont eu lieu au printemps de 1956 au large des côtes de l'Etat de Washington et de la Colombie Britannique, en utilisant un Sea Scanar équipé d'un prototype d'appareil enregistreur. Ces essais ont été effectués à bord du navire de recherches sur les pêches *John N. Cobb.* du Fish and Wildlife Service des Etats-Unis. Les poissons et autres organismes marins capturés en 66 traits de chalut ont été identifiés. Les profondeurs de chalutage ont varié de 10 à 213 brasses, sur des fonds de 15 à 950 brasses. Les quantités pêchées ont été très variables: de zéro après 60 min. de chalutage, à 5,500 livres, en grande partie du merlu, en 20 min. Les spécimens d'enregistrements obtenus par le Sea Scanar au cours de la pêche montrent différents types de tracés selon les espèces de poisson capturées, sans que chaque type soit absolument uniforme. Les auteurs comparent des tracés de bancs serrés de merlus avec d'autres correspondant à des groupes dispersés de chèvres. Le plancton, et notamment les euphausiides, était abondant et a été reproduit sur la bande enregistreuse sous forme de tracés que l'on a d'abord pris par erreur pour des tracés de poissons. L'expérience aidant, on est parvenu à identifier les échos avec une précision satisfaisante et à prédire ainsi les espèces de poissons composant la pêche.

Correlación entre la pesca obtenida mediante una red de arrastre pelágica y los ecogramas de sondeos hechos en el Pacífico nororiental

Extracto

Durante la primavera de 1956 se efectuaron, frente a las costas del estado de Wáshington, E.U.A., y de Colombia Británica, Canadá, experimentos con redes de arrastre pelágicas remolcadas a profundidades intermedias, usando un Sea Scanar con un prototipo de registrador. En 66 lances hechos por el barco de exploración pesquera *John N. Cobb* del Servicio de Pesca y Vida Silvestre de los E.U.A., a profundidades de 10 a 213 brazas (18·3 a 390 m.) en zonas cuyo fondo se hallaba entre 15 y 950 brazas (27,4 y 1·645 m.) se identificaron los peces y otros organismos marinos. Las redadas variaron considerablemente desde nada en un lance de 60 min. a 5·500 lb. (2·041 Kg.) de pescado, especialmente merluza, en 20 min. Los ejemplos de ecos registrados por el Sea Scanar durante dichos lances demuestran que los trazos correspondientes a las diversas especies capturadas no siempre tienen las mismas características. Los producidos por cardúmenes de arenque densos se compararon con otros que indicaban manchas de gallineta dispersas. Las formas plantónicas, especialmente euphausiidos, presentes en gran cantidad produjeron trazos que al principio se confundieron con los originados por peces. Con experiencia pueden identificarse los ecos y predecirse las especies que se obtendrán en el lance.

GENERAL

MIDWATER trawls, capable of fishing at any depth from the surface to the bottom, have mostly been developed within the last decade. They have been used successfully to capture herring and sprats in Scandinavian and other European countries, and in the inside waters of British Columbia[3]. The Larsen two-boat midwater trawl is probably the best known of those now in use.

Two of the major problems faced by commercial fishermen and research workers using midwater trawls are: (1) locating and identifying schools of fish in midwater, and (2) positioning the net at the proper depth to catch the fish. Experience has shown that few, if any, fish are caught by "blind" towing, and for good hauls it is necessary to locate concentrations of known species of fish, determine their depth and devise some accurate means of net positioning[7].

While midwater trawling thus far has been concerned primarily with the capture of herring, it has been proposed by some fishermen and researchers that other types of fish, which spend part of their time off the bottom, such as rockfish and cod, might be available to midwater trawls when they are not available to bottom gear[1]. To investigate this possibility, the Fish and Wildlife Service's section of Exploratory Fishing and Gear Research began developing gear and equipment several

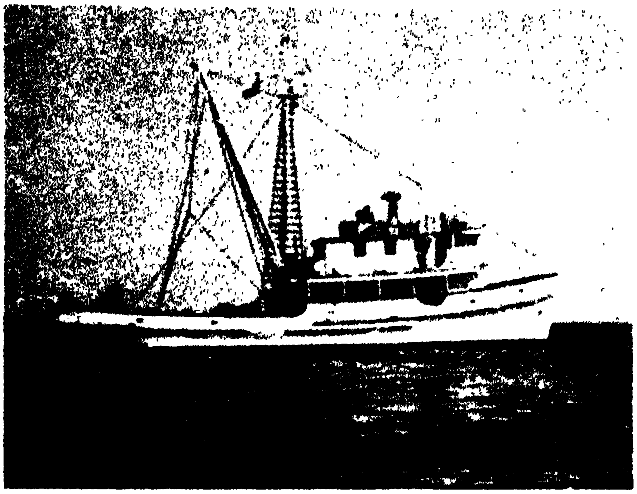


Fig. 1. The U.S. Fish and Wildlife Service's exploratory fishing vessel John N. Cobb *midwater trawling off the coast of Washington.*

years ago. The objectives were to develop suitable one-boat midwater trawls and accessory equipment which could be used on the Service's exploratory fishing vessels in the north-western Atlantic, north-eastern Pacific and Gulf of Mexico.

Development and testing of the gear and equipment were undertaken at the Gear Research Station at Coral Gables, Florida. Underwater television was used for direct observation of midwater trawls in action[8, 10], which were also inspected and photographed from a controllable two-man diving sled[9]. An acoustic depth telemeter for midwater trawl depth determination was constructed for the Service by the University of Miami.

In the spring of 1956 two midwater trawls and the telemetering equipment were shipped to Seattle for fishing trials. Exploratory midwater trawling was carried out aboard the M.V. *John N. Cobb* (fig. 1) during May and June off the coasts of Washington and British Columbia. Researchers from the Nanaimo Station of the Fisheries Research Board of Canada, with their gear, participated in part of the cruise.

GEAR AND EQUIPMENT USED

A Sea Scanar, equipped with a prototype recorder, was the principal instrument used on the *John N. Cobb* for locating fish in midwater. A standard type recording echo sounder was employed primarily for sounding the deeper bottom contours, but it was also useful in confirming the location of the more dense fish schools detected with the Sea Scanar.

The acoustic telemeter, for determining constant depth of the trawl gear, consisted of (a) a sensing and transmitting unit which was attached to the port warp immediately ahead of the trawl door; (b) a hydrophone, trailed on a boom just beneath the surface amidships, for picking up the sonic depth signal; and (c) a receiving set on which the operator listened for and determined the signal frequency. Sound frequencies were then

Fig. 2. The cumbersome acoustic depth telemeter unit, centre, has been replaced by the small electrical device, upper left, attached directly to the end of the trawl cable.

converted to corresponding depth by using a prepared conversion table[11]. Although accurate and quite dependable, the instrument was too large and complicated for practical use in fishing vessels, and it has since been replaced by a simplified electrical depth telemeter (fig. 2).

Three midwater trawls were used, all of nylon: the Canadian midwater trawl, and 40 ft. and 50 ft. square opening trawls made at the Service's Coral Gables Gear Research Station. The Canadian trawl had mesh sizes ranging from 5 in. in the wings to 1¼ in. in the codend[3].

The two trawls furnished by the Service were similar in design to the Canadian trawl, being made up of four equal side pieces and small wings on each corner. Mesh sizes were 4½ in. in the wings and body, and 3½ in. in the codend. The otter boards were of plywood, hydrofoil design, 4 × 6 ft., rigged with a conventional bridle arrangement, and not attached at the ends of separate pennants as with the Canadian gear. The last 9 ft. of each codend was lined with 1¼ in. cotton mesh to retain some of the small organisms which would normally pass through the larger mesh.

The midwater gear was first tested in inside waters and it performed satisfactorily after certain modifications. The hydrofoil boards were found to be extremely sensitive, with a tendency to collapse when set in choppy seas, but this fault was partly remedied by adjustment of the chains. Sounding the net from a motor launch revealed that the ground rope rode approximately 60 ft. deeper than the depth telemeter, which was attached just ahead of the port otter board, with 40 fm. bridles between the boards and the net. Consequently, correction factor of 60 ft. was added to telemeter readings to determine ground rope depth during towing.

Fig. 3. Midwater trawl catch, mostly hake, alongside the John N. Cobb.

FISHING RESULTS

Catches of fish and other marine organisms were identified from 66 midwater tows made in offshore waters between Grays Harbour, Washington, and Queen Charlotte Sound, British Columbia, from May 19 to June 21, 1956. The trawls were fished at depths ranging from 10 to 213 fm. over bottom depths varying from 15 to 950 fm.[2]. Sizeable concentrations of fish at mid-depths were difficult to find during most of the cruise.

Fishing results fluctuated widely, from no fish in a 60-min. tow to 5,500 lb., nearly all hake, in a 20-min. tow (fig. 3). The wide variation in catches was not unexpected on this initial effort. Although numerous echo traces of fish in the North Sea have been identified[5], it has been noted that the results do not have world-wide application and that intelligent interpretation of echo traces depends upon knowledge assembled locally[6]. Except for inshore schooling herring, characteristic fish traces and reactions of fish to midwater trawls were unknown for the area in which the *John N. Cobb* operated.

In addition to the lack of identifiable echo traces from the area, this was the first attempt to use the Sea Scanar with a recorder for midwater trawling. Consequently, there was no basis for interpretation of echoes received, and many of the early tows, made on likely-looking traces, caught only plankton, jellyfish, small feed, or a few larger fish.

It was only after considerable sounding with the Sea Scanar and numerous tows with the midwater trawls that reasonably sound opinion could be formed as

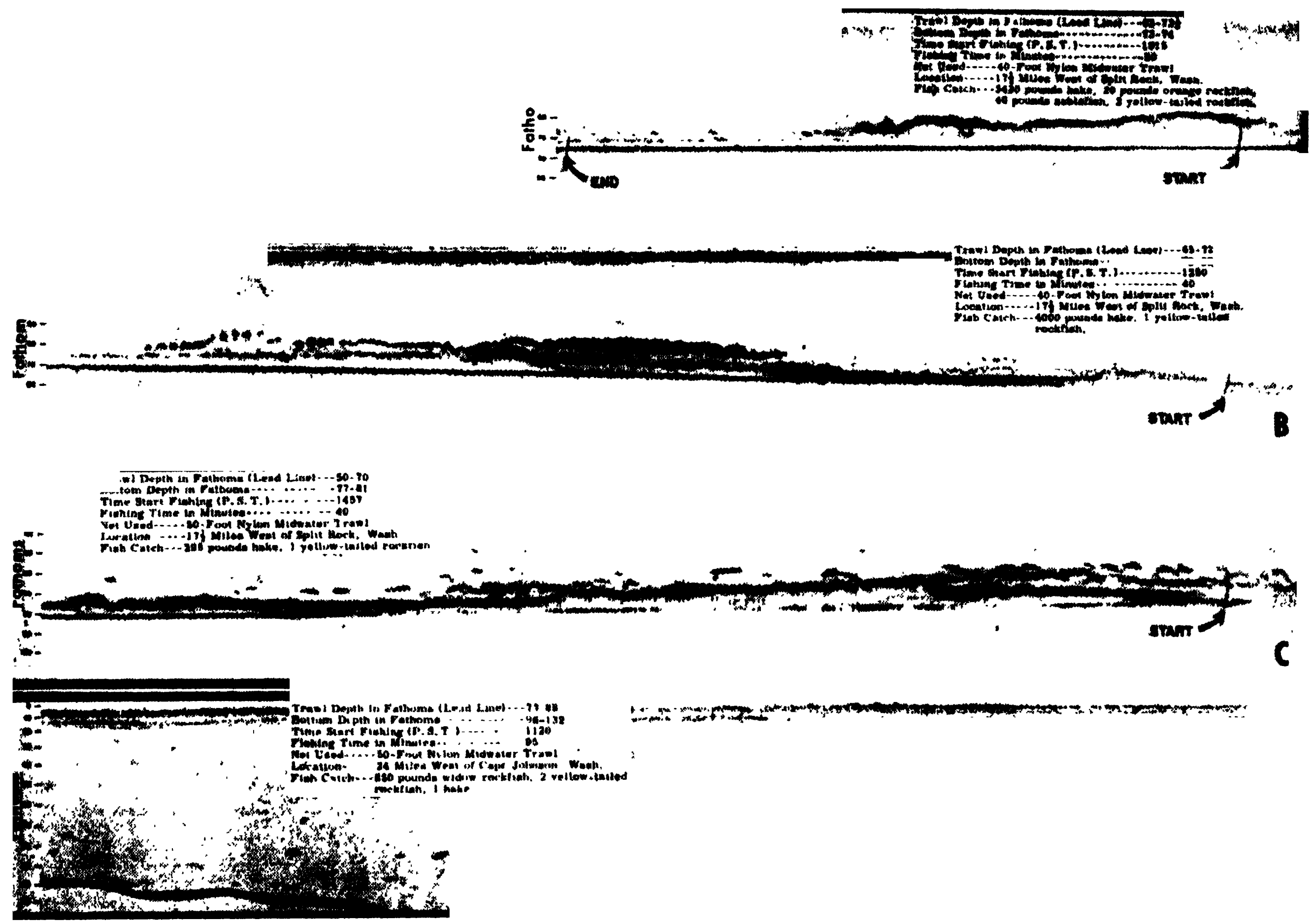


Fig. 4. Sea Scanar recorder traces made during productive midwater tows, mostly hake and rockfish.

to whether traces were caused by commercial-size fish, small feed fish, or by Euphausiids or other plankton forms. Even then, sets were made on doubtful traces to gain additional knowledge on the organisms present in midwater in this area, and these usually produced no significant fish catches. The Sea Scanar proved to be extremely sensitive to plankton (Euphausiids were abundant in most localities over the continental shelf), and it was often necessary to reduce the sensitivity of the instrument to eliminate much of the plankton trace so that fish echoes could be distinguished.

There was an indication from the composition of some midwater catches that hake and rockfish may school together or in close proximity. Mixed catches sometimes occur in the North Sea midwater trawl fishery where catches of brisling also contain herring and mackerel[4]. This degree of non-selectivity of midwater trawls probably will not create any greater problems in sorting the catch than is normally encountered on bottom trawlers.

INTERPRETATION OF SEA SCANAR TRACES

Examples of Sea Scanar records obtained during midwater tows are presented in figs. 4, 5 and 6. In all cases the Sea Scanar was operated with the transducer in depth-sounding position (vertical beam) to show what was directly under the vessel. Figs. 4 and 5 show traces obtained during tows which caught significant quantities of fish, while those in fig. 6 were made on tows which caught none or only a few fish. The entire recordings are presented for the shorter tows, while only representative sections of the longer tows are shown.

Traces in fig. 4A, B, and C are examples of dense schools of hake. 4A resulted in the best catch per unit of fishing time—5,430 lb. of hake and 70 lb. of other species in 20 min. The catch rate differed because, as shown by the depth telemeter, the net in 4A was in the most dense part of the hake school at the start and through most of the tow; while in 4B the net was too shallow for the main body of the school near the start and too deep during the middle of the tow. As for 4C, the net was too shallow during most of the tow.

As the net was known to be in the dense portion of the school in fig. 4A, it was hauled soon after it appeared that the main body of fish had been passed, which was not the case in 4B and C. Even though the telemeter provided continuous accurate information on the depth of the trawl, it was not always possible to keep the trawl in the most dense portion of the schools, which varied in depth considerably. The trawl depth was regulated by varying the length of towing warp or the speed

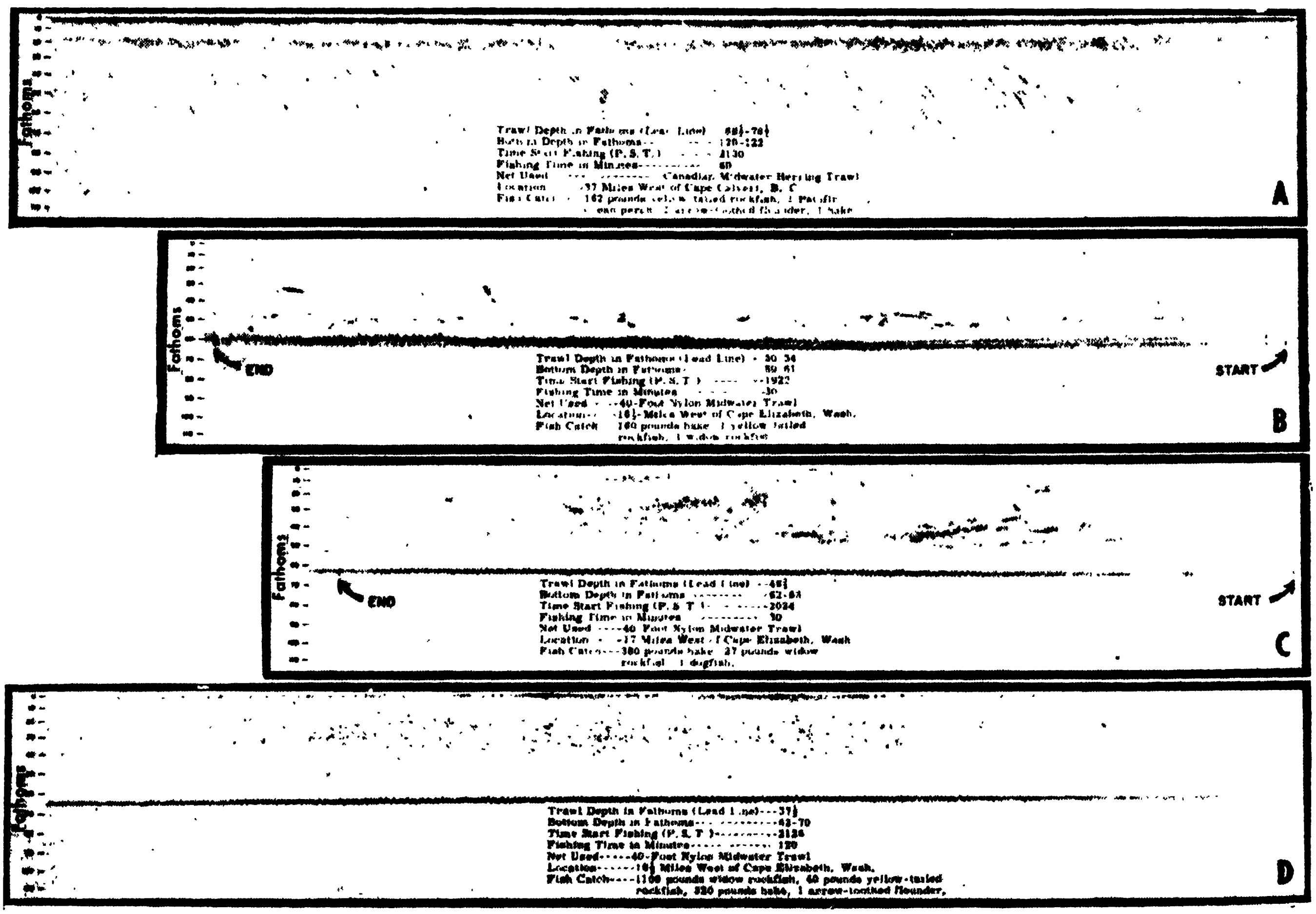


Fig. 5. Sea Scanar recorder traces made during productive midwater tows, mostly hake and rockfish.

of the vessel. After each adjustment, a short period of time was required for the trawl to stabilize at the desired depth; but by then the position of the school may have changed, requiring further adjustment to raise or lower the trawl to the indicated depth for best results.

Calculated towing speed in fig. 4A and C was from 3½ to 4 knots. Speed in 4B was slightly slower because of wind conditions. Normal towing speed during the cruise was approximately 3½ knots, although the speed was varied frequently as a quick method of raising or lowering the net to the desired depth during a tow.

In sharp contrast to the dense schools of hake shown in fig. 4A, B and C, are the scattered patches of widow rockfish in 4D. A 95 min. tow through these traces resulted in a catch of 850 lb. of widow rockfish, 2 yellow-tailed rockfish and 1 hake. It will be noted that the majority of the patches are at approximately the same depth although the bottom depth varies considerably. It may be a characteristic of this species of rockfish, as well as others, to gather near a steep edge and extend out over the edge at about the same distance from the surface rather than from the bottom. During this tow (only a portion of which is shown), the recording indicated that fish were present under the vessel only sporadically.

Traces made by hake and widow rockfish in fig. 5D are different from traces of these fish in fig. 4. Whether this difference may be related to time of day (tows in fig. 4 were made in daytime, fig. 5D at night) has not yet been determined. Also, no attempt is being made at this time to draw any conclusions as to which species are represented by which traces in 5D. Some similarity can be noted between the traces in 5D and 6C. Yellow-tailed rockfish, shown in 5A, produced distinctive elongated traces quite different from any other species shown.

The catch of pink shrimps in fig. 6C is noteworthy since shrimps are common bottom dwellers, but in this case the trawl was at least 20 fm. above the bottom at all times. Pink shrimps were also taken in other night tows, indicating that the species leaves the bottom to swim around at mid-depths after dark. Further evidence to support this conclusion was obtained during shrimp trawling explorations by the *John N. Cobb* in 1955 and 1956 when night-time drags produced only a few pounds of shrimps on the same grounds where catches averaged 1,000 lb./hr. during the day.

Midwater tows on traces in figs. 5B, C and D were made in approximately the same location on the same day, although the trawl was towed four times

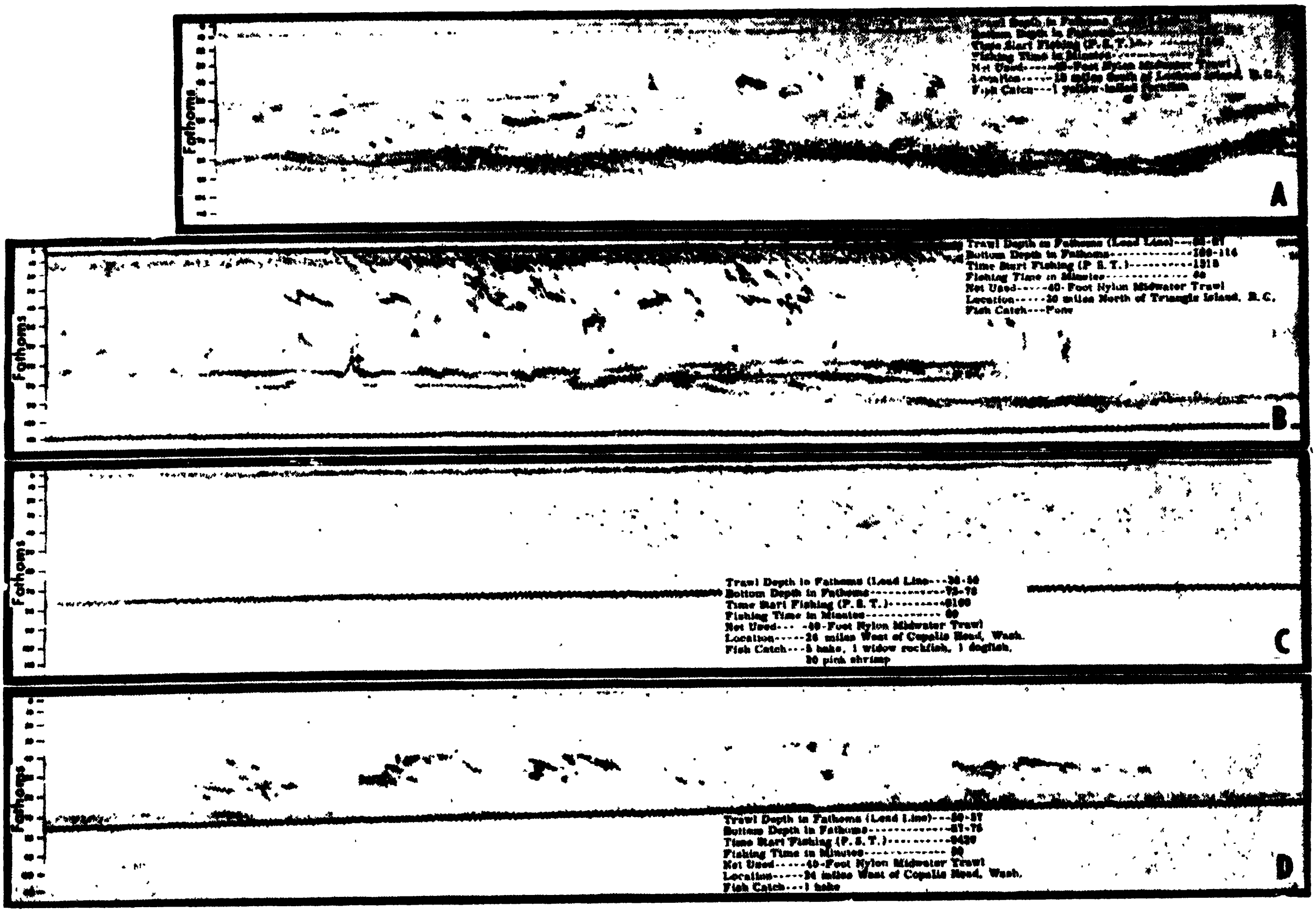


Fig. 6. Sea Scanar recorder traces, made during relatively unproductive midwater tows, believed to have been caused at least in part by plankton.

as long on the last-mentioned recording. It is interesting to note the changes in the trace patterns and catch composition for these three tows, with the earliest starting before sunset and the latest after dark. There was a definite movement of the fish toward the surface as darkness approached.

The recordings in figs. 6A, B and D are examples of traces which could have been interpreted as good indications of fish, but the total catch for the three tows was only two fish. The net was towed through what now appears to be a Scattering Layer in 6A and B rather than through the large patches above, which probably more closely resemble fish traces. However, in 6D the tow was made through traces resembling the large patches in 6A and B, with a catch of only one hake resulting.

Plankton forms, principally Euphausiids and jellyfish, were present in many catches, even those in which no fish were taken. After some experience, it was concluded that some of the Sea Scanar recorder traces, such as the layers in fig. 6A and B, were caused by dense concentrations of Euphausiids, with jellyfish sometimes mixed in. From then on, a fair degree of success in predicting catches was possible.

Exploration of these waters at different seasons of the year may show that other species of fish are available to midwater trawls. It is apparent that a great deal of experience on the local fishing grounds is necessary to identify species of fish from traces on the echo recorders, under different conditions and times of day. Suitable electronic fish-finding equipment, competently operated, and an accurate trawl-depth indicating method, are essential items for successful offshore midwater trawling exploration.

LIST OF FISHES

Yellow-tailed rockfish	*Sebastodes flavidus*
Orange rockfish	*Sebastodes pinniger*
Widow rockfish	*Sebastodes entomelas*
Pacific ocean perch .	*Sebastodes alutus*
Hake	*Merluccius productus*
Sablefish . . .	*Anoplopoma fimbria*
Arrow-toothed flounder	*Atheresthes stomias*
Dogfish	*Squalus suckleyi*
Pink shrimp . .	*Pandalus jordani*

REFERENCES

[1] Alverson, Dayton, L. and Powell, Donald E. The open ocean challenges the scientist and dares the fisherman. Pacific Fisherman, Portland, Oregon, vol. 53, No. 11. October pp. 25, 26 and 29; and vol. 53, No. 12, November, pp. 26 and 27. 1955.

[2] Anonymous. Promising results with midwater trawls by *John N. Cobb* (Cruise 27), Commercial Fisheries Review, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C. vol. 18, No. 8, August, pp. 39-40. 1956.

[3] Barraclough, W. E., and Johnson, W.W. A new midwater trawl for herring. Fisheries Research Board of Canada, Ottawa, Bulletin No. 104, 25 pp. 1956.

[4] Glanville, Alan. The Larsen midwater trawl. F.A.O. Fisheries Bulletin, Rome, vol. 9, No. 3, July-September, pp. 113-129. 1956.

[5] Hodgson, William C. Echo sounding and the pelagic fisheries. Ministry of Agriculture and Fisheries, London, Fishery Investigation, Series 2, vol. 17, No. 4, 25 pp. 1950.

[6] Hodgson, William C., and Fridiksson, A. (Editors). Report on echo sounding and asdic for fishing purposes. Rapports et Proces —Varbaux des Reunions, Copenhagen, vol. 139, September, 49 pp. 1955.

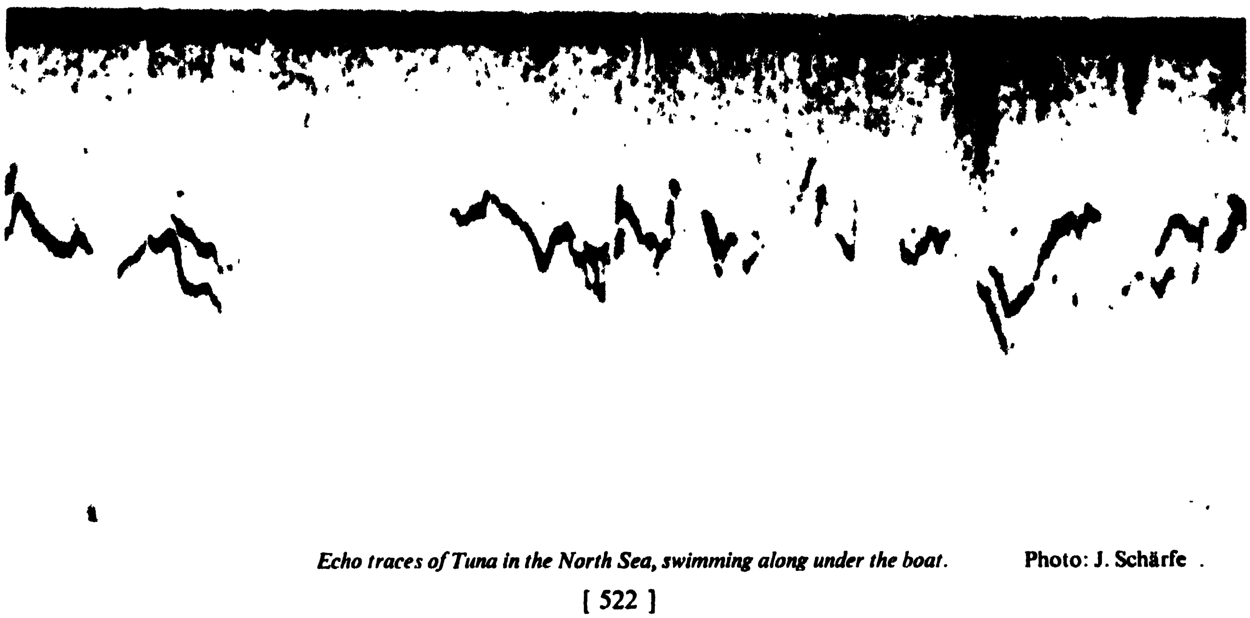
[7] Richardson, I. D. Some problems in midwater trawling. World Fishing, London, vol. 6, No. 2, February, pp. 28-31. 1957.

[8] Sand, Reidar F. Use of underwater television in fishing gear research (Preliminary Report). Commercial Fisheries Review, U.S Fish and Wildlife Service, Department of the Interior, Washington 25, D.C., vol. 17, No. 4, April, pp. 1-5. 1955.

[9] Sand, Reidar F. New diving sled. Commercial Fisheries Review, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C., vol. 18, No. 10, October, pp. 6 and 7. 1956.

[10] Sand, Reidar F., and McNeely, R. L. Underwater television vehicle for use in fisheries research. Special Scientific Report—Fisheries No. 193, U.S. Fish and Wildlife Service, Department of the Interior, Washington 25, D.C., December, 15 pp. 1956.

[11] Stephens, F. H. Jr., and Shea, F. J. Underwater telemeter for depth and temperature. Special Scientific Report—Fisheries No. 181, U.S. Fish and Wildlife Service, Department of the Interior Washington 25, D C, June, 22 pp. 1956.



Echo traces of Tuna in the North Sea, swimming along under the boat. Photo: J. Schärfe .

FISH-FINDING ON THE SALMON FISHING GROUNDS IN THE NORTH PACIFIC OCEAN

by

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Abstract

Experiments with echo sounders carried out from a research vessel in Aleutian waters showed that salmon could be easily located using frequencies of 28 and 200 kc. Certain points in the behaviour of the fish were noticed. For instance, the fish generally tended to concentrate at the DSL (Deep Scattering Layer) and would rise and fall with it, but on some occasions a part of the shoal would remain at 30 to 50 m. all day long, and the authors suggest that means should be devised for catching these fish.

Tests were made with Gain Control and it was found that salmon were recorded when the gain of the amplifier of the 28 kc. instrument was about 120 db, but not when it was 95 db. To avoid the effect of aeration and noise, the transducer was used from an iron arm suspended from the side of the boat, rather than have it assembled in the ship's hull.

Détection des poissons sur les fonds de pêche à saumon dans le Pacifique nord

Résumé

Des expériences au moyen de sondeurs à écho effectuées à bord d'un navire de recherche dans les eaux voisines des Iles Aléoutiennes ont montré qu'il était facile de détecter les saumons en utilisant des fréquences de 28 et de 20 kilocycles. Il a été possible de noter certaines particularités du comportement du poisson. C'est ainsi que les poissons ont eu généralement tendance à se concentrer vers la D S L (deep scattering layer) qu'ils suivaient dans ses remontées et ses descentes, mais à plusieurs reprises une partie du banc est restée toute la journée entre 30 et 50 metres et les auteurs proposent de mettre au point des méthodes pour capturer ces poissons.

Des essais ont été faits en réglant l'amplificateur et l'on a pu constater la présence de saumons lorsque l'amplificateur de l'appareil fonctionnant sur 28 kilocycles permettait d'atteindre 120 db., mais pas lorsqu'il n'atteignait que 95 db. Pour compenser l'influence de l'aération et du bruit, on a utilisé le sondeur à écho non pas en le montant dans la coque mais en le fixant à une tige de fer suspendue sur côté du bateau.

Localizacion de peces en los bancos de salmón del Océano Pacifico septentrional

Extracto

Los experimentos con ecosondas hechos a bordo de un barco de investigaciones en aguas de las islas Aleucianas, demostraron que es posible localizar salmón con facilidad usando frecuencias de 28 y 200 kc. Durante el curso de estos estudios se observaron ciertos puntos relativos a la manera en que reaccionan los peces; por ejemplo, generalmente tienden a concentrarse en la capa profunda de dispersión del sonido ("deep scattering layer") para ascender y descender con ella, pero en algunas ocasiones parte del cardumen permanece entre 30 y 40. durante todo el dia, sugiriendo los autores que deberian idearse medios para capturar estos peces.

Se hicieron pruebas de control de volumen, registrándose la presencia de salmón cuando el aumento de la amplificación del aparato que trabajaba con frecuencias de 28 kc. fluctuó alrededor de 120 db.,* pero no se optuvieron resultados con 95 db. Para evitar el efecto de la aeración y del ruido, la ecosonda se instaló en un brazo de hierro suspendido del costado del barco en vez de montarla en la quilla.

* db decibel

IN June and August 1955 experiments were carried out on the Aleutian salmon fishing grounds (fig. 1) by the Research Vessel *Katori-maru.* With a wind velocity of generally 3 to 4 m./sec., the height of the waves was almost always more than 3 m. with fog and rain.

Ultrasound of 28 kc. and 200 kc. was tested. The depth scale of the fishfinder was 50 m., and the pulse rate was 225/min. The transducer was not installed in the ship's bottom but fixed to a vertical pipe which was attached at 70 cm. distance to the ship's side. The depth of the transducer was 1·5 m. below the surface.

RESULTS

The installation of the transducer at the ship's side was very successful in avoiding disturbing aeration, and fish searching could be continued even at full speed (10 knots), which was impossible in the prevailing bad

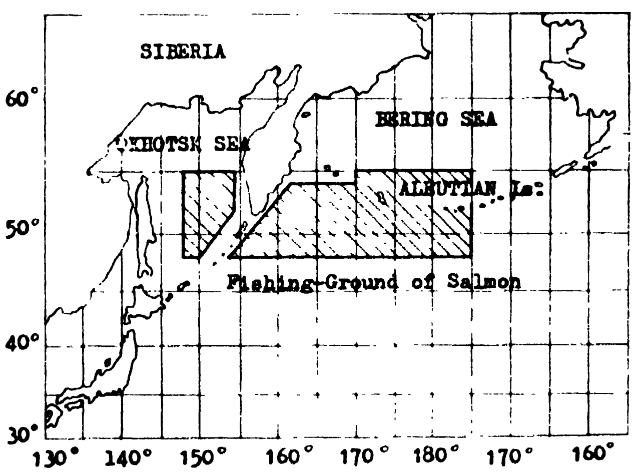

Fig. 1. The Aleutian salmon fishing grounds 1955.

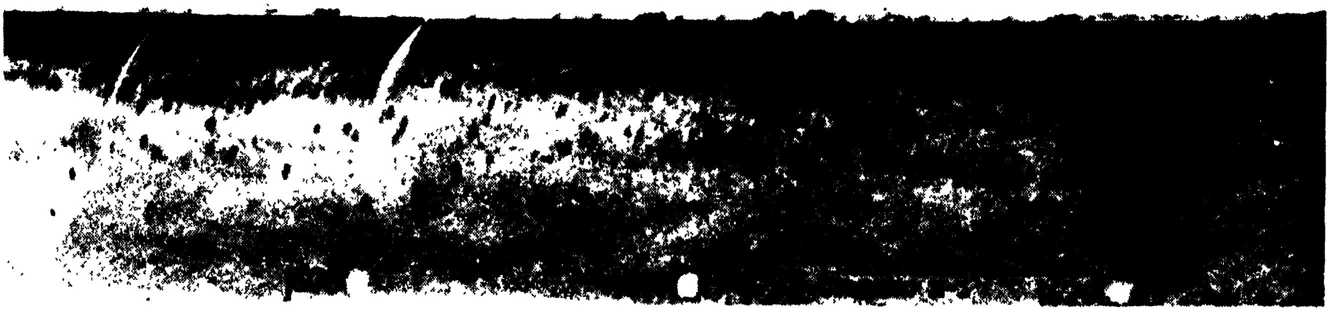

Fig. 2. Echogram of salmon in 15 to 40 m. depth obtained with 28 kc. on 17 July 1955. Catch 19·8 fish/40 m. net.

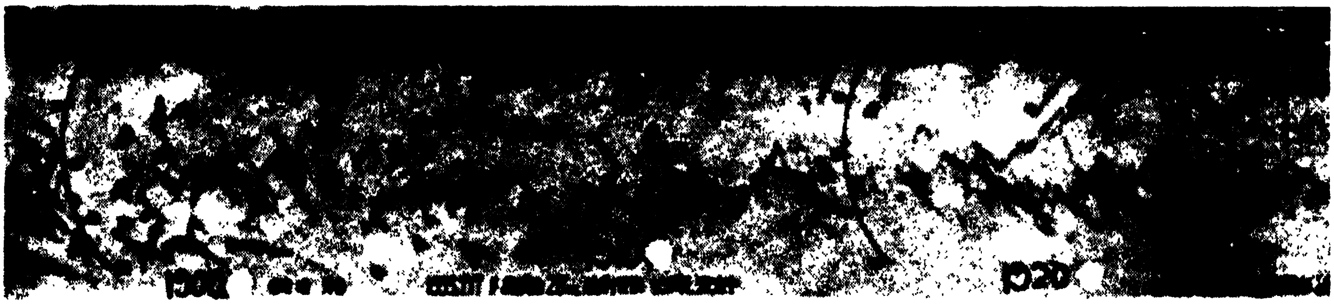

Fig. 3. Echogram showing salmon concentrated in the Deep Scattering Layer between 30 and 40 m. depth.

weather with the conventional installation at the ship's bottom.

With equal paper width a measuring range of 50 m. is superior to 100 m. for detailed observation of fish.

The higher pulse rate of 225 pulses/min. proved to be superior to the 144 pulses/min. rate for recording fish. A short pulse length is preferable for recording fish near the surface.

It was found that the distribution of the salmon depended on the time of day (illumination of the water). Much attention was paid to this point and the echograms have accordingly been provided with time indicators.

The density of the present salmon schools is rather low. Six fish per 40 m. of net is a usual catch and 30 fish per 40 m. of net is considered exceptionally high. The example given in fig. 2 shows a 28 kc. record of a rather good school. The catch was in this case 19·8 fish per 40 m. net.

Some of the salmon observed in 30 to 40 m. depth tended to ascend after sunset and descend again in the morning. Some of them even reached the surface. The rest of the salmon, however, remained in 30 to 50 m. depth all day. A new and effective method should be found to catch the latter fish as well.

The salmon obviously concentrate preferably in the Deep Scattering Layer (DSL) and move with it. Fig. 3 shows a record of the DSL between 20 and 30 m. depth on 14 July. Plenty of Euphausiids, probably from the DSL, were found in the stomachs of salmon caught here. The catch was 11·2 fish per 40 m. of net.

The DSL appeared at the clear thermocline where the temperature gradient was 0·8 degree C./cm. on 21st July. The depth of the DSL and the fish schools change in accordance with the depth of the thermocline. Using ultrasound of 200 kc., a study is being made of a DSL which appears at 200 m. depth and in which fish schools were found. The average length of the salmon caught during this experiment was about 50 cm.

REFERENCE

Hashimoto T. and Maniwa Y.: Fish-finding experiments on the Salmon fishing grounds in the North Pacific Ocean, Technical Report of Fishing Boat Agency, Nov. 8, 1956.

THE QUANTITATIVE USE OF THE ECHO SOUNDER FOR FISH SURVEYS

by

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Abstract

The use of echo sounders for fish finding is now almost universal, and in this paper the author shows how, by the use of Cathode Ray Tube presentation, an approximate correlation between "catch" and "amplitude" of the returned signal can be obtained.

The total signal amplitude, counted during a trawl haul, was multiplied by the square of the depth to correct for dissipation of energy and this was compared with the square root of the number of baskets of fish taken during the haul. In fig. 1 the catch/signal relationship in 1955 and 1956 is shown, but in three cases out of 40 observations the relationship broke down. These cases were of high signal strength and no catch, and it is considered that the error was due to fish swimming above the headline of the trawl, although the returned signal apparently suggested that they were actually below this level, which, the author points out, is quite possible.

The value of C.R.T. observations as a means of surveying a fishing area is shown by three successive runs over the grounds between Bear Island and Spitzbergen, and during a ten day period the movement of the cod on to the Bear Island Banks was clearly shown.

Utilisation quantitative de sondeur à écho

Résumé

Les sondeurs à écho sont maintenant d'une utilisation presque universelle pour la détection du poisson. Dans cet article, l'auteur a montré comment, par l'emploi d'un tube à rayons cathodiques, on pouvait obtenir un rapport approximatif entre la "capture" et l' "amplitude" du signal renvoyé.

L'amplitude totale des signaux comptés au cours d'un trait de chalut a été multipliée par le carré de la profondeur pour compenser la perte d'energie et ce chiffre a été comparé à la racine carrée du nombre des paniers de poisson capturés pendant le trait. La figure 1 représente les rapports entre la capture et les signaux en 1955 et 1956 mais, dans trois observations sur 40, ces rapports ne se sont pas vérifiés. Dans ces cas, les signaux, avaient une intensité élevée et les prises furent nulles. On s'explique cette erreur par le fait que les poissons se déplacaient au-dessus de la corde de dos du chalut, bien que le signal renvoyé ait fait penser qu'ils étaient en réalité au-dessous de ce niveau ce qui, comme le fait remarquer l'auteur, est tout à fait possible.

L'intérêt de ces observations réalisées grâce au tube à rayons cathodiques en tant que moyen de prospecter une région de pêche, a été démontré en faisant trois passages successifs sur les fonds situés entre l'ile aux Ours et le Spitzberg et, ainsi de suivre pendant 10 jours les migrations des morues vers les bancs de l'ile aux Ours.

El uso cuantitativo de la ecosonda

Extracto

El uso de la ecosonda para la localización de peces es actualmente universal, pero el autor ha demostrado en este trabajo que el empleo de un tubo de rayos catódicos permite obtener una correlación aproximada entre la "pesca" y la "amplitud" del eco.

La amplitud total de las señales obtenidas durante un lance se multiplicó por el cuadrado de la profundidad para corregir la disipación de la energía y el resultado se comparó con la raíz cuadrada del número de canastas de pescado que constituían la redada. En la fig. 1 se muestra la relación entre la pesca y las señales registradas durante los años 1955 y 1956, la cual no se mantuvo en sólo 3 de las 40 observaciones que se efectuaron. En estos casos se captaron señales de gran intensidad sin obtener nada de pesca, considerándose como causa de error el hecho de que los peces nadaban sobre la relinga de boyas de la red de arrastre, si bien la señal de vuelta sugería que, en realidad, estaban bajo este nivel, lo cual según el autor sería muy posible.

El valor de las observaciones con tubos de rayos catódicos como medio para reconocer o evaluar una zona de pesca, quedó demostrado por medió de tres pasadas sucesivas sobre un banco entre Bear Island y Spitzbergen; además, durante un período de 10 días se estableció claramente el movimiento de bacalao en los bancos de dicha isla.

GENERAL

THE recording type of echo sounder has been in use since 1948 for echo survey, the amplification being adjusted so that the recording paper was kept clean (without noise showing); the fish echoes were recorded necessarily at a high signal-to-noise ratio. The quantity of fish was estimated by measuring the width of the fish traces per unit time. The rough correlation obtained between signal distribution and fish distribution showed that the signal-to-noise ratio was sufficient, the power output was steady enough, and that the variations in depth were not too great[1].

Klust[2] has shown that heavier catches of fish were associated with signals of greater amplitude on the cathode ray tube presentation of the echo sounder. In an echo survey in the Bear Island area, we measured cathode ray tube signals from fish at three levels of amplitude in the first fathom layer above the bottom[3]. Thus the minimum signal-to-noise ratio was reduced from perhaps 10 to only 3 times, and the method, therefore, could only be successful if the power output was constant over the period of examination.

METHOD

A preliminary examination showed that a particular signal close to the bottom but separated from it should be disregarded. We learned to distinguish this "X" echo from a fish echo by its dull tone, sharp rise time and serrated edge; it was probably a weak bottom signal received from an angular range. A fish echo was smoother with slower rise time, and brighter, the amplitude being generally less.

In order to measure the amplitudes the time base was covered with a dark strip of paper, which excluded the noise traces. Three lengths of cotton were placed on the screen parallel to the time base, so signals could be classified in three levels of amplitude; the magnitude of the levels was maintained with the use of a signal injector in series with the receiver. Signals were counted by noting the duration in seconds of signals at each level of amplitude.

The levels of amplitude were frequently checked and noise measurements were frequently made. The transducer was mounted on a stalk extending 2 ft. from the ship's hull to reduce the number of missing signals. At the expense of 5 μV. of noise, the number of missing signals was reduced from an average of 30 to 50 per cent. down to about 5 to 10 per cent. So the counting method could be employed up to a state of sea and swell 5 and 6. If noise increased too much, the counting levels were increased to maintain the signal-to-noise ratio, so some sensitivity was lost.

THE RELATION BETWEEN CATCH AND SIGNAL

The signals counted were received from a spherical shell 1 fm. thick, of radius equal to the depth. Its extent in angle from the axis depends upon the directivity pattern of the transducers and the qualities of the object from which signals are received. As it was impossible whilst counting to distinguish between a single fish and a shoal of fish, the effect of directivity was not dealt with explicitly. The total signal counted during a trawl haul was multiplied by the square of the depth to correct for the dissipation of energy.

The catch, using the "basket" as a unit, was transformed by the square root. It is assumed that the signals counted were usually received from a shoal of fish. When catches were large, multiple signals were sometimes observed.

There are three sources of error within the method of counting, that due to a varying directivity pattern, that due to differences in the sizes of fish shoals, and that due to the inability to count multiple signals properly. There is a further source of error which is an effect of the beam angle of the transducers used (size 9 × 14 cm.; wavelength = 5 cm.). A signal presented in the last fathom of the cathode ray tube may be received from any part of the shell of the spherical wave tangent to the seabed which is limited by the respective angle of directivity. Thus a signal recorded in the last fathom of the cathode ray tube may be received from a height of more than 1 fm. from the bottom. As it is probable that a fish swimming more than 1 fm. off the bottom is swimming above the headline of the trawl, the catch-signal relationship in such cases can break down. For survey purposes this does not matter, but for fishing purposes it does.

On fig. 1, which shows the catch-signal relationship established in the Barents Sea in 1955 and 1956, there are three observations (indicated as squares) out of forty of high signal and no catch where the relationship

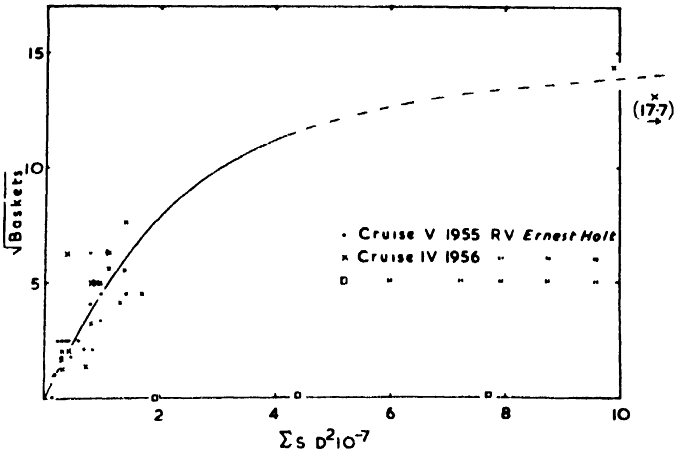

Fig. 1. The relation between the amount of catch (cod) and received fish echo signals. Barents Sea, June/July, 1955/56 s = signals × time; D = depth. Squares indicate observations when fish presumably above the headline.

broke down probably because the fish actually were above the headline. There is a possibility that this may happen more often when the fish are abundant; consequently, it may be a greater source of error for commercial vessels.

Different species have not been distinguished; in fact, it is quite reasonable to treat haddock as if they were small cod. On one occasion signals received from catfish were less than expected in comparison with cod; on another, when they were more abundant, a signal was observed which looked on the cathode ray tube like a thick flat plate on the bottom. Catfish have no air bladder, so the signal received from them is probably less than that received from cod.

The most remarkable result from the observations given in fig. 1 is that those of 1955 are indistinguishable from those of 1956. Hence the power output must have remained sufficiently constant to allow us to work at a fairly low signal-to-noise ratio.

Two results of importance emerge:

1. the steady power output of the echo sounder used and the steady level of water noise permitted a quantitative use of the instrument.
2. the catch-signal relation is necessarily rough, but it would allow contour levels of catch to be drawn on survey at 1, 5, 25 baskets/hr.[4].

THE USE OF THE METHOD ON SURVEY

If it is possible to predict roughly the catch in a given trawl haul, when steaming at 3½ knots, it is possible to search for the area of highest abundance. To do this, the ship has to steam faster and the noise level may be high. At full speed the noise is a little greater than at trawling speed with the trawl down; at a little less than full speed, the noise is reduced. The main component of noise comes from the propeller.

An example of such a survey is shown in fig. 2. The first survey was carried out by steaming on a gridded course across the edge of the Bear Island Bank and back again from Bear Island to Spitzbergen. Trawl hauls

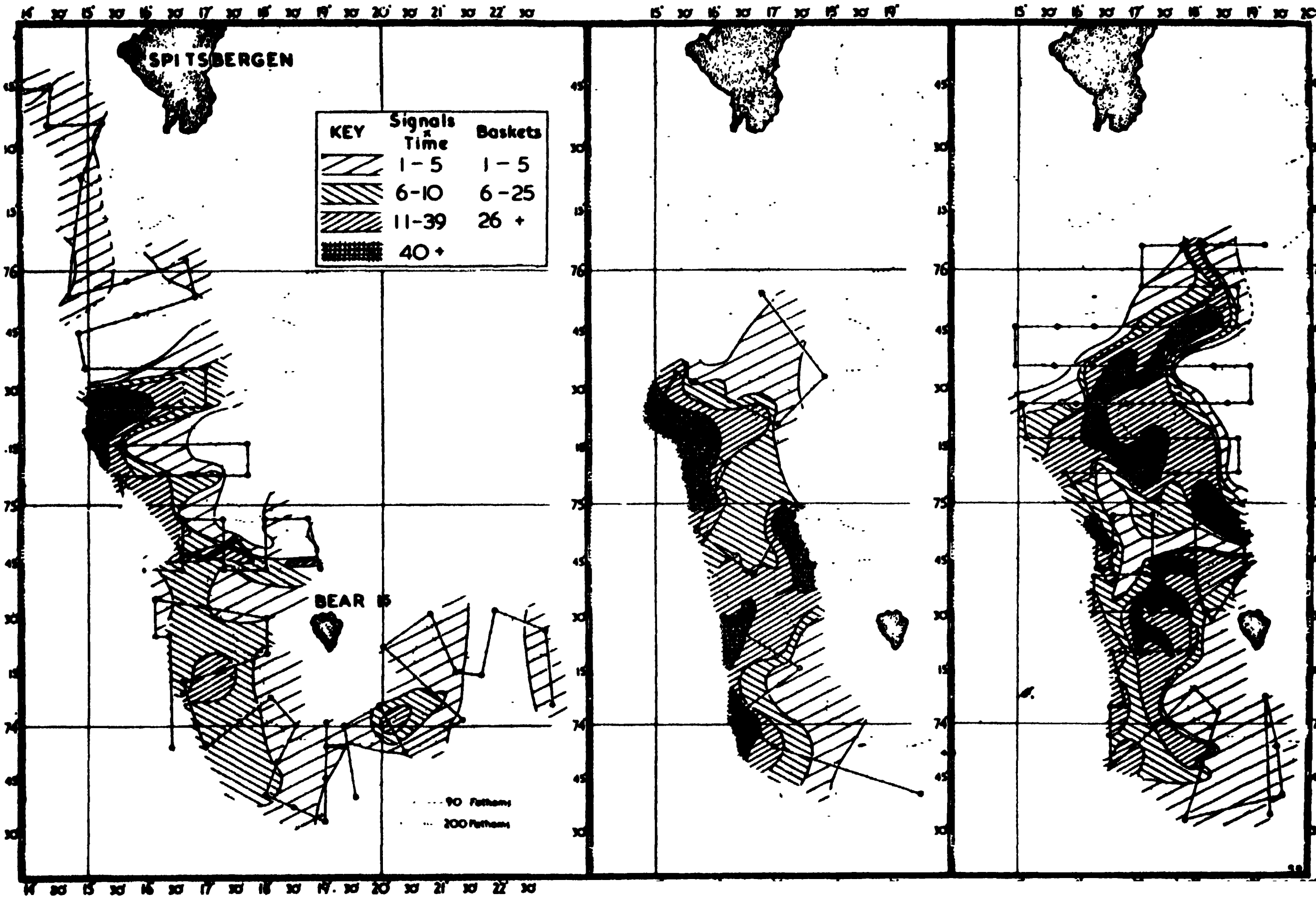

Fig. 2 Successive echo surveys made in the Barents Sea in June 1956. Note the movement of the fish on the bank.

were made at frequent intervals to check that the signals were still being received from cod, the species in which we were interested. A second survey was made on the return journey as an immediate check on the first. It will be seen that the main features are repeated with some minor variations. The third survey was carried out in the same way about ten days later. In this short time fish have moved to the shelf from the Storfjordrenna and from the N.W. Gulley; in depth they have moved from about 150 fm., to 70 to 100 fm.

The value of this technique as a research tool is obvious, but there is no reason why a fisherman should not make some sort of survey of this type before starting to fish. As an aid to fishing on a particular ground, it is possible that the catch-signal relationship is not sufficiently accurate to show when to haul, but it can be used to show where the fish were during a haul.

REFERENCES

[1] Cushing, D. H. Echo-surveys of fish. Journ. du Cons. XVIII, 1, p. 45. 1952.

[2] Klust, G. Über die Grössenschätzung von Schleppnetzfängen auf Grund der Echoanzeigen der ELAC-Fischlupe. Archiv für Fischereiwissenschaft III 3/4. p. 146. 1951.

[3] Cushing, D. H. and Richardson, I. D. New Echo Sounding Methods at Bear Island. World Fishing, Vol. 4, 10, p. 18. 1955.

[4] Cushing, D. H. Studies on plankton populations. J. du Cons., XIX, 1, p. 3. 1953.

[5] Cushing, D. H. and Richardson, I. D. Echo Sounding Experiments on Fish. Fish. Invest. Ser. II, XVIII, 4. 1955.

[6] Richardson, I. D., Cushing, D. H., Harden Jones, F. R., Beverton, R. J. H. and Blacker, R. W. Research on Echo Sounding in the Barents Sea. (in press)

LOCATING HERRING SCHOOLS ON THE ICELANDIC NORTH COAST FISHING GROUNDS

by

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Abstract

The Icelandic north coast herring fishery has until 1944 always been essentially an inshore fishery. Now, however, it has become almost an oceanic one, exploited by Norwegian, Russian and Swedish vessels, in addition to the large Icelandic fleet. This move to off-shore waters has made the location of shoals more difficult, but the shoaling behaviour of the herrings is such that the use of both Asdic and airplanes for this purpose is possible.

The shoals often break the surface in the evening and early morning and when the scouting planes locate these, they direct the fleet towards them. A ship using Asdic can locate the shoals before they break surface and before they can be seen from the planes, so by close co-operation, the Asdic and spotting-plane become formidable weapons of attack.

In 1956, in spite of many cancellations due to bad weather, some 750,000 square miles of sea were surveyed, and the two planes located herring shoals on 60 occasions, but it is impossible to gauge accurately the increase in total catch produced by these services.

Repérage des bancs de harengs sur les lieux de pêche de la côte septentrionale de l'Islande

Résumé

Sur la côte septentrionale de l'Islande, la pêche au hareng avait toujours été, jusqu'en 1944, une pêche essentiellement côtière. Mais maintenant elle est devenue presque océanique et est pratiquée par des navires norvégians, russes et suédois, sans compter l'importante flotte de pêche islandaise. Ce déplacement de la pêche vers le large a rendu plus difficile le repérage des banks de harengs, mais le comportement de ces bancs est tel qu'il permet l'emploi d'appareils Asdic et d'avions.

Les bancs remontent souvent à la surface dans la soirée et au début de la matinée, et lorsque les avions-éclaireurs les ont repérés ils dirigent la flotte de pêche sur leur emplacement. Un navire équipé de l'Asdic peut repérer les bancs avant qu'ils ne remontent en surface et qu'ils puissent être vus par les avions, en sorte qu'utilisés en étroite coopération, l'Asdic et l'avion-éclaireur constituent des armes d'attaque d'une efficacité considérable.

En 1956, malgré le mauvais temps qui a limité le nombre des vols, 750,000 milles carrés de mer ont été explorés, et les deux avions ont repéré à 60 reprises des bancs de harengs, mais il est impossible de déterminer avec précision la quantité supplémentaire de poissons capturés grâce à la mise en oeuvre de cet équipement.

La localización de cardúmenes de arenque en los bancos pesqueros de la costa septentrional de Islandia

Extracto

Hasta 1944, la pesca de arenque en la costa septentrional de Islandia era en su mayor parte de bajura. Sin embargo, en la actualidad, noruegos, rusos, suecos y la gran flota islandesa la han tornado de altura. Este alejamiento de las aguas costeras dificulta la localización de los cardúmenes, pero la tendencia del arenque a congregarse en bancos permite el uso de "asdic" y aeroplanos.

Los cardúmenes a menudo afloran durante el crepúsculo y en las primeras horas de la mañana, permitiendo a los aeroplanos localizarlos y dirigir la flota pesquera hacia ellos. Un barco provisto de "asdic" puede localizar los bancos de peces antes de que afloren a la superficie y sean oteados por los aeroplanos. Por este motivo, la estrecha cooperación entre el "asdic" y el aeroplano se ha transformado en una formidable arma de ataque.

En 1956, a pesar de las numerosas salidas canceladas a causa del mal tiempo, dos aviones pudieron inspeccionar 750,000 millas cuadradas localizando cardúmenes en 60 ocasiones; no obstante, ha sido imposible determinar con precisión el aumento de la pesca total que se obtuvo con ayuda de estos medios.

GENERAL

As an industry of importance the Icelandic North Coast herring fishery dates back to the 'eighties. Purse seining is the main fishing method although driftnets have been used as well. The season usually begins in late June or early July and ends after the middle of August or in September. Before 1944, fishing took place mainly in inshore waters, but in recent years it has largely developed into an off shore fishery in which a great number of Norwegian, Russian and Swedish as well as Icelandic vessels take part.

The Icelandic purse seine fishery has proved successful because of the compactness of the schools and the frequent surfacing of the fish, so that they can be located visually. As a rule the schools break the surface soon after sunset and just before sunrise, so that in the beginning of July the schools can be spotted just before and after midnight. Later on, as the time interval between sunset and sunrise increases, the times of surfacing change accordingly.

The schools can be spotted from the top of the wheel-house of a fishing boat at a distance of anything up to 5 nautical miles. From far away they are observed as small dark spots, almost like a patch of soot floating on the surface of the sea (fig. 1).

In fact, when coal was still the main source of fuel in the fishing fleet, many a soot patch was mistaken for a

Fig. 1. Herring school in the surface.

herring school at a distance. A closer view shows thousands of dark blue herring backs breaking surface.

The horizontal spread of a typical school does not exceed 100 sq. m. while its vertical spread may reach 30 to 40 m. Great variations are observed, so that the schools are sometimes very shallow with enormous horizontal spread; sometimes they do not break the surface at all or, in extreme cases, they may surface in the middle of the day in blazing sunshine. Nothing can be taken for granted and "typical" really means the behaviour most frequently observed.

The purse seine nets generally used by Icelandic fishermen nowadays measure approximately 400 × 80 m. Each shot usually takes from 1 to 3 hours, depending on the catch per shot which may range from nil—if the school dives before the net can be closed—to some 200 metric tons. This shows that the schools may be extremely compact.

Owing to the relatively small horizontal spread and the short time that the schools can be seen each day, the fishing boats may easily miss the herring concentrations. In a fishery of this kind aerial scouting would clearly be advantageous because the schools can be seen very distinctly from an airplane and a large area can be surveyed in a short time.

Due to the fact that the Icelandic north coast herring is usually found in compact schools, vertical echo-surveying is of limited value and may even be misleading because the chances of missing many of the schools are extremely great. On the other hand, the compactness of the schools makes it possible to detect them effectively by using horizontal ranging equipment such as Asdic or whale finders. Both aerial and Asdic surveys are made during the Icelandic north coast herring season.

AERIAL SCOUTING

Aerial scouting along the north coast fishing grounds started as early as 1928 when single engined Junkers seaplanes were used. From 1931 to 1938 the scouting was irregular but since 1938 it has been of an ever increasing importance to the fishery.

Before 1938 the immediate value of aerial scouting was greatly diminished because the radio telephone had not yet become a standard part of the vessels' "fishing" equipment. There were no means by which the results of aerial scouting could be effectively communicated.

In the last few years two airplanes have been chartered for aerial scouting and have been operated from the shore base at Akureyri, the position of which is shown on fig. 2.

Each crew consists of two pilots and an experienced herring skipper while two engineers at the shore base prepare the planes for each flight. One plane is a twin-

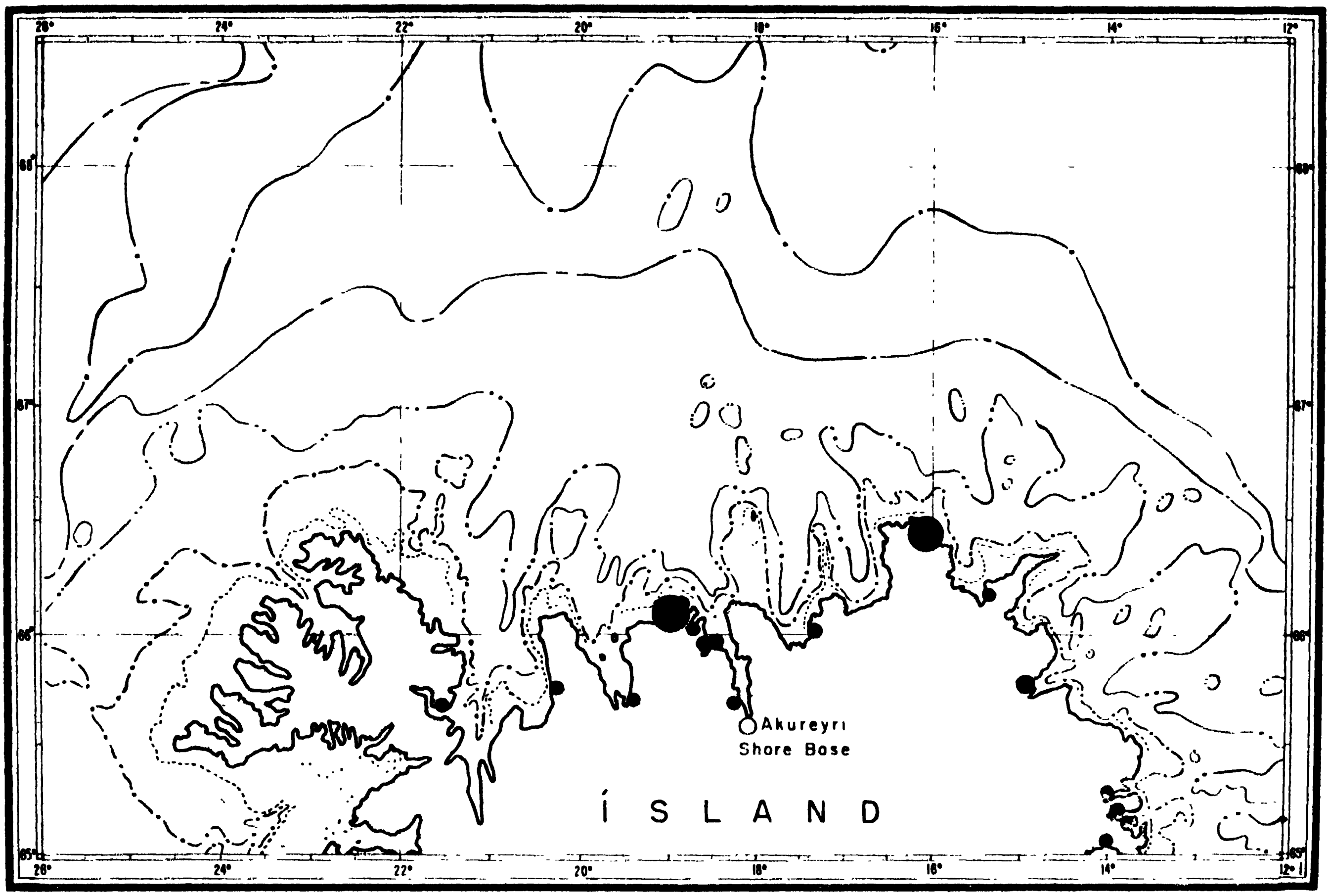

Fig. 2. Chart of the Icelandic North Coast showing shore base for aerial scouting and the main herring landing places.

engined De Havilland Rapide, the other is a twin-engined Beachcraft C.18. Both airplanes are capable of flying considerable distances on one engine only, so the added security of using flying boats is not considered sufficient to warrant their use, in view of their higher maintenance costs.

In 1956 the two planes were operated for 50 days, from the 3rd July to 23rd August, the total flying time amounting to 286 hours during which 37,800 miles (statute) were covered. After many years of experience it has been found that the optimum flying height for herring scouting is about 800 ft., from which herring schools can be spotted up to a distance of 10 miles so that in clear weather the plane covers an observational track 20 miles in width. In 1956 an area of approximately 750,000 square miles was surveyed, in spite of many cancelled flights because of fog or gales or because the base of clouds was well below 800 ft. If the plane is forced to fly much lower than the optimum height the observational field changes too quickly for proper inspection. When herring schools are located their position and approximate size are broadcast to the fishing fleet, but very often the planes fly to the nearest group of vessels and actually guide them to the schools. This practice has proved necessary in many cases when, far from the coast, the fishermen have some difficulty in fixing their position.

During the above period the two planes located herring schools on 60 occasions but it is difficult to estimate the increase in the total catch resulting from the aerial scouting. In most of the instances, however, the herring boats were guided from areas where herrings were very scarce to others containing workable schools in much larger quantities, so that this service is greatly appreciated by the fishermen.

ASDIC SURVEYING

In the autumn of 1953, a Kelvin-Hughes Asdic Whale Finder was installed in the Icelandic research ship, *Aegir*, and since then Asdic surveys have been carried out on the North Coast herring grounds. During these surveys, the best results have been obtained by aiming the centre of the Asdic beam horizontally with as small vertical or lateral spread as possible. The maximum range of the Finder is 2,000 yards and, during its four years of service in the *Aegir* herring schools have frequently been recorded at that distance.

During surveys the Asdic Whale Finder and a Simrad echo sounder are kept running continuously. The Asdic beam is then kept stationary and directed 60 degrees to 90 degrees to one side or used like a searchlight, slowly sweeping through 180 degrees.

Fig. 3 shows sample echograms of the Asdic (top)

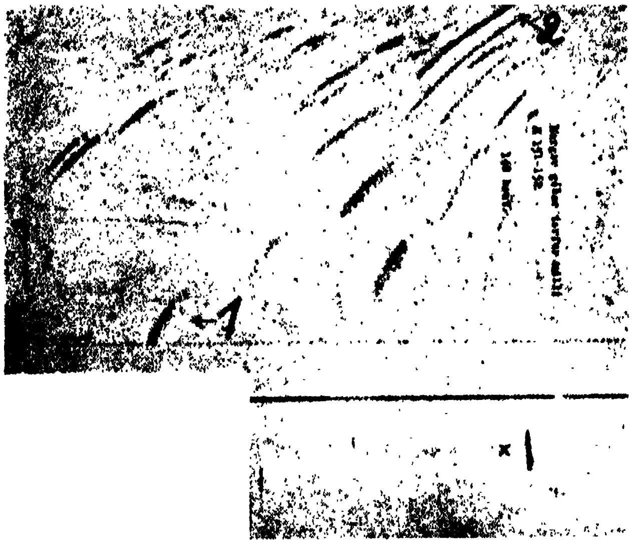

Fig. 3. Echograms of Asdic (top) and vertical echo sounding (below) showing traces of herring schools.

and of the Simrad echo sounder (bottom). On the Asdic record the diagonal dark bands represent the fish schools. Their distance from the ship can be found by calibrating the width of the paper from 0 to 2,000 yards, the zero line being at the top. On this occasion the beam was at first aimed 70 degrees to one side so that the trace of the schools disappeared soon after they had been observed at a considerable distance from the ship. Thus, the school marked "1" came into view at the maximum range of about 2,000 yards and disappeared at a distance of 1,700 yards. On the other hand the school marked "2" came into view only some 500 yards away and by heading the ship to this target it was kept in "sight" all the time until the ship passed over it so that it now could be "picked up" by the echo sounder (trace marked X).

Now and again it is found desirable to check by echo sounding the depth and size of a school selected at random. Some indication of size can also be obtained by considering the average maximum distance at which traces of the schools are recorded. The greater the distance the more compact must the schools be assuming constant acoustic conditions. At half hourly intervals the number of contacts observed on either instrument is recorded in a special Asdic/Echo sounder logbook, also noting the average maximum distance at which the schools come into view, their size and depth according to vertical sounding, bottom depth, weather conditions, the ship's course and speed as well as observations taken at any scientific stations that may have been worked during the period in question. By plotting on a chart the number of schools along the ship's route, a fairly comprehensive picture of the herring distribution is obtained. In 1956 the *Aegir* broadcast information regarding the herring distribution on 45 occasions. On some of these the fishing fleet was informed of new herring concentrations and, in other cases, a general summary of plankton and hydrographical information with information on the herring distribution.

Many valuable records regarding the relation between hydrographical information was given with information on the herring distribution.

THE TWO METHODS COMPLEMENT EACH OTHER

When the Icelandic north coast inshore herring fishery changed to an off-shore or even an oceanic one, the fishing grounds increased enormously in size. As a result, the problem of locating the herring concentrations became increasingly difficult but fortunately it has been possible to find a partial solution by employing modern techniques. Large areas are now surveyed quickly by airplanes but the results of these surveys are dependent on the diurnal schooling behaviour of the herring. If, for some reason or another, they do not come to the surface, aerial scouting is useless. On the other hand, an Asdic survey by a research ship can find herring concentrations regardless of the depth of the schools (within limits). The result of this kind of survey is, however, dependent on the compactness of the schools and the searchers are handicapped by the relatively small area covered by ships as compared with that covered by the 'planes. The two methods must be considered as complementary. By an Asdic survey it is often possible to get a general picture of the herring distribution before the schools come to the surface, and areas of herring concentrations will be watched very closely by the 'planes. The closest possible co-operation between the two kinds of herring surveying methods is thus of the greatest importance.

DISCUSSION ON FISH DETECTION

Dr. J. Schärfe (FAO), Rapporteur: As the scope of this Congress demands, the papers submitted on this subject deal exclusively with the most progressive developments in fish detection--of which echo sounding and ranging are obviously the most important ones. Only one, namely Jakobsson's paper, describes another method, i.e. aerial scouting.

The main value of this latter method consists in the possibility of surveying large areas in a short time. On the other hand it is restricted to fish shoals swimming at or at least very close to the surface and to favourable weather conditions. But, in spite of these limitations, certain fisheries can gain great advantage by using it. In the present paper it is shown that with not more than two planes, a whole fishing fleet can successfully be assisted by surveying big areas, broadcasting the observations to the fishing boats and thereby often leading them from poor fishing areas to more profitable ones.

The great value of echo sounding for certain fisheries, valuable to find suitable ground for bottom-touching fishing particularly bottom trawling, must be shortly mentioned. Its importance for navigation in shallow waters, checking D.R. (Dead-Reckoning) position in finding well known fishing places, as well as keeping to a desired depth when towing is commonly acknowledged. Alverson gives, from the offshore trawl fishery of the U.S. West coast, an example of how echo sounding can increase the fishable depth and thereby the operational area. Apart from the depth also shape and composition of the bottom is often important. Both Craig and Hashimoto and collaborators show how the representation of such bottom characteristics can be improved by choosing higher or different frequencies and a sharp sound beam. The knowledge of the bottom conditions is not only valuable to find suitable ground for bottom-touching fishing gear as trawls or Danish seines, and protect them from damage, but may also be helpful as an indication of the kind of fish likely to be caught. This remark leads back to fish detection as the main subject of the present report.

The possibility to locate fish acoustically was proved by means of normal echo sounders designed for depth measurement only. Of course, such apparatuses are not optimal for this new purpose and, due to the efforts of physicists from many parts of the world, remarkable technical progress has been achieved since.

Fish are less effective reflectors than the sea bottom. In order to get a sufficient working range for fish, the sensitivity of the equipment has to be increased. As a first step in this direction the receiving amplification was increased up to the level of the disturbing noise. Furthermore, good success was gained in decreasing this disturbing noise itself by optimal placing of the transducers in the ship's bottom, at a short distance below the ship's bottom or even at the ship's side (see Hashimoto and Maniwa). Thereby the working range for worthwhile fish schools could be extended to about 250 m. But for deep sea trawling, which is carried out in depths down to about 600 m., and then particularly for the detection of more scattered white fish, this performance proved to be insufficient. For further improvement the "effective" transmitting power had to be intensified. This has recently been done by increasing the sound output. Another possibility, the narrowing of the sound beam, which is proposed in Vestnes' contribution, would also have other advantages but at the same time leads to certain difficulties due to ship's movements in rough sea. It would therefore require measures for stabilizing the transducers and some methods on how this could be done, are described in the paper of Craig.

Besides the mere knowledge of the presence and the depth of fish, more detailed information was soon wanted such as on the size of fish schools and the species and therefore more suitable methods of representation were needed. As is well known, two methods of representing the echo traces are generally used now: firstly, the recording on wet or dry paper and secondly, the reproduction by means of a cathode ray tube (CRT). The characteristics of both methods are described in detail in the papers of Cushing, Woodgate, Haines, Hashimoto and Maniwa, and Craig. Each of these two methods has certain advantages and a combination of both in one and the same unit is, therefore, the optimal solution for acoustical fish location.

Such combined fish sounders came on the market some years ago. Besides such combined units, now also an existing recorder can be combined with an existing CRT set or a special CRT apparatus can later on be added to an existing recorder. Such dual apparatuses, particularly in combination with high sound output, are doubtless the most progressive but, of course, also the most expensive ones. Therefore, and also because of their great size, they are mainly used by the bigger craft as deep sea trawlers.

The main advantage of the CRT is its true quantitative representation of the echo amplitude and the possibility to easily expand the reproduction scale as desired. Both these qualities favour the resolving power which, as is well known, is of the greatest importance for detailed observation of fish, particularly bottom fish. On the CRT the representation of a single sounding is complete in itself so that, when in rough weather some or several soundings are lost because of aeration, those which do come through are complete and give all details. But unfortunately the CRT has no memory and therefore requires continuous attention on the part of the operator who must act as a kind of integrating machine comparing the complex of echo frequency and character from area to area, making due allowance for changes in depth. This is a severe disadvantage which doubtless acts as a strong handicap against the use of CRT equipment in fishery.

A highly interesting improvement is described by Woodgate. It consists of an additional electronic apparatus which gives an acoustical signal for every fish echo, hereby releasing the operator from continuous visual observation. An automatic counter of these fish echoes can also be attached to replace the "integrating duties" of the operator. Hereby the fish echoes are at least counted, although, of course, the quality of the echoes is not preserved.

Contrary to the CRT, the paper recorder has the immense advantage that it automatically integrates the echoes in completing a real echo chart of a continuous sequence of soundings. This makes continuous observation unnecessary. Furthermore, not only the number but also the duration and, to a certain degree, the strength of the echoes is preserved in a way which results in a very expressive picture of bottom conditions and fish distribution along the course of the ship. Unfortunately, the reproduction of the echo strength is unsatisfactory, due to the limited sensitivity of the recording paper. This does not matter so much with pelagic fish; but with bottom fish the distinguishing between fish trace and bottom trace may become difficult or even impossible. This happens as soon as the fish echo is strong enough to cause recording with maximal intensity (blackness). Then traces of such schools which, because of their position and density are of the highest interest for bottom trawling, may escape the perception or, furthermore, may resemble or hide obstacles on the bottom and thereby cause wrong action resulting in damage to the gear and loss of time. Also estimating the probable amount of catch which may be important for determining the proper time for hauling the gear, often becomes difficult or even impossible.

The second or double echo trace records only the strong bottom echo and not the weaker fish echoes. Hereby a discrimination between the two types of reflectors is possible. But having to record the second echo decreases the reproduction scale and is therefore an unsatisfying alternative.

Three far better solutions of this problem are described in five of the present papers. One of these solutions, which seems to have been found almost simultaneously in three different countries, i.e. in England, Norway and Japan, is the so-called "white-line" method described by Haines. Technically it consists of a gating circuit which operates only in response to signals above a certain amplitude. If this gating action is set at a value in excess of that of the strongest fish echo but below that of the bottom echo, the amplifier is cut out for about 1/100th of a second on receipt of the bottom echo resulting in a white gap immediately following the strike of the bottom echo. In a continuous sequence of soundings these white gaps build up a white line which follows exactly the contours of the bottom with the fish traces appearing easily distinguishable on top of it.

The "bottom blocking device" described by Vestnes and the "bottom suppressor" described by Hashimoto and Maniwa obviously have the same effect.

Kietz describes another method which by courtesy of the manufacturers I myself have already used for several years for the observation of bottom trawls. For this method, which is now available for commercial fishery, a special receiving amplifier was developed which records the strong bottom echoes in a black tone, and the weaker fish (or fishing gear) echoes in a gray tone. Hereby the operator can always distinguish between the traces of bottom and bottom fish. (This has later been reversed so that the bottom echo is gray and the fish trace black.—Editor).

Finally, Fahrentholz describes a third method where the gray traces of bottom and fish are separated by a narrow band in deep black tone which exactly represents the strike of the bottom echo, i.e. the surface of the bottom.

All three methods use the great difference in strength between bottom and fish echoes for a clearer representation of bottom fish. Thereby the recorder has doubtless gained one of the most important advantages of the CRT. Other advantages of the CRT remain, such as the better representation of the single sounding and the enlarged scale.

Another general problem of echo sounding is the resolving power which is not satisfactory with some of the equipment on the market. The resolving power depends on the duration of the sound impulse and the width of the sound beam and can therefore be improved by shortening the sound impulse and/or decreasing the angle of sound transmission. A higher resolving power is desired for a better representation of particularly the vertical dimension and also the density of fish shoals.

High frequencies are favourable for short impulse length. As the width of the sound beam is decreased by enlarging the value of the quotient of transducer diameter over the length of the sound waves, higher frequencies are favourable in this regard too. Unfortunately higher frequencies are subject to higher attenuation by which the working range is decreased. On the other hand, as stated by Hashimoto and Maniwa, higher frequencies have a better reflection coefficient with fish which may compensate the higher attenuation in regard to fish to a certain degree.

A narrow sound beam is only useful when it is steadily adjusted straight in the direction desired, therefore the effect of the rolling and pitching of the ship in rough sea has to be considered carefully and stabilizing of the transducers then becomes necessary. Craig mentions several methods of how this could be done. One possibility, i.e. the installation of the transducers in a streamlined body which is towed at a substantial depth below the surface should have the further advantages of avoiding the trouble connected with aeration and the depth variations caused by the vertical movements of the ship in rough sea. But all these measures would increase the price and in the latter case in addition cause difficulties in the handling of the equipment and are therefore not yet in practical use. Nevertheless the improvement of the resolving power is an important necessity which will have to be solved in the course of future development.

Until now only echo sounding in vertical direction was discussed by which only a limited area under the ship is covered. The experience made with Asdic, i.e. horizontal ranging, for locating submarines made the application of this method to fisheries purposes rather obvious. Vestnes describes probably the first attempt in this direction. It is very impressive how successfully powerful equipment of this type can be used to survey big areas to find out the distribution of pelagic fish schools and observe their movements. Similarly, as described by Jakobsson, the results gained by one echo-ranging scouting vessel are utilized to guide the fishing fleet to profitable catching places. Unfortunately, horizontal ranging which, at first, seems to accomplish all wishes, underlies certain restrictions which are due to physical laws governing the propagation and the reflection of sound in water. These are closely discussed in the papers of Haines, Craig, Feher and Vestnes. Nevertheless the fisherman obviously wants the possibility to scan in horizontal direction so strongly that at present almost all echo sounder manufacturers have developed a horizontal ranging device. To be economic these "fishery Asdics" have to be cheaper and consequently of much less complexity than those used for Naval warfare or whaling. Two fishery types may be distinguished according to their size. The *Lodar* described in Feher's paper is a good example of the big type. Besides such big ones, smaller equipment is available which is usually built up by simply combining a normal echo sounder with a transmitting device suitable for horizontal ranging. Examples of such smaller equipment are described in the papers by Woodgate, Feher and Fahrentholz. At present the commercial use of echo ranging is almost completely restricted to pelagic fish. Here it proves very useful for detecting fish and also measuring the horizontal extension of fish schools. The ranging of bottom fish is much more difficult except under extremely favourable conditions. The actual depth of fish schools located by ranging has to be checked by sounding. Therefore, ranging equipment is always combined with a sounder.

Finally, it must be mentioned that successful echo ranging of fish is rather more difficult than echo sounding and requires well-trained operators to obtain good results. In spite of these difficulties the value of echo-ranging for solving certain fishery problems is evident. As it is a rather new technique in fisheries, more experience and future technical development will certainly extend the possibilities of its application.

Doubtless the technical improvement of the equipment will further improve the value of these acoustical methods for the fishery.

Cushing's most valuable quantitative survey, together with the reports of Jakobsson and Vestnes, give a very good example how, besides their application to commercial fishery, these acoustical methods can be used most successfully as a tool for scientific work and thereby help to improve the knowledge of the distribution and behaviour of fish stocks.

Mr. P. A. de Boer (Netherlands): Echo ranging in deep water has been proved rather satisfactory in, for instance, the Norwegian and Icelandic waters, but what about echo ranging in shallow water? I have had some experience of it in the shallow waters of the southern part of the North Sea and found it quite possible although there are some restrictions to its use. In this connection I object strongly to the fixed position of the oscillator and I will tell you why.

It is generally thought that the unwanted bottom echo in shallow water is a source of much trouble. But the trouble is, I think, theoretical, not practical, because I found that, for example, a pier about 4 m. under water can be picked up by echo ranging at 3,000 m. This long range is, however, only obtained if the maximum of the sound beam is turned to the proper direction. The effect of the side lobes does not interfere seriously. What counts is the central maximum of the main beam which is about only ½ or 1 degree. I made the following experiment with the oscillator on our research ship which is pointed 6 degrees downwards. At a depth of about 25 fm. I found a wreck and that wreck was shown on the recorder at a distance of 1,100 m. At a certain distance the target disappeared from the echogram. Considering this distance and the inclination of the oscillator, the water depth at the position of the wreck could be calculated. Furthermore, a calculation can be made to determine how much the tilt of the oscillator must be decreased to bring the central maximum of the main beam clear of the shallow bottom. In this particular case, it was about 2½ degrees.

With the oscillator in the original position (6 degrees downward tilt), echoes from the pier already mentioned could be obtained only at 600 m. and less. But as soon as I altered the position of the oscillator, putting it up 2½ degrees, I could hear the pier at a distance of 3,000 m. and, as I said, it was recorded immediately at the maximum recording range of 2,000 m. With the oscillator at 6 degrees tilt, the wreck disappeared at 250 m. With 2½ degrees tilt, it disappeared at a distance of about 600 to 700 m. Now, the Asdics exhibited at this Congress all have the oscillators in a fixed position, between 0 and about 2 or 5 degrees downwards. With such a fixed oscillator, the varying trim of the ship must lead to variations in the direction of the sound beam. Such variations are particularly to be expected with fishing craft where the trim, for instance, depends on the catch obtained and on the varying load of fuel, water, ice and so on. It should, therefore, be possible to modify the position of the oscillator according to the trim of the ship, and enable the instrument to be turned from 0 to 8 degrees downwards. This flexibility, with the compensation for trim, would enable the oscillator to be used to search for fish not only near the surface but also in greater depth.

Mr. Max Schulte (Germany): Dr. Schärfe has mentioned in his report that horizontal echo ranging for bottom fishing is of little value, and that this fishery must depend on echo-sounding only. I should like to say that, in this statement, an essential factor which plays an important part in the German fishery, has not been taken into consideration. In our trawl fishery the skipper not only wants to see the fish but also to obtain some knowledge of the bottom conditions of the fishing ground. He is particularly interested in wrecks and in rock formations. Here we can say that *Lodar* has given good results by showing the fisherman that he is going to meet an obstacle which may interfere with his trawl.

Mr. de Boer mentioned that to date there was no horizontal echo ranging equipment with variable oscillator tilt, but our *Mini-Lodar* allows the oscillator to tilt anywhere between 0 degrees and 90 degrees.

One of the Congress papers mentions that the side lobes may cause trouble. We do not share this opinion, because in horizontal ranging, the side lobes can give additional information on the depth. The echogram then shows not only the horizontal distance to the target but also the water depth at the ship's position.

Mr. R. G. Haines (U.K.): I would like to refer very briefly to the problem of the correct angle of tilt for the transducer in an echo ranging set. I think Mr. de Boer has slightly oversimplified the problem. After all, the trim of the ship is concerned only when the oscillator is trained ahead; when the oscillator is on the beam it does not matter what the trim is. Also, of course, a fishing vessel at sea is pitching and yawing all the time, which means that any very accurate setting of the tilt will not be so valuable. Furthermore, as is probably well known to you, the horizontal beam in water is liable to be bent because of the temperature, salinity, and pressure of the water. This varies in different areas and different places, so the problem has to be considered from a technical point of view in rather more detail.

Mr. P. A. de Boer (Netherlands): I should like to answer the remarks made by Mr. Schulte from ELAC and Mr. Haines of Kelvin-Hughes about what I said on echo ranging. There is a small Lodar exhibited here in which the oscillator can be tilted in every direction. This is a very useful design, but I had the big Lodar in mind in which the oscillator cannot be so tilted.

Mr. Haines of Kelvin Hughes mentioned the problem of pitching and rolling, which would make useless any attempt at careful directioning of the oscillator and compensating for the ship's trim. My answer is that, as soon as a ship starts pitching and rolling, spot aimed echo ranging becomes impossible. It is restricted to smooth water. But this does not make the method useless. For instance, a ship, without Radar, which is approaching a coast in a thick fog can use Asdic to find the entrance of the harbour.

I am fully aware of the disturbances caused by unwanted bottom echoes, particularly in shallow water. A sandy bottom is often irregularly formed with waves or dunes, and, in my opinion, it is possible with Lodar to distinguish between such sand dunes and, for instance, herring schools near the bottom, because most of the sound reflected at the bottom goes away in another direction while the herring echoes are mainly reflected to the sound source. Thus, a stronger echo is obtained from the herring.

Dr. S. Fahrentholz (Germany): It was stated that horizontal echo ranging is restricted to calm weather. We have developed a special oscillator arrangement fixed to the ship's bottom, and working at a tilt of 4 degrees. I agree that echo ranging in a rough sea and in different depths needs a turnable oscillator, but such equipment, particularly for bigger working ranges, is rather expensive and the ordinary fisherman would not be able to afford it. We think, therefore, that a small and simple set ranging within a few hundred metres of the vessel would be useful too. The set with fixed oscillators we designed, is fit for alternative horizontal or vertical sounding and gives rather good results. This simple equipment is considered as a temporary solution and we hope to find a more suitable but still cheap solution in the future.

In order to improve the representation of bottom fish recording, I decided to use the black line method described in my paper. This can be effected by a specially developed apparatus which can be attached to any existing echo sounder model of my design. The sensitivity of the black line recording can be modified according to the echo strength. Bottom and fish echoes, which are divided by the narrow black line, are both recorded in grey.

With regard to CRT representation, a new device with two tubes is also described in my paper.

Mr. Kiyo Kazu Tsuda (Japan): Echo sounders are widely used in the Japanese fishery. Big fishing boats of more than 500 tons are usually fitted with two or three echo sounders. The frequency usually lies between 15-50 kc. The beam angle is around 30 degrees. Both paper recording and CRT display are used. Besides the normal frequencies, 200 kc. and more are also used and attempts are made to improve determination of the fish species.

Mr. H. S. Noel (U.K.): The tendency so far has been to regard the echo sounder as only an agent to a more general form of fish detection, that is to hydrographical and research generally, but when midwater trawling for sprat it is virtually impossible to catch any quantity of fish without an echo sounder.

You are working in waters where there is a tide running of about 3 knots and the fish, which are in fairly small shoals, cover quite a distance in the course of one tide. Therefore, it is essential to use an echo sounder, firstly to search for the shoal, secondly, to assess its extent, and thirdly to assess its depth, so as to be able to set the net at the requisite depth. This also applies to some degree, of course, to the herring fishery.

Another aspect occurs where one is catching fish for canning and the fish have to be returned to shore in a very fresh condition. Here a number of boats are virtually all working for the cannery, and they are more or less honour-bound to deliver a set quantity of fish day by day in good condition. Here an echo sounder is essential. Old fashioned methods of fishing for this type of fish in midwater depended entirely on indications, often wrong, such as were given by the presence of seabirds and boats were sometimes anchored for three days before fish were caught in sufficient quantity to land. It can be said that the canning industry, which uses most pelagic fish, is dependent on the echo sounder.

Mr. H. Kristjonsson (FAO): At present not enough use is being made of echo sounding by small craft, such as open boats, of the inshore fishery.

It does not appear to be generally known that sounders are available on the market, which could be of great help to this type of fishing. American, German, Japanese and Norwegian firms now produce small echo sounders of which the average dimensions range around 12 in. x 10 in. x 8 in. while the weight, excluding the transducer, is as low as about 20 lbs. The recording unit is usually designed for easy removal after use.

The sets are usually fitted for DC (direct current) power supplies of 6, 12, 24 volt, and the power consumption is around 50 watts.

The width of the (usually dry) recording paper ranges from about 2 to 6 inches. Measuring ranges differ according to manufacture and type. A typical example would be: 0 to 25 fm., 25 to 50 fm., 50 to 75 fm. However, lower and higher ranges are available to suit most needs. The transducer for these small sets can be mounted in different ways, either permanent or movable.

Permanent. The transducer is mounted on the hull inside a cofferdam in the usual manner or at the side of the keel with wooden fairings fore and aft to prevent the formation of bubbles. For removable recording units the connection with the transducer is made with a good quality watertight plug and socket.

Movable. When boats are frequently beached or in other cases where it is advisable to remove the transducer every trip, the transducer can be mounted on the end of a 1½ in. steel pipe which is then clamped to the side of the boat. The length of the pipe should be adjusted so that the transducer is always at least 3 ft. under the surface. The way of attachment depends mainly on the hull of the boat, but it usually can be done either with 2 clamps fitted on the vessel's hull in which the pipe is secured by fly nuts or, for lightly planked boats, with an arm near the top of the pipe which is clamped over the gunwale. With this last method the pipe should be secured in position with fore and aft stays.

In order to avoid aerated water at higher speed which would interfere with the sounding, the transducer is usually fitted in a streamlined container. When properly formed and mounted this side installing of the transducer can give better results in avoiding disturbance by aerated water than the common installation in the ship's bottom.

Captain D. Roberts (U.K.): Echo ranging for fishing, in my opinion, could only be useful for fleet fishing and not for individual vessels, except perhaps one particular case. In the North Sea particularly (I do not fish there but my colleagues do) they are finding fish close to wrecks and the fishing there has been very good at certain seasons during these last two years. But they must fish close to the wrecks. Can the biologists tell me why fish stay around wrecks? If there is a good reason for it, then echo ranging could be very valuable for pin-pointing wrecks. Skippers have pin-pointed the wrecks and incorporated them on their Decca charts. but perhaps this information could be valuable to more people.

Captain A. Hodson (U.K.): In my experience as a skipper in the North Sea I have found that grounds littered with wrecks often provide reasonable catches. As you will know, ships in convoy passed up the east coast of the British Isles and during the war, of course, many were sunk. We know only too well, because we have caught them with our nets, much to our cost in gear and fishing time. With the introduction of the Decca Navigator system individual skippers have made their own charts and, working in collaboration with each other, have covered quite a large part of the area. As regards echo-sounding for wrecks, I can only say it would be a very fine achievement to determine the presence, range, and identification of the wrecks as distinct from other features of the fishing ground. So far, we cannot be certain whether our gear has fouled a wreck or not. As in other areas, we have found that it is coral formations on the seabed that causes considerable damage, expense and loss of time. If the scientists eventually produce an instrument which enables us to determine wrecks and other obstacles, it will be a god-send from the point of view of British trawlers working in the North Sea.

Mr. B. B. Parrish (U.K.): I am very sorry to say that I am in no position to explain why fish accumulate around wrecks, but I do think that it is most important that the observation has been made. There is much confirmation, particularly in underwater films taken in the vicinity of wrecks, of this observation. Fish do appear to accumulate in the vicinity of wrecks, a fact which can be made use of in fishing operations, provided the locality can be accurately determined and is not too littered with wrecks for effective use of the gear. Yesterday we heard two excellent examples of fish location devices used by research vessels, one being thermometers, and the other plankton nets. These devices enabled the scientists to deduct the whereabouts of fish from observations of temperature and plankton. The value to a fisherman of such devices relies very much on an organized survey scheme by research vessels, pooling of information and transmitting it to the fishing fleet. There are devices which can be used by individual fishermen but these, to be workable, must be based on the simplest possible location factor. For instance, it is of no practical value to a fisherman to know that some chemical component of the water denotes the presence of fish if he is unable to estimate the quantity of this chemical in the water, or the process takes too long or it is too expensive.

Captain Roberts has told me that he had detected fish in the Iceland region by the colour of the water and asked me if there was any biological explanation of this. Undoubtedly there is, but I do not know it and, I imagine, biologists would have to conduct very intensive research over a long time to find the actual relationship between water colour and the presence of fish. Biologists naturally would like to know the answer but, so far as practical fishing is concerned, the important fact is the observation that water colour and the presence of fish are related. There is a danger, of course, that the apparent relationship is not valid, but the fishermen are probably much better than scientists in detecting and proving empirically such location factors. I think the biologists and the fishermen would both derive much benefit if there were more contacts and greater exchange of information between them.

Mr. H. Kristjonsson (FAO): I expect there is a question in the minds of many people here, in connection with the very significant advances made in detecting fish close to the bottom by bottom suppression, gating circuits, etc. Now, will it be possible to build these new features into the echo sounders now in use or do the fishermen have to throw out their existing units and buy new ones?

Mr. R. G. Haines (Kelvin Hughes, U.K.): The white-line modification is available for fitting as an optional extra to our full range of fishing echo sounders, including the model MS:24 which has now been superseded. It is also possible to add the white-line modification to earlier models. However, the cost of doing so would hardly be attractive and naturally in such cases, where the sets will have been in use for a number of years, we should recommend replacement with a modern equipment incorporating a number of other improvements in addition to the white-line amplifier.

Dr. H. Kietz (Atlas-Werke, Germany): The answer to the question "Can the grey-black amplifier be built into existing Atlas echo sounders of simpler design?" is yes.

Dr. S. Fahrentholz (for Behm-Echolotfabrik, Germany): Every existing Behm-Echolotfabrik echo sounder can be equipped with the black-line amplifier unit.

Mr. Th. Gerhardsen (Simrad, Norway): Yes, we can supply this extra feature, at a moderate cost, to all our equipment.

Mr. E. C. Bindloss (Marconi, U.K.): The answer is yes, but I would like to bring out one point: in order to show up bottom fish it has become apparent that very much greater transmitting power is required than that used by echo sounders up to two or three years ago. I think all makers agree that this is the key to the question. More powerful transmitters can be provided, of course, and are being provided with new gear, so, with that provision, my answer is yes.

Mr. J. Jakobsson (Iceland): The reason why the location and detection of fish has become so increasingly important is, I think, because the fishing fleets are growing bigger and the ships are costing more to build and operate. It has become very important that they should work in the most profitable areas. No matter how effective fish detection devices may be, I am quite convinced that no fishing skipper would have the time to make a complete survey over the whole fishable area to make sure of finding the best and most profitable sector. My experience in leading 200 herring boats convinces me that a man who continuously cruises the whole area and surveys it thoroughly, using the optimal devices provided on a research ship, will be better able to direct a fleet to more profitable grounds than the skipper who is occupied with the actual fishing. I am quite certain that it is very effective and very profitable to organise fish searching in this way.

Mr. D. L. Alverson (U.S.A.): I thought perhaps you might be interested in some of the experiments and statistical evaluations that we have carried out on various electronic gear, including fish finding devices. The population dynamics of fish are important to us and we are interested in any changes that various gears may cause in efficiency of fishing, fishing power, or measures of availability. For the past 5 years we have watched closely the introduction of devices into our trawl fisheries and recently we made a statistical evaluation of how these devices were affecting our fishery. I will not go into the methods and techniques used because they are very complicated. The results are to be regarded as of relative rather than absolute quantitative character. The devices we covered included Radar, Loran and the various fish finders, particularly the Cathode Ray Tube display which expands the trace above the bottom. It appeared that, as regards the fish-finder, we could not demonstrate statistically any change in efficiency of catching flat fish on the Pacific coast in the Washington trawl fishery. There was only some indication that we were approaching statistical significance with some of the round fish as, for instance, ocean perch and some of the codfish. It may be of some interest that the Loran, in almost every instance, did show a significant increase in efficiency aboard the vessel, which suggests that, for the trawler in this locality, maintaining precise position is the most important factor.

The same proved to be true for Radar but only for boats working inshore, inside of the Hekart Strait in the British Colombia waters, where they use Radar for positioning themselves. But no significant difference could be found for the same boats in their offshore operations. So we had two checks and both seemed to indicate that positioning was of utmost importance for trawling. This conclusion, of course, must not necessarily be true for other regions where the fish may behave differently and where different conditions exist.

Prof. Miroslav Zei (Yugoslavia): As you probably know, fishing off the Yugoslavian coast of the Adriatic Sea is mainly concerned with small pelagic species, such as pilchards, anchovies, mackerel. It is mainly a seine fishery combined with fish attraction by artificial light. Usually two or three light boats, belonging to one owner, operate near each other. As soon as enough fish have been attracted under each boat, they come together and collect the fish under one boat only. Before the introduction of echo sounders, this method presented no problems. Then a Simrad echo sounder was introduced and led to the discovery that most of the fish disappeared when the three boats came together. Thus it seems more efficient for the boats to catch the fish separately, although this, of course, takes much more time. The question now to be answered is: why is it that the fish do not stay together under the one boat? This lack of tolerance between the different schools might be caused by inequality in behaviour.

But this is only a vague suggestion. A satisfactory explanation has not yet been found. I think that a combined horizontal and vertical echo sounder could be of great help in solving this and many other biological problems about the behaviour of fish, and it is important for the future development of fishing that we should know the answers.

Dr. J. Schärfe (FAO): Echo sounders could probably be used effectively in connection with light fishing, for instance in the Mediterranean, both to find fish concentrations for optimal placing of the light boats and for observing the gathering of fish under the light to determine the proper timing of catching operations.

Dr. D. H. Cushing (U.K.): As a fisheries biologist I am interested only in certain biological problems concerned with fish populations and to understand how they are distributed. Therefore, I am interested in echo sounding as a means to describing their distribution in the sea, to count the fish and, possibly, identify them. By identifying them I do not mean establishing the species, but getting an idea of the size ranges. We already know that, when single fish are being recorded, a big fish gives a stronger and more extensive signal so, in certain circumstances, you can say there are a lot of big fish or a lot of little fish present. Similarly, you could determine from a paper record that this school is a large one or a small one and, I think, this line of thought and approach may eventually lead us towards getting some idea of the sizes of fish in the sea. We are already progressing towards counting the fish in the sea, which has obvious uses for fishery biologists and, I think, for the fishermen too, because they are interested in knowing how many fish there are present before they start catching operations. They are also interested in finding out how the fish are distributed. This is how, in several ways, the interests of the fishery biologist coincide with those of the fishermen.

SUMMARY OF EXPERIMENTS ON THE RESPONSE OF TUNA TO STIMULI

by

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Abstract

The aim of the experiments described in this paper was to obtain information which might lead to improved methods of tuna fishing, and especially in finding a substitute for baitfish. In a series of tank experiments, it was found that yellowfin and little tunny responded to white light of moderate intensity but not to a weak light. Their reactions to chemical stimuli were also observed and a positive response was obtained by using clear aqueous or alcohol extracts of tuna flesh. They were repelled, however, by copper acetate—the shark repellent. The possibility of electrofishing for surface tuna was investigated and since it was demonstrated that electrotaxis could be induced in tuna with an electric field of known characteristics, the problem becomes one of electrical engineering rather than of biology.

Résumé des expériences relatives à la réaction du thon aux stimuli

Résumé

Les expériences décrites dans cet article avaient pour but de recueillir des renseignements susceptibles de conduire à l'amélioration des méthodes de pêche au thon, et plus particulièrement de trouver le moyen de remplacer l'appât vivant. An cours d'une série d'essais en bassin, on a observé que les thons à nageoires jaunes et les "little tunny" (*Euthynnus yaito*) réagissaient à une lumière blanche d'intensité modérée mais non à une lumière faible. On a également observé leur comportement aux stimuli chimiques et l'on a obtenu une réaction positive par l'emploi d'extraits aqueux ou alcooliques de chair de thon. Toutefois, l'acétate de cuivre, utilisé pour écarter les requins, les a éloignés. La possibilité de pêcher les thons de surface à l'électricité a été étudiée. et comme il a été démontré que l'on pouvait provoquer l'électrotaxie chez le thon au moyen d'un champ électrique de caractéristiques connues, le problème relève plus de la technique de l'électricité que de la biologie.

Resumen de los experimentos sobre la reacción del atún a los estímulos

Extracto

Los experimentos descritos en este trabajo tuvieron por objeto reunir información para encontrar métodos mejorados de pesca de atún y, especialmente, un sustitutivó del cebo vivo. En una serie de experimentos en estanques se encontró que el atún de aleta amarilla y el atunito reaccionaban bien a la luz blanca de intensidad moderada pero no así a una débil. Además se observó el efecto de las substancias químicas lográndose una reacción al usar extractos acuosos o alcohólicos transparentes de carne de atún. Sin embargo los peces se alejaron al utilizar acetato de cobre que se utiliza para repeler a los tiburones. También se investigó la posibilidad de emplear la electricidad para la captura de los peces que nadan en la superficie, demostrándose que es posible producir la electrotaxia en el atún mediante un campo eléctrico de características conocidas, pero este problema cae más bien dentro del terreno de la ingenieria eléctrica que de la biología.

DURING the period 1951 and 1956, several staff members of the University of Hawaii conducted experiments, under contract with the Pacific Oceanic Fishery Investigations (POFI) of the U.S. Fish and Wildlife Service, on the response of tuna to various types of stimuli. The writer was leader of several of these projects prior to joining the Service in 1955. This is a brief summary of the work to date.

The primary objective of the study was to obtain information which might suggest new or improved methods of tuna fishing. Efforts were directed particularly at devising a substitute for baitfish, the scarcity and high mortality of which limits the catch of surface tuna in Hawaii and prevents the expansion of the live-bait fishery to potentially productive offshore areas.

ESTABLISHING TUNA IN CAPTIVITY

Methods of fishing, transporting and establishing tuna in captivity are described by Tester[6]. Several species of tuna and tuna-like fish were caught by surface trolling off the windward shore of Oahu, including the skipjack (*Katsuwonus pelamis*), yellowfin (*Neothunnus macropterus*), and little tunny (*Euthynnus yaito*). Immediately after capture, fish were placed in the vessel's livewell (67½ × 43 × 32 in.), which was supplied with running sea water (20 to 40 gallons/min.) but which, in addition, was aerated with finely-divided bubbles of oxygen from a pressure tank. They were then transported to ponds and tanks at the Hawaii Marine Laboratory (1 to 2 hours run), to which they were transferred by dipnet. Yellowfin (about 2 to 8 lb. in weight) and little tunny (about 1 to 6 lb. in weight) were successfully established in one of the large ponds (350 ft. long, 65 ft. wide and averaging about 6 ft. deep) which was flushed by tidal currents. Yellowfin and little tunny were also maintained in a concrete tank (35 ft. long, 11 ft. wide and 4 ft. deep) which was supplied with running salt water (about 25 gallons/min.). Skipjack were not successfully established;

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of numerous trials only one fish was transported alive from the fishing grounds to the laboratory and it died shortly after being released into the tank.

Except when on an experimental diet, the little tunny and yellowfin were fed cut-up fish, usually small tuna which died during our fishing operations or large tuna from POFI longline catches. The tunas generally started to feed within a week of introduction; otherwise they would die. When feeding fish were already present in the pond or tank, newly introduced fish would usually join the school and start to feed within one or two days.

The established (feeding) tuna survived for various lengths of time, ranging from but a few days to over 2 years. Some loss occurred from extraneous factors such as poaching or accidental stranding of the fish on dry land. Several of the fish developed partial or complete blindness and died either from starvation or injury. Others eventually became "sick", they moved slowly, listlessly and individually, ceasing to feed and eventually dying. Mortality occurred mostly during the fall and winter, and perhaps was associated with lowered temperature and salinity in the inshore environment.

Yellowfin, both in the live well of the boat and in the pond and tank, were relatively slow, leisurely swimmers. When two fish were present, they usually swam together. When several were present, they formed a loose school but often swam individually or in two's or three's. In contrast, the little tunny were rapid swimmers and usually formed a single, compact school. On occasions, when a large population (15 to 30 fish) was present in the pond, they formed two schools, but rarely more.

More detailed observations on the captive fish are included in the papers summarized below.

RESPONSE TO VISUAL STIMULI

During the summer of 1951, Hsiao[1] studied the response of two yellowfin and five little tunny to artificial light. The fish were confined in the concrete tank. The experiments were performed after dark, with the tank illuminated constantly with two 60 W. bulbs. He found that both yellowfin and little tunny were attracted to continuous white light over a range of moderate intensity (about 70 to 450 ft. candles). They were not attracted by a light of weaker intensity, and they were repelled by a light of stronger intensity. Both species were attracted to coloured lights of moderate intensity, but to no greater extent than to white light. Similar results were obtained with interrupted white light. There appeared to be no relationship between the strength of the response and the frequency of interruption of the light. Although the tuna approached an interrupted light of moderate intensity, they were repelled from the near vicinity at the instant the light flashed either on or off.

The above experiments suggest that tuna at sea might respond to continuous light of moderate intensity. To my knowledge, however, only tuna larvae and young have been caught by this method. If adults in their natural habitat were attracted by light, it seems likely that this already would have been discovered and utilized by tuna fishermen.

The response of a school of 12 captive little tunny to moving objects of various colours in the large pond was studied by Hsiao and Tester[2] during the summer of 1952. During daylight hours, a pair of lures was momentarily dipped into an "attraction" area once every 2 sec. by a remote control from a high tower. The lures consisted of 2 in. sections of rubber tubing of various colours. The number of "fish-seconds" in the area, the number of "passes" at the lures, and the time were recorded on a kymograph. Observations were made under control conditions, when lures were introduced, and when lures were used along with an extract of tuna flesh (see later) which was introduced into the pond from one end. Activity of the fish (number of school entrances, time spent in the area, and swimming speed) was greater when lures were used, as compared with control conditions, and was still greater when lures and extract were used together. Although, in general, the fish made more passes at white than at coloured lures (red, black, silver), the superiority of the white lures was slight. It may have been associated with greater visibility rather than colour preference. There is no assurance that white lures would be superior to coloured lures in the open ocean. Trolling data collected during 1951 and 1953 (Tester and Nakamura[9]) show no preference by the tuna with respect to either form or colour of the lure.

The above experiments deal with only one aspect of visual response, namely lure preference. Specific pond experiments on visual acuity were not undertaken. Casual observations indicated, however, that both yellowfin and little tunny could perceive objects such as stones or pieces of food which were thrown to them while the objects were still in the air. The fish would speed rapidly toward the point where such objects would hit the water. If the objects were not thrown so that the fish could see them in transit, the tuna could be attracted either by the splash made when the object hit the water, or perhaps by the object itself over a distance of about 50 ft.

In view of the conclusion (see later) that visual perception was of prime importance in attracting tuna to the stern of a fishing boat by the use of livebait, Matthews[3,4] studied the comparative morphology of tuna eyes, during 1955-56, using species of diverse habits and habitats (skipjack, yellowfin, and bigeye). No significant differences were observed. In addition, he conducted experiments to determine the focal length of the lens and other optical properties of the excised eyes of freshly-killed tuna immersed in a long salt trough, viewing a light source through a "window" in the chorion of the vitreous chamber, but with confusing results (unpublished). Contract work in 1956-57 was devoted to a study of the comparative histology of the retina in skipjack, yellowfin, bigeye, and albacore, including observations on the frequency and arrangement of the rod-cone mosaics. Preliminary results[3,6] indicate a relatively large number of rods in the retina of the albacore, suggesting relatively greater adaptation to dim light than with the other three species.

RESPONSE TO AUDITORY STIMULI

Miyake[4] conducted experiments with captive yellowfin and little tunny during 1951-52 to discover (1) if tuna produced any sound and (2) if they could be attracted or repelled by sounds of various frequencies. Using a listening frequency ranging from about 0·1 to 70 kc., he was able to identify low frequency sounds produced by the sudden movement of the tail of the yellowfin in the tank. This might have some significance with respect to the mechanism of school formation. No sounds produced by tuna were detected at listening frequencies in the moderate, high, or supersonic range. In attempting to attract or repel tuna by continuous sound stimulation in the pond, sounds were emitted at many frequencies from 0·1 to 70 kc. Although the results were inconclusive, there were indications that yellowfin might be attracted by complex sounds of low frequency.

RESPONSE TO CHEMICAL STIMULI

Van Weel[12] studied chemoreception in both yellowfin and little tunny in the concrete tank during 1951. He found that both fish had a well-developed sense of smell or taste whereby they were attracted to certain food substances. They were strongly attracted to clear, colourless extracts of tuna flesh. Moreover, it was found that the attractant was contained in the *protein* rather than in the *fat* fraction of the clear extract. In general, the response of the little tunny was more pronounced than that of the yellowfin. On the other hand, there was no positive response of either species to *conditioned* water in which baitfish had been living, nor to extracts of either baitfish or squid. Copper acetate, a shark repellent, was also repellent to tuna, although its effect was not as pronounced as on fish of other species which were also present in the tank.

The above study was continued in 1952-53 by Tester, Van Weel, and Naughton[10]. In the tank, improvements were made in the techniques of observation, introduction of test material, and measurement of the response. Testing was hampered by accumulation of test materials because of the small volume of water in the tank and its slow replacement. This problem was reduced by conducting tests on tuna established in the large pond, introducing test material through a continuous stream of water supplied at one end of the pond by a pump, and observing the response of the fish from a 20 ft. tower, which overlooked an "attraction" area extending from about 40 to about 80 ft. below the outlet. Pond testing was hampered by such factors as poor visibility due to weather, power failure, and erratic behaviour of the fish.

The results confirmed Van Weel's[12] observations that a positive response was obtained from clear, aqueous or alcohol extracts of tuna flesh. This took the form of a feeding reaction and included one or more of the following components: speeding or acceleration of the swimming rate, a return to the area of stimulation, surfacing, fanning-out and eventually a breakdown of school formation, circling, splashing, and biting at incidental objects on the surface of the water. It was postulated that an attractant was present in the flesh, viscera and blood of several species of tuna and certain other fish. Successful methods of concentration and preservation of this substance were achieved in preparation for large-scale sea-testing. Considerable time was devoted to its fractionation, purification, and identification.

In addition some 40 chemical compounds were tested, including amino acids, vitamins, aromatics, proteins, etc. With some of these there seemed to be a sensing of the dissolved or suspended materials but in no case did the response include all the typical components of a feeding reaction induced by fish extract.

The conditioning of the tuna was discussed with respect to their response to fish extract. Obviously they had become conditioned to feeding on inert, dead rather than motile, living food for they had little interest in schools of small baitfish which at times were present in the pond in fair abundance and which would leisurely withdraw as the tuna approached. Obviously, also, they had become conditioned to being fed for they would mill close to an observer on his approach to the pond. It was concluded that the response of the tuna was not directly conditioned by the kind of food, i.e. the species of fish used as food. However, there was the possibility that the tuna formed an association between feeding and the smell or taste of the dead food, which was cut up or otherwise macerated and which might exude juices of similar composition. If so, the response would not necessarily be obtained from wild fish at sea.

Tester, Yuen and Takata[11] reported on further experiments with little tunny in the pond and with skipjack schools at sea. Pond experiments were improved by introducing test substances into a continuous stream of water which flowed directly into the attraction area at the foot of the observation tower. Continued screening of some 75 known compounds indicated a mere "sensing" of strong smelling materials. A carefully designed experiment involving feeding the fish at successive weekly intervals with cut-up squid, skipjack, and shrimp and testing their response to extracts of these same substances was conducted. A response to all three extracts was obtained regardless of the food being fed, but the response to a particular extract was slightly greater when the substance from which it was prepared was being used as food. This experiment tended to confirm the suspicion voiced earlier that the fish were conditioned to the smell of juices exuded from the food which presumably contained common or similar substances which stimulated the feeding response. It was hoped that, even so, tuna in their natural environment would respond to the extract, which might contain a substance exuded by living, injured, or uninjured prey to which "wild" fish were naturally conditioned. This hope was not realized.

Large quantities of extracts of skipjack, yellowfin, and anchovy were prepared during the winter, spring, and summer of 1953, tested on the captive little tunny and presented to schools of skipjack at sea. In a few instances the schools consisted mostly of skipjack but included yellowfin, little tunny, or frigate mackerel. In some tests the concentrated liquid extract was sprayed on the surface or pumped in a stream in the path of the schools. In others, it was presented to schools which had been *chummed** to the stern of the vessel by livebait (*Stolephorus purpureus*). The results were either negative or inconclusive. Unchummed schools could not be stopped by an arc or circle of extract. Chummed schools could not be held at the stern even when the extract was

Chum*—live or chopped fish used as a lure.

bucketed overboard. In a few tests, on releasing a large quantity of the extract after the school had been chummed to the stern and chumming was stopped, a few fish were seen jumping in or passing through the material. It was uncertain whether they were responding to the extract or chasing stray baitfish. The apparently negative results discouraged any further testing of extracts except in conjunction with lures as reported below.

RESPONSE TO EDIBLE AND INEDIBLE LURES

Tester, Yuen, and Takata[11] describe pond tests with edible lures, and sea trials with both edible and inedible lures. The pond tests showed that little tunny would eat edible preparations such as gelatin capsules, pieces of macaroni, and strips of agar gelatin, and that these were more avidly consumed it they were made chemically attractive, or palatable, with concentrated extracts of skipjack or anchovy. In some cases, also, the feeding response seemed to be greater if the lures were made more visually attractive, i.e., silvery in colour. The fish showed a distinct preference for the agar preparations.

Again, the results of sea tests of edible lures were negative. However, they were conducted during the autumn when skipjack schools were scarce and erratic in their behaviour. Several of the schools which failed to respond to our most promising preparation (agar strips impregnated with concentrated extract and with aluminum powder) also failed to respond to livebait.

Several types of inedible lures were tested at sea. These were used as chum both alone and along with liquid extract after the fish had been initially chummed to the stern of the ship with baitfish. There was a momentary response to shiny objects such as strips of tin (several of which were eaten), to silvery objects such as squares of aluminum foil, and to effervescing objects such as calcium carbide pellets. Similarly there was a momentary response to dead baitfish. The addition of extract had no apparent effect. The results indicated that the sense of vision plays a much greater role in feeding than the sense of smell. However, neither the visual lures nor a "drag-lure array" (designed to simulate a school of baitfish) towed behind the vessel, was successful in holding the fish at the stern.

On the hypothesis that motion was an essential component in visual attraction, attempts were made (unpublished) to devise an expendable, self-propelled motile lure which would simulate baitfish movement, and which would be made both visually and chemically attractive. Many types of "motors" (mostly generating air or gas) were devised, but none was satisfactory. A compressed-air "machine gun" was designed to project and at the same time activate compressed air cartridges. Following an unsuccessful sea trial, hampered by imperfections in the machine and poor behaviour of the released cartridges, this idea was abandoned.

RESPONSE TO ELECTRICAL STIMULI

Before conducting experiments on the response of tuna to electrical stimuli, it was considered best to obtain pertinent basic data on a more readily available marine species which could be easily kept in captivity. During 1951, Tester[7] studied the response of aholehole (*Kuhlia sandvicensis*) to interrupted direct current using a D.C. generator and various types of mechanical interrupters. In a small salt water tank (12 × 2 × 1 ft.) the fish were forced to swim to the positive electrode when subjected to suitable combinations of current and frequency of interruption. The results indicated that, at a frequency of 15 cycles a progressive saving of power could be obtained by reducing the "current-on" fraction of a cycle from about 0·7 to 0·1. Power conservation, of course, is an important consideration in the practicality of marine electrofishing.

The above results were confirmed and extended by Miyake and Steiger[5] in further experiments with aholehole during 1954 and 1955, using storage batteries as the source of power. They concluded that the optimum frequency for electrotaxis was 10 cycles and that the minimum peak current for satisfactory response (12 amp) was associated with an "on-fraction" of 0·06 to 0·08. Total peak current requirements decreased with increase in length of the fish extrapolating the above results, they concluded that a current of 130 amp. at a potential of 60 V. would be required to induce electrotaxis in a fish the size of a small tuna (30 cm.) using plane 11 × 4 ft. electrodes spaced a distance of 33 ft. This was best achieved by condenser discharge. Accordingly an apparatus was constructed for experiments with tuna and other large fish in the concrete tank. It consisted of a bank of capacitors (55,000 mfd.) charged by any number up to 10 pairs of automobile storage batteries arranged in series parallel. The charging and discharging of the capacitors was controlled by a variable speed mechanical contactor.

With electrodes spaced at 33 ft. perfect electrotaxic response was obtained with a jack (*Carynx sp.*), using 60 V. (2 banks of 10 batteries) at 10 cycles. However, with little tunny and yellowfin the results were either inconclusive or negative. By spacing the electrodes a distance of 16 ft., thus increasing the electric field, an excellent electrotaxic response was repeatedly obtained with yellowfin tuna (about 50 cm. in length). The results showed that power requirements decreased (10 to 6 pairs of batteries) as the frequency increased to 20 cycles, the limit of the apparatus. Theoretical calculations indicated that 23 times as much power would be dissipated in the open sea as in the closed tank and that a correspondingly higher power output would be required to effect electrotaxis with the same electrode spacing and frequencies

In the same report, Miyake and Steiger[5] presented theoretical studies of the potential, electric field, and current density for spherical electrodes submerged in a large body of water. They also investigated the theoretical relation ship between the head-to-tail potential and current density in a fish as determined by the relative conductivities of the fish and water.

Following the 1954-55 results, reported above, the possibilities of utilizing an amplidyne to generate a pulsed direct current of satisfactory strength, waveform, and frequency for inducing electrotaxis were investigated in the laboratory with promising results (unpublished). Unfortunately continuation of the contract work has not been possible because the contractors have assumed other responsibilities.

DISCUSSION

Despite the large amount of information which has been obtained on the response of both captive and wild tuna to stimuli of various kinds, little progress has been made toward attaining the main objective. This was to devise a method of catching surface tuna, which was independent of the use of livebait.

It was realised at the outset that our approach was largely "trial and error" and that the probability of success was small. It was also realized that results obtained on captive fish, conditioned to pond life, might not be capable of extrapolation to wild fish of the open sea. Nevertheless, the approach seemed worthwhile in providing leads which might be tested by sea trials.

The pond tests demonstrated that the active little tunny and the less active yellowfin both have a keen sense of smell (or taste), together with excellent vision both through water and, with a calm surface, through air. The sea tests indicated that the sense of smell plays little, if any, part in natural feeding, although this is still an open question (a) because of the difficulty in making observations on the response of fish at sea, and (b) because the materials tested may not have included those which might be associated with living prey. These studies might well be repeated or perhaps extended in view of our recent discovery of a natural laboratory, a spot or "concourse" in the lee of an island where skipjack are always present and where their behaviour and response may be readily observed by underwater viewing devices which are presently being perfected.

Sea tests further indicated that vision played an important, and perhaps a dominating part in natural feeding and that motility of a lure, whether living or dead, whether edible or inedible, was an important attribute. These observations, also, can be repeated and extended at the skipjack concourse.

Although most of our pond observations were made on little tunny and, to a lesser extent, on yellowfin, our sea tests were conducted mostly on schools of skipjack. This again leaves an element of uncertainty in drawing conclusions regarding the negative results of sea tests.

The response of tuna to auditory stimuli was not adequately investigated; this work was abandoned in favour of the more promising fields of chemical and electrical stimulation.

The possibility of electrofishing for surface tuna, either with or without the use of bait, remains a promising area of study. Now that it has been demonstrated that electrotaxis may be induced in tuna with an electric field of known characteristics, the problem is one of engineering rather than biology.

Future efforts to devise new or improved methods of tuna fishing will be enhanced by further studies of the behaviour of tuna and their response to factors of the environment. Behaviour studies are rapidly becoming one of the major areas of research of the Pacific Oceanic Fishery Investigations and will occupy more and more of our attention in the years to come.

REFERENCES

[1] Hsiao, Sidney C. Reaction of tuna to stimuli—1951. Part III. Observations on the reaction of tuna to artificial light. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 91, pp. 36-58. 1952.

[2] Hsiao, Sidney C. and Tester, Albert L. Reaction of tuna to stimuli—1952-53. Part 2. Response of tuna to visual-chemical stimuli. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 130, pp. 63-76. 1955.

[3] Matthews, Donald C. MS. (a) A comparative morphological study of tuna eyes. MS. (b) A comparative histological study of tuna retinae.

[4] Miyake, Iwao. Reaction of tuna to stimuli—1951. Part IV. Observations on sound production and response in tuna. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 91, pp. 59-68. 1952.

[5] Miyake, Iwao and Steiger, Walter R. The response of tuna and other fish to electrical stimuli. U.S. Fish and Wildlife Service. Spec. Sci. Rept.—Fish. No. 223 (in print). 1957.

[6] Tester, Albert L. Establishing tuna and other pelagic fishes in ponds and tanks, U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 71, 33 p. 1952a.

[7] Tester, Albert L. Reaction of tuna to stimuli—1951. Part I. Background and summary of results. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 91, pp. 1-7. 1952b.

[8] Tester, Albert L. Reaction of tuna to stimuli—1951. Part V. Notes on the response of a tropical fish (*Kuhlia sandvicensis*) to interrupted direct current. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 91, pp. 69-83. 1952c.

[9] Tester, Albert L. and Nakamura, Eugene L. Catch rate, size, sex, and food of tunas and other pelagic fish taken by trolling off Oahu, Hawaii, 1951-1955. U.S. Fish and Wildlife Service, Sp. Sci. Rept.—Fish. No. 250, 1957.

[10] Tester, Albert L., Van Weel, P. B. and Naughton, John J. Reaction of tuna to stimuli—1952-53. Part I. Response of tuna to chemical stimuli. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 130, pp. 1-62. 1955.

[11] Tester, Albert L., Yuen, Heeny and Takata, Michio. Reaction of tuna to stimuli, 1953, U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 134, pp. 33. 1954.

[12] Weel, Van P. B. Reaction of tuna to stimuli—1951. Part II. Observations on the chemoreception of tuna. U.S. Fish and Wildlife Service, Spec. Sci. Rept.—Fish. No. 91, pp. 8-35. 1952.

FUNDAMENTAL STUDIES ON THE VISUAL SENSE IN FISH

by

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Abstract

This paper deals with the efficiency of the fish's visual sense. The direction of its optical axis and its angle of vision and certain facts concerning this subject are given.

The author describes the anatomy of the various optical systems of different fish and shows how different visual axes are associated with different modes of living. Interesting experiments on the ability to see cotton and nylon threads were carried out, and the fish's reaction to bait was studied. For instance, there must be movement before the fish is interested, and while a fish can probably see its prey at some distance, it is the motion of the water produced by the bait which makes the fish snap at it.

Etudes fondamentales sur le sens visuel des poissons

Résumé

Cette étude traite de l'efficacité du sens visuel des poissons. L'auteur indique, l'axe optique et l'angle de vision des poissons ainsi que certains faits relatifs à cette question.

L'auteur décrit l'anatomie des systèmes optiques de différents poissons et montre comment les axes visuels différents se trouvent associés à des modes d'existence également différents. Des expériences intéressantes ont été effectuées sur l'aptitude du poisson à voir les fils de coton et de nylon et la réaction du poisson à l'appât a été étudiée. Il faut par exemple qu'il y ait mouvement pour intéresser le poisson, et si celui-ci peut probablement apercevoir sa proie à une certaine distance c'est le mouvement de l'eau engendré par l'appât qui fait que le poisson se précipite pour l'avaler.

Estudios fundamentales sobre el sentido de la vista en los peces

Extracto

Este trabajo trata de la eficiencia de la vista de los peces y da la dirección del eje óptico y el ángulo visual; además trata de diversos asuntos relacionados con la materia.

El autor describe la anatomía de los órganos de la vista de varias especies y da a conocer las diferencias de sus ejes ópticos con sus diferentes maneras de vida. Se han hecho interesantes experimentos para determinar si los peces ven los hilos de algodón o nylón y la manera en que reaccionan con los diversos tipos de cebo. Por ejemplo, si bien pueden probablemente ver su presa a cierta distancia, el cebo debe mover el agua delante de ellos para que despierte su interés y lo atrapen.

FORM PERCEPTION

ABILITY to perceive form depends on two factors: the resolving power of the dioptric system, and the resolving power of the retina. The first is a function of both the resolving power of the lens and accommodation. The second presumably depends on the spacing of cones in the retina. The direction along which the visual acuity is highest is considered to be the direction of the visual axis of the fish.

Resolving power of lens and retina

In fish, the cornea and the vitreous humour are not responsible for image formation. The crystalline lens is the only dioptric element of the eye involved in image formation. The resolving power of crystalline lenses over approximately 5 mm. in diameter was found to range from 54 to 90 seconds of arc.

The cone density varies with different species and also with regions of the retina. The retinae of all the fish examined were therefore studied topographically. Each retina was divided into seven regions: temporal, dorso-temporal, ventro-temporal, dorsal, nasal, ventral and bottom. The cone density of each region was measured from photomicrographs.

The fish were divided into three groups according to the retinal region where the cone density is highest: i.e., dorso-temporal (*Sparus hasta*, etc.); temporal (*Epinenphelus septemfasciatus*, etc.); ventro-temporal (*Trachurus japonicus*, etc.).

The minimum separable angle was calculated on the assumption that image lines can only be resolved when they fall on cones separated by at least one unstimulated cone. The calculated angle, which varies from 4·2 min. of arc in *Epinephelus septemfasciatus* to 15·4 min. in *Chlorophthalmus albatrossis*, is obviously more than the resolving power of the lens. It may be concluded, therefore, that the resolving power is a function of the retina rather than of the lens.

Accommodation and visual axis

Beer[1], in his thorough investigation of accommodation in the fish's eye, showed that fish eyes are myopic in the resting state, and that accommodation to distant objects is accomplished by retraction of the lens towards the retina. Retraction is effected by the *musculus retractor lentis* (Campanula Halleri).

The method of measuring accommodation used by Tamura[7] differed somewhat from Beer's, and produced additional information.

All the eyes examined in fish immovably fixed in sea water between two pieces of rubber sponge (called "pre-treatment"), were either emmetropic or hypermetropic, but became myopic in certain directions when atropine or curare was injected or when the optic nerve was sectioned ("post-treatment"). The results of these refraction measurements are not directly comparable with Beer's. In Tamura's report the pre-treatment state is assumed to be the resting state of the eye, whereas Beer assumed the resting state to be that produced when curare or atropine was injected. Whether fish eyes are myopic, emmetropic or hypermetropic in the true resting state in nature is an important problem for future research.

Further, the degree of myopia obtained by Beer does not necessarily reflect the highest myopia of the fish, because he consistently measured refraction along one line only, i.e., a line passing through the centre of the lens to a point near the *scotema*. In Tamura's experiments, refraction was measured from six points in the visual field: fore, upper-fore, lower-fore, upper, lower, and lateral. In most cases, the fore and upper-fore or lower-fore fell within the binocular field.

Beer's values of myopia ranged from -3 to -10 diopters, and -12 in one extreme case (mean $-$ 6·1), while Tamura's values ranged from -10 to -25 diopters (mean -14).

For experiments on the direction of accommodation, Tamura divided the fish into three groups: accommodation performed along the lower-fore, the fore, and the upper-fore directions. These directions are usually served by the retinal region of highest cone density and coincide with the visual axes.

The relative positions of the *ligamentum suspensorium* and *retractor lentis* in relation to the lens offer another means of estimating the direction of accommodation, namely the visual axis. Fish having lower-fore visual axes have the ligament attachment on the naso-dorsal surface of the lens, and the muscle attachment on the ventro-temporal surface of the lens. Contraction of the muscle would move the lens up and back towards the dorso-temporal region of the retina. Similarly, fish having the fore visual axes have the ligament attached dorso-temporally and the muscle attached ventronasally, indicating less movement along the upper-fore axis.

The ecological significance of different visual axes is evident when one considers the feeding behaviour of the various fish examined.

Pagrosomus, *Sparus*, *Evynnis*, *Leiognathus* and *Xerusus*, which have lower-fore visual axes, are bottom feeders.

Epinephelus, *Sebastiscus*, *Helicolenus* and *Pseudoblennius*, which have somewhat conspicuous *areae laterales* and fore visual axes, tended to take food in front of them. These are fish which live amongst rocks and seaweed, where they attack the small animals as they swim by. The eyes have considerable scope of movement and are often focused simultaneously on an object directly ahead, indicating the importance of binocular vision.

Lateolabrax, *Trachurus* and *Priacanthus*, judged to have upper-fore axes, tended to take food ahead and above them. This was particularly true for *Priacanthus*, which ordinarily ignored static food, unless it was in the upper-fore or upper portion of the visual field.

The entire monocular field, usually about 180 deg., is, however, quite important to all fish. Peripheral perception of movement, for which high acuity is not essential, facilitates their detection of both prey and predator over the entire visual field. An instance of this movement perception in *Lateolabrax japonicus* is given below. So as to face an interesting object which is first perceived by its movement, the fish bends or turns its head and body and keeps it in the visual axis which is, in general, included in the binocular field. It is then that the clear form perception, for which the accommodation and the acute image are indispensable, begins to play an important part in discerning the object.

The binocular field tends to be broadest in the direction of the visual axis.

SOME ASPECTS OF THE VISION OF FISH

Diameter of nylon twine that fish can recognize

The recognition of nylon twines by fish was investigated by means of fish training experiments.

Young *Sparus aries* and *S. swinhonis* body length about 3 cm., and fed previously on fresh but dead *Ami* (*Neomysis japonicus*), were used as test fish. Two kinds of nylon monofilament, respectively 0·42 mm. and 0·14 mm. in diameter, were tested.

A round tank (45 cm. dia.), having a white inside surface, was filled with sea water. Two white dishes 3 cm. high were placed in the tank. A 30 cm. wire pole was fastened to the side of each white dish and a white cotton twine was hung from one of the poles into the dish (Dt). The bait, *Ami*, was put in each dish. Five fish were then placed in the tank. The fish selecting the dish (Dt) with the cotton twine were driven away by a small bamboo stick. The fish entering the dish (Do) without the twine were allowed to eat the bait.

Training was repeated many times a day, and the positions of Dt and Do were constantly changed. After about two days' training, most of the fish learned to avoid the dish with the twine.

Of the five fish, the one which seemed to learn the most was subject to still further training. When the fish decided to select the dish Dt, punishment was inflicted by a series of electric shocks produced by electrodes placed in the tank. This training was performed under the dispersed light in the room.

When the training was considered to be complete, nylon monofilament was substituted for the cotton twine, and the results were recorded. During this period no punishment was inflicted even though the fish selected the dish with the nylon.

The results are clearly shown in Tables I and II. The thick nylon monofilament (0·42 mm. dia.) was almost always avoided but the thin one (0·14 mm. dia.) was not. It could not, however, be concluded that the thin filament was not recognized by the fish.

In order to see whether fish could recognize the thinner twine *S. swinhonis* were trained to avoid the thinner nylon instead of the cotton twine. The results are given in Table III, which shows that fish have the ability to perceive a thin nylon monofilament.

Fish which were trained to avoid the cotton twine also avoided the thicker nylon (0·42 mm. dia.) but tended not to avoid the thinner one (0·14 mm.); they did, however, have the ability to perceive the thinner nylon.

Food searching of *Lateolabrax japonicus*

Lateolabrax japonicus, popularly called *Suzuki* in Japan, is an important source of food for the Japanese. It is generally believed that this fish lives on live fish and shrimps; live bait is therefore used in fishing.

The experiments were carried out with young *Suzuki* (body length from 4 to 6 cm.), using for food *Medaka* (Japanese *killifish*, *Oryzias latipes*) (body length from 1 to 1·7 cm.). A hungry *Suzuki* of such size can usually eat about ten *Medakas* within a few minutes.

A preliminary experiment showed that *Suzuki* placed in complete darkness or blinded by removing both its eyes, can barely find and eat any bait unless it is very plentiful.

A wooden model of a *Medaka* and a dead *Medaka* were hung by a thin wire in a tank which contained a blind *Suzuki*. Even when the blind *Suzuki* swam near these baits, it showed no reaction; however, if the bait was slightly agitated before the mouth of the blind *Suzuki*, it was always snapped at. When the bait was a dead *Medaka*, it was quickly devoured; when it was the model, it was vomited immediately upon being recognized.

It may, therefore, be concluded that the visual sense allows the *Suzuki* to detect its prey at some distance. The motion of the water produced by the bait, either by swimming or by being agitated, may play an important role in making the *Suzuki* snap at the bait.

For the second trial, five *Suzukis* were put in a large wooden tank. Two dead *Medaka* were used as bait. One fixed bait was suspended in the water by a thin nylon monofilament attached to the tip of a rod extending out over one side of the tank, the other (moving bait) was hung on the other side of the tank so that it could be moved back and forth.

A moving bait, expecially that going back and forth rather rapidly (i.e. 'irregular' motion), at less than 30 sec./cycle, one stroke being about 20 cm., is more

TABLE I

The training results in *Sparus aries*

Date/June			14	15	16	17	18	19	20	21	22	23	24	25	26	Total
Cotton		Correct	7	9											7	23
twine		Error	0	0											0	0
	Thick	Correct			8	5	7	11	4							35
Nylon		Error			0	1	0	0	1							2
monofilament	Thin	Correct								6	4	4	5	5		24
		Error								1	3	1	2	3		10

TABLE II

The training results in *Sparus swinhonis*

Date/July/August			20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	Total
Cotton		C.	7	8	9	4	7	10	7									5	6	63
twine		E.	1	0	0	0	0	0	0									0	0	1
	Thick	C.								2	6	6	5							19
Nylon		E.								0	1	0	1							2
monofilament	Thin	C.												2	3	1	2			8
		E.												1	1	3	8			13

TABLE III

The training results in *Sparus swinhonis*

Date / July / August		20	21	22	23	24	25	26	27	28	29	30	31	1
Thin Nylon	Correct	2	4	2	3	12	7	11	2	5	15	15	12	10
monofilament	Error	4	2	2	4	3	7	2	2	5	3	0	0	0

easily detected by *Suzukis* than a fixed bait. Further, the sense used in this case was found to be visual.

Other experiments showed that bait moving lineally and uniformly was by no means more detectable than fixed bait.

It is, therefore, concluded that *Suzukis* find their prey at some distance mainly by visual movement-perception; a bait at rest or moving in a linear uniform motion has scarcely any attraction. *Suzukis'* sense (perhaps lateral line sense) of the motion of the water produced by a bait either by swimming or being agitated, is indispensable in making them snap at it; the senses of smell and taste are not essential for their food-searching, although these senses may be indispensable, along with the tactile sense in the mouth, for *Suzuki* to ascertain whether the bait once snapped is worth swallowing.

Light fishing

It has already been reported by von Frisch[2] and others that light causes a shortening, and darkness a lengthening of the cones in the fish's retina. Welsh and Osborn[10] and Wigger[11] and others have shown that, when fish are kept constantly in the dark, the cones show greater elongation (extreme dark adaptation) at midnight than at noon. This may be called diurnal rhythm of the cone shifting.

This study was carried out to find the illumination intensity at which the cones change from dark to bright adaptation. This intensity varies by species and times.

According to the several sets of experiments, the change in the cones of *Lateolabrax japonicus* was seen in the illumination intensity of 0·04 lux before midnight and that of 0·01 lux after that. In *Cyprinus carpio*, it was 0·0005 lux before midnight and less than 0·00006 lux after. Generally speaking, when fish are kept in a very low intensity of illumination, the retinae show more marked dark adaptation before than after midnight.

Kawamoto and Konisi[3] have shown that when fish (*Girella punctata*) were kept in a dark tank and a small part of the water surface was illuminated, the fish gathered in the bright region (220 lux) during the daytime and in the less bright region for which the luxmeter was not available, during the night. Although the position of the cones in the fish's retina was not examined, it is unquestionable that the dark-adapted retina in the daytime showed less marked dark adaptation than in the night time. It may, therefore, be concluded that fish gather to the dim region when their cones are in the maximum dark-adapted condition.

Considering this conclusion, together with the author's findings, the phototaxis of fish may occur in lower illumination before midnight. This may be one of the fundamental reasons why fishing with use of light is usually more effective before than after midnight.

The fact that the transitional situation of the cones in *C. carpio* can be seen in much lower illumination than in *L. japonicus* may show that the retina of the former fish is the more sensitive to low illumination.

Optimal intensity of illumination

When a cone of the fish retina is illuminated, the inside potential of the cone changes. The changed potential can easily be measured by the ultramicro-capillary-electrode method, as shown by Svaetichin[5], and Mitarai and Yagasaki[4]. The amplitudes of the produced potentials can be changed by the various intensities of the light stimuli, i.e., the cone response is a graded one and does not follow the *all or nothing* law. The higher the intensity of the light stimulation, the larger the amplitude of the cone potential. The amplitude, however, becomes constant at a certain intensity of illumination, called *the lowest intensity of illumination*, to produce the maximum amplitude.

From *the lowest intensity*, which is peculiar to the particular fish species, the author was able to deduce the upper limit of the most suitable illumination for the daily life of the fish.

According to the several sets of experiments, the *lowest intensity* to produce the maximum cone response is between 64 and 175 lux for *Sparus aries* (Sparidae), about 175 lux for *Cyprinus carpio* (Cyprinidae) and far more than 800 lux for *Lateolabrex japonicus* (Serranidae).

It may be assumed that the cone can discriminate between the intensities of illumination only when less than the *lowest intensity*. In other words, the cone may be excited fully when the illumination of the cone reaches the *lowest intensity*, because there is no additional increase in the amplitide even though the intensity of the light is increased further. When the fish retina is illuminated by higher intensities of light than the *lowest one*, the fish can hardly separate objects within the visual field.

Therefore, the *lowest intensity of illumination* to produce the maximum cone response may be useful as a measure of the environmental illumination which is suitable for the daily life of the fish. Since this intensity was measured as between 64 and 175 lux for *S. aries*, about 175 lux for *C. carpio* and more than 800 lux for *L. japonicus*, it may be concluded that these fish adapt themselves to darker environment in this order. This conclusion may be supported by the fact that *S. aries* lives in rather deep water and eats its food chiefly at night, *C. carpio* usually lives in turbid water and searches for food mainly by chemoreceptors, while *L. japonicus* usually inhabits littoral clear water and forages for food in the daytime.

It was assumed above that the cone sensitivity for *C. carpio* might be superior to that of *L. japonicus*. This assumption also harmonizes with the present findings.

From careful observation of records of the cone potential, it is supposed that the flicker fusion frequency, which is a measure of the ability to perceive a moving object, is highest for *L. japonicus*, lowest for *S. aries* and intermediate for *C. carpio*. Further studies, however, are necessary.

REFERENCES

[1] Beer, T. Die Akkommodation des Fischauges, Pflüg. Arch., 58: 523-650. 1894.

[2] Frisch, K. von. Farbensinn der Fische and Duplizitätstheorie. Z. vergl. Physiol., 2: 393-452. 1925.

[3] Kawamoto, N. Y. and Konishi, J. Diurnal rhythm in phototaxis of fish. Rep. Faculty of Fisheries, Pref. Univ. Mie., 2: 7-17. 1955.

[4] Mitarai, G. and Yagasaki, Y. Resting and action potentials of single cone. Ann. Rep. Research Institute of Environmental Medicine, Nagoya Univ. 1955, 54-64. 1956.

[5] Svaetichin, G. The cone action potential. Acta Physiol. scand., 29, Suppl. 106: 565-600. 1953.

[6] Tamura, T. On the senses of food-searching in *Lateolabrax japonicus*. (in Japanese with English summary). Bull. Jap. Soc. Sci., Fish., 17: 296-300. 1952.

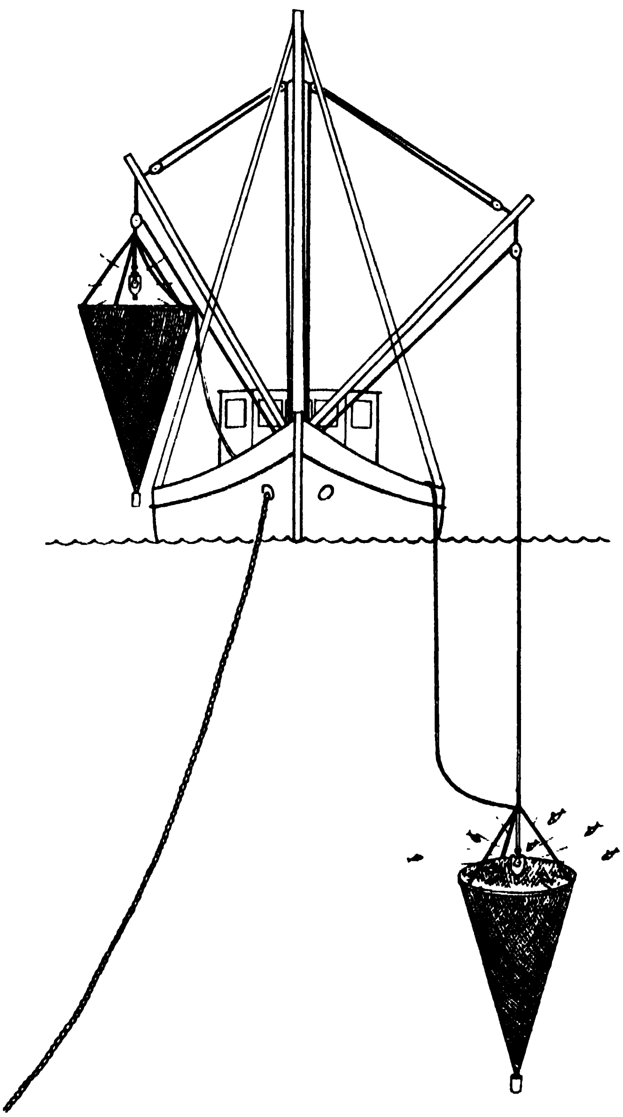
[7] Tamura, T. A study of visual perception in fish, especially on resolving power and accommodation. Ibid. 22: 536-557. 1957 a.

[8] Tamura, T. On the relation between the intensity of illumination and the shifting of cones in the fish retina. (In Japanese with English summary). Ibid. 22: 742-746. 1957 b.

[9] Tamura, T., Mitarai, G. and Sugita, Y. The lowert intensity of illumination to produce the maximum cone potential in the fish retina and its ecological meaning. Ibid., 23:86-91. 1957.

[10] Welsh, J. H. and Osborn, C. M. Diurnal changes in the retina of the catfish, *Ameiurus nebulosus*. J. comp. Neurol. 66: 349-359. 1937.

[11] Wigger, H. Diskontinuität und Tagesrhythmik in der Dunkelwanderung retinaler Elemente. Z. f. vergl. Physiol. 28:421-427. 1941.



Conical lift nets being used for light fishing of Kilka in the Caspian Sea (U.S.S.R.)

ATTRACTION OF FISH BY THE USE OF LIGHT

by

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Abstract

The concentration of fishes around a lamp is usually attributed to "positive phototaxis" and one view is that the concentration is due to the search for a preferred light intensity. The author considers, however, that when the behaviour of light-trapped fish is taken into account, there is reason to doubt this view.

He puts forward the theory that the abnormal behaviour is due to the abnormal conditions of illumination around the artificial light source and that, if the central nervous system is controlled by stimuli from the optical sense organs, any deviation from the fish's normal environmental illumination will ultimately affect the movement of the fish and its behaviour.

Attraction du poisson par la lumière

Résumé

La concentration des poissons autour d'une lampe est généralement attribuée à la "phototaxie positive" et certains experts sont d'avis que cette concentration est provoquée par la recherche d'une intensité de lumière préférée par les poissons. Toutefois, l'auteur considérant le comportement du poisson attiré par la lumière, estime qu'il y a des raisons de douter du bien fondé de cette opinion.

Il avance la théorie d'après laquelle le comportement anormal du poisson est imputable à des conditions anormales d'illumination autour de la source artificielle de lumière, et que si le système nerveux central est commandé par les stimuli provenant des organes optiques, toute altération des conditions normales d'illumination du milieu ambiant affecte en dernier ressort les mouvements du poisson et son comportement.

Atraccion de peces mediante la luz

Extracto

La concentración de peces alrededor de una lámpara generalmente se atribuye a la "fototaxia positiva" y algunos investigadores piensan que puede deberse a la búsqueda de la intensidad luminosa preferida. Sin embargo, el autor considera que al tener en cuenta la reacción de los peces atraídos por la luz puede ponerse en duda este parecer.

Además, expone la teoría de que la conducta anormal se debería a condiciones anormales alrededor de la fuente de luz artificial y si el sistema nervioso central es regulado por los estímulos del órgano visual, cualquier cambio de la iluminación normal del medio ambiente del pez influiría sobre sus movimientos y reacción.

THE concentration of fish around a lamp is generally attributed to positive *phototaxis* but the mechanisms involved are not yet clearly understood. The theory that the concentration is due to a search for a preferred light intensity is disproved by the behaviour of the fish themselves. The behaviour of the *Clupeids*, caught in many parts of the world by the use of light, is particularly instructive. The fact that some *Clupeids* are captured in the daytime with bottom-nets and during night with drift-nets has already indicated a diurnal vertical migration. Echo sounding has revealed that this migration is photophobically produced. This points towards a preference for a low light intensity. When considering the abnormal behaviour of these and other fish in the vicinity of a lamp and the negative influence of the moon on this fishing technique, the capture of *Clupeids* with lamps bears a striking resemblance to the collection of nocturnal insects with lamps.

This behaviour may be due to the abnormal illumination conditions around the light source. It is suggested that the normal photo orientation of animals depends on the functioning of higher and lower levels of the central nervous system, controlled by the feed-back from the optical sense organs. The system's purposeful functioning can only be maintained in conditions of normal environmental illumination, which are not fulfilled by an artificial light source.

This theory is based partly on the observation of animals in the vicinity of light traps, partly on similar observations under experimental illumination conditions in the laboratory, and partly on an analysis of the mechanisms of normal photo orientation.

The normal movements in search of a preferred light intensity are caused by higher or lower intensities. These movements are guided by the normal differences between the illumination intensities of the photo-sensitive surfaces of the two eyes and of different parts of the photo-sensitive surface of each eye. The fixation mechanisms of the eyes are used during more detailed orientation and they are operated and controlled by sign stimuli (congener, prey) that are qualitatively different from the many stimuli all around.

The normal values of all these stimuli are controlled by the normal light distribution in the environment. This distribution is determined by:

1. the nature of the light sources (the sun or the moon);
2. the scattering capacity of the media (the atmosphere and the water); and
3. the reflecting capacity of the background.

In the vicinity of an isolated artificial light source in an optimal "attracting" arrangement, the influences of factors (2) and (3) upon the illumination are modified considerably, resulting in abnormal values of the respective stimuli.

The abnormal feed-back resulting from the abnormal differences between the illumination intensities of the eyes and of different parts of each eye causes the animal to deviate from its course. Moreover, the servo mechanisms of the lower coordination centres, controlling the fixation movements, become a plaything of the stimuli from the artificial light source that are quantitatively super-normal as compared with the other available light stimuli. The sign stimuli that normally activate the higher coordination centres of the fixation mechanisms lose their releasing power, thus the higher centres are eliminated from the orientation process.

Under extreme laboratory illumination conditions—a lamp in a dark room many creatures, such as insects, fish and birds, are forced to move in a straight line towards the light source, irrespective of factors that are incompatible with survival (injuriously high light intensities, temperature). This classical *telotactic* movement is thus the result of optical disorientation.

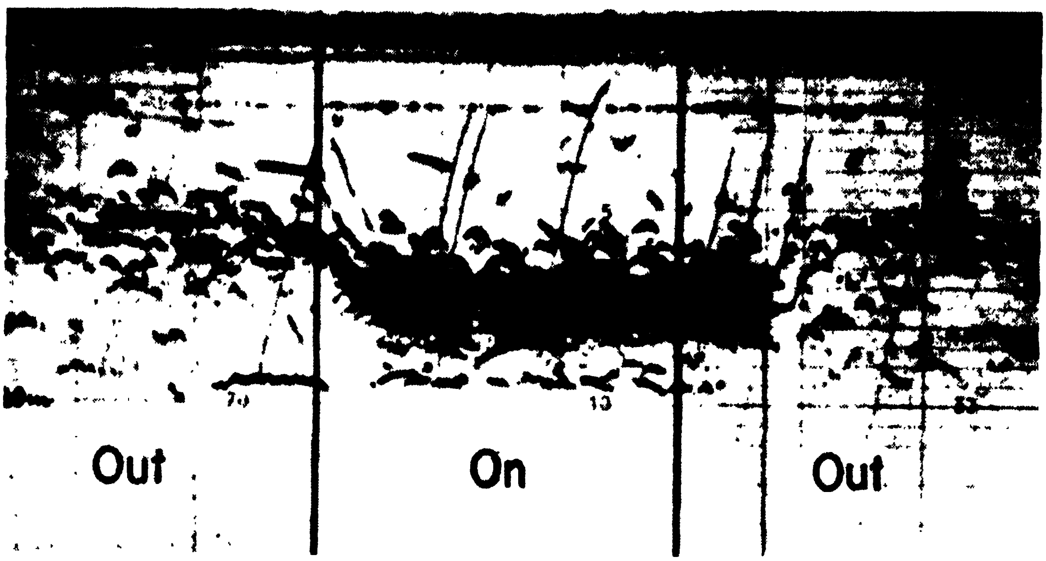
When a lamp is introduced into the natural habitat of animals, a drift towards this light source is superimposed upon their random movements. The observed concentration of the animals in the vicinity of the lamp is the statistical result of this drift.

The application of the light trap technique will yield optimal results only when several conditions are realized. For instance, the animals to be captured must be active at night when the natural light intensities are low enough to permit the required illumination conditions around the lamp (no moon). As for fish, the water must be sufficiently clear to reduce the absorption of the light rays and to reduce the scattering that would counteract the production of the required light conditions. Moreover, the depth of the water must be sufficient to eliminate reflection from the bottom.

These are the very conditions under which fish, such as sardines and anchovies, are caught with the help of lamps in many parts of the world.

REFERENCE

Verheyen, F. J. The mechanisms of the trapping effect of artificial light sources upon animals -Arch. Néerl. Zool. 13, pp. 1-107. 1958.



Echogram showing the reaction of freshwater fish to artificial light. Electric lamp of 100 *w. in* 5 *m. depth.* Photo: J. Schärfe

ON THE BEHAVIOUR OF FISH SCHOOLS IN RELATION TO GILLNETS

by

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Abstract

Reaction of fish to a fishing net is an important aspect for studying the performance of the gear and thereby improving its efficiency. In this paper the relationship between the reaction of the fish and the performance of the gear is investigated on the basis of the data made available through gillnet operations.

Some of the environmental factors that control the activity of fish are supposed to be the light condition of the surrounding water as well as underwater visibility of nets, which have been studied in relation to the behaviour of fish. In addition, a few different ways of paying out drift nets with the help of fishfinders in the daytime have been compared to find the best way of shooting the nets under a given circumstance.

Les rapports entre l'action du filet maillant et le comportement d'un banc de poisson

Résumé

La réaction du poisson à un filet de pêche est un élément important lorsqu'il s'agit d'étudier les résultats fournis par un engin et par suite d'en accroitre l'efficacité. Dans cette étude, on a recherché les rapports entre la réaction du poisson et les résultats fournis par l'engin en se fondant sur les données recueillies au cours de l'utilisation de filets maillants.

Parmi les facteurs du milieu qui influencent l'activité des poissons, on pense qu'il faut ranger la luminosité de l'eau ambiante ainsi que la visibilité sous-marine des filets qui ont été étudiées d'après le comportement des poissons. En outre, on a comparé, à l'aide de détecteurs de poissons, un petit nombre de manières différentes de mettre à l'eau les filets dérivants en plein jour, pour découvrir la meilleur manière d'immerger les filets dans des conditions données.

Relación entre la manera como actúa un cardumen y la acción de una red de enmalle

Extracto

La manera en que reacciona un pez ante una red es de importancia para estudiar el efecto del arte y, por consiguiente, para mejorar su eficacia. En este trabajo se ha investigado la relación entre el pez y la forma como actúa una red sobre la base de los datos disponibles durante las faenas con artes de enmaile.

Entre los factores ambientales que regulan la actividad de los peces se han estudiado las condiciones de luz en el agua que los rodea y la visibilidad de la redes sumergidas. Además se compararon, con ayuda de ecosondas, las diversas maneras de tender las redes de deriva durante el día para determinar el calamento más conveniente en determinadas condiciones.

THE fishery operating for sardines in the south-western part of the Japan Sea has advanced in recent years partly because of improvement in fishing practice. Since about 1953 the majority of fishermen here have operated during the day instead of at night as they used to do. From 1955 until now, nearly 70 per cent. of the fishing craft have been equipped with fish finders which have increased their efficiency. This study is based on data obtained from a drift-netter.

DEPTH OF NET AND AMOUNT OF CATCH

Studying the relation between the amount of catch C and the length of the buoy line* L, one may find that under the present conditions a good catch can be expected when length of the buoy line is more than 30 kens (45 metres) (fig. 1). In the relation between C and L to D (fig. 2)—here D is the mean distance from the surface

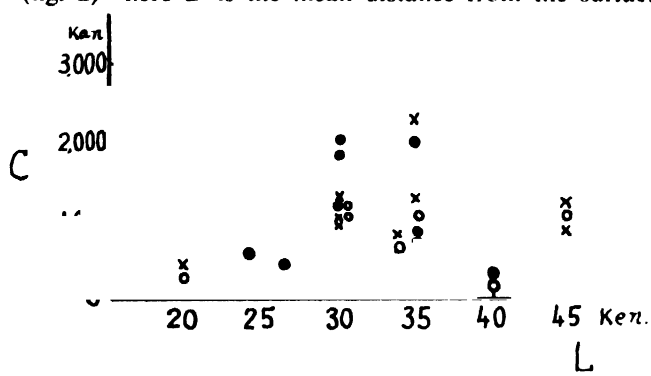

Fig. 1. The relation between the amount of catch C and length of the buoy lines L. (1 ken = 1·5 m.; 1 kan = 3·75 kg.)

● During Dec. 29th 1955 to Jan. 10th, 1956.
x „ Jan. 13th to Jan. 21st, 1956.
o „ Jan. 22nd to Feb. 8th, 1956.

* The net is suspended by buoy lines and L denotes the distance from the surface to the upper edge of the net.

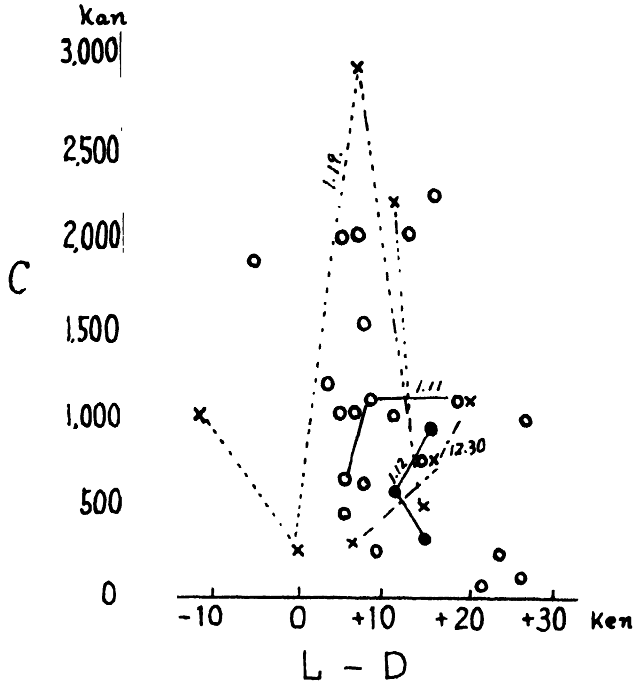

Fig. 2. The relation between L – D and the amount of catch C. (1 ken = 1·5 m.; 1 kan = 3·75 kg.)

to the upper edge of the fish traces it can be seen that a good catch is made when the value of L to D ranges from +5 to +15 kens (7·5 to 22·5 m.).

REACTION OF FISH APPROACHING A NET

Data on the depth distribution of the fish schools have been collected from fish finder records of commercial boats operated off Yamaguchi Prefecture in 1956 and 1957. To clarify the reaction of fish schools approaching the net, the number of fish schools traced on a recording paper before and after setting were counted. Regarding A as the number of the schools found already above the depth of the floatline expected before setting and A′ as the one still remaining there after setting, A—A′ is assumed to be the number of schools that has sunk below the floatline after setting, neglecting the schools reacting otherwise. In the same manner, B – B′ is assumingly the number of schools that has risen above the leadline after setting.

Fig. 3 indicates the relation between the numbers of schools probably sinking and those rising. From figs. 2 and 3, it appears that the schools of sardine tend to dive when they approach the net. Perhaps the fish mostly move downwards to seek darker surroundings when they are exposed to a stimulus. This movement, of course, will differ according to the surrounding conditions, kind of fish, size of school, degree of stimulus, and so forth.

INFLUENCE OF LIGHT

In the drift net fishing for bluefin tuna off Ibaraki Prefecture, the nets were lifted twice a day: about ten at night and four in the morning[1]. The spiny lobster

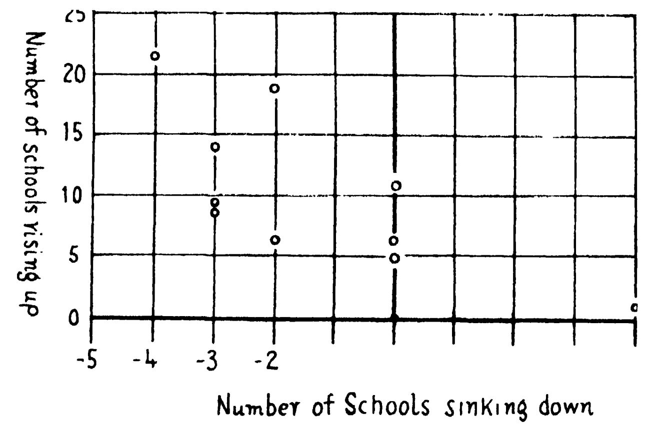

Fig. 3. The relation between the number of schools probably sinking down and the number of schools rising up.

P. japonicus, is active mainly during the hours from six to eight in the evening and two to four in the morning[2]. The activity of fish seems to be closely related to the degree of light under water, and as the net is less visible in dark water, fishing is reckoned to be more favourable at night than in the day, in turbid rather than limpid water, and with a net of subdued rather than bright colour.

There must be some relation between the moon and the catch in gillnetting. It is said that during the spring tide no good yield of spiny lobster can be expected. In drift netting for bluefin tuna off Hokkaido some years ago, the average catch was reported to be abundant when the moon was three to eleven days old[3]. On the east coast of England, the herring drift net catch is said to be greatly influenced by the phase of the moon[4]. Herring and small pilchard in England[5] and herring off Sakhalin, Russia[6], stay deep during the day but near to the surface at night. Sardines in the Japan Sea are said to sink after sunset but rise again from eight to ten at night for spawning[7].

Fig. 4 shows the distribution in depth of fish schools as recorded and the underwater luminosity measured at the time. The data were made available from the same source referred to in the preceding section. It seems that the fish, having stayed at forty metres or deeper till sunrise, surface just before sunrise when the underwater luminosity in the area becomes 10^{-1} to 10^{-2} lux. They submerge again deeper than thirty metres at the luminosity of 10 to 10^{3} lux. The movement of plankton, as influenced by light, must also be taken into account in this activity of fish.

COLOUR OF THE NET

The colour of the net is another factor which changes in accordance with the depth. A test was made with nine coloured nets—red, orange, yellow, blue, green, purple, white, grey and black—to determine their light reflection properties. At 50 metres or deeper, the reflective light energy of the different nets differs considerably, although the colours themselves are almost lost. A comparison was made between every two adjacent nets. The results showed that a better catch

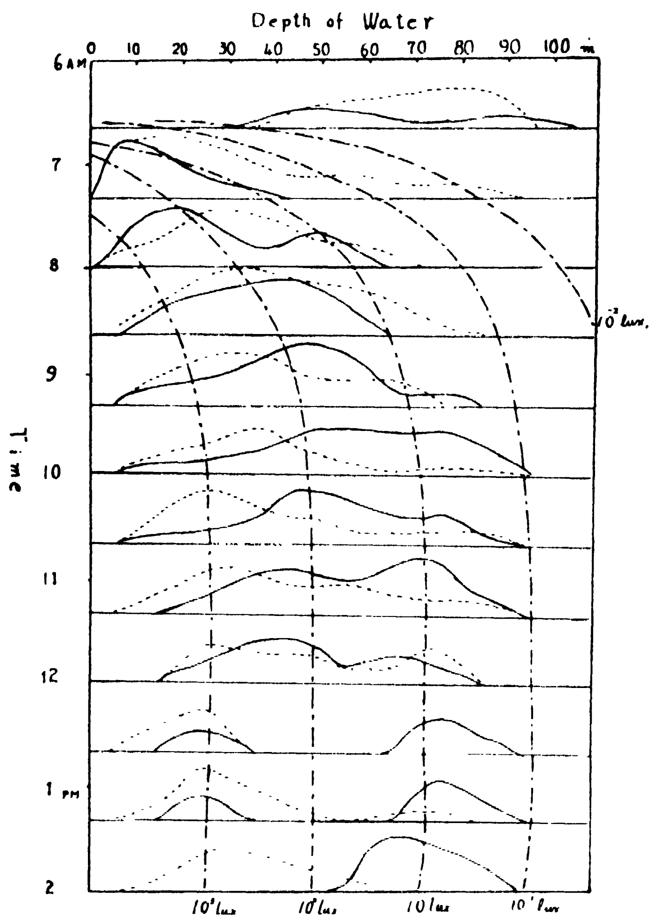

Fig. 4. The distribution of fish schools and the underwater luminosity according to the time.
— - ———fine weather, ... cloudy weather.

can be expected in daylight with the darker net, but no difference was found at night (fig. 5).

VALUE OF ECHO-SOUNDING

Of various improvements made in fishing technique since the introduction of synthetic fibre nets* and fish

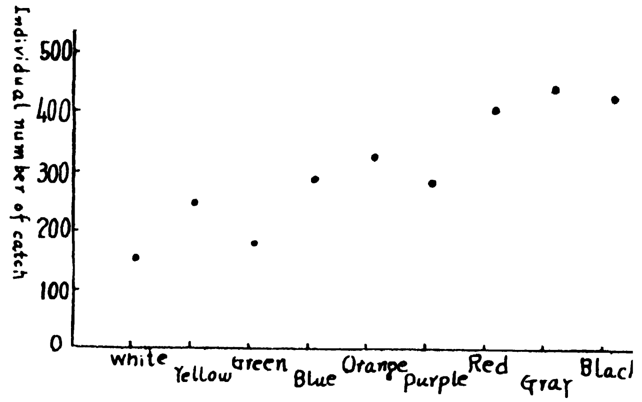

Fig. 5. The relation between the brightness of the coloured nets and the amount of catch in daylight.

finders, a remarkable feature is the change from night to daylight fishing.

The application of fish finders for choosing the optimum fishing location and gear adjustment can still be improved. A decision must first be made as to whether the fish school detected is likely to be worth fishing. This is determined by the number, size, type and density of the echo traces. Secondly, the fishermen must find out if the school is of the type that tends to sink when approaching the net. Present findings indicate that a good catch can be expected when the nets reach down 5 to 15 kens (7·5 to 22·5 m.) deeper than the fish school, and when the school seems to be swimming against the current. In these circumstances, it is advisable to pay out the net in such a manner that it is drifted by the current just in front of the fish.

REFERENCES

[1] Isomae, K. The bluefin tuna drift net off Ibaraki Prefecture (Japanese). J. Fish. Soc. Japan, 146. 1894.

[2] Kubo, I. The best time for fishing the Japanese spiny lobster (Japanese). The Aquiculture, 1 (1). 1953.

[3] Kawana, T. Oceanographic conditions and bluefin tuna fishery (Japanese). Rep. Fish. Invet. of Hokkaido Fish. Exp. St., 31. 1934.

[4] Savage, R. E. and Hodgson, W. C. Lunar influence on the East Anglian herring fishery. J. du Conseil, 9 (2). 1933.

[5] Richardson, I. D. Some reaction of pelagic fish to light as recorded by echo-sounding. Fish. Invest., 18 (1). 1952.

[6] Yu, B. Yudovich. The detection and fishing of herring at Sakhalin (Russian), Rybnoe Khoziastvo, 10. 1954.

[7] Ito, Y. and others. The behaviour of sardine at night in Noto area of the Japan Sea (Japanese). An. Rep. Jap. Reg. Fish. Res. Lab. 1. 1957.

* About 40 per cent. of sardine gillnets of Yamaguchi Prefecture are made of synthetic fibre (Cremona).

THE SIGNIFICANCE OF THE QUALITY OF LIGHT FOR THE ATTRACTION OF FISH

by

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Abstract

Many aspects of the influence of light on the behaviour of fish have been studied and in this paper the author describes his experiments on the effect of light of different wave-lengths, the correlation between wave-length and radiant energy, the daily rhythm in phototaxis and the influence of the moonlight on fish.

Many types of young marine fishes and *Oryzias latipes* (a fresh-water fish) were used in the experiments, and one, *Anguilla japonica*, the Japanese eel, showed no definite light-seeking tendency. Many fishes were especially attracted by blue and green lights and it was found that "spectral luminosity" played an important part in deciding which one of two light sources was the best "fish-gatherer". The ratio of the gathering rates in two lights is equal to the ratio of their spectral luminosities. It was also found that lamps could be used on moonlight nights to attract fish, provided that the intensity of the lamp was adjusted to a sufficiently high level in comparison to the moonlight.

Considerations sur l'efficacite des lampes pour attirer le poisson

Résumé

L'influence de la lumière sur le comportement des poissons a déjà été étudiée à bien des points de vue et l'auteur décrit dans cet article ses expériences personnelles sur l'influence de lumières de différentes longueurs d'onde, les rapports entre la longueur d'onde et l'énergie rayonnante, le rythme journalier de la phototaxie et l'influence exercée sur les poissons par la lumière de la lune.

Les expériences ont porté sur de nombreux types de jeunes poissons marins ainsi que sur l'*Oryzias latipes* (poisson d'eau douce). L'un de ces poissons, l'anguille japonaise (*Anguilla japonica*) n'a manifesté aucun phototropisme net. De nombreux poissons ont été attirés tout particulièrement par le lumière bleue et la lumière verte et on a constaté que la luminosité spectrale jouait un role important pour choisir entre deux sources lumineuses celle qui inciterait le mieux les poissons à se rassembler. Le rapport des taux de rassemblement dans ces deux lumières est égal au rapport de leurs luminosités spectrales. Il a également été constaté que l'on pouvait utiliser des lampes pour attirer le poisson pendant les nuits de lune, à condition de régler l'intensité de la lampe à un niveau assez élevé par comparaison à la lumière de la lune.

Consideración sobre la eficacia de las lámparas para atraer a los peces

Extracto

Los estudios relativos a los numerosos aspectos de la influencia que tiene la luz sobre la manera como reaccionan los peces indujeron al autor de este articulo a describir sus experimentos sobre el efecto de la luz de diversa longitud de onda, la correlación entre la longitud de onda y la energía radiante, el ritmo diario de la fototaxia y la influencia de la luz de la luna sobre los peces.

En estos experimentos se utilizaron diversas especies marinas jóvenes, *Oryzias latipes* (especie de agua dulce) y también una *Anguilla japonica*. Este ultimo pez no demostró ninguna tendencia a buscar la luz, pero muchos otros fueron especialmente atraídos por las luces azul y verde, encontrándose que la "luminosidad espectral" juega un papel importante en decidir cual de estas dos fuentes luminosas es más apropiada para reunir peces. La relación de la proporción en que estos animales se congregan junto a dos luces es igual a la relación de sus luminosidades espectrales. También se ha encontrado que en las noches con luna pueden utilizarse lámparas para atraer peces, siempre que la intensidad de ellas sea lo suficientemente alta como para compararla con la luz de la luna.

LABORATORY experiments were carried out with several species of marine fishes such as:

Oplegnathus fasciatus (T. et S.)
Stephanolepis cirrhifer (T. et S.)
Scomberomorus niphonius (C. et V.)
Fugu niphobles (J. et S.)
Sphyraena japonica (C. et V.)
Anguilla japonica (T. et S.)
Mugil cephalus (L.)
Girella punctata (G.)
Fugu rubripes (T. et S.)
Oryzias latipes (T. et S.)
Pempheris japonicus (D.)
Trachurus japonicus (T. et S.)
Plotosus anguillaris (L.)

Experiments had, unfortunately, to be restricted to young fish about 2 to 15 cm. in length.

THE SIGNIFICANCE OF THE WAVE LENGTH

Experimental set-up

A lustreless, black, round wooden tank, 100 cm. in diameter and 25 cm. in height, was divided radially into eight compartments, open to each other at the centre. A window in each compartment, covered with a colour filter was lighted by a 60 W. electric bulb[1].

The colour filters were prepared by dissolving the respective colour in a 6 per cent. gelatine solution. Their transparencies were measured by a recording spectrophotometer.

The experiments were carried out during the daytime in a dark room. The fish, kept in an aquarium for about one week after being caught, were allowed to become accustomed to the darkness in the tank for at least 30 min. before each experiment. After lighting the 8 lamps simultaneously, the number of fish which entered each compartment during a total time of 10 min. was recorded. Those leaving a compartment were neglected and those present at the beginning were counted as newcomers. During this experiment all species were very active and changed their place frequently. The experiment was repeated five times for two different filter arrangements. The average distribution, the *gathering rate* for the respective source of light, was expressed in percentages.

Results

The filter arrangement, i.e. in order of the wave length or at random, had no significant influence on the fish behaviour. All species tested, except *Anguilla*, remained mostly in the green and blue compartments. *Anguilla*, however, was indifferent to blue, green, indigo and yellow, but was attracted by violet and red[1].

THE SIGNIFICANCE OF THE RELATION BETWEEN WAVE LENGTH AND RADIANT ENERGY

Experimental set-up

Only two species, i.e. *Fugu rubripes* (T. and S.) (marine fish), and *Oryzias latipes* (T. and S.) (fresh water fish) were tested. Two 40 W. light bulbs were placed 10 cm. above slits on two sides of the square fish tank. Mazda colour filters (types V-B2, V-G1, V-Y1, V-R2) were placed over the slits, and the radiant energy was adjusted by inserting sheets of screening paper with a transparency of 75 per cent.

For each test, 10 fish were brought into the tank while the laboratory was dimly lit. After 30 min. for accustoming, both bulbs were lighted simultaneously, and the numbers of fish gathered in each illuminated field (13 × 45 cm.) were recorded in 30 sec. intervals for a total test time of 10 min. To avoid accustoming due to repetition, different fish were used for each experiment.

The *gathering rate* was again expressed in percentages. The influence of the different colour filters on the radiant energy was carefully eliminated until equal *gathering rates* for both lights were obtained. The following combinations were tested: blue to white, yellow to white, red to white, and red to green.

Results

The total energy of transmitted coloured light can be calculated from the spectral radiant energy of the light bulb and the transparency of the colour filter. The values for the coloured lights tested are shown in the uppermost column in Table I.

TABLE I

Visual Efficiency

	White	*Blue*	*Green*	*Yellow*	*Red*
Relative energy:	4892	186	100	3464	2179
Fugu rubripes Visual efficiency:	0·16	0·46	0·62	0·15	0·01
Oryzias latipes Visual efficiency:	0·13	0·54	0·53	0·12	0·004

Wave lengths of more than 750 mμ. are beyond the limit of susceptibility of fish. It was suggested that the *gathering rate* may be influenced by the energy of the coloured light and the perceptibility of sensory cells of the fish retina, and that the quantitative relation between radiant energy, wave length and visual perceptibility affecting phototaxis may be easily explainable. C. Hess (1912) observed that the visual curve of fish shows fairly good accord with the human rod vision curve. Heht (1930) confirmed this, and H. Grundfest (1932) has also studied this problem of visual perceptibility in fish. For the present considerations, therefore, the human visual curve was accepted with a certain displacement of the maximum.

The product of the *relative radiant energy* (φ_λ) of light of a certain wave length (λ) and the *relative visual perceptibility* (V_λ) for light of the same wave length is generally called the *spectral luminosity* of light of the wave length λ. With light of a spectral distribution between λ_1 to λ_2 the total *spectral luminosity* (H) may be figured by the expression

$$H = \int_{\lambda_1}^{\lambda_2} \varphi_\lambda \ V_\lambda \ d\lambda$$

The relative *spectral luminosity* values for each experimental light source were calculated by several visual curves of 500 mμ. to 540 mμ. In the experiment, white light was combined in turn with each coloured light.

It was found that the gradual decrease in the intensity of a light in the area where the fish showed greatest aggregation, resulted in an inversion of phototaxis between the two lights. Fish gathered round one light will migrate to the other. The fish gathered equally under two lights of equivalent *spectral luminosity*. Consequently the relationship between the ratios of *gathering rates* of light sources, coloured (G_c) or white (G_w), is equal to the ratios of their *spectral luminosities* (H_c/H_w):

$$G_c/G_w = H_c/H_w$$

According to the present experiments this relationship holds also with lights of different wave lengths and fish of different visual perceptibility. When testing lights of different wave lengths but equal *radiant energy* the fish gathered in the light with the spectrum of higher subjective visibility. On the other hand, the influence of the subjective visual perceptibility of a certain wave length can be outruled by accordingly higher *radiant energy*. It is suggested, however, that this holds only within a certain range of *radiant energy*.

The ratio of *relative spectral luminosity* to *relative radiant energy*:

$$\frac{\int \varphi_\lambda \ V_\lambda \ d\lambda}{\int \varphi_\lambda \ d\lambda}$$

was called *visual efficiency*.

In the case of *Fugu rubripes*, the green light shows the largest *visual efficiency*, blue next and red the smallest. Though *radiant energy* of red light is 22 times as much as that of green light, its visual efficiency is 1/62 of green. In the case of *Oryzias latipes*, blue and green lights are equivalent and red extremely small, Differences with various kinds of fish may be easily understood as the visual perceptibility curve of *Oryzias latipes* is of shorter wave length than that of *Fugu rubripes*[5].

DIURNAL RHYTHM IN PHOTOTAXIS

Experimental set-up

A tank 95 cm. in length, 45 cm. in width and 30 cm. in depth was used, with the inside painted lustreless black. Two lights were arranged at each side of the tank. The required wave length was ascertained by Mazda colour filters (V-G1, V-R2). Ten fish were used for each test, allowing 30 min. for accustoming. The *gathering rate* was determined in the usual way.

Results

In general, many kinds of fish show no definite diurnal rhythm in phototaxis. *Mugil cephalus*, for example, shows nearly constant gathering rate over a twenty-four hours period.

The behaviour of certain fish, however, is quite different. *Girella punctata*, for example, shows a notable diurnal rhythm, an extremely strong light-seeking tendency in day-time and a less activity at night.

With *Rudarius ercodes* (J. and F.) the strong tendency to seek green light during day-time is similar to that of *Girella punctata*. Unlike the latter, however, the activity of *R. ercodes* decreases to a remarkable degree at night and they no longer respond to light but fall asleep, resting near the sides of the tub. In general, the so-called "nocturnal" fish, i.e., *Anguilla japonica*, *Plotosus anguillaris*, showed no definite light-seeking tendency and they gathered in larger numbers in the red light[7].

THE SIGNIFICANCE OF LIGHT GRADIENT FOR ATTRACTION

Experimental set-up

A lustreless, black, wooden tank, 3 m. in length, and 24 cm. in height and width, was placed in a dark room. The only light source was installed at one end of the tank, separated from the water by a pane of glass. The *gathering rate* was determined in regard to the distance from this light source.

Results

The fish tended to gather farther away from the light when the light intensity was either stronger or weaker than a certain optimum value. The differences of the *gathering rates* obtained by day and night coincided with those found in the experiment on diurnal rhythm[2].

INFLUENCE OF MOONLIGHT

Experimental set-up

A rectangular net, 3 m. deep, 20 m. long, and 6 m. wide and made of 1·8 cm. mesh, 12 thread cotton yarn, was suspended from a moored bamboo float 200 m. off shore. An electric light was fixed less than 1 m. under the water at one end of the net: 20 W., 60 W. and 100 W. bulbs were used with a green glass filter 18 cm. in diameter. Adult horse-mackerel, *Trachurus trachurus* (L) were tested and the *gathering rates* of the fish in the rectangular net were determined in the dark and in the moonlight.

Results

The *gathering rate* decreased when the ratio of luminosity of the lamp and luminosity of the moon decreased to a certain value. It was found that some horse-mackerel will gather at the lamp even on a light night if sufficient strength of light is used[6].

REFERENCES

[1] Kawamoto, N. Y. and Takeda, M. The influence of wave lengths of light on the behaviour of young marine fish. Rep. Fac. of Fish., Pref. Univ. of Mie, Vol. 1, No. 1, pp. 41-53, Sept. 1951.

[2] Kawamoto N. Y. and Nagata, S. On the relation between light gradient and fish behaviour. Rep. of Fac. of Fish., Pref. Univ. of Mie, Vol. 1, No. 2, pp. 151-173. 1952.

[3] Kawamoto, N. Y. and Kobayashi, H. Influence of various light conditions on the gathering rates of fish. Rep. of Fac. of Fish., Pref. Univ. of Mie, Vol. 1, No. 2, pp. 139-150. 1952.

[4] Kawamoto, N. Y. and Niki, T. An experimental study on the effect of leading fish by fish attraction lamps. Rep. of Fac. of Fish., Pref. Univ. of Mie, Vol. 1, No. 2, pp. 175-196. 1952.

[5] Kawamoto, N. Y. and Konishi, J. The correlation between wave length and radiant energy affecting phototaxis. Rep. of Fac. of Fish., Pref. Univ. of Mie, Vol. 1, No. 2, pp. 197-208. 1952.

[6] Kawamoto, N. Y. and Uno, H. Studies on the influence of the moonlight upon efficiency of the fish lamp. Rep. of the Fac. of Fish., Pref. Univ. of Mie, Vol. 1, No. 3, pp. 355-364. 1954.

[7] Kawamoto, N. Y. and Konishi, J. Diurnal rhythm in phototaxis of fish. Rep. of the Fac. of Fish., Pref. Univ. of Mie, Vol. 2, No. 1, pp. 7-17. 1955.

THE USE OF LIGHT ATTRACTION FOR TRAPS AND SETNETS

by

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Abstract

This paper describes tests which were made to find out if a directed beam of light was better for attracting fish than the ordinary scattered light. Experiments with bag nets and setnets showed that greater catches were taken when the directional beam was used.

A new method of fishing with setnets has been introduced. Here, the fish are guided into the bag by switching on a succession of lamps coupled together so as to form a lead. The lamps can be controlled from the shore and several "fishings" can be made during the course of a night.

The catch by this new method was at least twice as big as by the old method.

Engins de pêche munis d'un système de lampes pour attirer les poissons

Résumé

Ce document décrit des essais ayant pour objet de déterminer si un faisceau lumineux dirigé attire mieux le poisson que la lumière diffusée ordinaire. Des experiénces avec des filets-sac et des filets fixes ont montré que les captures les plus importantes correspondaient a l'utilisation d'un faisceau dirigé.

Une nouvelle méthode de pêche au moyen de filets fixes a été adoptée. Dans cette méthode, les poissons sont attirés à l'intérieur du filet par l'allumage en succession d'une série de lampes associées. Ces lampes peuvent être allumées depuis le rivage et on peut faire plusieurs pêches pendant une nuit.

Les captures obtenues par cette méthode nouvelle ont été au moins deux fois plus importantes que les captures obtenues par la méthode traditionnelle.

Equipo de pesca con un sistema de lámparas para atraer los peces

Extracto

En este trabajo se describen las pruebas efectuadas para determinar si un rayo de luz dirigida da mejor resultado para atraer los peces que la luz dispersa. Los experimentos con "cielos" y redes fijas han demostrado que se obtuvieron redadas más abundantes al usar haz luminoso dirigido.

Se ha puesto en práctica un nuevo método de pesca con redes fijas, a las cuales se guian los peces encendiendo y apagando una serie de lámparas conectadas de manera que formen una especie de guía o rabera. Estas luces pueden operarse desde la orilla permitiendo hacer varias "redadas" durante el curso de la noche.

La pesca mediante este nuevo método fué, por lo menos, igual al doble de la obtenida con el equipo antiguo.

GENERAL

THE catching system of setnets consists in leading the fish into the bag of the gear by means of leader nets stretched across the path of their migration. It is believed that the final catch in the bag net represents only about 20 per cent. of the total fish coming into contact with the leader net.

In order to increase the catch, the author has made a series of investigations with underwater fish attraction lamps.

EFFECT OF A DIRECTIONAL FISH ATTRACTION LAMP

Experiment 1

A directional light source (6 V., 50 c.p.) was submerged at depths of 1 to 3 m., with the beam parallel to the water surface. Immediately, plankton and fry swarmed around the light, and after about 1 min. the fish became stationary. The fish scattered in about 30 sec. when the light was put out, but regathered within 1 min. after switching the light on again.

This observation was then applied to trap fishing, i.e. three traps were set as shown in fig. 1, and a directional light source was placed at the end of the middle one so that the direction of the beam coincided with the axis of the trap. The result of a comparison of the number of fish caught during one night in each trap (Table I) shows that this type of light source has an attracting effect on some kinds of fish including, for

TABLE I

	Trap No. 1	2	3
Crab	3	4	0
Lobster	0	22	0
Lateolabrax japonicus (Cuvier)	0	3	0
Harengulazunasi (Bleeker)	0	4	0

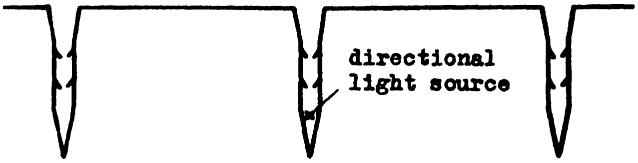

Fig. 1. Arrangement of three traps for testing the effect of two directional fish attraction lamps (Experiment 1).

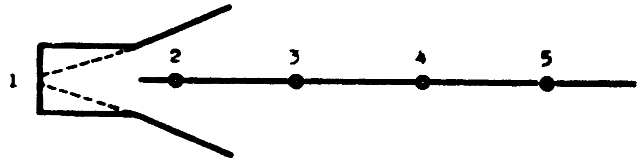

Fig. 3. Experimental arrangement of fish attraction lamps (1 to 5) and a V-shaped trap (Experiment 3).

example, crab and lobster. The experiment indicated that there were good prospects for the use of such directional light sources for fishing purposes.

Experiment 2

For further investigations the same lamp was tested in connection with some of the traps generally used in Lake Hamana, a salt lake, in the Shizuoka prefecture.

Three sets of traps of the type shown in fig. 2 were used, each one consisting of two groups of three bag nets connected by a leader net: a directional lamp was put into one of the bag nets of each of the three sets but used only on alternative days. The catch consisted of Snipefish, Lobster and Flatheads and the results showed quite definitely that the biggest catches were obtained from the bag nets with the light.

Experiment 3

The combined effect of directional light and scattered light on leading fish into a V-shaped trap, was studied in Sumoto Bay in the Hyogo prefecture.

The general arrangement of this experiment is shown in fig. 3. The water depth was 6 m., and the lamps (1, 2, 3, 4, 5) which were set 20 m. apart, were 1·5 m. under water.

The time required for gathering the fish after lighting the lamp is, of course, dependent on the intensity of illumination and the transparency of the water. Lamp (5) was switched off after 5 hrs. and the fish which had gathered moved to the next lamp (4). Five minutes later, lamp (4) was turned off, and so on until all the lamps except (1) were extinguished. Finally, the fish were led into the bag and the entrance of the net was closed. The time needed for this operation depends on the kind of fish and on other conditions.

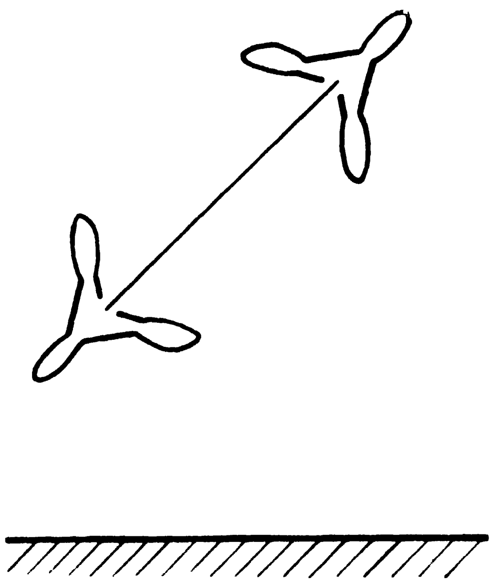

Fig. 2. Arrangement of freshwater traps for testing the effect of a directional fish attraction lamp (Experiment 2).

Experiment 4

A normal fish attraction lamp was suspended from a boat on a selected fishing ground and the fish which gathered around the lamp were led to the trap by moving the boat. A directional lamp was placed beforehand in the net. After the fish had been led into the entrance of the net it was closed as in Experiment 3. The results are shown in Table II.

These experiments have furthermore shown that it is not necessary to have the string of lights in a straight line. The lights may be placed in any curved line according to the condition of the sea and the fishing ground where the net is operated.

APPLICATION OF A STRING OF FISH ATTRACTION LAMPS TO A SETNET

The experimental results obtained in Lake Hamana and Sumoto Bay were applied to setnets used in Atami Bay in the Shizuoka prefecture.

The arrangement of the string of fish attraction lamps for use with a setnet varies according to the type of net and the character of the fishing ground. In one of the experiments, a string of 20 underwater fish attraction lamps of 100 to 150 W., was applied to a setnet (55 × 38 m.) at a certain angle to the leader net (230 m.) (fig. 4). The lamps were placed at a depth of 1·5 m. The distances between the first to the nineteenth lamp were equal, but the distance between the 19th and 20th lamp was bigger (40 m.). The reason for this was that the 20th lamp fixed at the end of the bag net was a

TABLE II

	Leading distance	*Velocity of the lamp*	*Velocity of the fish (swimming velocity)*	*Catch*
First experiment	150 m.	100 cm./sec.	107·5 cm./sec.	horse mackerel 210
Second experiment	300 m.	50 cm./sec.	53·3 cm./sec.	horse mackerel 175

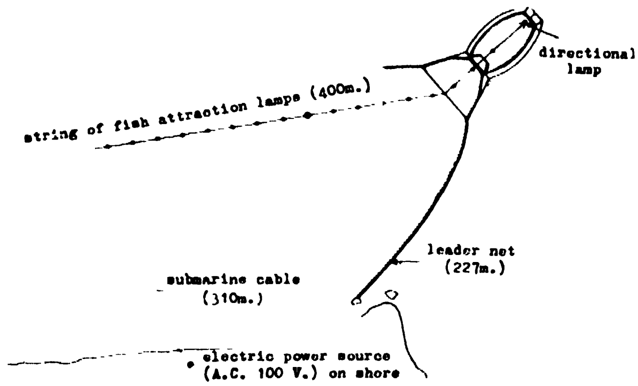

Fig. 4. Combination of a fish attraction lamp system with a big setnet.

directional one and the beam was directed to the entrance of the bag.

After sunset, the lamps were lit simultaneously by switching on the current from the shore. After waiting till enough fish had been attracted around all the lamps, the first lamp was turned off. Consequently the fish moved to the 2nd lamp. The time required to complete such a transfer from one lamp to another depends on the intensity of illumination and the kind of fish, but generally 1·5 min. are sufficient. After 17 lamps have been turned off successively, a fairly large amount of fish is concentrated around the 18th lamp. When the 18th lamp is turned off, the fish swiftly move through the narrow entrance of the setnet (8 m. in width) towards either the 19th or the 20th lamp, both of which are kept alight until the next morning.

With gear of this size, it takes approximately 1½ hrs. to lead the fish into the bag of the setnet, starting from the 1st one and successively turning off one of the lamps every 5 min. In order to achieve an almost continuous catching operation, the 1st and following lamps are relit at the same time as the 9th and following lamps are turned off in the previous leading operation. This operation is repeated 2 or 3 times during the night, with the number of repetitions depending mainly on the time required to attract enough fish. The net is hauled in the morning, usually just before sunrise.

The switching operations of the lamps can be done automatically and, depending on the facilities available, the electric power may be taken from shore or, for instance, from a mother ship by means of a cab-tyre cable.

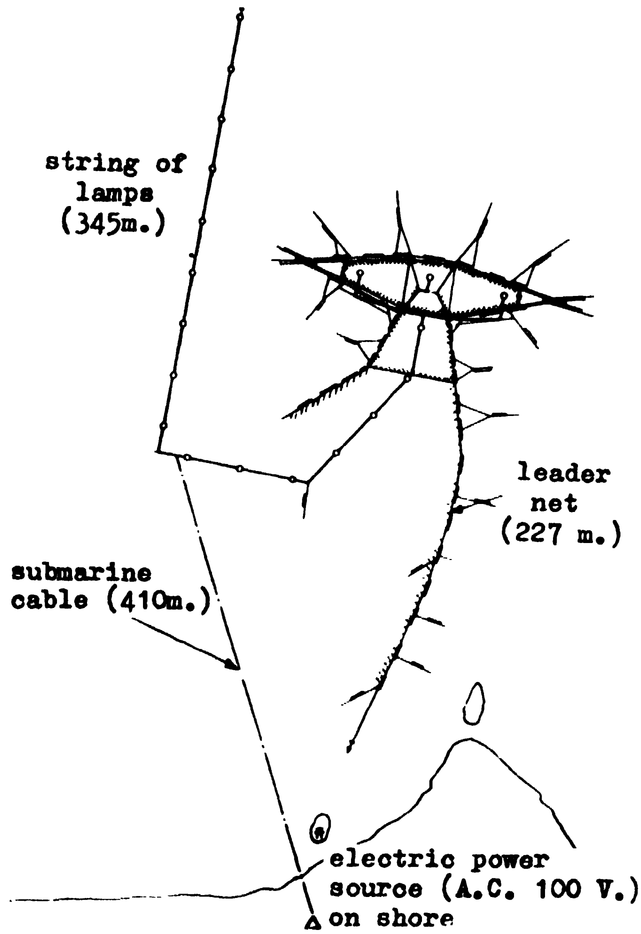

Fig. 5. Combination of a fish attraction lamp system with a big setnet. The string of lamps is arranged in a certain way to lead off-shore fish.

During the experiment carried out in Atami Bay, the string of lamps was arranged at an angle of about 180 degrees to the leader net, in order to attract off-shore fish. (fig. 5).

The catches made with this new method and with the old one were compared over several months by alternate testing, and it is considered that, after many observations, the new method is at least twice as efficient as the old one.

THE BASIC PRINCIPLES OF FISHING FOR THE CASPIAN KILKA BY UNDERWATER LIGHT

by

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Abstract

Fishing for kilka (a small clupeid fish) by underwater light has been practised in the Caspian Sea since 1951. Before 1954 cone-shaped nets of a very simple construction were only used but then an entirely new type of gear—the fish pump—was introduced, following extensive research on the behaviour of the kilka, including underwater observation and filming.

By 1956 the light fishing fleet had grown to 450 vessels, catching a total of 1,500,000 cwts.; eleven of these ships were equipped with pumps, but now there are over thirty.

A suction hose, with electric lights attached at the opening, is lowered down to the proper depth. Fish attracted by the light to within the critical range of the hose-opening are sucked in and pumped to the fish hold. Various factors affecting the efficiency of this fishing method are discussed from both a theoretical and empirical point of view.

Les principes fondamentaux de la pêche à la lumière du kilka dans la Caspienne

Résumé

Depuis 1951 on pratique la pêche du kilka (un petit clupéidé) dans la mer Caspienne à l'aide de lumières sous-marines. Avant 1954 on utilisait seulement des filets coniques d'une construction très simple, mais depuis on a introduit un type d'engin entièrement nouveau—la pompe à poissons après des recherches poussées sur le comportement du kilka comprenant des observations et des prises de vues sous-marines.

En 1956 la flotte de pêche à la lumiere était passée à 450 bateaux, pêchant un total de 1.500.000 cwts.; onze de ces bateaux étaient munis de pompes, mais maintenant ils sont plus de 30.

On immerge à la profondeur voulue une manche d'aspiration munie de lampes électriques à l'ouverture. Les poissons attirés par la lumière dans le rayon d'action de la manche sont aspirés et pompés dans la cale à poissons. Divers facteurs affectant l'éfficacité de cette méthode de peche sont examinés des points de vue théorique et empirique.

Principios básicos de la pesca de "kilka" con la ayuda de luces submarinas en e mar Báltico

Extracto

Desde 1951 los pescadores del mar Caspio caputran "kilka" (clupeido de talla pequeña) atrayéndolo mediante luces submarinas. Antes de 1954 usaban redes cónicas de construcción muy sencilla, pero a partir de esa fecha se introdujo un nuevo tipo de arte (la bomba para peces), después de investigar cuidadosamente los habitos de este especie, incluso valiéndose de la observación y fotografia submarinas.

En 1956 la flota de pesca con luz habia aumentado a 450 embarcaciones que pescaron un total de 150.000.000 libras. Once de estas unidades poseian bombas pero, en la actualidad, mas de treinta cuentan con dicho equipo.

Para pescar, se baja a la profundidad deseada la manguera de succión que lleva luces en su extremo. Los peces atraidos por la luz a la zona crítica de la boca de la manguera son aspirados y bombeados a la bodega. En el trabajo se analizan desde los puntos de vista teórico y empírico los factores que influyen sobre la eficacia de este método de pesca.

THE DEVELOPMENT OF THE FISHERY

FISHING for kilka by underwater light has been successfully practised in the Caspian Sea since 1951. Before 1954 the fish attracted by light were caught with a cone-shaped net of a very simple construction. In 1954 an entirely new type of gear the fishing pump—was introduced.

The tjulka or kilka is a small clupeid fish of the genus *Clupeonella*, native to the Azov, Caspian and Black Seas. The Caspian kilka is a small pelagic fish of schooling habits, with a mean body length (after Smith) of 7 to 11 cm. and a weight of 3 to 10 g. There are three species which differ in respect to size, colour and area of distribution. The common kilka is essentially a coastal fish; the anchovy form is found relatively far offshore, whereas the big-eyed prefers deeper waters and very rarely enters the coastal zone.

The stocks of Caspian kilka, especially those of the anchovy form, are very rich. In total it ranks next to three clupeids: the herring (*Clupea harengus*), sardine and menhaden (*Brevoortia tyrannus* (menhaden)).

Before 1951, the Caspian fishery mainly exploited the stock of common kilka; since 1957 following the investigations of Prof. P. G. Borissov (1945-47), a fishery for the anchovy form of kilka was developed, using a cone shaped net to which the fish was attracted by submerged electrical light. In 1954 an entirely new type of gear, the fish pump, was introduced, based on the results of research work carried out at the Caspian Institute of

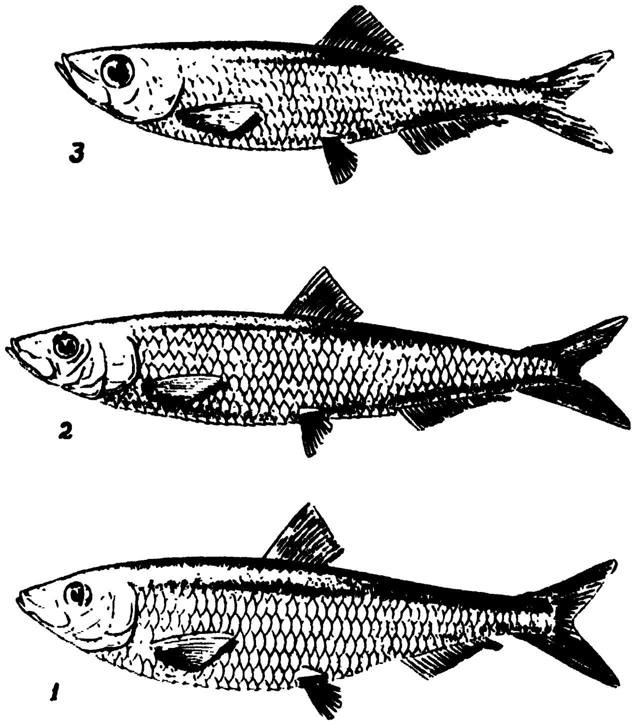

Fig. 1. Caspian kilka: 1 – common form; 2 – anchovy form; 3 – big eyed form.

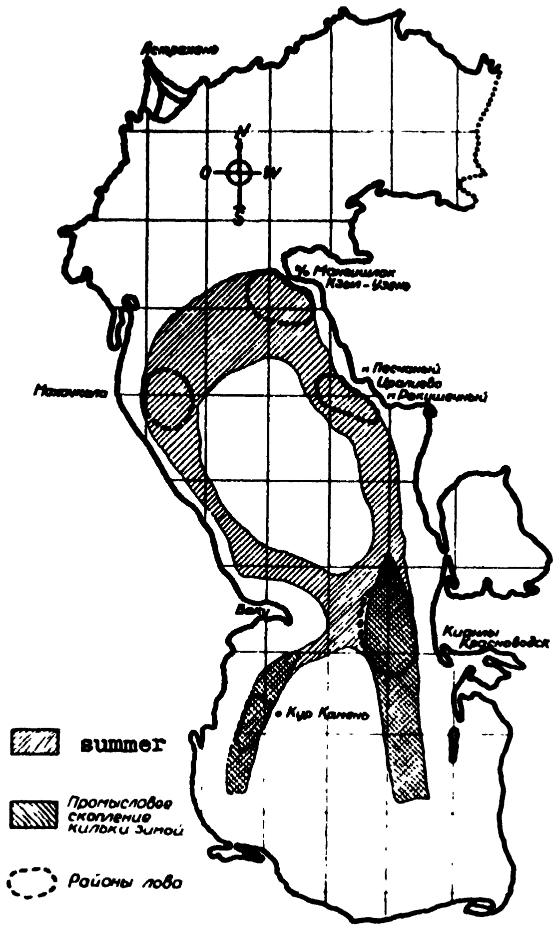

Fig. 2. Distribution of anchovy form kilka and commercial fishing areas.

Marine Fisheries under the direction of the author.

The development of fishing by light has been very rapid. In 1951, there were 170 commercial fishing vessels engaged in this fishery and their total catch amounted to about 7,700 tons. By 1956, the fleet had grown to 450 vessels, and the total catch was about 68,000 tons. Eleven of these ships were equipped with pumps and their catch totalled 4,500 tons.

THEORETICAL PREMISES OF SUBMERGED LIGHT ATTRACTION

The cause of the attraction exerted by underwater light on kilka and on many other fishes, is not yet established. There is some controversy on this question. The author agrees with the viewpoint of S. G. Zusser[2] and Borissov[1] that the attraction of fish by light is essentially a feeding reflex.

We know that kilka feed in daytime. Hence it may be inferred that daylight acts as a stimulus for an unconditional feeding reflex. In the dark, an artificial light will produce the same effect and stimulates a feeding reaction inducing the fish to swim toward the source of light. This is confirmed by a marked increase of the catch before dawn when the contents of the stomach sharply decreases, and, consequently, the feeding reaction becomes stronger and the approach of the fish to the source of light is more intense.

The Caspian kilka rarely rises to the surface and is usually found in deeper water layers so that it does not concentrate around a surface light but is strongly attracted by underwater light located at its own depth. The approach of kilka to a source of light (and, partly, its concentration within the lighted zone) depends to a considerable degree on the temperature of the water.

Kilka will not approach a source of light placed above or beneath the level of optimum temperature. If the lamp is slowly raised or lowered, the kilka will follow it for some time, until it reaches unfavourable temperature conditions, then it will retreat. This is consistent with the theory of I. P. Pavlov, that animals react only to those external factors that exert the greatest stimulating influence on the organism. In our case, the conditional signal of feeding, determined by light, is superseded by the stronger stimulus of the temperature of the water. Consequently all attempts to induce kilka to rise from the level of optimum temperature to the warmer upper layers, or, inversely, to descend into colder waters, were unsuccessful.

It has also been observed that in the presence of predators a school of kilka will assume a flattened shape and swim in circles, rapidly withdrawing at a considerable distance from the source of light, resulting in an abrupt decrease of catch both of the cone-net and the fish pump.

The submerged lamp may be considered as a point source, emitting a flow of light equally in all directions.

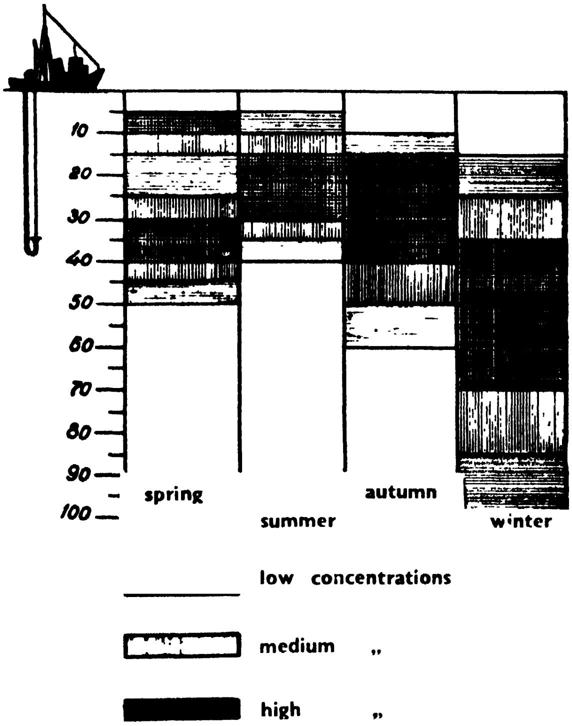

Fig. 3. Depth distribution of kilka in regard to the season.

The distance from which kilka are attracted by light (radius of attraction R_1) depends on the illumination

$$E = \frac{F}{S} \qquad (1)$$

where E — illumination
F = flow of light
S — lighted area

The attracting action of rays of light will depend on the distance from the light source. The more distant the lighted area is from the source of light, the lesser will be the flow of light received per unit of area.

The surface area S of a sphere, drawn from the centre of a source of light of a force J, with a radius R_1 is:

$$S = 4\pi R_1^2$$

The illumination of this area will be:

$$E = \frac{F}{4\pi R_1^2} \qquad (2)$$

Let us assume that the boundaries of the sphere are the limit at which kilka begin to be attracted by light (fig. 4); if the flow of light is:

$$F = 4\pi J,$$

Then the illumination is:

$$E = \frac{J}{R_1^2} \qquad (3)$$

The illumination is proportional to the force of the source of light J and inversely proportional to the square of distance R_1^2.

From two sources of light with different forces of light J_1 and J_2 and equal illumination can be obtained at proportional distances.

If $E_1 = \frac{J_1}{R_1^2}$ and $E_2 = \frac{J_2}{R_2^2}$,

and it is assumed that $E_1 = E_2$, then:

$$\frac{J_1}{R_1^2} = \frac{J_2}{R_2^2} \text{ or } \frac{J_1}{J_2} = \frac{R_1^2}{R_2^2} \text{ or } R_2 = R_1\sqrt{\frac{J_2}{J_1}} \qquad (4)$$

Knowing the values of J_1 and R_1 the radius of attraction R_2 from a source of light with a force J_2 can be determined.

As kilka approach the source of light, their concentration per 1 cu. m. greatly increases and becomes most dense near the lamp. The process of entering the lighted zones being continuous, favourable conditions are created for uninterrupted fishing at one and the same place. The stronger the source of light, and the wider the radius of attraction, the denser will be the concentration of kilka and hence the greater the catch.

Further experimental work is necessary to define the distance at which the dense concentrations of kilka spread from the source of light in relation to its intensity, and the magnitude of the radius of attraction. There is some evidence indicating that bright illumination may have a reverse effect so that the density of kilka will tend to decrease near a lamp of too great a brilliancy.

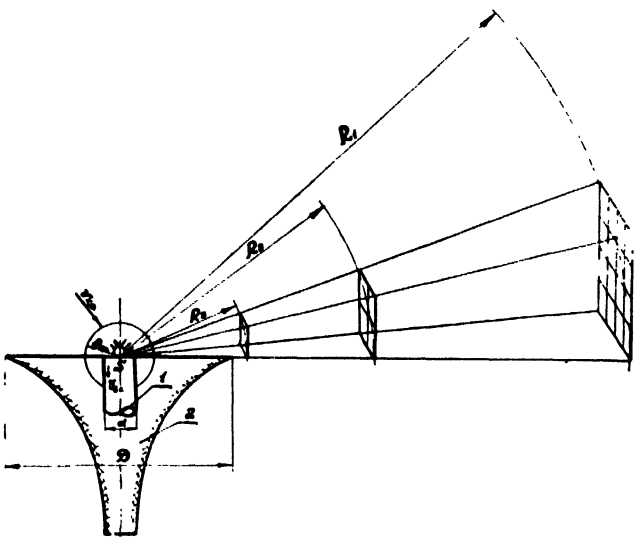

Fig. 4. The general conditions when attracting fish to a lamp. R = radius of attraction; 1 = suction nozzle; 2 = cone-net.

OBSERVATIONS ON THE BEHAVIOUR OF KILKA IN AN ILLUMINATED ZONE

During experimental work by the Caspian Institute on board of a specially equipped vessel in 1952 to 1954 to improve the existing methods of fishing and to prove the possibility of fishing with a pump, extensive observations were carried out on the behaviour of kilka in an illuminated zone within the range of action of a fishing pump. Various methods of investigation were employed, including underwater observations and underwater filming.

The investigations disclosed that kilka begin to enter the field of light almost immediately (i.e. in some

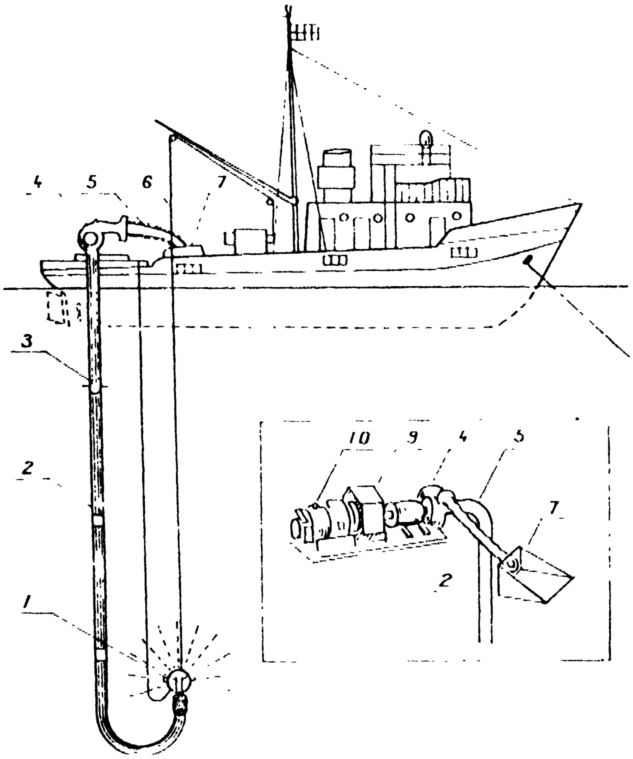

Fig. 5. Diagram of the experimental assembly used for kilka fishing with a fish pump of 100 h.p. 1—suction nozzle; 2—hose, 3—return valve; 4—fish pump; 5—forcing hose; 6—hauling line; 7—separator; 8—cable for lamps; 9—speed regulator; 10—electromotor.

seconds) after the underwater light is turned on and that the fish approach the light very closely, even brushing against the lamp. Commercial aggregations are formed in 0·5 to 2·5 min. depending on the abundance of fish in the region and on the intensity of light. It was also observed that kilka approaching the source of light, avoid narrow, restricted spaces. Therefore the construction of catching devices for a fishing pump must permit a free, unhindered approach of fish to the source of light; the latter must be placed near the intake nozzle, or, if fishing with a net, in the centre of the net mouth. The critical velocity of suction at the intake aperture of the nozzle, where kilka are unable to resist the sucking action of the water currents, was determined under laboratory conditions and found to be 0·35 m./sec. kilka approaching the critical zone try to get away; if the schools are sparse some fish do escape, but when the concentrations are dense the foremost fish are prevented from swimming away by new arrivals, who push them into the critical zone.

Some other peculiarities were observed in the behaviour of the fish. In summer, on moonlight nights, when kilka are fished at small depths, the schools are small and dispersed and much less attracted by light, resulting in an abrupt decrease of catch.

In an electrical field of direct current, kilka swim toward the anode only when the lines of force of the electrical field are uniformly and horizontally directed. Underwater sound of bells, or a barrier of air-bubbles, have no effect on the behaviour of kilka.

INVESTIGATIONS OF PUMP-FISHING WITH LIGHT ATTRACTION

The results of investigations bearing on the behaviour of kilka, as well as practical experience gained in working with fish-pumping gear, show that the catch of kilka

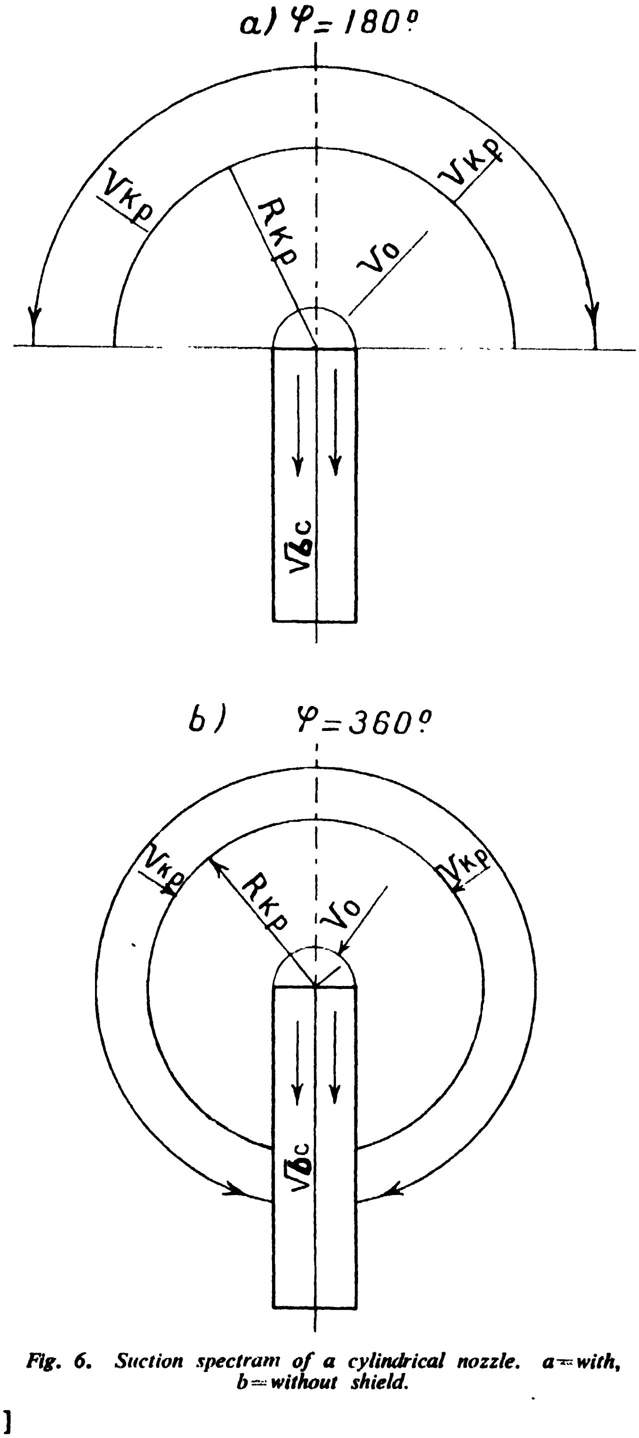

Fig. 6. Suction spectrum of a cylindrical nozzle. a—with, b—without shield.

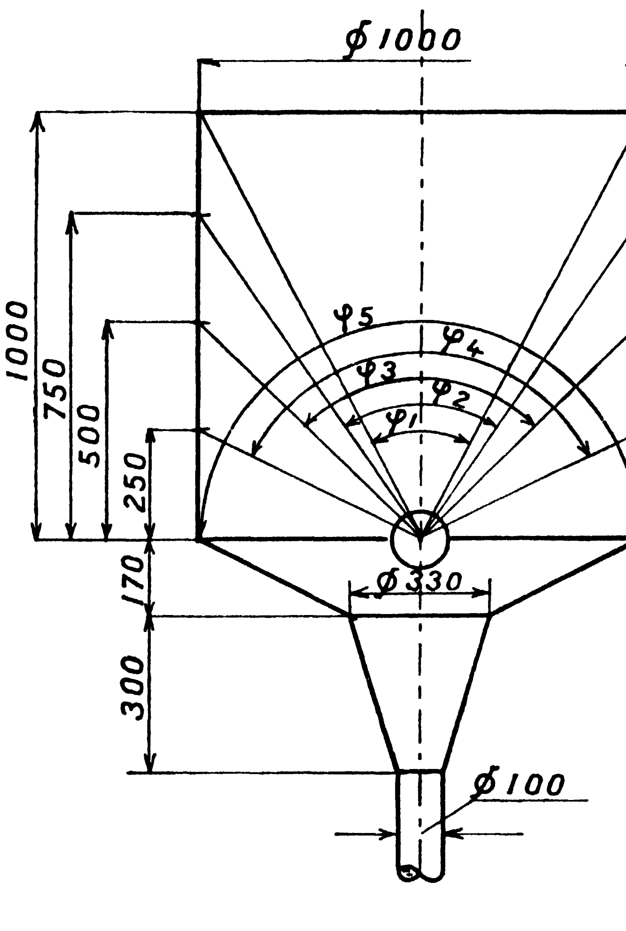

Fig. 7. Catching device for experimental modification of the field of light at constant value of suction.

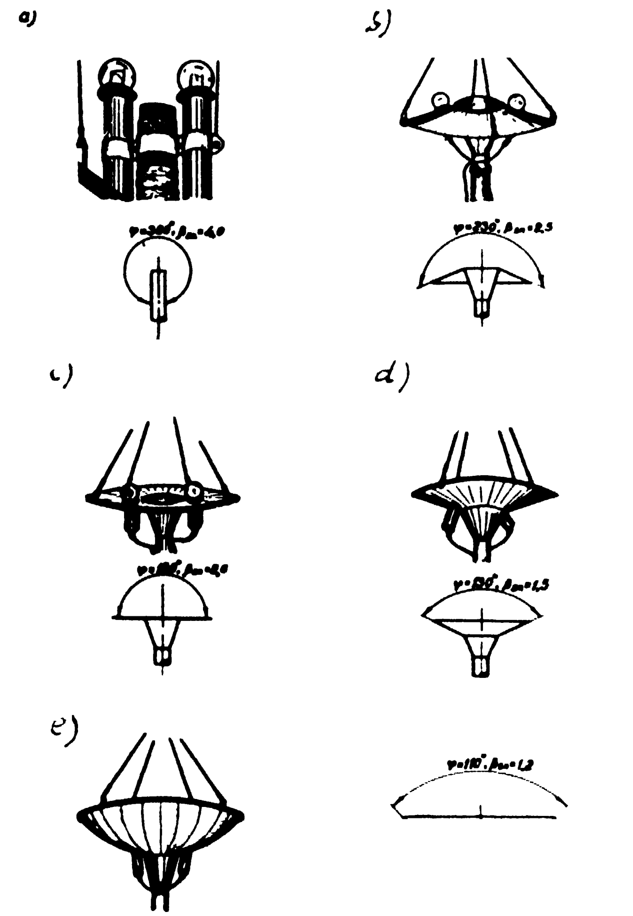

Fig. 8. Different suction nozzles for experiments with varying suction characteristics at constant field of light.

depends (all other conditions being equal) on two essential factors:

(1) the value of the critical sphere of suction at the intake nozzle R_{kp}, determined by the capacity of the pump, and

(2) the value of the field of light S_n at the intake nozzle.

Mathematically this relation can be expressed as:

$U_p = f(R_{kp}; S_n)$, where U_p = catch

The catch of the cone-net also depends on these factors, but then the value of the critical sphere of suction R_{kp} must be replaced by the volume of water filtered by the net during hauling. This volume is determined by the area of the intake aperture and the depth of the fish, or, in other words, the catch of the cone-net depends on the area fished and the speed of hauling, as well as on the value of the field of light, i.e.:

$$U_{kc} = f\left(\frac{\pi D^2}{4}; V_n; S_n\right) \text{ where}$$

U_{kc} = catch
D = diameter of the opening of the cone-net
V_n = velocity of hauling
S_n = value of the field of light

The value of the critical sphere of suction R_{kp} at the nozzle (fig. 6) is determined from the formula:

$$R_{kp} = r_0 \sqrt{\frac{V_{hc}}{\beta_{vn} V_{kp}}} \qquad (4)$$

which is derived from the theory of sources and discharges; it connects by a simple relation the two relevant values—radius of the sphere R_{kp} and radial velocity V_{kp} by the essential parameters of the flow V_{hc} and the radius of the pipe r_0, where β_{vn} coefficient of restriction of the field of velocity (constructive coefficient).

At $\beta_{vn} = 4$ the fluid will be drawn from sphere $\varphi = 360$ degrees, and at $\beta_{vn} = 2$ the fluid will be drawn from hemisphere $\varphi = 180$ degrees.

At the cylindrical nozzle, limited by a plane bearing the underwater lamps, the field of light S_u is restricted to a hemisphere, i.e. $S_n = 2\pi R_1^2$ (figs. 4 and 6) provided that the circular shield on the nozzle fully reflects all the rays of light received. When, on the other hand, the lamps are disposed around the cylindrical intake of the nozzle or in the centre of the cone-net's opening without a shield, the field of light can be assumed to form a sphere, $S_n = 4\pi R_1^2$. Generally speaking, the value of

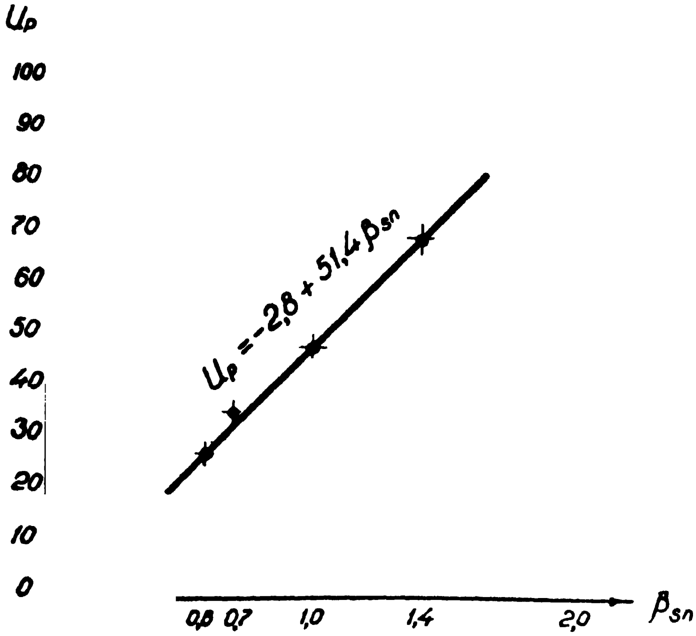

Fig. 9. Changes in amount of catch in relation to the value of the coefficient of restriction of the light field, obtained with the equipment shown in fig. 7.

the field of light depends on the constructive form of the nozzle, and is:

S_n — $\pi R_4^2 \cdot \beta_{sn}$, where
R_1 — radius of the field of light and
β_{sn} — coefficient of restriction of the field of light.

Consequently the theoretical value of the catch taken by

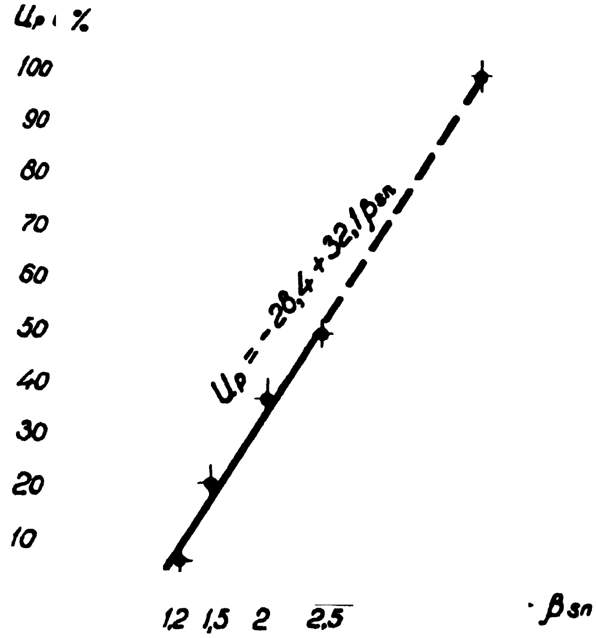

Fig. 10. Changes in amount of catch in relation to the value of the coefficient of restriction of the light field, obtained with the equipment shown in fig. 8.

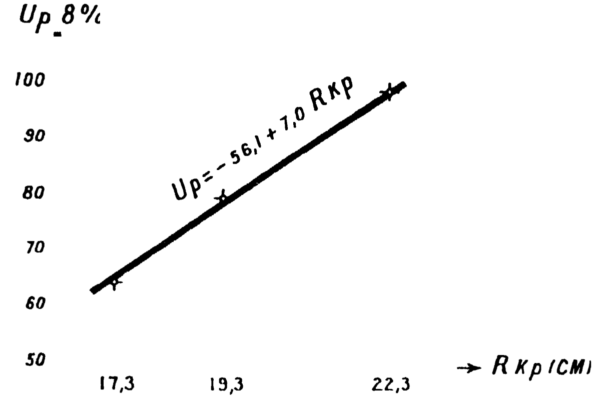

Fig. 11. Changes in amount of catch in relation to the value of the critical sphere of suction as obtained with the nozzle shown in fig. 8 d.

a fish pump (U_p) or a cone-shaped net (U_{kc}) can be expressed by

$$U_p \quad f\left(r_0 \sqrt{\frac{V_{bc}}{\beta_{sn}\, U_{kp}}}\ ;\ \pi R_1^2 \cdot \beta_{sn}\right)$$

$$U_{kc} \quad f\left(\frac{\pi D^2}{4}\ ;\ V_n\ ;\ \pi R_1^2 \cdot \beta_{sn}\right)$$

To establish the fishing efficiency of the fish pump as related to changes in values of the fields of light and velocity, experiments were carried out with a catching device (fig. 7) in which the value of the field of light changed according to changes in height of the cylinder, whereas the field of velocity (suction) remained constant, i.e. the fish pump worked at a constant capacity. The relation U_p $f(\beta_{sn})$ for the different values of the field of light was determined.

Analogous experiments were carried out with different types of nozzles and different fields of light between φ -110 degrees to φ=230 degrees (fig. 8). The value of the critical sphere of suction in the field of velocity

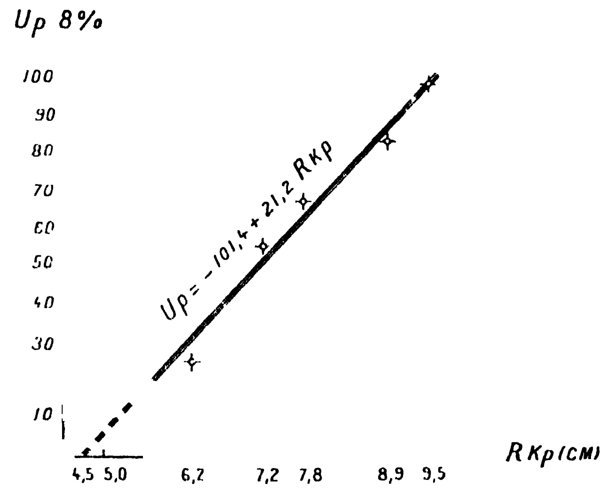

Fig. 12. Changes in amount of catch in relation to the value of the critical sphere of suction as obtained with the nozzle shown in fig. 8 a.

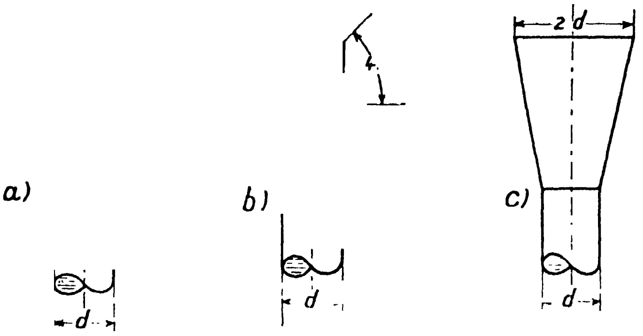

Fig. 13. Different nozzle designs. a—cylindrical; b—cylindrical with a shear; c—conical.

remained constant, except in that of the nozzle tested. All nozzles were tested under similar fishing conditions and the catch of the pump was checked every five minutes. The variation of catches U_p from 12 observations, as related to β_{sn}, could be expressed by a straight line to which empirical formulas were fitted (figs. 9 to 10).

Some experiments were also carried out with constant field of light and modification of the value R_{kp} of the critical sphere of suction on the field of velocity (fig. 8).

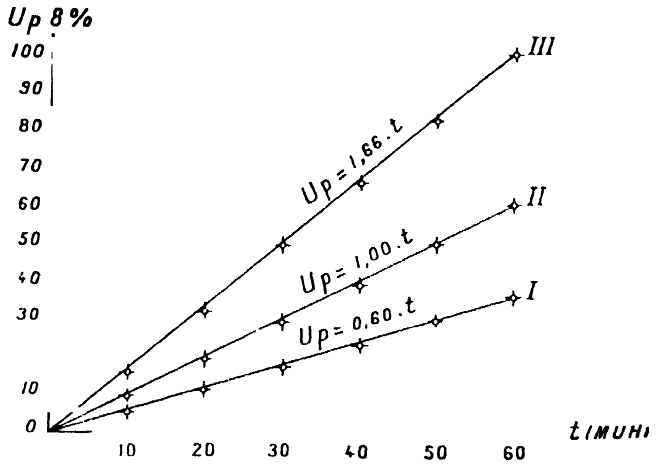

Fig. 14. Changes in amount of catch in relation to the operation of the sucking device. I—nozzle unmoved; II—nozzle raised during pumping; III—nozzle lowered during pumping.

The relation $U_p = f(R_{kp})$ was determined and the result is shown on figs. 11 and 12.

Thus the catching efficiency of this new fishing gear is

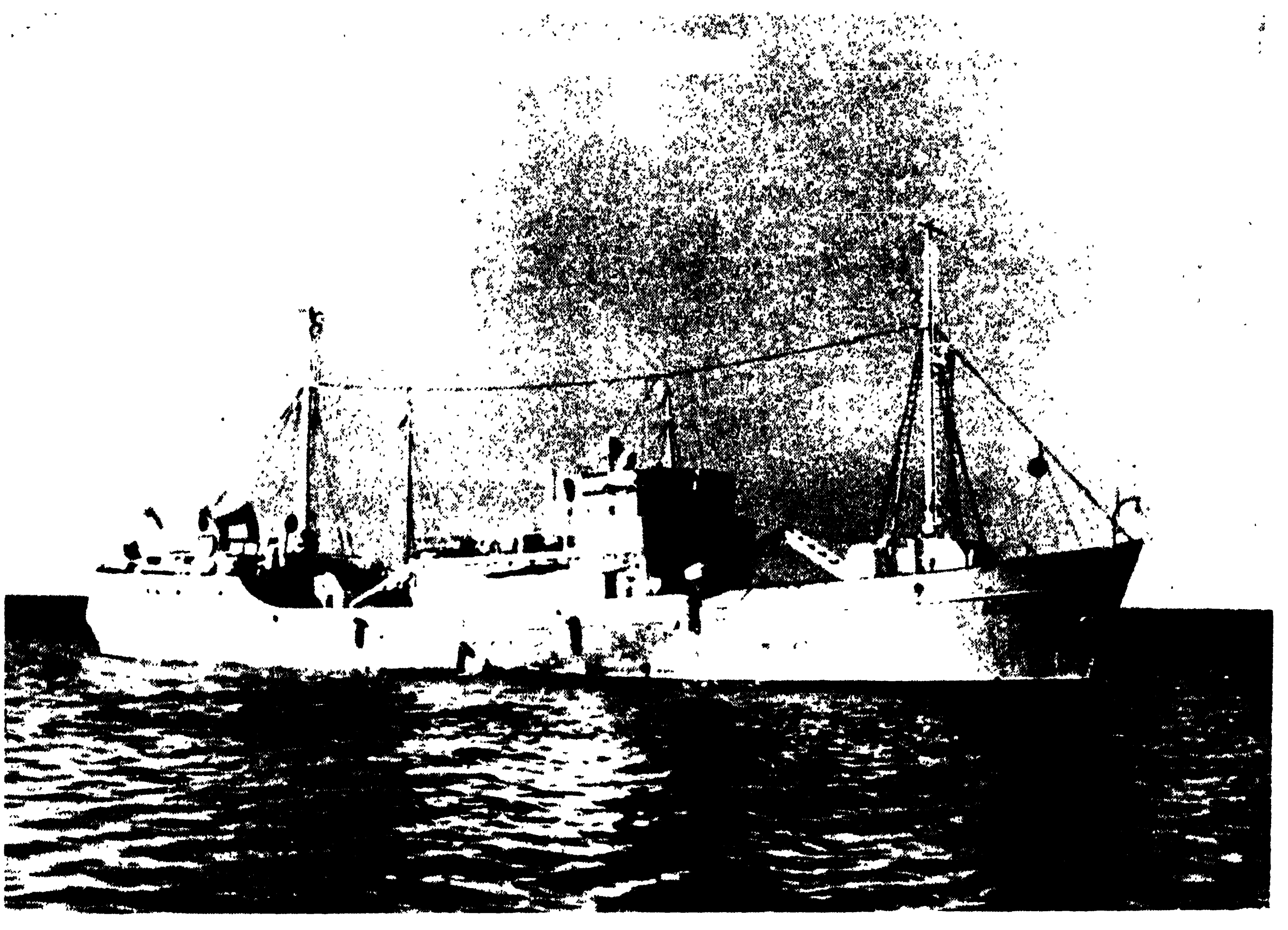

Fig. 15. Diesel-electric motor vessel equipped with two fishing pumps.

determined by two factors, i.e. the values of the fields of light and velocity.

This fact explains the different efficiency of different catching devices as related to constructive parameters, and permit a theoretical approach to the construction of nozzles with optimum fishing efficiency by means of formula (4):

$$R_{kp} = r_o \sqrt{\frac{V_{bc}}{\beta_{vn} V_{kp}}}$$

Given an unchanged pump output and r_o, V_{bc} and V_{kp} const. the value of R_{kp} increases with decreasing coefficient β_{vn}, characterizing the construction of the nozzle. A lower coefficient β_{vn}, however, can only be obtained by an additional cone—a confuser—at the end of the cylindrical nozzle (fig. 13c). This cone has the disadvantage of increasing the distance between the lamps as compared with a cylindrical nozzle. It was therefore necessary to devise a nozzle combining a maximum value of the field of velocity with a satisfactory arrangement of the electrical lamps. The sloping shear instead of a cone nipple, increases the area of the intake aperture without increasing the diameter of the nozzle. Such a nozzle was designed and tested by the author during the summer of 1957. Long term investigations proved it to be more efficient than conical and cylindrical nozzles, and it is now successfully used on fishing vessels (fig. 13b).

Similar relations were obtained for the cone-net. An increase of the diameter of its aperture and the speed of hauling, results in increased catches. If the catch of a cone net with an opening diameter of 2·5 m. is taken as 100 per cent. then with 3·0 m. diameter the catch will increase to 150 per cent. and with 1·5 m. diameter will be reduced to 52 per cent.

Some other factors affecting the fishing efficiency of fish pumps were experimentally established and theoretically grounded. Most important are the brief periodical changes of the depth of fishing, i.e. raising or lowering of the nozzle within the layer of greatest abundance of kilka. This leads to a denser concentration of the fish around the lamp in the sphere of suction and to heavier catches. Lowering the nozzle proved to be more effective than raising, or working at a constant depth (fig. 14). An analogous effect is achieved by a brief dimming of the light, and some effect by periodical extinguishing.

The catch of a cone-net can be increased in a similar way by lowering and raising the net. The fishermen, being aware of this peculiarity, used to sink the net briskly before hauling up.

More than thirty ships are now fishing kilka with fish pumps in the Caspian Sea, and the pumping method has proved to be more effective than the use of cone-nets. Pump fishing is, furthermore, less affected by moonlight.

The advantages of pump-fishing are manifold: labour saving; lower operation costs; increased production and better exploitation of the commercial fishing fleet. Particularly good economic results have been achieved with the introduction of diesel-electric motorships of 850 tons, fishing simultaneously with two 150 h.p. pumps (fig. 15).

With a wider commercial use of this new and progressive system of fishing, improvements along the following lines are indicated:

1. More precision in the design of the catching device, use of a more suitable source of light, and determination of a working scheme that would ensure the formation of dense concentrations of kilka within the critical (active) sphere of velocity of the water suction.
2. Possible additional attraction of kilka by means of a "path of light" and determination of its operation as related to varying environmental factors as well as to the biological condition of fish.
3. Increasing the active sphere of suction at the catching device by using highly economical, small-size pumps of great capacity.

REFERENCES

[1] Borissov, P. G. Use of artificial light in the world fisheries. Moscow, 1956 (in Russian). 1956.
[2] Zusser, E. A. J. Gen. Biol. XLV (2) 1953 Acad. Sci. U.S.S.R. (in Russian). 1953

Mediterranean light boat with three big gas lamps for attracting fish. Photo: FAO.

FISHING JIGS IN JAPAN WITH SPECIAL REFERENCE TO AN ARTIFICIAL BAIT MADE OF LATEX SPONGE RUBBER

by

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Abstract

Various types of lures are used in the Japanese line fisheries, all differing in colour arrangement and shape. The shaft of the jigs is made of horn, hoof, bone, zinc or wood painted with powder of mother-of-pearl, while feathers or fish skin is used for the jig-tails.

In the longline fisheries, however, fish bait is preferred to artificial lures. With a view to reducing cost and labour needed for preservation and transportation of fish bait used by the longline vessels when operating in the tropical zone, tests were carried out with a sponge rubber lure which has a dull lustre and a squid-like shape and smell.

Although the field experiments with this artificial bait gave inferior results as compared with those of fish bait, a close scrutiny of the data shows that this may be due to the relatively unfavourable position the lures had on the line.

Les Leurres Artificiels au Japon, en particulier un appat Artificiel de Caoutchouc-Mousse

Résumé

Dans la pêche aux lignes japonaise on utilise divers types de leurres qui diffèrent tous par la disposition des couleurs et la forme Le cörps des leurres est en corne, en sabot d'animal, en os, ou zinc ou en bois peint avec de la poudre de nacre, alors que pour les parties arrières on emploie des plumes ou de la peau de poisson.

Cependant, pour la pêche aux palangres on préfère les poissons comme appât plutôt que les leurres artificiels. En vue de diminuer les coûts et la travail nécessaires pour la conservation et le transport des poissons servant d'appât utilisés par les palangriers quand ils opèrent dans les regions tropicales, on a effectué des essais avec un leurre de caoutchouc-mousse mat qui possède une forme et une odeur voisines de celles du calmar.

Bien que les expériences sur les lieux de pêche avec cet appât artificiel aient donné des résultats inférieurs à ceux obtenus avec des poissons servant d'appât, une analyse serrée des données montre que cela peut être du à la position relativement défavorable des leurres sur la ligne.

Añagazas para pescar empleadas en el Japón, con especial mención de un cebo artificial hecho de caucho esponjoso elástico

Extracto

Los pescadores japoneses que se dedican a la pesca con líneas emplean diversas clases de añagazas, todas ellas de colores y formas distintos. El cuerpo de la añagaza se hace de cuerno, pezuña, hueso, zinc o madera, pintado con polvo de madreperla y para las colas se emplean plumas o piel de pescado.

Sin embargo los que se dedican a la pesca con palangres prefieren el pescado a las añagazas artificiales como carnada. Con objeto de reducir los gastos y la mano de obra necesaria para la conservación y transporte del pescado empleado como cebo en los barcos palangreros que pescan en la zona tropical, se han realizado ensayos con una añagaza de caucho esponjoso que tiene la forma y el olor análogos a los del calamar y color mate.

Aunque los resultados obtenidos en la práctica con este cebo artificial han sido inferiores a los logrados con pescado, el análisis detallado de los datos indica que puede deberse a la posición relativamente desfavorable que ocupan las añagazas en el palangre.

INTRODUCTION

JIGS are meant to imitate some kind of small fish and at the same time retain a fishing efficiency as high as that of live-bait. The jigs must therefore be adapted to the particular type of fishing operation and well suited on the basis of a physiological study of the sensory functions of fish such as vision, smell, taste, and touch. However, among dozens of different types that have been in service for trolling and pole-and-line fisheries in Japan, the majority have been devised, not on a biological ground, but on ideas coming from years of experience on the part of skilled fishermen. Some of these jigs appear to be as effective as live bait in luring fish. Here a brief description will be made of some of the representative types of jigs employed by Japanese fishermen with special reference to the result of experimental long line fishing in which artificial bait made of latex sponge rubber was used.

JIGS FOR TROLLING AND ANGLING

In trolling and pole-and-line fishing, the jigs are designed with special attention to their shape and colour as they are intended to appeal mainly to vision of fish. Nevertheless, it is not always necessary for the jigs to have an exact similarity in appearance with live fish. Instead, a substance roughly looking like a fish is enough for the purpose, as far as the shape is concerned. On the other hand, a subtle arrangement of colours, much brighter than actual ones, is needed, because the colours appear to be more important than the shape in enticing

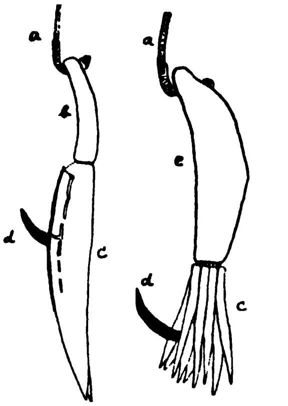

Fig. 1. Skipjack jigs. a—*Angling line;* b—*Zinc bar;* c—*Fish skin;* d—*Hook;* e—*Horn.*

Fig. 2. Troll line with float. a—*Angling line;* b—*Float;* c—*Jig*

the fish to strike. In addition, the effect of a jig will be enhanced by quick and continuous movement in and out of the water, as is the practice in pole-and-line fisheries. Jigs used in this type of angling are illustrated in fig. 1. The above facts explain the reason for adding a float to a troll line as in fig. 2 which gives the jig a jerking movement in the water. It also explains why fish appear to strike better in a rippling sea than when it is calm.

In some types of angling for squid, mackerel or perch, jigs have been found as good as, and sometime better than live bait (fig. 3).

When fish are so excited as in the case of pole-and-lining for skipjack and frigate mackerel, jigs are preferred to live-bait to save time and labour (fig. 4). Even where jigs are not as effective as real bait, fishermen keep them handy for use when the stock of live bait on board is exhausted, as in trolling for tuna or yellowtail (fig. 5).

In construction, most jigs are provided with a shaft and one or two hooks. Those which have only a polished hook or a hook furnished with fish skin or a glass bead, form an exception.

The shaft is usually made of horn, hoof, bone, zinc or wood, and painted with powder of mother-of-pearl. Bird feathers, fish skin, or seaweed are used for the tail of the jigs.

For freshwater angling, jigs are made to imitate insects or flies, while for marine fisheries they are made to resemble squid, sardine, octopus, shrimp or crab, each being near to life size. Some hooks have no barb, this to facilitate dehooking, others have double hooks depending on types of operation. Fig. 5 shows some of the lures in general use in Japan.

A rather new type of jig-tail, is thrust over a hook in the same manner as is done with real bait. With the recent application of plastics and sponge rubber to fishing industry, this type of jig is being produced to look like squid, crab, saury or fish eggs. Sometimes they are used together with, and sometimes independently of, true baits[1].

ARTIFICIAL BAIT FOR LONGLINE FISHERY[2]

Up to the present time, artificial bait has been rarely used for longline fisheries, probably because of the lack of movement in the hooks compared with trolling and angling. An efficient artificial bait has long been sought to relieve cost and manpower needed for preservation, transportation, and storage of the bait fish used by the tuna longline fleets operating far into the equatorial

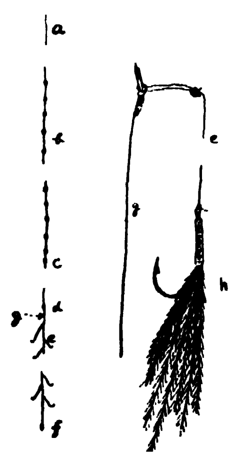

Fig. 3. Handline for mackerel.

a—*Sisal;* b—*Silk;* c—*Gut;* d—*Swivel;* e—*Branch line;* f—*Lead;* g—*Main line;* h—*Jig with feather.*

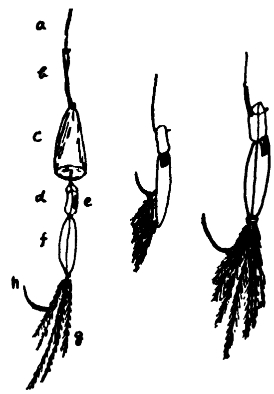

Fig. 4. Tuna and frigate mackerel jigs.

a—*Angling line;* b—*Eye for tying the line;* c—*Lead;* d—*Shell of abalone;* e—*Inlaid lead;* f—*Fish skin;* g—*White feather;* h—*Hook.*

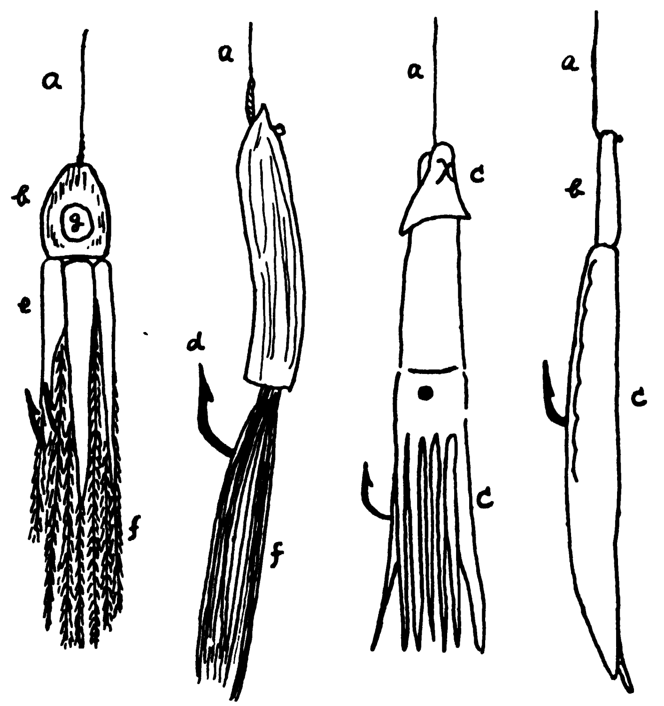

Fig. 5. Trolling lures.
a—*Angling line;* b—*Zinc;* c—*Fish skin;* d—*Hook;* e—*Cattlehorn;* f—*Feather;* g—*Shell of abalone.*

TABLE I

Details of longline operations

Test number	*Date (1953)*	*Position Lat. N.*	*Position Long. E.*	*Time Setting*	*Time Hauling*	*Surface temp. 0° C*	*Baskets*	*Bait*
I	Mar. 15	5° 35′	163° 2′	0335-0755	1230-2230	28·6	330	Frozen squid on 1st hook, lure on 5th hook. Frozen saury on others.
II	Mar. 16	5° 4′	163° 11′	0300-0725	1230-2320	28·6	350	
III	Mar. 17	5° 0′	163° 2′	0315-0740	1230-0020	28·6	350	
IV	Mar. 19	4° 51′	163° 1′	0335-0740	1230-0020	28·4	350	
V	Mar. 20	4° 53′	163° 1′	0345-0740	1215-2145	28·1	320	
VI	Mar. 21	4° 58′	163° 0′	0345-0725	1155-2245	28·4	350	Frozen saury except on last 5 baskets which had lures.
VII	Mar. 23	4° 39′	163° 39′	0305-0715	1140-2300	28·4	356	
VIII	Mar. 24	4° 39′	162° 30′	0330-0740	1205-0100	28·4	350	
IX	Mar. 25	4° 48′	162° 30′	0330-0750	1205-2250	28·4	335	
X	Mar. 26	4° 46′	162° 30′	0314-0700	1145-2045	28·3	310	

region. With this in mind, a type of artificial bait shaped like a squid has been prepared from latex sponge according to a design of the author (fig. 6).

A series of field experiments with this bait was entrusted to the crew of the R.V. *Sagami Maru* (200 gross tons) of the Kanagawa Prefectural Fisheries Experimental Station when they operated for tuna in the equatorial region in March 1954. Because of a limited number of experiments and other difficulties encountered in the field, the results were inconclusive.

The longline used for the experiments had 5 hooks per basket of 225 m. length and is outlined in fig. 7. The design is essentially the same as that of the commercial longlines used in Japan. For the comparative experiments conducted ten times during March 15 to 26, 1953, the lure was fixed on the 5th hook of every basket of test I, while in tests V to X, all hooks of the last five baskets of the line had an artificial bait. The other hooks, as a control, had either frozen squid or frozen saury bait.

The artificial bait, made of latex sponge rubber, was painted with micaceous powder to give it an opaque glimmering lustre (fig. 6). It measures 35 centimetres in total length, and weighs 40 grams. About 60 grams of sand was stuffed inside the trunk and after soaking for about 5 minutes, the weight was about 130 grams in air; the weight under water being approximately that of a real squid of similar size. To give it a squid-like smell and taste, it was soaked, before use, in a saponified solution of squid oil, and hooked through the trunk as is done with true squid bait.

Table II shows that the fishing efficiency of the arti-

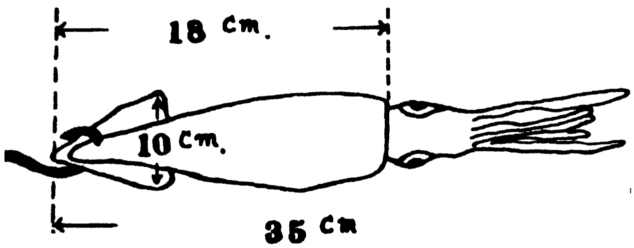

Fig. 6. Latex sponge artificial squid.

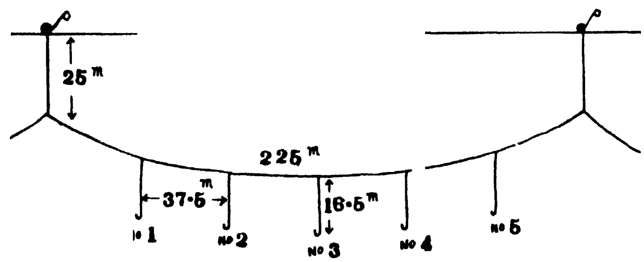

Fig. 7. Details of one basket of longline.

TABLE II

Catch in Tests I to IV

	Test I						*Test II*						*Test III*						*Test IV*					
Hook Number	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
Bait used ...	SQ	S	S	S	L		S	S	S	S	S		S	S	S	S	S		S	S	S	S	S	
Yellowfin ...	1	2	9	5	1	18	8	9	10	8	3	38	11	12	9	16	5	53	20	28	28	10	14	100
Bigeye	1	–	2	2	1	6	3	1	1	1	–	6	–	1	1	–	–	2	1	–	–	–	1	2
Ground shark	–	2	1	1	1	5	1	6	3	2	1	13	1	2	2	4	2	11	1	2	4	2	1	10
Black marlin ...	2	1	4	2	–	9	7	1	5	5	5	23	6	2	1	2	3	14	2	2	5	–	–	9
Sailfish	–	–	–	–	–	0	2	–	1	1	–	3	3	–	–	1	2	6	–	2	–	1	–	3
Other sharks ...	–	–	2	–	–	2	1	2	4	4	1	12	4	2	2	2	4	14	–	–	1	1	2	4
Skipjack ...	–	1	1	–	–	2	1	1	2	2	–	6	–	2	2	1	–	5	1	–	2	1	–	4
Spanish mackerel	–	–	–	–	–	0	–	1	–	1	–	2	2	–	1	1	–	4	1	1	1	1	–	4
Dolphin ...	–	–	–	–	–	0	–	–	–	–	–	0	–	1	–	–	1	2	1	1	–	–	–	2
Barracuda ...	1	–	–	2	–	3	1	–	–	–	2	3	–	–	–	–	–	0	–	–	–	1	3	4
(Total catch) ...	5	6	19	12	3	45	24	21	25	24	12	106	27	22	18	27	17	111	27	36	41	17	21	142

TABLE III

Hooking rates according to position on line

Test number / Hook number	I		II		III		IV		Mean for Tests II to IV
	Cn	λn	Cn	λn	Cn	λn	λCn	n	λn
1	5	0·111	24	0·226	27	0·243	27	0·190	0·220
2	6	0·133	21	0·198	22	0·198	36	0·253	0·219
3	19	0·422	25	0·236	18	0·163	41	0·288	0·229
4	12	0·267	24	0·226	27	0·243	17	0·120	0·196
5	3	0·067	12	0·113	17	0·153	21	0·148	0·138
C	45		106		111		142		

TABLE IV

Catch in Tests V to X

Test Number	Total		Artificial bait		Saury-bait	
	Number of basket	*Number of catch*	*Number of basket*	*Number of catch*	*Number of basket*	*Number of catch*
V	320	142	5	4	315	138
VI	350	147	5	0	345	147
VII	356	150	5	3	351	147
VIII	350	183	5	0	345	183
IX	355	196	5	0	330	196
X	310	85	5	1	305	84
Total	2,021	903	30	8	1,991	895
Mean rate	0·447		0·267		0·449	

ficial bait on the 5th hook of every basket in Test I is inferior to the bait used on the other hooks. However, this may have been caused by the relative position of the hook on the line, a factor that has been known to affect the efficiency of longline operation. In Tests II to IV in which all the hooks were provided with true baits, the 5th hook also shows a lower efficiency.

Disregarding species of the catches, one may indicate the rate of fishing efficiency, λn, of nth hook by

$$\lambda n = Cn/C$$

where C : total catch of one longline operation
Cn : the number of catch by nth hook.

Table III, showing λn compared for each hook is suggestive of this. In Tests II to IV where only frozen saury were baited, the 3rd hook was the best, while the 5th hook had the lowest average efficiency. Because of the limited number of the experiments, and the difference in the number of baskets the experiment is of course inconclusive.

The efficiency of the artificial bait on the 5th hook can be compared to that of the true squid-bait on the 1st hook, by comparing the ratio of efficiency between these hooks in tests I to IV.

The calculated efficiency of the artificial bait on the 5th hook corresponding to its efficiency if used on the 1st hook may be estimated where:

$$\lambda\, 1a = \frac{\lambda 5a \quad \lambda 1s}{\lambda\, 5\, s}$$

where: $\lambda\, 1a$: calculated efficiency of artificial bait if on 1st hook
$\lambda\, 5a$: catching rate of artificial bait on the 5th hook
$\lambda\, 1s$: catching rate of saury bait on the 1st hook
$\lambda\, 5s$: catching rate of saury bait on the 5th hook

Inserting the numerical values of Table III into the above equation gives:

$$\lambda\, 1a = 0{\cdot}067 \times \frac{0{\cdot}220}{0{\cdot}138} = 0{\cdot}107$$

This brings the efficiency of the lure near to that of the true squid-bait which has 0·111.

Although unreliable, as the result of only one test it may indicate that the efficiency of the artificial bait is better than its catch rate shows.

When the artificial bait was used in the last five baskets in tests V to X, the results as shown in Table IV indicate that the fishing rate of the artificial bait per basket is again inferior to, or about 60 per cent. of the mean rate. In test I, the artificial bait had a rate per basket ranging 45 per cent. to 60 per cent. of the saury bait. (Fishing rate per basket is proportional to the catch per hook in the same haul.)

Although the efficiency of the artificial bait appears to be merely about half as good as the saury-bait, one should not overlook the influence which the position of the hook or basket exerts on the catch, as pointed out before.

If the catches of Tests V to X are arranged, in accordance with the position of the baskets, into three sections comprising the first five baskets, the intermediate baskets, both being baited with saury; and the last five baskets with the artificial bait (Table V), then the catch per basket in the first section is no more than 50 per cent. of the last section and still lower than the intermediate section. Thus, so far as the results of the present experiments are concerned, it may be reasonable to conclude that the ratio of catch per basket between the artificial bait and the saury bait may be higher than 60 per cent. as has been computed from the values in Table IV.

REFERENCES

[1] Suzuki, S. One hundred types of commercial anglings. Ohashi and Co., Tokyo, 1931.

[2] Koyama, T. Study on bait for tuna longline. I—An artificial bait of latex sponge shaped like a squid. Bull. Tokai Reg. Fish. Lab. No. 15. 1957.

TABLE V

Catch rates according to line section

Test Number	First 25 hooks with saury-bait		Middle section with saury-bait		Last 25 hooks with lure bait	
	Number of basket	*Number of catch*	*Number of basket*	*Number of catch*	*Number of basket*	*Number of catch*
V	5	1	310	137	5	4
VI	5	1	340	146	5	0
VII	5	0	346	147	5	3
VIII	5	1	340	182	5	0
IX	5	0	325	196	5	0
X	5	1	300	83	5	1
Total	30	4	1,961	891	30	8
Mean rate	0·133		0·454		0·267	

DISCUSSION ON FISH ATTRACTION

Dr. M. Ruivo (Portugal) Rapporteur: The ultimate aim of location, detection and attraction of fish is the establishment of a connection between man and the fish through a signal or stimulus. So far as fish attraction is concerned, man would set off a particular signal or stimulus with the intention to produce a directed response of the fish.

The extent and the characteristics of the response would be a function of the quantitative and qualitative properties of the stimulus used, of the ambient conditions, and of the specific conditions of the fish.

The stimuli may be luminous (visual), sonorous (audial), mechanical or chemical. The response of the fish to electrical stimuli will be discussed at another session of this Congress. These stimuli act separately or combine in a more or less complex manner. External factors of the surrounding medium may cause qualitative and/or quantitative changes of a stimulus during its course from origin to the sensory organs of the fish. Factors specific to the individuals must also be considered; the anatomy and physiology of the sensory organs, the level of reaction, the type of reaction and its degree of intensity, vary according to the physiological state of the fish and its adaptation to the ecological conditions of the medium and/or the stimulus itself. Furthermore, the effect of group reaction (herd instinct) must be studied.

In applying methods previously used only in laboratory experiments to the natural field, practicability and cost must be in reasonable relation to expected yield.

The adaptation of the various attraction methods and equipment to the various types of fisheries is done according to the type of fishing gear (fixed or mobile, nets, hooks, suction pumps, etc.) and its particular characteristics (material, colour, shape, chemicals used for the preservation of the nets) which may influence the behaviour of the fish.

In commercial practice the attraction of fish may be based on either empirical factors or by applying a strictly scientific method. When measured in terms of time and yield, the results obtained by these two approaches are very different. Physical and chemical stimuli (light, bait, lures, sound) to attract or direct the fish have been used in a more or less empirical manner throughout the ages.

The evolution of light-fishing over the centuries is particularly demonstrative. The light source was at first obtained by burning coal or torches. Then oil and acetylene, and more recently gas and electric lamps came into use. The fact that electric lamps can be immersed has rendered "light" fishing far more efficient and has permitted its use in regions where the state of the sea and the turbidity of the waters had hitherto been limiting factors.

This evolution has, however, been very slow and is far from having reached its end. That these various lighting systems still coexist in various parts of the world, may be explained by the lack of technical and scientific bases, scarcity of information, and the geographical isolation of certain communities of fishermen.

These factors are stressed by Fukuhara, Kawakami and Mihara, who discuss light-fishing, its growing importance in certain regions (i.e. Japan and the Philippines), and suggest its possibilities in others.

Experiments made with a directed light beam have led to the development of a new method by which the fish is attracted and guided into a fixed net by the successive lighting of a series of associated lamps (Sasaki). This doubles the catching capacity of the fixed net.

Kawamoto and Tamura demonstrate how basic research may furnish scientific information of fundamental importance for the development of new fishing methods and the interpretation of results obtained by old ones. Experiments with various species of fish on the significance of the wave-lengths of light have shown that blue and green lights have the strongest effect. The daily rhythm in phototaxis and the influence of moonlight were also investigated. The reactions of fish were bound to be far more complex, under natural conditions due to the influence of external factors (temperature, turbidity, currents), making the interpretation of test results difficult.

Further studies on the significance of the visual sense for the behaviour and ecology of fish will greatly assist gear technology, particularly in regard to the reaction of fish to nets, hooks, bait, etc. and subsequently in the problem of gear selectivity.

When catching fish by trolling, the lure must be seen. Nets, however, should preferably not be clearly visible. Tamura has carried out experiments to determine the visual reaction of fish to cotton and nylon lines. He, furthermore, found that the reaction to bait is the result of a complex process in which both the visual stimuli (localization) and the water motion produced by the bait or prey (capture) are important.

Useful data for interpreting the bathymetrical distribution of fish, and consequently for the design of gear and the planning of fishing operations, may be obtained by investigating the anatomy of the optical system (optical axis and angle of vision), the ideal lighting conditions and the phototaxis rhythm, which are closely connected with the ecology of the species under observation.

Chemical stimuli play an important part in the use of bait and lures (complex forms of chemical, visual and mechanical stimuli).

Certain fisheries (for instance, tuna and cod) are to a certain extent dependent on the possibility of obtaining live or dead bait in certain quantities and quality in a determined period of time. Such bait is often available only in waters far from the fishing area and a seasonal species sometimes may have to be preserved (frozen, salted, etc. or, in the case of live bait, kept alive in tanks). Capture may affect the problem of the conservation of natural resources. The eventual value of the bait fish for human consumption must also be considered.

These factors imply a number of limitations and contingencies to the main fisheries. The development of artificial lures or other stimuli capable of attracting fish could radically change the economy of these fisheries.

The problem is, however, extremely complex, and the research necessary covers a very wide field.

Tester describes a very interesting series of experiments made with a view to improving the fishing techniques for tuna, and particularly with the aim of discovering a substitute for bait fish. Experiments were carried out in fish ponds and at sea, to determine the reactions of different species of tuna to chemical, visual (artificial light, bait or moving lures), and audial stimuli. It was found that in tuna the sense of smell is less important than vision, although a positive response to aqueous or alcohol extracts of tuna meat was observed. The response to audial stimuli was weak.

Koyama refers to tests with artificial bait made of latex sponge rubber, of squid-like shape and smell, which could eventually reduce the cost and work necessary for the preservation and transportation of bait fish needed for longlining in the tropical zone. These lures, although found to be less attractive than natural bait, could very probably be improved.

Repellent substances can also be profitably utilized in fishing. Recent studies in Canada have revealed the repellent action of mammal skin extracts on salmon. These extracts are extremely active even when much diluted, and might be used to deviate the salmon from their course and orienting them in a determined direction.

Another barely investigated sector is the use of auditory stimuli to attract fish. In recent years, new equipment (hydrophones, tape-recorders, etc.) has enabled some progress to be made and has brought many new facts to light. It is possible that one day either artificial noise or the tape-recorded sounds of sea animals may be used as attraction signals along with a particular fishing method.

A better knowledge of the behaviour and the reaction of fish to the various types of stimuli, as well as of the processes which are at the basis of directed movement (be it of attraction or repulsion) could increase the efficiency of fishing operations —either by improving the catching possibilities of existing gear, or developing new methods.

Dr. A. W. H. Needler (Chairman): Developing the means of locating fish by understanding their association with conditions and understanding more of their reactions so as to attract them, is a very interesting study. On the East Coast of Canada there is a small fishery for herring with lights. The fishermen have found that the yellow flickering light produced by kerosene soaked waste, burning in a basket on the bow of the boat, attracted the herring much better than any of the much stronger artificial lights which they tried to use. This sort of thing shows how little we know about the behaviour of fish.

Dr. F. J. Verheyen (Netherlands): I came in contact with the light fishing technique in the Mediterranean in 1954 in night fishing for sardines, anchovies, etc. I soon became convinced that it was erroneous to believe that the concentration of fish around the lamp depended on light intensity. I have approached the problem from the point of view of a comparative biologist and I have made an extensive review of data available on fishing with lights, on attracting insects with light and on birds flying towards lighthouses. This review suggests that widely separated species of animals are attracted to artificial light under essentially the same conditions, and I have found an explanation of the mechanisms involved in this photic disorientation. Certain features of man-made illumination are abnormal as compared with natural illumination and provoke the disorientated concentration around a lamp. The mechanisms involved are too complicated to be dealt with in detail here but I have given a short outline of them in my paper. In this connection I think it very important to point to some misleading experiments in this field.

A number of Japanese workers have tried to analyse the attraction mechanisms by experiments in an aquarium, but it can easily be demonstrated that the gathering of fish by a lamp in an aquarium is not comparable with the concentration of fish around a lamp at sea. First, very young fish were used in the experiments, and it is generally agreed that young fish have a higher light intensity preference than have adult fish of the same species. Secondly, there are variations in the photo preference of fish and many other animals. Some fish that are active in the day time then have a relatively high intensity preference but much less at night. Kawamoto and Konishi in 1955 observed this phenomenon in some of their young experimental fish. At night some of the fish even fell asleep in the darkest area of the tank. But it is just during this period, the night, that fish must be gathered with the aid of light and, obviously, the incompatibility of these facts has escaped unnoticed. A number of workers have carried out experiments with various lamps, such as searchlights and water lamps to get some insight into the vertical migration of such fish as the herring, the pilchard and other species. This is the equivalent of looking at nocturnal insects flying towards a street lamp or observing birds dashing themselves against the lantern of the lighthouse. When a searchlight is shone into the sea the behaviour of herring and pilchards, as indicated by the echo sounder, is a result of an unknown and very complicated interference between their normal preference for low light intensities and the disorientated attraction towards the light source. The movements resulting from these two behaviour patterns are dependent upon a number of factors, the fluctuating character of which accounts for the contradictory results of this kind of experiment. I should like to emphasize that such rather primitive experiments are unlikely to yield any consistent results. I should also like to make a comment upon the distinction between detection and attraction in this respect. Detection is perceiving the fish at a certain location, while attraction is directing the fish towards a preferred fishing place by means of certain stimuli. Now the question arises, what is the action radius of a lamp? In attracting insects by light, it is known that the action radius of very strong lamps is small, perhaps some hundred metres. As the absorption of light in water is much greater than in the atmosphere, the action radius of a lamp in water will be less. Fish only gather around the lamp when they happen to enter its immediate environment, thus a lamp might be regarded as a simple instrument to detect a school of fish which passes by accident. As such, it is much inferior to an echo sounder. The lamp has the advantage that, under certain conditions, the fish remain near it. This light fishing technique is, then, passive and based on the random movements of the fish, but the technique can be activated as described by Sasaki. Fish concentrated around the lamp follow the lamp when it is moved. It would be useful to know the maximum rate at which the fish can be moved in this way towards a favourable catching place. Perhaps use can be made of floating lamps moved along the water surface, thus increasing the chance of meeting schools of fish, especially if a number of lamps could be moved from several directions towards a catching place.

Mr. Kristjonsson (FAO): Some Italian purse seine fishermen have in recent years replaced their traditional kerosene or gas pressure lamps with underwater electric lamps such as the one shown to the left in fig. 1. Normally two 500 W lamps are submerged approximately 3 to 4 ft. below the surface under a small boat which carries a gasoline or diesel powered electric generator set of 2 to 3 kw. Occasionally an additional light, as the lamp held by the man in the figure, is also used above the water. Such above-water lamps give a wide horizontal spread of light, but naturally they are mainly useful when the sea surface is unruffled. Generators of 32 V are normally used with 24 V lamps. Thus the light intensity can be varied from yellowish light over to bright white despite the voltage drop in the rubber cables.

Commonly the intensity of the light is kept constant although theoretically it would seem advantageous to use a light of maximum intensity and brightness during the early stages, in order to obtain maximum range for attracting fish into the area under the lamps, and then gradually dim the light somewhat to compact the school before setting the net around it. Of course, any change in light intensity will have to be extremely gradual so as not to scare the fish which often seem to be extremely sensitive.

Before sunset each purse seiner usually tows out to the fishing grounds two light boats which are anchored at a considerable distance from each other. One man is left in each boat to tend the lights and to look for signs of fish gathering below, such as air bubbles rising to the surface when the fish jettison air from their swimming bladders in order to maintain neutral buoyancy when swimming up to shallower depths. If no signs of fish are noticed after two or three hours, the light boats may be moved to another place.

Fig. 1. Electric underwater lamp (left) and above-water lamp (centre) used for attracting sardine and anchovy.

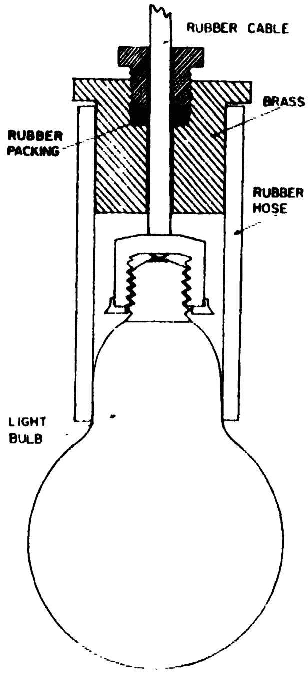

Fig. 2.

From time to time the purse seine boat communicates with the light boats and when it is decided to make a set, the man in the light boat ties its anchor to a float with a small lantern and drifts or rows very slowly a short distance away, in order to enable the purse seiner to set the net around the school without interference from the anchor rope. As soon as the net has been shot and pursing begins the light boat is rowed slowly towards or across the centrepiece of the corkline in order to induce the fish to swim away from the opening of the net under the purse seiner.

The light boat remains just outside the net until pursing is completed, when it either returns to the anchor buoy or else transfers to another likelier fishing location.

Although some underwater lamps are available as a standard commercial commodity, the Italian fishermen in Fiumicino (a small fishing place at the mouth of the Tiber) have their lamps made in a local workshop. Such lamps can really be made by the fishermen themselves (see fig. 2).

The first step is to get hold of the electric bulb; then to find a strong rubber hose, such as an automobile radiator hose, which fits closely over the neck of the bulb. An ordinary socket can be used with the bulb as it is dry and well protected by the rubber hose which fits at the upper end closely over a brass cylinder through which is drilled a central hole for the rubber covered cable of not less than 3 mm^2 conductor area.

To prevent water from entering along the cable a conical rubber packing can be used, pressed down by a screw plug. Finally, it is good practice to apply several coats of shellac where the rubber hose meets the bulb and the brass cylinder.

A reflector above the bulb will improve the illuminating efficiency but should be small and a heavy weight must be attached below the bulb—like the thick iron ring shown in fig. 1—in order to keep the lamp vertical despite the up and down movement of the boat.

As compared with the surface lights, the main advantages of underwater lamps are: better utilization of the light as there is no loss due to reflection from the surface of the sea and a less powerful light is needed (caution : in shallow water a too strong light reflected from a light-coloured bottom may scare the fish); the underwater light is steady while the above-the-surface lamp will give a flickering and uneven light, especially when the surface waters are ruffled. With underwater lamps the fishermen are able to attract fish effectively in rougher weather, and less time is lost during the full moon period. Better penetration is achieved in turbid water and fishing can be resumed earlier after rains and storms.

I. V. Nikonorov*: Pump fishing, which is one of the new modern methods of fishing, has been continuously used since 1954 in the Caspian Sea in the Soviet Union. This method excludes the application of traditional conventional net materials and it has proved to be very efficient and labour saving. The film which was shown here was shot in 1954 and illustrates the contents of the paper on this fishing method better than I could with further words.

Some developments have been made since 1954 and the technique has been improved. Forty ships are now (Oct. '57) using the light-pumping method in the Caspian Sea. The maximum rate of catch is about 30 tons per 24 hours, and this method is gradually replacing the conical lift nets with lights, being about 50 per cent. more productive. When the fish comes out of the pump on to the deck it is alive, and in no way damaged.

Mr. Traung (FAO): I would like to know if these pumps are in the market for commercial use and if they are sold commercially, can Mr. Juvoy let us know the price and where we can buy them?

Mr. Juvoy (U.S.S.R.): The whole installation costs about 10,000 roubles and could be bought in Astrakhan, the main port on the Caspian Sea coast.

* Spokesman for U.S.S.R. participants.

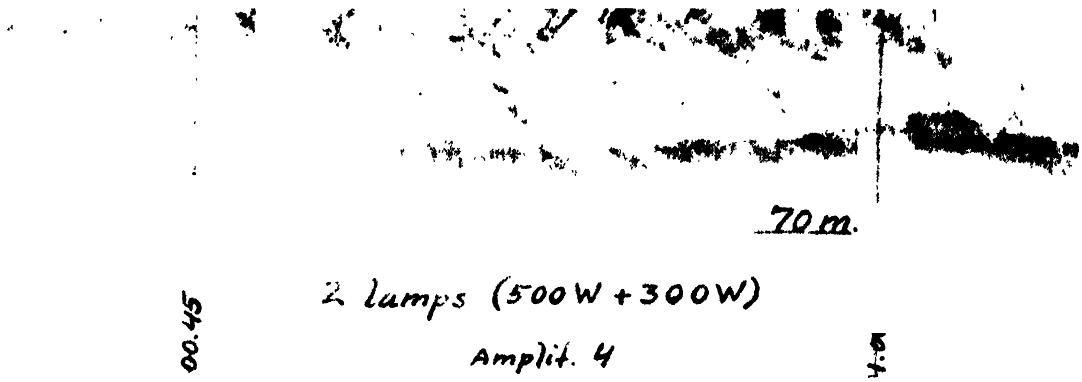

Fig. 1. Echograms of sardine attracted by underwater electric lamps off Tunis. When the lights were put on at 00.45 hrs. hardly any fish were indicated on the echo sounder (Japan Radio Co., "Midget", portable unit). Towards 01.00 hrs. some scattered young fish have gathered near the surface and a school is forming at about 35 m. depth.

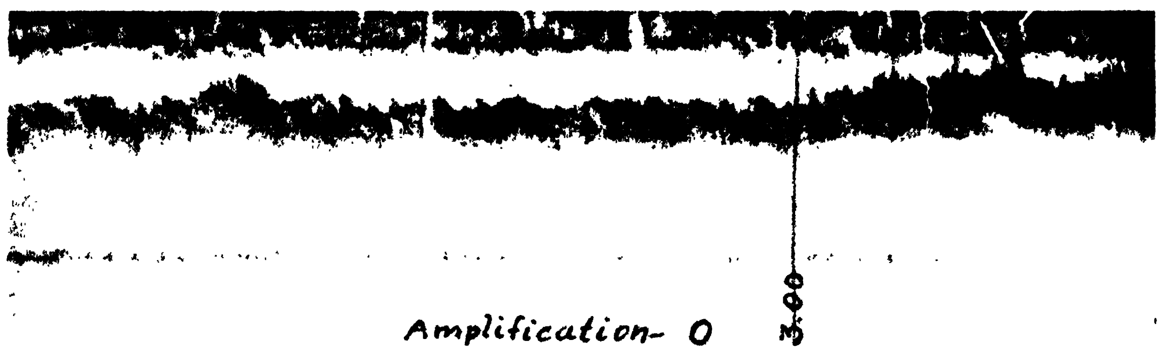

Fig. 2. At 03.00 hrs. the echo sounder (at amplitude 0;— weakest strength) showed more fish had collected at 30-35 m. depth. Without an echo sounder this station might have been abandoned at this stage as the fish were so slow to rise, probably due to different temperature of the surface waters.

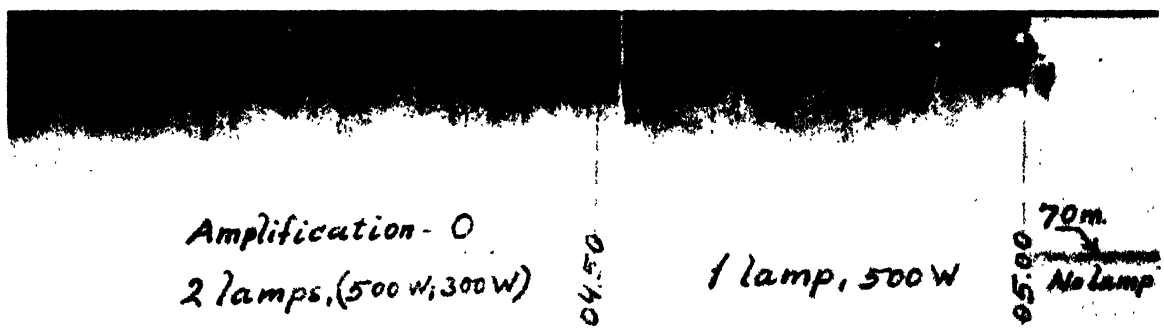

Fig. 3. After about 4 hrs. illumination the fish had finally risen and formed a dense school (about 6 tons) around the light. As soon as the light was extinguished (at 05.00 hrs.) the fish dispersed.

THE EFFECT OF PULSATING ELECTRIC CURRENT ON FISH

by

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Abstract

In this paper the author discusses the different forms of electrical impulses and their effect on the behaviour of certain fishes, and the results of experiments show that the type of impulse that has a steep initial rise followed by a gradual decline of the current is the most suitable one for fishing purposes.

Furthermore, the number of impulses per unit of time is important and it was found that each species of fish had a specific *narcotizing impulse limit* at which, with a minimum of electrical energy, narcosis begins. The connection between the metabolism and current density was also investigated.

L'effet du courant électrique pulsé chez le poisson

Résumé

Dans cet article l'auteur examine les différentes formes d'impulsions électriques et leur effet sur le comportement de certains poissons. Les résultats des expériences montrent que le type d'impulsion à élévation initiale abrupte du courant suivie d'une diminution graduelle est celle qui convient le mieux pour la pêche.

En outre, le nombre d'impulsions par unité de temps est important et on a trouvé que pour chaque espèce de poisson il existe une "limite d'impulsion narcosante" à laquelle la narcose commence pour une énergie électrique minimum. On a aussi fait des recherches sur la relation entre le métabolisme et la densité du courant.

El efecto de la corriente eléctrica pulsatoria sobre los peces

Extracto

En este trabajo el autor analiza las diversas formas de impulsos eléctricos y su efecto sobre la manera en que reaccionan algunos peces. Los resultados de los experimentos hechos demuestran que el tipo de impulso que aumenta en forma pronunciada seguido por una disminución gradual de la correinte, es más adecuado para la pesca.

Además juega un papel de importancia el número de impulsos utilizados por unidad de tiempo, encontrándose que cada especie requiere cierto "máximo y minimo de impulsos narcotizantes" para la iniciación de la narcosis con un minimo de energia eléctrica. También se investigó la relación que existe entre el metabolismo y la intensidad de la corriente eléctrica.

GENERAL

FISH swim towards the anode when under direct or pulsating current of a certain type, whereas under alternating current they show a so-called *oscillotaxis* and take up a transversal position to the direction of the current, in order to tap off as little voltage as possible. As the cause of these phenomena had up to now not been completely explained, the reactions of the isolated nerve were investigated to understand the importance of the *principle of polar stimulation* in the behaviour of fish in electric fields.

Stimulation of the nerves occurs only in response to changes in current and the *threshold value* (the minimum voltage which produces a just visible reaction of the nerve) is smaller when closing the circuit than when opening it. Moreover, stimulation occurs within the range of the cathode when closing, and within the range of the anode when opening the circuit. This *principle of polar stimulation* causes the so-called *Pflüger-effect* of vibration. If the nerve in a nerve muscle preparation is stimulated by placing the anode on the nerve near the muscle and the cathode at the end of the nerve, there will be no muscle reaction because the anode has a paralysing effect (*anelectrotonus*). If the position of the electrodes is exchanged, a vibration of the muscle will be stimulated.

These phenomena observed in the isolated nerve and muscle are parallel to the reactions of the whole animal. If a fish is brought into an electric field, it will show a clear reaction to the anode when direct current is applied, the circuit closed and a certain *threshold value* reached. This reaction can be explained by means of the *principle of the polar stimulation*: When the circuit is closed, a stimulation occurs under the cathode, which the fish tries to escape by swimming towards the anode. If, at the moment of this stimulation, the fish is headed towards the anode, the tip of its tail will be strongly excited and the jerk of the tail will assist this movement towards the anode; if the fish is headed towards the cathode, the current will produce only a slight vibration of the tail, the head will turn towards the anode, and the stimulative effect of the cathode, gradually expanding over the whole muscular system will cause a turning towards the anode (fig. 1).

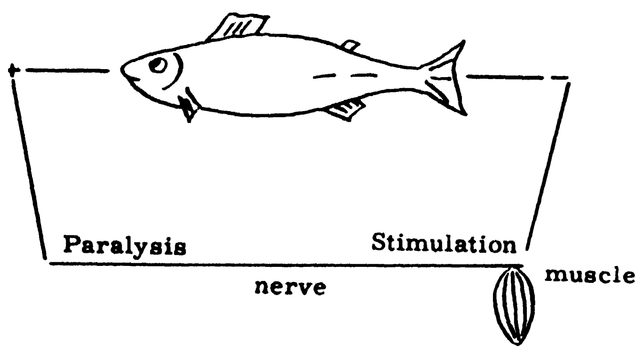


Fig. 1. The fish in the Pflüger Test.

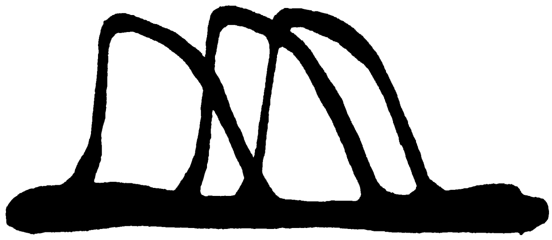


Fig. 2. Shape of impulse discharged by an electrical fish (Electrophorus electricus).

THE EFFECT OF VARIATION IN THE PULSE TYPE

The author has investigated the reactions of fish in relation to variations in the pulse type. He found that when a current of a very slow increase passes through the body of a fish, there may be no reaction at all. Only a fairly strong current flow causes a reaction. This corresponds to the observations made on the isolated nerve where a slow increase or decrease of current has no stimulative effect, as the nerve becomes accustomed to the current passing through (accommodation of the nerve). Not only the change of current but also the speed of this change is of importance for an effective stimulation. The more gradual the increase the higher the *threshold value* for producing an irritation, until, from a certain point onwards, there will be no more stimulation.

When such a slow rise of current is combined with a steep decline, a distinct *opening vibration* occurs towards the cathode. This is parallel to the stimulative effect observed in the nerve under the anode when the circuit is opened, provided the difference of excitation is great enough. Whenever closing and opening reaction (stimulation from both cathode and anode) come into effect at the same time, as is the case of a quick sequence of impulses of this type, their effects might counterbalance each other and disturb the reaction towards the anode.

When the circuit is suddenly closed, i.e. when the current rises steeply, the fish reacts anodically. When immediate opening follows the closing, the cathodic opening vibration does not occur, because the difference of excitation is too small to effect stimulation from the anode.

When the circuit is closed and opened only after some time (maximum 2 minutes), the fish shows a cathodic opening vibration from a certain current-density onward, which corresponds to the *threshold value* for galvanotaxis. This may be called *accommodating vibration.* In this case when the change in excitation is great enough the opening of the circuit has a specific stimulative effect on the fish.

These investigations show which type of pulsating current is the most suitable one for electrical fishery.

A current with slow increase and slow or steep decline characteristics is unsuited for electrical fishing, as it excludes the desired movement towards the anode. With steep increase and gradual decline of the current the fish reacts anodically. The steeper the increase, the lower is the threshold value necessary to obtain the desired reaction. Steeply increasing and slowly declining currents, which are the most suitable for electrical fishing, are technically produced by condenser discharges. Nature itself produces this ideal type of current in the discharges of the electrical fish. This type of current (fig. 2) has a maximum effect under most favourable conditions as far as energy is concerned.

The impulse rate and the length of impulses (impulse period) are also of considerable importance for the effect of pulsating current on the fish[3, 4].

THE EFFECT OF VARIATIONS IN THE PULSE RATE

Kreutzer[8] pointed out that small fish require higher impulse rates than large fish. A large tuna, for instance, only needs 7 to 10 impulses/sec. The explanation is as follows: Each individual impulse causes a muscular vibration in the fish. When the next impulse follows before the mechanical movement caused by the previous impulse has been finished, the muscle is constantly irritated, which causes a cramp. The movement in larger fish is slower than in smaller ones as larger masses have to be moved. Therefore, with bigger fish already a lower impulse rate is sufficient to cause muscular cramp. According to Kreutzer, the *narcotizing impulse limit*, i.e. the impulse rate which, with a minimum of electric

TABLE I

Narcotizing impulse limits **for some freshwater fish (according to Halsband)**

Size of the experimental basin: 35 × 22 × 22 cm.
Size of the electrodes: 22 × 22 cm.
Temperature of the water: 15 degrees C.

Species of fish and average length in cm.	*Voltage of the individual impulse required for galvanonarcosis (in volts)*	*Narcotizing impulse limit*
Trout (*Trutta iridea*) 15-17	6·5	80
Carp (*Cyprinus carpio*) 12-15	7·5	50
Catfish (*Silurus glanis*) 14-16	11·5	40
Eel (*Anguilla vulgaris*) 20-22	13·5	50
Goldorfe (*Idus melanotus*) 13-15	7·5	30
Stone Perch (*Acerina cernua*) 14-16	7·5	50
White Bream (*Blicca björkna*) 12-15	11·5	40
Minnow (*Phoxinus laevis*) 7-9	8·5	90
Stickleback (*Gasterosteus aculeatus*) 6-7	13·5	100
Perch (*Perca fluv.*) 12-14	9·5	70
Loach (*Misgurnus fossilis*) 24-27	9·5	40
Tench (*Tinca tinca*) 16-18	7·5	40

TABLE II

Narcotizing impulse limits for some seafish
Temperature of the water: 15 degrees C.

Species of fish and average length in cm.	*Voltage of the individual impulse required for galvano-narcosis (in volts)*	*Narcotizing impulse limit*
A. acc. to Halsband		
Fatherlasher (*Cottos scorpius*) 15-19	6·2	40
Eelpout (*Zoarces viviparus*) 17-21 ..	10·0	60
Plaice (*Pleuronectes platessa*) 23-26 ..	10·0	30
Five-bearded Rockling (*Onos mustela*) 16-17	11·5	60
Smelt (*Osmerus eperlanus*) 18-22 .	12·0	50
Flounder (*Pleuronectes flessus*) 16-20	11·5	40
B. acc. to Kreutzer		
Herring of medium size		45
Cod of medium size		25
Red Tuna (200-300 kg.)		7-10

energy, just narcotizes the fish, is best for electrical fishing.

The author made investigations on the *narcotizing impulse limits* of various fresh-water and marine fish and found out that each of the tested species had a specific value. Tables I and II give summaries of the results of the experiments.

The fish can be induced to swim towards the anode, if the strength of impulses required for narcosis and a certain pulse rate, usually ten units below the *narcotizing impulse limit*, are applied. The impulse rate must never be so high as to cause constant muscular cramp. It has to be adjusted so that a slight flight movement is still possible between two stimulations, and the fish is gradually directed towards the anode. Narcosis should not be obtained until the anode is almost reached.

When the voltage of the individual impulse is increased beyond the minimum required for narcotizing effect, the *narcotizing impulse limit* will decrease accordingly. In this case, more electrical energy would be needed than the minimum required at a proper impulse rate.

When there is enough voltage to produce the narcotizing effect and the number of impulses/sec. is increased beyond the *narcotizing impulse limit*, the reaction of the fish will be decreased until, at a certain value corresponding approximately to the doubled *narcotizing impulse limit*, the same narcotizing effect sets in again.

The tests made with carp provide a suitable example. A voltage of 7·5 V. at a rate of 50 impulses/sec. caused galvanonarcosis of the fish, 60 pulses/sec. decreased the reaction, 70 impulses/sec. caused a temporary loss of equilibrium, 80 impulses/sec. left the fish in upright position, and 100 impulses/sec. caused loss of equilibrium again. The different reaction of the individual species of fish to impulse rates may well be brought into relation to the different size. Yet it is assumed that other factors, such as different values of *chronaxy*, of speed of conductivity and of *refractive time*, also have a decisive influence on the specific behaviour of the fish. The varying reactions of the species of fish to different impulse rates make it possible, to a certain extent, to select the kind and size of fish in electrical fishing.

THE EFFECT OF VARIATIONS IN THE IMPULSE PERIOD

Scheminzky[11] found out that the physiological effect of pulsating current did not change, when the impulse period was reduced to 1/10. In fact, this reduction means a decrease in energy of, for instance, 2 kw. to 0·2 kw. This saving of energy, however, is of great importance for the economy of electrical fishing, especially in salt water[10]. At first it was supposed that the impulse period must not be below the *half value time* of 1 msec. Recent investigations by American, Japanese and German authors[1, 8, 9], however, prove that the impulse period required for effective fishing may be much smaller than that. For instance, as average value for trout, a *half value time* of 0·3 msec. may be assumed. These values, however, vary according to the species, size and physiological condition of the fish.

The author made investigations into the relation between intensity and period of impulses[8].

It is known from nerve physiology that each electrical stimulation must have a certain minimum strength (*rheobasis*) and a minimum flowing period (*effective period*) in order to produce a reaction in the nerve. As this minimum period has the desired effect, any additional time is wasted. Current intensity and time of application are in a certain relation to each other allowing for a great number of different *effective periods*. The greater the intensity of stimulation, the shorter the *effective period*. When the *effective period* is calculated for each potential and the values obtained are classified into a system of coordinates, a curve resembling a hyperbola will develop. As mentioned before, the required potential decreases with increasing period of stimulation until a certain *threshold value* is reached, after which the effect remains constant throughout any extension of time, even if the pulses are infinitely long. This curve, indicating the potential needed for a certain period of stimulation, thus runs in linear shape from a certain point onward. The turning-point of the hyperbola is where stimulation can be obtained with the smallest consumption of energy.

The author studied the reactions of the fish under the influence of pulsating current of different potentials and impulse periods to find out to what extent the principles prevailing in the isolated nerve could be applied to the behaviour of the whole fish. Curves relating to the potential and stimulative period were developed for the behaviour of the whole fish in order to determine the most favourable relation of energy and impulse period needed. The energy was worked out according to:

$$E = \frac{T}{2R} V^2 F;$$

where T = impulse period in sec.
R = resistance in Ohm.
V = the peak voltage of the pulse.
F = the impulse rate per sec.

Two kinds of freshwater fish (trout and carp) of 8 to 12 cm. length were tested at a water temperature of 15 degrees C. As the fish were of similar size, the results obtained are considered comparable.

First, applying the maximum *half value time* of the impulses of 2 msec., the *threshold value* which just produced a reaction in the whole fish was determined. This threshold value corresponded to the *basic voltage*

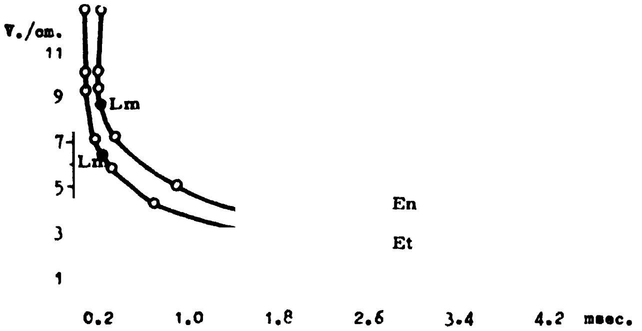


Fig. 3. The significance of voltage and duration of stimulation for the reaction of fish. Test fish = carp, 9·5 cm long. *G* = basic voltage; *Lm* = minimum of efficiency; *Et* = galvanotaxis; *En* = galvanonarcosis.

(*rheobasis* when measured in the nerve). After that, potential and impulse period were gradually increased and the various stages of reaction i.e. *first reaction, electrotaxis*, and *electronarcosis*, were registered continuously. The values obtained were classified into a system of coordinates giving the *half time value* of the impulses in relation to the voltage per cm. By this procedure typical curves resembling hyperbolas, were obtained for each stage of reaction.

The results of the experiments show that the effects on the fish are similar to those which are decisive in the case of the isolated nerve. All the fish used in the experiments showed that the pulse periods necessary for producing a certain reaction decrease continuously with the increase of the potential of the pulse. From a certain threshold value onward, the curve presenting the reactions of a fish runs linear, indicating that a further increase in time has no additional effect. Figs. 3 and 4 show the results of two typical series of tests. These curves help in calculating the minimum values of efficiency for producing a certain reaction by means of the formula:

$$E = \frac{T}{2R} V^2 F.$$

The results given in figs. 5 and 6 prove that the consumption of energy is great when the impulse period is long or the impulse period is short.

In between these two extremes there is a point of

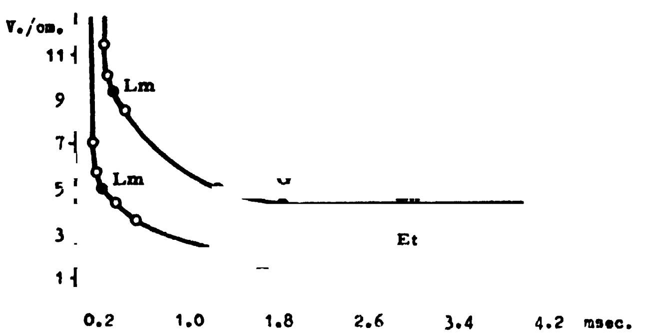


Fig. 4. The significance of voltage and duration of stimulation for the reaction of fish. Test fish = trout, 9·0 cm. long. *G* = basic voltage; *Lm* = minimum of efficiency; *Et* = galvanotaxis; *En* = galvanonarcosis.

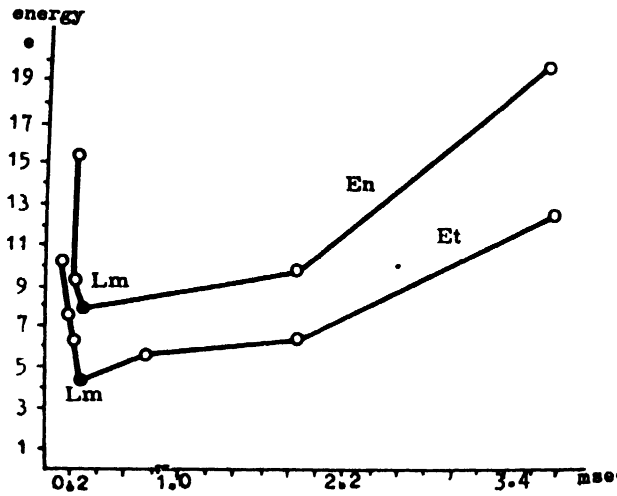


Fig. 5. Energy curve for carp, 9·5 cm. long. Lm = minimum of efficiency; *Et* = galvanotaxis; *En* = galvanonarcosis.

lowest consumption of energy, the *minimum of efficiency*, marked by Lm in the curves. This *minimum of efficiency* does not coincide with the turning-point of the hyperbola, but is slightly above it, on the steeply rising branch of the curve.

The results of the experiments prove that the most favourable impulse periods required for the stages of reaction are below the *half time value* of 1 msec. for either species of fish. As far as the *minima of efficiency* are concerned, there exist slight differences between the species. The trout needs a smaller *minimum of efficiency* than the carp for the stage of *electrotaxis*. For the stage of *electronarcosis*, however, the trout requires a greater *minimum of efficiency*.

Knowing the *minima of efficiency* for the various species of fish is of practical importance as this makes it possible, when pulsating current is applied, to operate with optimum potentials and impulse periods under the most favourable conditions. For instance, the curve indicating the voltage in relation to the stimulative impulse period for trout shows that the optimum period

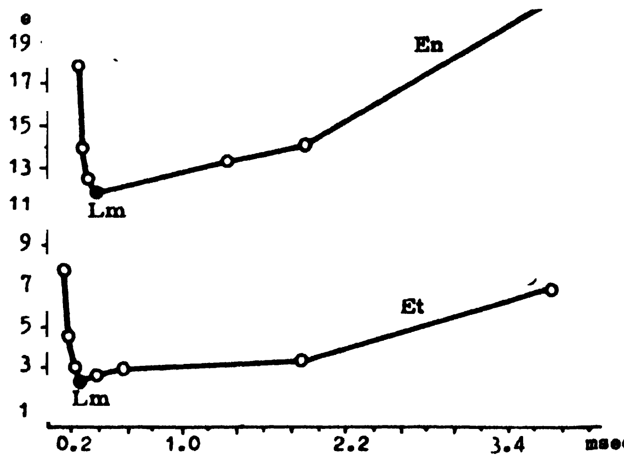


Fig. 6. Energy curve for trout, 9·0 cm. long. Lm = minimum of efficiency; *Et* = galvanotaxis; *En* = galvanonarcosis.

is reached at the *half value time* of 0·3 msec. For example, if longer impulse periods of 2 msecs. are used, the stimulative effect will not increase, but double the energy will be required, as can be seen from the energy curve. If the impulse period of 4 msec. is applied, treble the energy will be required.

If the impulse period is shorter than 0·3 msec. the desired effect can still be produced, if the voltage is increased; the energy required, however, is also treble to that of an impulse period of 0·1 msec.

THE INFLUENCE OF THE INTENSITY OF METABOLISM

We see from the above investigations that different species of fish show specific reactions to the electric current, especially to pulsating current. *Salmonidae*, for instance, require a stronger electric field for narcosis than *cyprinidae*, but they are more easily excited by the electric current and induced to certain movements (*galvano-* or *oscillotaxis*). Furthermore, the intensity of the reactions in the electric field may vary at different times of observations, even among fish of the same kind. It is known that, for instance, trout are more easily stimulated in summer, when the temperature of the water is higher, than in winter. Finally, it is supposed that the intensity of metabolism and activity of the fish are of importance in this connection.

One of the main factors influencing the physiological state of fish is the ion composition of the water. It is proved by earlier investigations[2] that an increase of the concentration of the potassium-ions in the water results in an increase of metabolism, whereas an increase of the concentration of the calcium-ions causes decreasing metabolism. Potassium and calcium are also responsible for the physiological equilibrium. Potassium increases the excitability of the nerve, whereas calcium reduces it. Any change in the physiological state, however, will more or less influence the behaviour of the fish in the electric field.

The influence of the intensity of metabolism on the excitability of fish in the electric field was investigated. As before, two different species of fish (trout and carp) were compared, and different intensities of metabolism among fish of the same species were tested. The *first reaction*, *galvanotaxis*, and *galvanonarcosis*, were observed.

The results of the experiments proved that the trout, a fish with highly intensive metabolism, needed smaller current-densities than the carp to develop the first two stages of reaction. The carp, however, was sooner narcotized than the trout. In this case, a low intensity of metabolism is combined with the paralysing effect of the current.

When the fish became acclimatized to solutions of substances which effected a decrease of metabolism ($MgCl_2$—salt mixture, etc.), the threshold values for the *first reaction* and *galvanotaxis* were distinctly higher. The current-density for the stage of *galvanonarcosis*, however, was lower. Where the level of the metabolism of the trout was increased (for instance by application of KCl) the current-densities required for producing the first two stages of reaction were lower. Greater threshold values, however, were required for narcosis (Tables III and IV).

TABLE III

Test fish : *Trutta iridea*

Temperature of the water: 15 degrees C.

Substance decreasing metabolism: salt-mixture of the following combination :

NaCl = 0·230 g./l. $MgCl_2 . 6 H_2O$ 2·386 g./l.
KCl = 0·005 g./l. $CaCl_2 . 6 H_2O$ – 0·537 g./l.
$MgSO_4 . 7 H_2O$ = 2·812 g./l.

Length of fish in cm.	Medium	1. Reaction current-density δ	1. Reaction current-density in per cent. of the normal	Galvanotaxis current-density δ	Galvanotaxis current-density in per cent. of the normal	Galvanonarcosis current-density δ	Galvanonarcosis current-density in per cent. of the normal
9·0	Fresh-water	0·374	100	1·430	100	4·004	100
	Salt-mixture	0·660	177	1 826	127	3·146	79
8·5	Freshw.	0·396	100	·496	100	4 202	100
	Salt-m.	0·682	172	·936	129	3·278	78
8·0	Freshw.	0·396	100	·474	100	4·070	100
	Salt-m.	0·682	172	·914	130	3·036	75
9·0	Freshw.	0·396	100	·430	100	4·752	100
	Salt-m.	0 704	178	·804	126	3·542	74
8·5	Freshw.	0·330	100	·430	100	4·070	100
	Salt-m.	0·598	180	826	127	2·970	73
8·0	Freshw.	0·352	100	·408	100	4·488	100
	Salt-m.	0·660	188	·804	128	3·300	74
9·0	Freshw.	0·330	100	·430	100	4·180	100
	Salt.m.	0·528	160	·870	129	2·926	70
9·0	Freshw.	0·308	100	·469	100	4·185	100
	Salt-m.	0·506	167	·900	129	2·706	65

TABLE IV

Test fish : *Trutta iridea.*

Temperature of the water: 15 degrees C.

Substance increasing metabolism: KCl, concentration: 400 mg./l.

Length of fish in cm.	Medium	1. Reaction current-density δ	1. Reaction current-density in per cent. of the normal	Galvanotaxis current-density δ	Galvanotaxis current-density in per cent. of the normal	Galvanonarcosis current-density δ	Galvanonarcosis current-density in per cent. of the normal
9·0	Fresh-water	0·315	100	1·418	100	4·180	100
	KCl	0·205	65	0 821	58	5·348	128
9·0	Fresh-water	0·368	100	1·366	100	4·501	100
	KCl	0·228	62	0·835	61	6·098	134
8·5	Fresh-water	0·335	100	1·382	100	4·300	100
	KCl	0·229	68	0·829	60	5·598	130
8·0	Fresh-water	0·305	100	1·372	100	4·449	100
	KCl	0 203	66	0·851	62	5·601	126
8·5	Fresh-water	0·350	100	1·392	100	4·744	100
	KCl	0·220	63	0·871	63	6·302	133
9·0	Fresh-water	0·342	100	1·436	100	4·210	100
	KCl	0·230	67	0·874	61	5·426	129
9·5	Fresh-water	0·345	100	1·451	100	4·499	100
	KCl	0·203	59	0·884	61	5·974	133
8·5	Fresh-water	0·330	100	1·319	100	4·101	100
	KCl	0·202	61	0·779	59	5·288	129

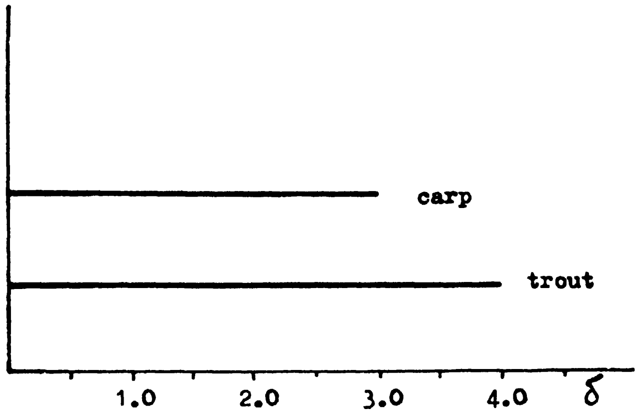


Fig. 7. Width of narcosis *for carp and trout. δ - curren. density.*

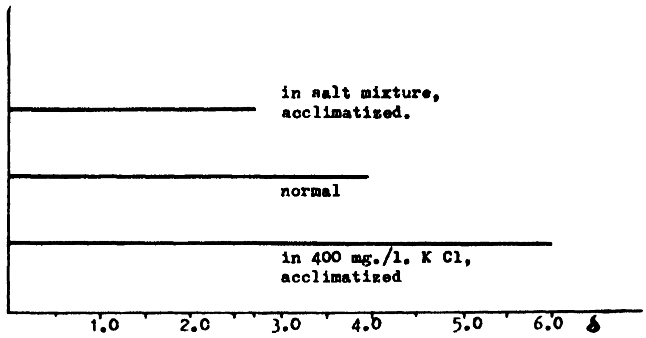


Fig 8. Width of narcosis *for trout at different intensity of metabolism. δ -- current density.*

Active fish with high intensity of metabolism are more easily stimulated by electric current, but their resistance against narcosis is stronger. This phenomenon may be called *width of narcosis*. Such fish possess a greater *width of narcosis* than fish with smaller intensity of metabolism (figs. 7 and 8). The physiological state of a fish is thus of great importance in its reaction to electric current.

REFERENCES

[1] Bary, Mck. The effect of electric field on marine fishes. Mar. Res., No. 1, pp. 1-32, 1956.

[2] Halsband, E. Untersuchungen über das Verhalten von Forelle (Trutta iridea, W. Gibb) und Döbel (Squalius cephalus, Heck) bei Einwirkung verschiedener Aussenfaktoren. Zeitschr. f. Fischerei, 2., Heft 3/4, p. 228, 1953.

[3] Halsband, E. Untersuchungen über die Bedeutung des polaren Erregungsgesetzes für die Reaktion der Fische im elektrischen Feld. Arch. f. Fischereiw., 5., Heft 3/4, 1954.

[4] Halsband, E. Untersuchungen über die Betäubungsgrenzimpulszahlen verschiedener Süsswasserfische. Arch. f. Fischereiw., 6., Heft 1/2, 1955.

[5] Halsband, E. Die Betäubungsgrenzimpulszahlen verschiedener Salzwasserfische. Arch. f. Fischereiw., 6., Heft 3/4, 1955.

[6] Halsband, E. Die anodische Reaktion der Fische im elektrischen Feld. Arch. f. Fischereiw. 6., Heft 3/4, 1955.

[7] Halsband, E. Untersuchungen über den Einfluss verschiedener Stromarten auf den Stoffwechsel der Fische. Arch. f. Fischereiw., 6., Heft 5/6, 1955.

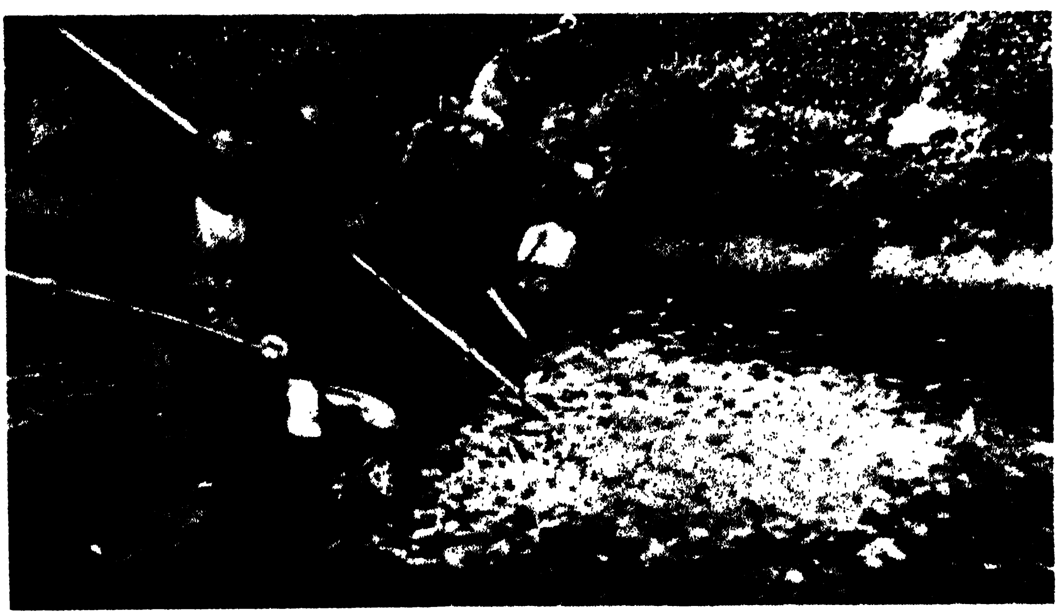
[8] Halsband, E. Die Beziehungen zwischen Intensität und Zeitdauer des Reizes bei der elektrischen Durchströmung von Fischen. Arch. f. Fischereiw., 7., Heft, 1, 1956.

[9] Kreutzer, C. O. Elektrofischerei. Elektrotechn. Zeitschr. B, Heft 5, 1954.

[10] Kuroki, T. On the selection of effective frequencies. Kagoshima Univ., Japan.

[11] Meyer-Waarden, P. F. Electrical fishing. F.A.O. Fisheries Study No. 7, 1957.

[12] Scheminzky, F. Versuche über Elektrotaxis und Elektronarkose. Arch. f. d. ges. Physiol. (Pflüger), 202., p. 200, 1924.



Electro-fishing of small Bream with a battery driven impulse gear in fresh water. The attracted fish are stunned and then collected by means of scoop nets. Photo: Inst. f.Küsten u. Binnenfischerei, Germany.

ELECTRICAL FISHING IN JAPAN

by

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Abstract

Patent rights for an electrical fishing apparatus were obtained in Japan in 1895, but fundamental studies were not begun until 1924. Before 1940, the electrical fish-screens, energized by commercial alternating electric current, were mainly studied with the object of attracting fish schools.

Remarkable progress has been made with electrical fishing in several countries of the world during the last 10 years. Fishing by means of low frequency electrical impulse have been studied in Japan.

In this paper, the author outlines the progress of these investigations, the operation of electric harpoons and hooks, and the future plan to use electric-fences, etc. in Japan. It is emphasized, however, that he is not too optimistic about using the apparatus in open sea.

La pêche électrique au Japon

Résumé

Au Japon, un appareil pour la pêche électrique avait déjà été breveté en 1895 mais l'étude fondamentale de ce système n'a été entreprise qu'en 1924. Avant 1940, l'étude des écrans électriques alimentés par du courant alternatif à la tension industrielle normale a été principalement entreprise dans le but de chercher à attirer les bancs de poisson.

Depuis 10 ans la pêche électrique a fait des progrès remarquables dans plusieurs pays, et au Japon on a étudié la pêche au moyen de décharges électriques à basse fréquence.

L'auteur expose dans cette étude l'état d'avancement de ces recherches, le fonctionnement d'harpons et d'hameçons électriques et les plans élaborés au Japon pour l'emploi futur de barrières électriques, etc .... Il convient de souligner toutefois qu'il n'est pas très optimiste sur l'utilisation de la pêche électrique en mer.

La pesca con electricidad en el Japón

Extracto

En 1895 el Japón otorgó la primera patente de invención para un equipo de pesca con electricidad, pero sólo en 1924 comenzaron a estudiarse los principios fundamentales que gobiernan a estos aparatos. Antes de 1940 ya se habían estudiado las rejillas electrizadas con una corriente alterna industrial, especialmente, como medio para atraer a los peces.

En varios países se han logrado notables progresos en la pesca con electricidad mediante impulsos de baja frecuencia.

El autor describe, en general, los adelantos logrados en este campo, el funcionamiento de arpones y anzuelos electrizados y los planes para el uso de barreras eléctricas en el Japón. También hace notar su pesimismo en cuanto se refiere al empleo de este equipo en el mar.

ELECTRIC SCREEN, STUDIED AND USED BEFORE 1940

IN Japan, Takahashi was granted a patent for using electrical apparatus as fishing gear in 1895. Fundamental studies on the electric fish screen were started by Tauchi[2] in 1924 and later continued by Okada[3]. They concerned methods of guiding fish schools from the main to a side stream, by arranging several rows of electrodes to produce a gradient of alternating current (A.C.) voltage.

Tauchi and Yasuda[4] then used intermittent current in order to save power, but the results were inconclusive owing to lack of electro-physiological information. The reactions of fish to intermittent A.C. stimuli were very irregular.

Miyahara[5] studied the stimulating effect of high-frequency current (alternating, low-frequency modulated, semi-rectified, etc.) and Senuma[6] investigated the polarity of stimulation by direct current (D.C.)

As a result of these studies, the electric fish screen was brought into use. Screens to guide migrating fish schools were set up at the electric power plants on the Shinano River, Nagano prefecture, and other places (1937-1940). Estimates of the practical effectiveness of these screens were conflicting.

FUNDAMENTAL INVESTIGATIONS DURING THE LAST TEN YEARS

The recent progress in the study of electro-physiology has made the influences of electric stimuli on fish somewhat clearer. The optimum electric current (or voltage) and the most effective pulse-shapes to electrocute fish were determined by Kuroki's investigations on the relationship between *chronaxie* and *rheobase* of the muscles and nerves of fish[7]. Through the use of electric gear in longline fishing, he confirmed that only about 3·5 W. min. was needed to electrocute even a large and active shark[8,9].

Before these experiments, Kuroki found that a particular, sensitive electro-physiological point, the so-called "ζ" point, exists in the body of some species of fish, and that the motion (forward or backward) of the fish could be controlled by shifting the point of stimulation accordingly[10]. By calculating the relations between the swimming velocities of fish and the existence of this point, he determined the most effective rhythms of electric stimuli, i.e. 10 to 20 pulses/sec. for electrifying, and 1 to 2 pulses/sec. for electrocuting[11]. Furthermore, he concluded that it was necessary to use the "double intermittent method" in electrical trawl fishing for maximum catching efficiency. If, for example, the electric energy for a trawl net is supplied in the form of low-frequency electric pulses for 30 sec., the current must then be interrupted for 90 sec.[12].

Lately, Suzuki and Fukuyama[13] showed by physiological experiments that this ζ point is within the region of the vagus nerve. They demonstrated that fish can be made to move clockwise or counter-clockwise by a negative or positive needle-electrode stabbed at this point.

Electrical fishing at sea has now been introduced, using low-frequency pulse current.

TRIALS WITH ELECTRIC HARPOONS, HOOKS, SCREENS, AND TRAWLS

An A.C. electric harpoon for whaling was tested in 1950 by the Japanese whale catcher, *Fumi-maru No. 7.*[1] Low-frequency pulses were later applied to harpoons and also to hooks used in longlining[14]. In this apparatus, the low voltage of A.C. or D.C. is transformed into 300-400 V., and low frequency shock waves ($2—3 \times 10^{-4}$ sec.) are sent to the harpoon or hook electrodes through the mechanical contact points. Only a few seconds are required to bring large tunnies on board. Even the fiercest sharks can be killed by electrocution in about 10 sec.

Electric hooks of this design were operated successfully about 360 times by the *Kuroshio-maru No. 15* for longlining, decreasing fishing time considerably.

Trot line fishing with the low frequency electric hooks is now coming into use.

A low-frequency screen was set and operated by Hokkaido Electric Power Co., in *Toya* Lake, at the inlet water gate of the Abuta Power Plant[15], and small electric trawls of bottom and midwater types were operated on Ikeda Lake in the Kagoshima Prefecture by Kuroki[16]. It was difficult to estimate the results of the first experiment: the latter experiment proved unsatisfactory.

FUTURE POSSIBILITIES

If the towing speed in midwater trawling were to be increased and the depth of the net controlled more exactly, the efficiency could be improved by applying electricity.

The operation of a 3-phase electric fish screen, as Kuroki has shown[16], could be improved by using low frequency pulses.

While not yet in actual commercial use, there are various types of defensive electric fences for surrounding shellfish in shallow water, and for defending the larvae or eggs of fish from natural enemies on rocky seabeds.

The economy of electric fishing in sea water, other than with harpoons or hooks, will have to be considered carefully because of the high initial and operational costs.

Electrical devices can be used for protecting the larvae and eggs of some fish and also for increasing the efficiency of some types of fisheries, but they should not be applied to fisheries which may be in danger of overfishing. Even cheapness of operation would not justify the universal application of electrical fishing until the problem of conservation of the fish stocks is solved.

REFERENCES

(In Japanese; * with summary in English)

[1] Kuroki. "Electrical Fishing", Giho-do, 190 pp. Book. 1955.
[2]* Tauchi and Sugii. J. Fishery Sci., *19*, 12. 1924.
[3]* Okada. J. Imp. Fish. Inst., *24*, 2 and 5: *25*, 1. 1929.
[4]* Tauchi and Yasuda. Ibid., *27*, 2. 1932.
[5]* Miyahara. J. Hiroshima Tech. Coll., *1*, 4. 1929.
[6]* Senuma. Suisangaku-kaiho, *5*, 2. 1925.
[7]* Kuroki. Bull. Jap. Soc. Sci. Fish., *18*, 1. 1952.
[8]* „ Ibid., *18*, 12. 1953.
[9]* „ Ibid. *18*, 8. 1953.
[10]* „ Suisan-kagaku-kenkyukai, Kagoshima Univ., Prints. 1949.
[11]* „ Bull. Jap. Soc. Sci. Fish., *16*, 4. 1950.
[12]* „ Ibid., *18*, 9. 1953.
[13] Suzuki and Fukuyama. Jour. Physiol. Soc. Jap. *15*, 4. Kagaku, *23*, 7. 1953.
[14]* Kuroki and Morita. Jour. Kagoshima Fish. Coll., *1*, 1950. Report of Tateyama Branch, Chiba Pref. Fish. Lab. 1952.
[15] Tamori. Rep. Lab. Hokkaido Elect. Power Co., No. 1. 1949. Shimura. Ibid., No. 2. 1952.
[16]* Kuroki. Mem. Fac. Fish. Kagoshima Univ., *3*, 1. 1953.
[17]* Kuroki and others. Bull. Jap. Soc. Sci. Fish., *18*, 1. 1952.

ELECTRO-FISHING

by

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Abstract

This paper shows the different methods of electro-fishing distinguishing between the applications of electrotaxis and electronarcosis and "the first reaction."

Some successful trials are described.

Proved methods are enumerated such as the electro tuna hook, a procedure for supporting the power block operation, the gun-pump method, narcotizing of sardines, and electric fences. Possible developments considered are the electric trawl (for improving the catch and the quality), the "fish magnet" and electric whaling.

A description is given of the technique and construction of pulse devices. A direct connection of pulse devices to 3-phase alternating current generators instead of high tension direct current generators, has now become possible. After a short description of the pulse devices themselves, there is a paragraph concerning security circuits.

La pêche électrique

Résumé

Cette feuille illustre les différentes méthodes de la pêche électrique et distingue entre l'application de la "taxis électrique", la narcose électrique et "la première réaction".

Quelques essais couronnés des succês font l'objet d'une description.

Quelques méthodes, ayant fait leurs preuves, sont, énumérées telles que le hameçon électrique pour le thon, un procédé pour supporter l'opération du "power block", la méthode de pêche avec électrode lancée et pompe à poisson la narcotisation des sardines et les barrières électrique. Les développements éventuels, entrant en ligne de compte, sont les chaluts électriques (pour l'amélioration de la prise et de la qualité), "l'aimant à poissons" et la pêche électrique à la baleine.

L'on donne une description de la téchnique et de la construction de e'impulsion. Une connexion directe des dispositifs d'impulsion aux générateurs de courant triphasé alternatif, au lieu de celle aux générateurs de courant direct de haute tension, est devenue possible maintenant. Après une brève description des dispositifs d'impulsion il existe un paragraphe ayant trait aux circuits de sécurité. Après une presentation des grandes possibilités de la pêche électrique il est egalement fait allusion a ses limitations.

Pesca por electricidad

Extracto

Esta hoja hace ver los distintos métodos de la pesca por electricidad, diferenciando entre la aplicación de la "electroitaxis" y la narcosis por electrieidad, así como la "primera reacción". Ya han sido descritos algunos ensayos de buen resultado. Se establecen algunos métodos acreditados, tales como el anzuelo eléctrico para pescar atún, un procedimiento para apoyar la "power-operation", el método de la bomba de canón, y la narcotización de las sardinas por barreras de rejillas eléctricas. Desenvolvimientos posibles, tomados en consideración, lo constituyen la red de arrastre, eléctrica, (para mejorar la pesca y la calidad), el electroimán de pesca y la pesca de la ballena por electricidad. Se describen la técnica y la construcción de los aparatos de impulsos. Ha sido ahora posible una conexión directa entre los aparatos de impulsos y generadores de corriente trifásica, en lugar de con generadores de corriente continua, de alta tensión. Tras breve descripción de los aparatos de impulsos sigue un artículo sobre las conexiones de seguridad. Después de las grandes posibilidades de la pesca por electricidad se describen asimismo sus límites.

POSSIBILITIES OF APPLICATION

THE *First Reaction*, i.e. the frightening effect at the border of the stimulating area, can be used for electric fences, either movable or fixed, made of metal electrodes or cables.

Electrotaxis, i.e. the anodic attraction, can improve or even replace (in certain cases), conventional fishing methods, particularly in purse seining, hook-fishing and trawling.

Electronarcosis and *Electrocution* are most useful in angling and harpooning big fish, and in whaling.

The *Selectivity* of electric stimulation in regard to the size of fish allows for a certain choice of marketable species and/or size. Since small, immature fish react little or not at all, they are not affected or caught. Electro-fishing, therefore, bears no danger of over-fishing but may, indeed, be a means of avoiding it.

ESTABLISHED OR SUCCESSFULLY TESTED METHODS

Electric tuna hook

Immediately the fish takes the hook it is electro-stunned. Any struggle is therefore avoided, and the fish cannot break away after biting. Fishing time is saved, and there is no danger of loss of catch.

Application to purse seining

Successful trials with herring-sized fish have shown the advantage of an electrified suction hose for brailing fish by means of a pump. The fish, even those from the bottom of the purse seine, are attracted by electrotaxis to the mouth of the suction hose. Another advantage is that, when using power blocks, the net is released from the weight of heavy catches and hauling can be

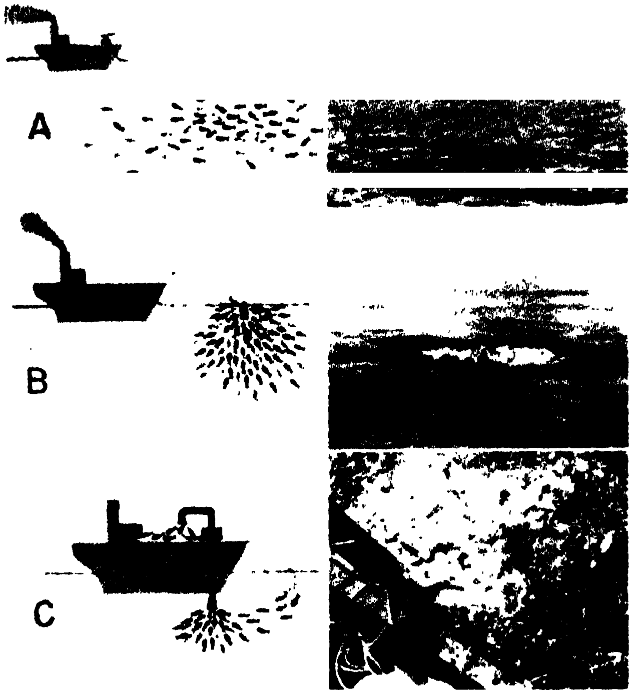

Fig. 1. The gun-pump method.
A. The electrode being shot into the school.
B. The fish gather around the electrode.
C. Pumping with the fish concentrated around the electrified suction hose.

continued smoothly during brailing. If no fish-pump is used, a simple electrode can support the hauling and brailing operation by attracting the fish to the surface, so reducing the weight in the net.

Narcotising sardines

A small hand electrode, mounted on a wooden stick, has been tested for stunning sardines, to prevent struggling after the net is pursed. This reduces the risk of damage and loss of scales, and so increases the quality and marketable value of the catch.

The gun-pump method

After locating a school of fish, an electrode missile is shot, by the Dethloff-Electronic airblast gun, into the centre of a fish school (fig. 1, A). This electrode floats like a buoy and is connected by a floating cable to a pulse generator on board. The pulse current starts automatically when the electrode touches the water. The fish immediately concentrate around the electrode (fig. 1, B) and can be pumped into the boat (fig. 1, C). This combination of shooting and pumping has been successfully tested. The power used for this test was about 80 kw., but can now be decreased considerably. The gun-pump method is applicable to pilchards, sardines, and other fish up to herring size. It can also be used in combination with a stick-held dip net for bigger fish, e.g., bonitos and other tunas.

The diameter of the effective field around the electrode, which depends on the length of the fish, is about 25 to 35 m., when an economical amount of power is used.

Fencing

For electric fences, cables are more suitable than metal electrodes, as they make it possible to obtain any form of electric field. The reason for this is that pulse current returns through the water *along* the cable, which is installed in a "one-way" system, i.e. its end is connected to an electrode.

A smaller installation of this kind has been successfully tested by Dethloff-Electronic for fishing big tuna. This trial provided the basic data for the calculation of larger installations

FUTURE POSSIBILITIES

The electro-trawl

With trawls, electricity can be used in two different ways: firstly, as a means of improving the quality of the catch by reducing the period of death struggle; secondly, in combination with the above, by using electrodes to attract fish to the mouth of the trawl. Fish caught in trawls are gathered in the congested space of the codend, where struggling causes the muscles to produce a considerably higher degree of fatigue, thus affecting the quality of the flesh. Electrocuting reduces the period of death struggle, resulting in a progress of *rigor mortis*, which is more favourable in the processing of the fish. Flexible non-insulated bronze or copper cables are interlaced in the webbing of the codend, and a special cable is connected with a pulse generator on board. The power needed for this electrocuting apparatus is less than 50 kw.

Electrodes can be placed in front of the trawl mouth to improve the catching ability of a conventional trawl. The electrodes attract and narcotize the fish before they can escape. One of the great advantages would be to attract fish which stay some meters above the sea bottom, beyond the range of the trawl. Stunned by the electric pulses, the fish will sink and be collected by the net, as shown in fig. 2 A and B. This electric catching device

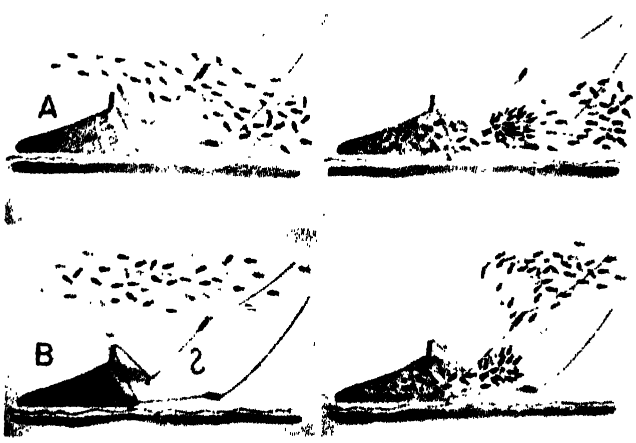

Fig. 2. Electro-trawling.
A. Bottom fish.
B. Fish above the trawl.

can be combined with the electrocuting apparatus without increasing the electric power.

Fish magnet

The use of *electrotaxis* for leading fish by means of a movable electrode has been successfully tested. This led to the idea of constructing a "fish magnet". This could be very useful for lifting a school which stays too deep for the working range of a purse seine. The electrode can easily be watched by echo sounding and switched on when about 3 to 5 m. above the school. After the fish have gathered around the electrode, it will be lifted together with the fish. The fish are likely to stay in *electrotaxis* for 1 to 3 min. before they are stunned and commence to sink, and the pursing operation must be finished in this time. The method could also be employed for larger fish, e.g. bonitos, alistados, etc. It would be more advisable for herring-sized fish to be pumped into the vessel, as described above. A method of collecting bigger fish, other than with a purse seine, still remains to be designed.

Fencing

Fishing trials have yielded a calculation basis for big cable fences to lead fish in desired directions. Such fences could be installed as deep as 100 to 150 m. While technically the length of such fences may be unlimited, the actual fishing conditions would decide the economic size. The main use for such fences would be to replace the conventional leader nets, particularly in depths beyond about 50 m., which are now used for the *tonnaras* or *almadrabas*. As 50 m. is about the maximum depth for real leader nets, the leading range of such traps could be considerably extended by using electric fences.

Whaling

Electrocution of whales by pulse current has an immense advantage over the continuous alternating current method. In the latter case, a short circuit caused by a contact of the metal harpoon or its conductive head with the water will result in a breakdown. With the pulse method only the pulse length will change but not the voltage, i.e. there is no breakdown. Furthermore, the pulse method requires no change in conventional guns and harpoons.

TECHNIQUE AND CONSTRUCTION OF PULSE DEVICES

Latest developments have made it possible to use the common three-phase alternating current board supply, with cheaper generators than the high tension direct current types previously needed.

The pulse generators are of simple and robust construction. The pulses are produced by condenser dis charges, using ignitrons as switches. The ignitron—a valve containing liquid mercury—is suspended in gimbals. The pulse generator is mounted inside the vessel. Remote control allows free choice of location of the switch panel.

As electric fishing methods need a higher voltage than the usual shipboard voltage, special arrangements for prevention of accidents must be made. Existing regulations for the construction and installation of the appliances give sufficient protection, and special care is needed only in the handling of the electrode and cables. Some very efficient and absolutely safe security circuits have been developed. They prevent a connection to the pulse generator, if there is any defect, before the electrode touches the water. This even includes the security circuit itself.

LIMITATIONS

The limitations for *electrotaxis* and *electronarcosis* are set by one physical law, expressed by the following formula:

$$W = \left(\frac{r^2 \cdot V_b \cdot 4\pi}{L \cdot K} \cdot R\right)^2 \cdot \frac{Z}{2} \cdot C \cdot 10^{-6}$$

W	Wattage	K	conductivity of water in Ω/m.
r	range in m.	R	resistance of water in Ω
V_b	body voltage of each species of fish in V.	Z	pulses per sec.
L	length of fish in m.	C	capacitor in μF

if r = 10 m.

$$W = \frac{10{,}000 \cdot V_b^2 \cdot 16\pi^2 \cdot R^2}{L^2 \cdot K^2} \cdot \frac{Z}{2} \cdot C \cdot 10^{-6}$$

if r = 20 m.

$$W = \frac{160{,}000 \cdot V_b^2 \cdot 16\pi^2 \cdot R^2}{L^2 \cdot K^2} \cdot \frac{Z}{2} \cdot C \cdot 10^{-6}$$

This means that doubling the range demands 16-fold power. Experience has shown that powers beyond 200 kw. are not economic. In the author's opinion, appliances will be used with a power of less than 100 kw., even less than 50 kw., depending on the purpose. According to a rough estimate, working range diameters of more than 40 m. for smaller fish (herring size) and 50 m. for bigger fish (e.g. 1 to 2 m. tunas) cannot be obtained economically by present technical means.

Electric fences, some miles long, may be constructed if so required and their effective range may reach from 100 to 150 m. Their limitations depend also on economic considerations as well as on the actual fishing conditions.

ELECTRO-FISHING IN LAKE HULEH

by

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Abstract

Under the particular fishing conditions of Lake Huleh, i.e. very shallow water, narrow channels, and dense reed vegetation, electro-fishing has proved to be the only successful method for catching the catfish, *Clarias lazera*. The amount of catch could be increased about six times, raising the percentage of this species in the total yield of Lake Huleh from approximately 8 to 36 per cent. The electric equipment, supplying 7·5 kw., 500 V. direct current, is installed in a specially designed boat. The catching electrode (anode) is combined with the catcher net and operated in the usual way by a wooden stick of 1·5 m. length.

La pêche à l'électricité dans le lac Huleh

Résumé

Dans les conditions particulières de la pêche dans le lac Huleh, c'est-à-dire, des eaux un peu profondes, des chenaux étroits et une dense végétation de roseaux, la pêche à l'électricité s'est montrée la seule méthode efficace pour pêcher le poisson-chat *Clarias lazera*. Le volume des captures pourrait être augmenté d'environ six fois, en augmentant le pourcentage de cette espèce dans le rendement total du lac Huleh d'environ 8 à 36 pour cent. L'équipement électrique, débitant 7,5 kw sous 500 V en courant continu, est installé dans un bateau spécial. L'électrode de capture (anode) est combinée avec le filet de capture et est manoeuvrée de la façon habituelle par une perche de bois de 1,5 m de long.

La electropesca en el lago Huleh

Extracto

Dadas las condiciones especiales de la pesca en el Lago Huleh, es decir, aguas muy poco profundas, canales estrechos y densa vegetación acuática, la pesca con electricidad ha demostrado ser el único método eficaz para la captura del bagre *Clarias lazera*. El volumen de las capturas podría incrementarse alrededor de seis veces, si el porcentage de esta especie en el rendimiento total del lago Huleh se aumentase de 8 a 36 por ciento. El equipo eléctrico, que suministra 7,5 kw a 500 V., corriente continua, está instalado en una embarcación especial. El electrodo de captura (ánodo) está combinado con la red de captura y se maneja de la manera habitual, por medio de una vara de madera de 1,5 m de longitud.

GENERAL

LAKE HULEH is the smaller of the two natural fresh water lakes in Israel. Before the big drainage project was started, its main surface area was about 13 sq. km., with an additional area of water covered by swamps and marshes of considerable size. Its maximum depth was about 3 m. but a large area along the shores was much shallower and covered with a dense vegetation of papyrus (*Cyperus papyrus*), cane (*Phragmites communis*), water lilies (*Nymphaea alba*) and *Nuphar luteum*, *Polygonum*, etc., being a serious obstacle for fishery[2].

The fish species of conventional commercial importance were mainly *Tristramella simonis* a cichlid, carp (*Cyprinus carpio*). Among the many other species, *Tilapia galilea*, *T. zilli*, *Barbus longiceps*, *B. canis*, *Varicorhinus damascinus* and *Acanthobrama lissneri*, should be mentioned as of limited commercial importance. All these species could be caught by conventional methods and gear, such as trammel nets, gillnets, beach seines, and traps[4].

Only another species, the catfish, *Clarias lazera*, which was well known to be abundant, easily evaded these types of gear by keeping in the vegetation, digging themselves into the mud, or by simply avoiding the gear. Since no suitable method could be found locally, one of the leading fishermen of the area was sent on a study tour to Europe, where he found that the electro-fishing methods used there would probably be the solution for his particular problem.

The introduction of electro-fishing in Lake Huleh immediately had the expected result. The catches of *Clarias lazera* increased considerably from about 8 tons/year (1949-1950) over about 29 tons/year (1950-1951), to a preliminary maximum of 52 tons/year (1954-1955), with the respective percentages of the total catch from Lake Huleh of 8 per cent., 21 per cent. and 36 per cent. With the progress of the drainage project, the area of Lake Huleh will be considerably reduced, only a small part of it being preserved as a Nature Reserve, so that future data will no longer be comparable for the present purpose[1].

The electric fishing gear which led to this remarkable success was mainly developed locally, on information

Fig. 1. The electro-fishing unit as developed for Lake Huleh.

obtained from various European countries. Since it represents a combination of boat and electric equipment particularly designed for shallow canals and reed-covered areas, the following description might be of some general interest[3].

BOAT AND ELECTRIC EQUIPMENT

The boat is of a special design, constructed to suit the unusual requirements of the lake, and the various bottom conditions. It is built of a light material (mainly of laminated wood) and has a flat bottom and square bow. Its dimensions are: 5 m. overall length, 1·5 m. wide, with a draft of 0·2 m. in the stern. The boat lines are such that the bow is far above the waterline, which gives it an unusual quality of being able to slide on the mud far into the drainage channels, the tight corners of the approaches, and in between the vegetation. This does not interfere with the easy manoeuvrability and handling of the boat. Even so, it has a capacity of carrying 500 kg. of fish without losing these qualities. The boat is divided by a bulkhead into two main compartments for the catch, and the electric generator unit stands on a wooden foundation in the stern (fig. 1).

The boat is driven by a 5·5 h.p. outboard motor, fixed at her transome stern. There is an elevated seat providing the fishermen with maximum visibility and easy steering. Since a trip sometimes takes a full day, from very early morning until evening, the boat is equipped with a small locker, containing kitchen utensils, for cooking and preparing light meals. A quantity of spare fuel and lubricants for both engines is provided. The forward part of the boat serves as storage space for the catch, leaving an elevated space for the fisherman who operates the cathode from the tip of the bow.

The generator is a sturdy make, supplying 7·5 kw., 500 V., direct current, at 1500 r.p.m. It is driven by a 16 h.p. air-cooled petrol engine. The unit is arranged in such a way that the stability of the boat is not affected. The electric unit is spray-water tight, and is coupled to the engine with a flexible type flange-coupling. To reduce the vibration of the boat, the unit is bedded on rubber mats.

The negative pole (the cathode) is attached to the bottom of the boat to an aluminium plate, while the positive pole (the anode) forms the metal ring (0·5 m. ⌀) of the catcher net which is attached to a 1·5 m. long wooden stick. The anode is connected to the generator by a 5 m. long rubber insulated cable.

OPERATION

The unit is operated by two fishermen, one of whom acts as the mechanic and the helmsman of the boat, while the other is in the bow and handles the catcher. While the boat moves along the bushes and the growth,

Fig. 2. Small fishes being attracted experimentally by electrotaxis from out of their hiding places between stones. Some are already stunned.

the fisherman at the bow has to follow any movement appearing on the surface and try to detect the direction of the fish. Since the water is shallow and muddy, this is sometimes not very easy, and only a practised eye can recognize the underwater life. Some fishermen can even tell the type and size of fish. When the catcher is submerged and the electric circuit is closed the fish show electrotactic reaction and really jump into the field of the anode (the catcher) (fig. 2). While *Clarias lazera* reacts very strongly, other species are less affected, and experience and quick action is needed then to manoeuvre the fish into the catcher. Since the fish are aware of the approaching boat they try to hide in the undergrowth. It takes all the skill and good collaboration between both fishermen to find the fish and obtain good catches. Sometimes the fish are found in such quantity in one spot that the catcher had to be used several times. In this case particularly quick action is needed because the fish may have recovered and try to escape, before the withdrawn catcher is submerged again. This is especially true for smaller fish, because they are less affected by the electric current. Fish which for some reason are not collected are stunned only for a few minutes, recover quickly and the shock does them no harm. The effective radius of this gear is about 2 to 2·5 m. from the catcher. Within this radius the fisherman can see that the hiding fish react a little to the electric shock. After having detected them by this minor reaction, the fisherman moves closer to the spot, re-throws the catcher into the water, and catches the fish which, this time, have received the full power of the electric current.

REFERENCES

[1] Division of Fisheries. Fisheries of Israel, *Statistical Bulletin* Hakiryah, (in Hebrew). 1948-1957.

[2] Karmon, Y. The northern Huleh Valley, its natural and cultura landscape. The Magness Press, The Hebrew University, Jerusalem, pp. 108, maps and figures, Jerusalem (in Hebrew). 1956.

[3] Lewin, S. Electric fishing in Lake Huleh, *Fishermen's Bulletin*, *2* (13): 12-13. (in Hebrew). 1957.

[4] Steinitz, H. The freshwater fishes of Palestine. An annotated list. *Bull. Res. Council of Israel*, *3* (3) : 207-227. 1953.

DANGERS AND PRECAUTIONS IN THE ELECTRICAL FISHERY

by

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Abstract

In spite of opinions to the contrary, the current used in electrical fishing can be a danger to human life, depending on the amperage, type of current, etc. The maximum contact voltage permissible is about 24 V. and direct current is less dangerous than alternating or pulsating current. Also, high frequency currents are not dangerous. The paper deals with the changes in human physiology associated with increasing amperages and the author suggests that danger can be reduced by taking suitable precautions and by employing properly trained fishermen.

Les dangers présentés par la pêche électrique et les précautions à prendre

Résumé

En dépit des opinions contraires, le courant utilisé dans la pêche électrique peut présenter un danger pour la vie humaine selon l'intensité, la sorte de courant, etc. Le voltage maximum avec lequel on peut entrer en contact est d'environ 24 volts et le courant continu est moins dangereux que le courant alternatif ou pulsé. Les courants à haute fréquence aussi ne sont pas dangereux. L'auteur traite des changements dans la physiologie humaine associés à des intensités croissantes et il pense que le danger peut être diminué en prenant des précautions convenables et en employant des pêcheurs correctement entraînées.

Peligros y precauciones en la pesca con electricidad

Extracto

A pesar de diversas opiniones contrarias, la corriente usada en la pesca con electricidad puede ser peligrosa para la vida humana según el número de amperios, tipo de energía, etc., utilizados. La intensidad eléctrica máxima permitida no debe ser superior a 24 voltios; la corriente continua es menos peligrosa que la alterna o pulsatoria y las de alta frecuencia no ofrecen tantos riesgos. El trabajo también trata de los cambios fisiológicos en el cuerpo humano asociados con el aumento del número de amperios, sugiriendo el autor que el peligro puede reducirse tomando las precauciones adecuadas o utilizando personal propiamente adiestrado.

SIGNIFICANCE OF ELECTRICAL ACCIDENTS

THE human body is adversely affected by electric current which passes through it. The consequences of this effect depend on the amperage, the kind of current (direct current, alternating current, high frequency current, pulsating current), the time of exposure and the way the current passes through the body, as well as the individual resistance.

According to Koeppen[1] the following degrees of amperage are to be distinguished:

Degree I up to 25 mA.	0·1 to 1 mA.: slight contractions of the muscles in the fingers.	increase of blood pressure depending on the amperage, no influence on the beating of the heart and the central nervous system.
	0·8 to 2·4 mA.: concussion of the nerves in the fingers up to the underarm.	
	9 to 15 mA.: releasing the contact still possible	
	19 to 22 mA.: releasing the contact impossible without help	
Degree II 25 to 80 mA.	28 to 50 mA.: still bearable amperage, without unconsciousness setting in	irregular beating of the heart, increase of blood pressure, reversible standstill of the heart.
Degree III more than 80 mA.		fluttering of the ventricles of the heart.
Degree IV 3 to 8 A.	Pulmonic palsy	increase of blood pressure, standstill of the heart, irregular rhythms.

The intensity (i) of current passing through the human body depends on the voltage existing at the moment of contact (U_B) hereafter referred to as contact-voltage and the electric resistance (R_K) of the body. According to Ohm's law, the formula is:

$$i = \frac{U_B}{R_K}$$

The contact-voltage is the amount of voltage which can be endured by the human body. It can be measured, for instance, between hand and foot or between left and right hand respectively, according to the parts of the body where the current enters and leaves. Water or earth as well can be current conductors. The electric resistance of the body fluctuates considerably[2]. It consists of the resistance of the skin and the internal resistance of the body which depend greatly on temperature, voltage, period of influence, the points of contact on the body, pressure of the contacts on the body, condition of the skin and various physiological and psychological factors. Wet skin, which is often a condition with fishermen, represents the most unfavourable case, as the total resistance then amounts to the mere internal resistance of the body, which has been proved to be about 800 Ω. Fifty mA. is the dangerous maximum amperage which means that the dangerous contact-voltage is 800 Ω × 0·05 A. = 40 V. If this voltage is exceeded, the lives of fishermen will be in danger. To be on the safe side, the maximum contact-voltage should not exceed 24 V. Löbl[3] and the Verband Deutscher Elektrotechniker[4] (Association of German Electro-Engineers) both recommended this.

Experience shows that direct current is not so dangerous as alternating or impulse current of 40 to 600 cycles and that high frequency currents of millions of cycles are not perilous (e.g. diathermic frequency). The effect of Faradic stimulation on the body can still be felt up to 500 kc.

Currents of more than 50 mA. are dangerous to life, if the influence exceeds 0·2 sec., whereas brief shocks apparently have no damaging effects on health. Finally the manner in which the current runs through the body is of importance. If the current entered the index finger and left the thumb of the same hand, only burns might occur, but deadly fluttering of the ventricles of the heart and paralysis of the breathing organs must be expected if the heart and the central nervous system are in the circuit and amperage and period of influence are sufficient. This is the case when the current, for instance, runs from one hand to the other, or from hand to foot, or from one foot to the other. In the latter case, the amperage has to be double the amount to show the same effects.

PARTICULAR DANGERS OF ELECTRICAL FISHING

Accidents are always possible because of the kind of current and the voltage used for fishing. This applies to direct current as well as to impulse current. Because of the wet hands and feet, the resistance of the skin is especially small.

The following accident possibilities exist:

Freshwater fishery with two electrodes (cathode and anode): The worst case would be if each hand touched one of the electrodes at the same time. The human body would feel the total voltage, the heart would be in the circuit and a deadly effect would be unavoidable if the current continued to pass through the body for some time. Similar conditions occur if, for instance, somebody is standing barefoot in a metal boat, used as a cathode, and touches the bare anode with his hand. In this case, the voltage would be between hand and foot.

Supposing a generator is installed in a wooden boat and one of the electrodes is connected with the metal casing of the generator. The fisherman touches this casing with one hand and the catching electrode with the other hand at the same time. He would be exposed to the total voltage. The danger would be considerably smaller if only one electrode is directly touched. The main drop of voltage occurs in the closest neighbourhood of an electrode, underwater or in the earth, so that a distance of only 0·5 m. from the electrode the potential decreases to about $\frac{1}{6}$ of that existing at the electrode itself. Therefore, if someone fell into the water from a metal boat used as cathode, with his feet 0·5 m. away from the live anode submerged under water, and clinging with his hands to the metal boat, he would not suffer the total voltage of, for instance, 220 V. but

$$110\text{ V.} + \frac{110\text{ V.}}{6} = 128\text{ V.}$$

His life would still be in danger, but less so than if he made direct contact with both electrodes.

Supposing that both electrodes are under water, with the voltage between them amounting to 300 V., if somebody in the boat dipped one of his hands into the water at a distance of 0·5 m. from one of the electrodes and his second hand at a distance of 1 m. from the same electrode, the potential difference between both hands in the water would amount to about 15 V. which would be absolutely safe.

This distribution of voltage is independent of the conductivity of the water and, to a large extent, of the distance between the two electrodes.

PRECAUTIONS

It is obvious that the greatest dangers occur when one or both electrodes are unprotected so that they can be touched with the hand or the bare foot. In order to prevent accidents, only skilled electro-fishermen should be employed. Fishing should be directed by a responsible expert, trained in a special course, who possesses authenticated proof of his qualification and permission from the responsible authorities to operate the gear. He should be assisted by at least one instructed person. People not concerned with the fishing should be kept away from the gear. In Germany, the electro-fisherman and his assistant have to know the VDE 0134 "Anleitung zur ersten Hilfe bei Unfällen"[5] (Instructions for First Aid in case of accidents, edited by the Association of German Electro-Engineers) and must be familiar with at least one life-restoring method. The fishing gear must be prepared carefully. The main electric cables especially have to be thoroughly examined with regard to external damage. Above all, the insulation must be without defects. Special instructions for constructing electrical fishing gear and for its operation, are being prepared in Germany, giving all necessary details.

Even the best preparations cannot prevent accidents which are caused by defectively constructed gear. Therefore, the use of self-made equipment must be forbidden, and, in future, the construction of electrical fishing gear will have to comply with special instructions of the VDE, which are being prepared. The operating handles for instance, will have to be made of insulating material. All insulation will have to comply with VDE 0100, 3[4]. The coating of the movable cables leading to the electrodes will have to be made of insulated material of especially high resistance against abrasion and buckling. An all-pole safety-switch, interrupting the circuit in case of defective voltage or body contact, will be prescribed. It will have to be installed as near as possible to the primary source of power, to increase working reliability as well as safety and protection against incidental contacts.

Fuses will be provided in the line to cut out excessive current. The safety-line-system, according to VDE 0100, 3,[4] is applicable to fishing equipment on metal boats.

In many cases, a *Totmann-switch* at the catching-electrode, which is handled by the electro-fisherman, is recommendable. This guarantees that the electrode cannot be switched on before all people concerned are ready for the operation. In case of failures, the circuit can be interrupted immediately.

REFERENCES

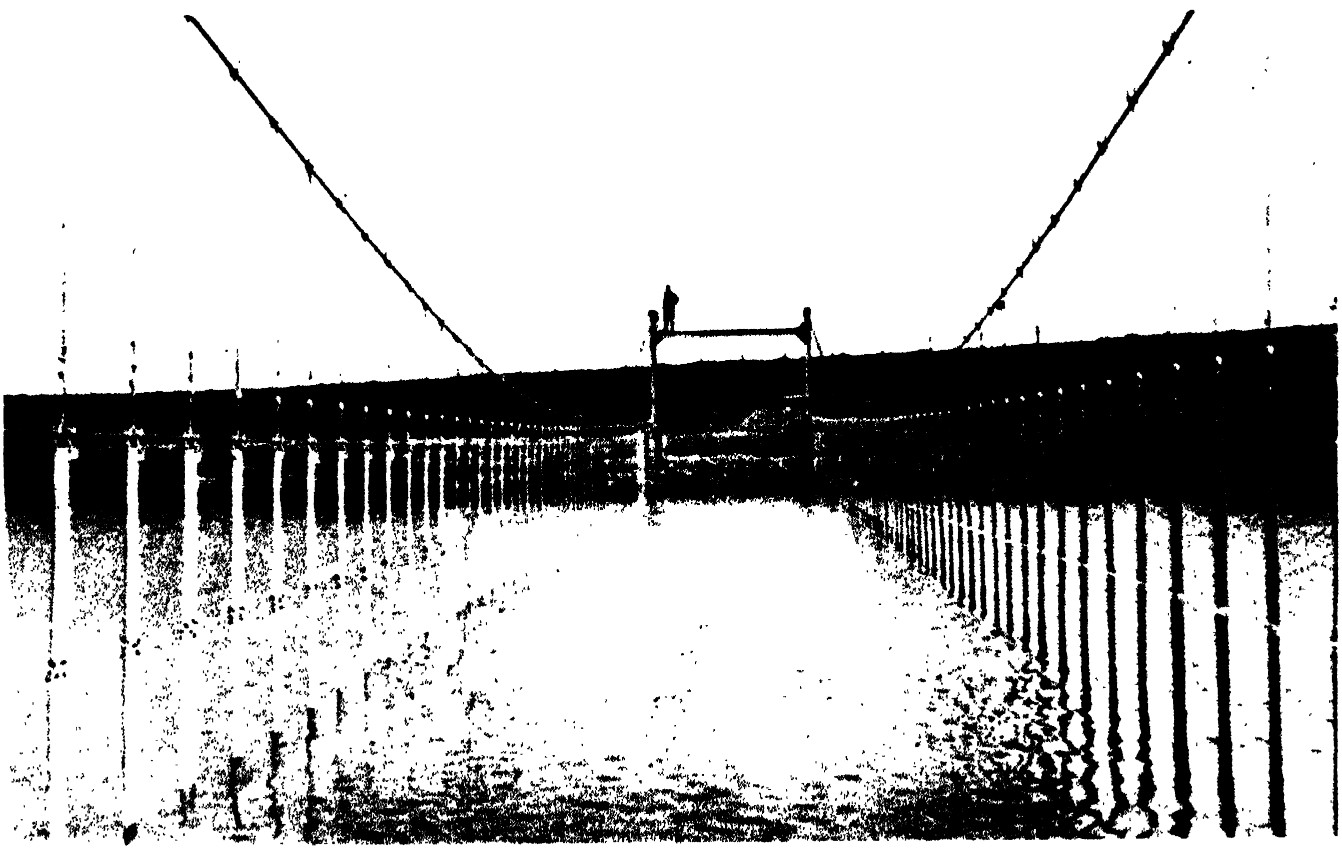
[1] Koeppen, S. Erkrankungen der inneren Organe und des Nervensystems nach elektrischen Unfällen, Springer-Verlag, Berlin-Göttingen-Heidelberg. 1953.

[2] Freiberger, H. Der elektrische Widerstand des menschlichen Körpers gegen technischen Gleich- und Wechselstrom.

[3] Löbl, O. Erdung, Nullung und Schutzschaltung, S.11; Springer-Verlag, Berlin. 1933.

[4] VDE 0100. Vorschriften nebst Aüsfuhrungsregeln für die Errichtung von Stromanlagen mit Betriebsspannungen unter 1000 V., § 15, e.; VDE-Verlag, Berlin-Charlottenburg. 1957.

[5] VDE 0134. Anleitung zur ersten Hilfe bei Unfällen; VDF-Verlag, Berlin-Charlottenburg. 1955.



Chain of electrodes of an electrical fish barrier across a 120 m. wide canal near the river Maas (Netherlands).
Photo: Institut für Küsten und Binnenfischerei, Hamburg.

DISCUSSION ON ELECTRICAL FISHING

Prof. P. F. Meyer-Waarden (Germany) Rapporteur: The main points regarding electrical fishing which should be considered are: what is the present situation of electrical fishing? and to what extent can the presently used electrical fishing method be applied for catching fish and in other fields of fishery? Very special problems of basic research, such as electro-physiology, are not for discussion here.

The technical development of electrical fishing gear in the German Federal Republic is illustrated by the products of various German firms. Sabo, Dieringhausen, making battery and gasoline engine generators (0·4 to 4 kw.), of various sizes, for fishing in brooks and rivers. These have already been in use for some years. Franz Plöger, Hamburg, make a combined gasoline generator and impulse gear for use under unfavourable conditions of conductivity in freshwater (Model Hamburg II), and frightening gear for fencing rivers, for guiding fish, and for frightening fish away from larger freshwater areas. The Atlas-Werke, Bremen, have an electrical tuna line, while Dethloff-Electronic, Hamburg, make impulse gear for stunning and catching fish schools, as well as electrical fencing and guiding gear for use in seawater, and electrical whaling gear.

It was only after the war that electrical fishing gained interest, principally because of the introduction of impulse-current. Until this event, electrical fishing gear only operated with direct or alternating current, suitable only for freshwater and with rather limited working ranges even under particularly favourable conditions of conductivity. The savings in power obtained by impulse-current made it possible to extend the working range of the gear. Waters with unfavourable conditions of conductivity, such as polluted freshwaters, and even slightly salty inland waters, became workable. Finally, the technological basis was provided for stimulating marine animals, which had been immune because of the much greater conductivity of seawater as compared with freshwater.

Denzer first drew attention to this type of current long used in electrotherapy, and Kreutzer designed the first impulse gear for electrical fishing. Within two years (1948 to 1950) the working group Kreutzer/Peglow, in co-operation with the Siemens-Schuckert Werke, the German Federal Research Institute of Fisheries, assisted by the German fishing industry and the A.E.G., succeeded in solving the basic problems of electro-stimulating fish in the sea.

An experimental generator was developed with a converted average output of 180 to 200 kw. which was able to produce current-pulses of more than 10,000 amp. By means of this gear, herring of 20 cm. in length could be affected up to a radius of 10 m. around the anode, cod of 40 cm. in length up to a radius of 15 m., and cod 90 cm. in length up to a radius of 25 m. Moreover, Kreutzer had succeeded in computing the range of efficiency of the electrical current depending on the size of the fish. Furthermore, a trawl net for electrical fishing was designed, and Süberkrüb developed a hydrofoil electrode which could be towed in front of the net-opening. These experiments were the basis of all future developments and experiments in the electrical sea fishery. About the same time, but independent of the German investigations, the Japanese, and later the Americans, the British and the New Zealanders, began to use impulse-current for electrical fishing.

The use of impulse-current opened many new aspects for the technical development of electrical fishing, but some extremely complicated and intricate conditions exist which still require investigation. The most important results of recent research work have shown that:

1. Compared with direct and alternating current, impulse current has the greatest neuro-physical effect, but the least damaging after-effect on fish.
2. The fishing effect produced by the impulse-current depends on:
   (i) the shape of the current impulse;
   (ii) the average electrical flow of current;
   (iii) the impulse rate.
3. The optimal impulse shape for fishing has a steep increase and a gradual decrease. This impulse form causes a definite anodic reaction in the fish, and can easily be produced by condenser discharges. For frightening fish, the impulse should have the shape of a quarter sinus curve.
4. The duration of the single impulse should not be below a certain minimum. For commercial fishing it should, furthermore, correspond to the so-called *period of efficiency*, e.g. to that period which guarantees the stimulative effect needed at the lowest expense of energy. The optimum length of the impulse depends on the species and on the size of fish. It is usually below the half-time value of 1 m sec.
5. There is an optimal impulse rate for each species of fish, at which the desired effect is attained with a minimum effort. The larger fish require a lower impulse rate for reaching electrotaxis and electronarcosis.
6. The optimum impulse rate ranges from 7 to 20 for tuna, 20 to 25 for medium-sized cod, 45 to 50 for carp, and 60 to 65 for trout. The impulse rate is chosen according to the effect wanted, either anodic attraction or killing. It has been found, for instance, that an active fish with highly intensive metabolism (trout) needs a lower impulse rate for electrotaxis than a less active fish with less intensive metabolism (carp), but electronarcosis occurs more quickly with carp than with trout.
7. Biological factors such as: (i) the biological character of the fish; (ii) the particular physical condition of the fish; (iii) the surrounding conditions are also decisive for the electrical effect.

For electro-stimulation, the stage of maturity of fish is also important. The eel, for instance, is rather lethargic in maturity, and is then considerably more resistant to electric current than it is when younger. Moreover, exhausted or sick fish, or those which have often been subjected to electric current, may be more resistant than healthy fish.

The degree to which electric current affects fish depends also on physical and chemical environmental factors, as, for instance, the conductivity of the water in which the fish live. Such conductivity can vary from distilled rainwater with 1 million ohm/m. to seawater with 0·01 ohm/m. Average conductivity for European freshwater lies between 10 and 10,000 ohm/m.

Waters with medium conductivity are best suited to electrical fishing as they possess the most favourable correlation between the energy produced by the gear and the voltage. The conductivity of seawater being 500 times greater than that of freshwater, electrical influence on the fish has only become possible by means of pulsating current.

Tester found that tuna react definitely to pulsating current, which was produced by means of condenser discharges, by moving towards the anode. An impulse rate of 20/sec. was found effective for yellow-fin tuna 50 cm. in length. Dethloff also discusses electro stimulation of tuna by means of pulsating current, but without mentioning impulse rates.

Thus the effect of pulsating currents on fish depends on many factors, the correlation of which is frequently very complicated and sometimes not quite recognisable. These complicated conditions are responsible for many failures experienced not only in electrical fishing research but also in practical commercial application.

Anodic (attraction) effects, and, more recently, frightening effects, and killing effects, are used in electrical fishing.

The catching effect was formerly the main one in use, but it was proved that in the marginal zones of the electric field a strong frightening effect occurs, which originally was undesirable. This frightening effect, however, is now used, for example, in fencing hydraulic structures.

The killing effect was also formerly avoided, but is now used for special purposes as, for instance, in electrifying the tuna lines used in the North Sea. This reduces considerably the losses of hooked tuna. The killing effect can also be used for controlling vermin, such as Chinese crabs. Recently it has been suggested that the killing effect could be used to maintain and even improve the quality of fish. It is already possible, to kill sardines caught with the ringnet within 2 to 3 sec., and avoiding the loss of scales caused by struggling in the net, with a resultant decrease in the quality and price of the sardines landed. The Japanese and German investigations also indicate that the killing effect appears to improve the quality of the fish flesh.

Many experiments have already been made in this field in Japan and Kuroki gives a detailed report. When testing the degree of freshness of electrically and normally killed fish, the contents of lactic acid, glycogen, organic acid and basic nitrogen, as well as the firmness and the pH value, were investigated. The result showed that electrically killed fish possessed more favourable values and thus have a better keeping quality. According to the Japanese, however, when rigor mortis is over, the decomposition of the flesh of electrically killed fish proceeds more quickly than that of normally killed fish. Electrically killed fish, therefore, must immediately be packed in ice.

In Germany, only organoleptic tests have been carried out. The German Federal Research Institute of Fisheries also found that electrically killed fish usually have a better storing quality than other fish. Ludorff and Kreuzer in "Der Fisch vom Fang zum Verbrauch" (The Fish from Catch to Consumer) give the following description: 'An exhausted fish, chased for some time or having struggled at the line or in the net, would very quickly use up its glycogen content. That would block the contractive mechanism in the muscle fibres and consequently shorten the period of rigor mortis which is very essential for maintaining the quality. Moreover, there occurs a shortage of basic substances for the development of lactic acid and for the simultaneously required decrease in the pH value. The less distinct and the shorter the rigor mortis, and the less the decrease in the pH values, the more the keeping quality of the fish flesh decreases and the earlier the rotting bacteria begin their destruction.'

Certainly, very thorough chemical-physiological investigations have yet to be carried out to ascertain the changes which develop in the electrically killed fish.

I shall now return to the electrical fishing gear.

Easily portable gear already exists and has proved efficient in freshwater fishing. In the Federal Republic of Germany the various types of gear are used for many purposes.

Generally speaking, there are portable battery and gasoline generators of various sizes of 0·4 to 4 kw, which can be used in small or fairly large bodies of water of medium conductivity. Franz Ploger, Hamburg, with our assistance, designed a combined gear. It transforms the direct current of a gasoline generator into pulsating current in order to increase the working range.

In recent years types of electric gear for frightening fish have been developed in America, Japan and in the Federal Republic of Germany.

Fish barriers were usually operated with alternating current, but since the war pulsating current has been introduced in Japan as well as in America and in Germany. The Japanese types of frightening gear, as stated in Kuroki's paper, are characterized by their high pulse rates of 1 to 20 per sec. In Germany the pulse rates used range between 20 and 100 per sec. for catching, or between 10 and 70 per min. for frightening, depending on the water conditions and the species of fish.

The frightening effect can be used for many purposes:

1. for fencing certain water areas to prevent the fish from migrating or escaping;
2. for blocking the entrances of turbines and pumps to prevent the fish from being damaged or killed;
3. for guiding the fish to ladders, ways and traps.

Dethloff also describes the use of such electrical barriers for guiding the fish into large tuna traps, the so-called *tonnaras* and *almadravas*. Whereas hitherto chains of electrodes have been used. Dethloff uses electrically loaded cables. The electric barriers used in freshwater have in many cases proved their efficiency.

There already exists gear for killing fish, such as the electrical tuna line already mentioned.

A gear for killing fish (for instance, sardines) within the direct radius of the anode is manufactured by Dethloff-Electronic, Hamburg and by Franz Plöger, Hamburg. Dethloff has also designed impulse gear for electrical whaling.

The effect of electrical fishing gear in both freshwater and seawater is limited to a relatively small area. The gear, therefore, can scarcely endanger the fish population. The main reason for this relatively small range is the great loss of energy, which occurs in freshwater as well as in seawater. It it particularly great in seawater so that satisfactory results may only be achieved by means of very great energy (100 kw.). In saltwater fisheries, with medium conductivity of the water and with fishing gear up to 4 kw., the limit of the electrical effect is approximately 4 to 5 m. According to Dethloff, the extension of a fishing range in seawater from 20 m. to 40 m. would need approximately 16 times the 100 kw. mentioned above.

Gear with extended range could also be designed for freshwater, but one should ask whether the catch would be in reasonable relation to the expended energy. This would no doubt be the case if especially valuable fish (tuna, salmon) are concerned, or if fish schools are sufficiently concentrated. But whether it would be profitable in the case of bulk fish, such as menhaden or sardines—particularly in view of the difficult marketing and economic conditions of the fishing industry—must be left to the future.

Efforts are being made in Germany to fit electrical fishing gear with adequate safety equipment. As Hösl's article shows, it is essential to take protective measures, as electrical fishing gear is dangerous to man. A Commission established by the Verein Deutscher Elektrotechniker (Association of German Electro-Engineers) is preparing regulations for the use of electrical fishing gear in freshwater and in seawater.

The manufacturers have spared neither money nor time to design efficient gear. But various types of electrical gear must be thoroughly tested in practice and, generally speaking, this is outside the scope of the manufacturers. A way should therefore be found to test these types of gear on research vessels in sea areas ideally suited to such operations (for instance, sufficiently large, with dense fish schools). Only then will it be possible to find out whether the electrical fishing method can become of essential importance to the fishing industry.

Mr. K. Schefold (Austria): Deep sea fishing is, of course, more important than inland or freshwater fishing, but freshwater fishing has hardly been mentioned although it has for some countries considerable importance. In Austria there exist a number of big lakes and many smaller ones, and here the interest lies in electro-fishing in freshwater and the possibilities of applying electric fishing to small lakes and ponds. The bottom of such ponds and lakes usually has obstructions which make it nearly impossible to use trawl or seine nets, particularly for deep lake fish, such as carp. The fish also are apt to escape into small depressions in the lake bottom. In waters where it was known that several hundreds of carp existed, not one could be caught with the seine net. Seining in these particular inland waters is quite ineffective and here electric fishing might help to produce better results. Repellent gear might be particularly suitable, but the lakes and ponds are sometimes as much as 70 m. deep and such gear might not be effective. Much depends on the behaviour of the fish when coming under the repelling influence of the apparatus; if they tend to dive to deeper water then such gear would be useless. The total amount of fish caught in these inland waters is quite important. Freshwater fishing is subject to very rigid laws, the fish can be caught only at certain seasons and the size is restricted; the use of certain types of gear is prohibited and subject to very rigid legislation for conservation of stock.

Mr. D. R. Lenier (France): Mr. Schefold may be assured that electrical fishing in freshwater is more highly developed on an international level than in sea fishing, where it is only done sporadically. There is considerable literature on freshwater fishing, and this method is constantly used with success in lakes and rivers. It allows one to catch only the big fish leaving aside the smaller ones. At Prince Edward Island 60 to 70 per cent. of the fish are caught electrically and unwanted fish are not touched. The structure of the nets used is well known while the electrical apparatus used generates direct current of 1,200 W. at 115 V. In West Virginia they use direct current of 2,500 W. at 120 or 230 V. The latter voltage seems to be more effective.

Dr. H. Halsband (Germany): Research work at the Institut für Kusten und Binnenfischerei has determined that impulse current has a great effect on the fish and that its influence on the metabolism is less harmful than either continuous or alternating current. With alternating current the normal metabolism of the fish was reached only after 120 min., with direct current after 70 min., but with impulse current only 20 min. were needed.

In our type of fishing gear the anodic effect is used to concentrate the fish around the anode. Besides this attracting effect the frightening effect of the same anode, which is caused outside the range of attraction, can be used for fishing gears suitable for rivers and larger bodies of water. Experiments carried out by the Institute have shown that it is possible to drive the fish into a net even in water 32 m. deep. Another application of the frightening effect of impulse current consists in towing an electrified cable of up to 300 m. length between two boats and driving the fish into a trap or to a certain area in the lake where they can be caught by means of a seine or other type of net. This method is also applicable in rivers where we succeeded in driving the fish for kilometres towards nets to finally catch them there electrically. Such gear could also be switched from a frightening to an attracting effect; for this purpose the frequency has to be raised.

The significance of the impulse rate for the reaction of different species can be used to fish selectively.

Prof. S. Takayama (Japan): Experiments carried out by the Japanese Fisheries Agency on electric fishing, divide the subject into three aspects: physiological studies, commercial application and technical problems.

With regard to physiological considerations, there is a point in the body of fish which is very sensitive to electricity and which our research workers call ζ point. This point is about the middle of the body, but the position varies in different species of fish.

If a fish feels electricity in a part of the body anterior to this point, it swims back out of the electric field. On the other hand, if the fish feels electricity in a part posterior to the ζ point, it tends to swim forward.

By installing series of electrodes and switching electricity, in accordance with the progress of fish from one pair of electrodes to the next one in front of them, it may be possible to lead fish in a desired direction. So far these studies are at an experimental stage. Efforts are being made to determine the position of the ζ point for various species of fish and to determine the technical conditions essential for this type of electric fishing such as distance between electrodes.

In Japan three types of commercial technique have been attempted so far: (i) electrified hook for sword fish, tuna and sharks, in which case electricity is used only for killing the hooked fish. (ii) electric shocks to whales through the harpoon so that the whale is killed instantly. One of the difficulties in electric whaling appeared to be discoloration of the meat which sometimes changed to a greenish tint specially when refrigerated. (iii) electricity for trolling lines, mainly for Spanish mackerel and small tuna.

The amount of electric energy the fish receives differs according to the kind of electricity applied. When continuous current is used, the energy supplied to the fish is determined by the voltage and the amperage of the current.

In Japan the current applied to whaling had in most cases about 220 V. and 60 A. When low frequency shock current is to be employed, one has to consider the impulse duration and its rate. In experiments of electric harpooning and trolling, the duration was 3/10,000 sec. at an impulse rate of 10 per second with 280 V. However, these values have to be adjusted according to the species of fish the gear is intended to catch.

Electrotaxis concentration of anchovy around pump-hose opening with electrode, during pump-fishing test in Morocco (Oct./Nov., 1958).
Photo: Int. Electronics Lab., Hamburg.

DISCUSSION ON FUTURE DEVELOPMENTS

Mr. A. W. Anderson, General Chairman: We have reviewed much of the gear that is currently being used and also the latest innovations. Many of the future developments therefore are obvious to us all; yet there are future trends, problems and less obvious developments, especially those caused by factors outside the fishing industry. For example, by the end of the next 20 years the United States will need 30 per cent. more fish just to supply the normal increase in our population. For the U.S. Fisheries this is quite a problem; either our domestic production or our imports must increase. In either case fishing gear must become more productive.

I do not intend to discuss every item on the Agenda in detail, but some statements have to be brought forward. It has been stated that the ideal fibre for nets is not yet developed. This, then, certainly must be a development of the future and if the ideal fibre can be made into a knotless net we may find that the knotted net really will become a museum piece, as our Japanese colleague said.

Then we know too little of fish behaviour and net action. These are both present and future problems. I believe the television camera will unlock many of the secrets in these fields. It would not be surprising if the next Fishing Gear Congress were overwhelmed with reports of research based on the use of television cameras, and I do not think it is looking too far into the future to say that even fishing skippers will be able to look at a television screen in the pilot house, watch the net and how it operates, and observe the fish and the evasive action they may or may not take.

Fish location is another problem. Finding solutions to this problem through devices which accurately determine the vessel's position or detect fish by vertical sounding or horizontal ranging are in good competent hands, as you may have noted during the discussion earlier this week. Surely the competition in this field will find us advancing steadily and perhaps spectacularly, in the next few years. Fish location by means of studies of the food and feeding habits of fishes, together with allied factors such as studies of the currents, temperatures, water colour and so forth, offer both logical and fascinating possibilities. More studies in this field can be expected to be initiated when more knowledge becomes available.

Handling of the gear and handling of the catch must be improved. The production of fish and the fish themselves are in keen competition with other food products. As competitors lower costs with more modern machines by increasing volume with less labour, the fishing industry must keep pace. More and more mechanical aids seem to be the answer. Not only will they cut costs and increase volume of production, but often they make the handling of gear more agreeable to the fishermen, and difficulties in obtaining manpower are a definite future problem. In the United States we find more and more of our fishermen taking jobs ashore because of a 40 hour week for a comparable pay, easier work and the comforts of being at home every night. The greatest possible mechanisation of the handling of gear can help to stop this trend by making the work less difficult and the pay greater. This said, without expecting that trawler Captains will soon be able to sit before a row of buttons and push one to set the trawl, another to haul it back and perhaps a third to open the codend, although that certainly would be something to look forward to.

Mechanization as well as the use of the most efficient gear has sometimes been hindered by regulations preventing their use. I know of no comparable industry that is in some cases bound to out-moded gear or forbidden to use more modern mechanical devices. This occurs in the fishing industry when measures are taken to maintain a less perfected method of production by excluding others, particularly more advanced types, to maintain the maximum sustained yield, considering only the biological and not the economical side of the problem Frequently it seems easier to regulate the less efficient gear and methods so the more efficient methods are thereby ruled out. Biologists and administrators should recognize that this is only a partial answer to the problem.

Quality of the catch is another problem. Fish from a 21 day trawling trip is edible, perhaps, but not fresh. The time will come when fish, which really is a very perishable product, will be given the same care as milk, butter and other perishable agricultural products. Trawlers freezing fish at sea represent a beginning towards this objective. As they increase in number, size and complexity they will stimulate new thinking in regard to gear and in regard to handling methods. They might well be responsible for changes in the near future which otherwise might have been long delayed. There can be no doubt that their advent means change or new types of gear, or new techniques for handling the catch.

Perhaps we can look for the greatest developments and the brightest future in mid-water trawling. Since we now fish the surface waters and the shallow bottoms, only the great depth and the midwater areas remain. At the moment the researches in midwater look most promising. Much effort has been expended on midwater gear without appreciable result except under special conditions. However, so much work has been done, and is being done, on gear for the purpose that someone is bound to find the answers we seek.

The final thing I look for is a much greater interest by Governments in research on fishing gear. I believe this will occur for two reasons. First, it is difficult for the fishing industry to conduct and finance basic study needed to solve the problems, and second this Congress and the reports which have been made to it should reveal to Governments the very great interest in the subject and the need for a solution to fishing gear problems.

Mr. C. P. Halain (Belgian Congo): I should like to draw your attention to a point which is not generally realized and which I have stressed during other Congresses. A ton of fish delivered in the market for consumption represents the value of 4 to 5 head of cattle at the slaughterhouse. But in order to send 4 to 5 head of cattle to a slaughterhouse it is necessary to have 35 to 40 animals in pasture, so that every ton of fish caught is equal to the meat production of 35 to 40 head of cattle on the range. A country that has the opportunity of catching 100,000 tons of fish per year as the Belgian Congo presently does has therefore practically the same wealth as a country having 3½ to 4 million head of cattle on the range.

A country which possessed such a stock of cattle, would use all means to maintain this stock in good health and condition, as it represents a considerable protein capital. I am sure a great number of laboratories would be set up and many veterinarians employed to look after such stock of cattle. When producing 100,000 tons of fish each year, we have the same obligation, of course, to maintain research, to maintain laboratories and to undertake the necessary measures to exploit this capital as rationally as possible. The population of the world is increasing much faster than the production of food. The limit to what can be achieved by agriculture is perhaps near. Every fish producing country should value fish production on at least an equal basis with other food production methods and provide in its budget the means for financing an efficient scientific and practical research, aimed at conservation and rational development of their fish production.

We must endeavour to exploit the fish capital in this world as rationally as possible. The FAO has now shown us a means to achieve this by interchange of knowledge on an international basis. Hunger is one of the biggest factors against peace in the world, if everybody in the world had sufficient to feed themselves satisfactorily, both quantitatively and qualitatively, I think a great many problems would be solved.

Mr. M. Kawakami (Japan): The development of fishing gear and methods was in the past a very slow process, but has, during the past few decades, advanced very rapidly. Our future development work must not only take into account the technical progress but also the conservation of the fish resources for the future. It appears we have now reached the point where each new technical development not only has to be assessed in relation to its practical or commercial value, but also in relation to its biological effect on the conservation of fish stocks.

Due to the increasing demand for fish food, the total catches all over the world are continuously increasing, but very little is being done to see that the stock of young fish is increased at the same rate by hatchery or conservation methods. In Japan fishermen and scientists work together also on this problem. My company has three Fisheries Institutes where research work is carried out not only on fisheries technique, but also on conservation methods with a view to preserving the fish stock. At one of these Institutes, research is also carried out on the problem of fully utilizing the catch. For example, years ago in whaling only the oil was utilized, whereas today the whale meat, intestines and even the blood is used, either for human consumption or for other purposes.

Another point which I would like to bring up is that due to language difficulties we Japanese research workers are virtually cut off from the other countries. Yet we would like to exchange our papers on research work and if translators could be found we would be able to compare experiments. Maybe FAO can also be of assistance here.

Mr. P. A. de Boer (Netherlands): In doing technical research myself I feel the need of all possible assistance from other people all over the world. There exists already one valuable means for making contacts between all who work on fishery research and that is the FAO World Fisheries Abstracts. I have found that these Abstracts often gave me a lot of help and ideas for designing instruments and for improving my research programme. As these abstracts are published rather late due to the work involved, I would propose that every research worker should send his own abstract immediately to FAO to avoid loss of time.

Mr. A. Kutsch (Germany): I have spent 40 years of my life making nets for the fishing industry and speaking as a net maker I would like to bring forward two of our main problems.

1. The netmaker has to keep pace with the progress made in the other branches of the trade, principally when it concerns the size and type of vessels and the improvements in deck gear and operation techniques, so that the construction of the nets has to undergo constant changes and large scale production is dangerous.
2. The users of our product, the fishermen, are not very communicative and reluctant to give information on catches and performance of gear. Whenever they discover something they try to keep it to themselves to continue bringing the biggest catches.

Many errors could be avoided and much faster progress made in the matter of net construction if the fishermen who use the nets would discuss their problems and ideas more openly with the netmaker. We are always willing to cooperate.

Mr. Rack (Rhodesia): In considering the future of fishing gear, I may perhaps refer to the future of the inexperienced people with whom I work and for the many millions of inexperienced people not directly represented but who are served by so many people all over the world. I refer particularly to those people who are emerging from subsistence fishing over the economic barrier to commercial fishing. The primary development must always of course be education. Then they must be shown how to apply that education and it is in the application of the education where you can help us, you, the manufacturers, scientists, FAO and all those who represent the greater fishing industries. The proposed standardisation of materials and gear will protect such people from being imposed upon and will strengthen their position.

We need equipment and our equipment may for a long time not be on such a scale as your equipment, but nevertheless it must be good. Let us take the case of light fishing; on the lakes of Africa kerosene pressure lamps are used and it may take many years before the natives can turn to better lamps or fish pumping. But already these lamps are bringing a higher standard of living to hundreds of thousands of people in their small villages with their small canoes. Now we are still a long way behind, but these Conferences nevertheless are helpful to us because they enable us to make contacts and catch up on what is being done.

Mr. H. S. Drost (Netherlands): The fact that so many participants are present indicates to me that the interest in fishing is indeed great. I think we are all aware that the fishing industry is on the way to becoming an important and modern industry, much more than it has been in the past. The fishermen and the shipowner do not stand alone any more; they are working and co-operating with the scientists and from the very minute this started we see an amazing modernisation of the fishing industry, and it is time this happened for the world food supply.

We see now an accelerating speed in development. Since the last world war nearly every year some amazing technical development in the fishing industry has taken place. This development was and is furthered by international co-operation. We have had a Fishing Boat Congress in 1953, a Fish Processing Congress in 1955 and now in 1957 we have this Fishing Gear Congress. I would not be surprised if we had in the future a second Fishing Boat Congress in 1959, a second Fish Processing Congress in 1961 and in 1963 a second Fishing Gear Congress; and so on, every two years an International Congress concerning the fishing industry. We owe these International Congresses to the FAO. Although future Congresses may be wishful thinking, I mean to speak on behalf of all the participants when I express our thankfulness for the work FAO has already done so far for the fishing industry. This Fishing Gear Congress, I am sure, has been very useful, it has given us all opportunity for international contact. From now on we will be able to keep contact one with another far more than before, Another very important result of this Congress is that we have now, for the first time, a nearly complete inventory of the many problems concerning fishing gear.

I think we all hope that FAO will be able to arrange such international Congresses in the future for the benefit of the fishing industry.

But, furthermore, I suggest that we cannot just wait and see until 1963. I, therefore, propose that the Congress requests from FAO Fisheries Division to create an official FAO Committee on Fishing Gear immediately after this Congress. We have discussed the many problems on fishing gear and as I see it, they form a wider and more distributed field of work than those of the Fishing Boat Congress and Fish Processing Congress. Therefore I would suggest that FAO, furthermore, approaches the different governments, requesting the formation of National Committees on Fishing Gear, from which representatives could be sent to the meetings of the aforementioned FAO Committee on Fishing Gear. These National Committees should include working groups such as have been established at the beginning of this Congress for standardization. The National Committees should not consist of government officials only but also of private experts. I think this is essential to keep the action virile. At least 50 per cent. of the members of the National Committees should come from commercial firms who are in business and who feel daily the financial responsibility of the industry.

Stated briefly, I think the task of the National Committees would be to go on with research on present and future problems, and in doing so to prepare for the next Congress.

The creation of such National Committees will mean that research on fishing gear will have to be established in some countries and improved in others. This requires appropriate budget allocations. I suggest that FAO should urge the governments to support research on fishing gear morally and financially and apart from the biological research which usually is already well established. There is no doubt that applied research, such as on fishing gear, will pay itself, as Mr. Parkes stated already for fishing vessels during the Fishing Boat Congress in 1953.

There is another and most important aspect of this International Congress: it contributes to world peace. We must continue what we have been doing this week: collaborate on an international scale for the benefit of the fishing industry and for the benefit of world peace.

Prof. Dr. A. von Brandt (Germany): Speaking for the scientists working on fisheries problems, I would like to emphasise that we fully support the suggestion of Mr. Drost. Some of my colleagues meet from time to time but we need still better international contacts with people of our profession, i.e. not only scientists but also net makers and fishermen. We, therefore, do hope that Mr. Drost's proposal will be accepted and FAO Fishing Gear Committees be formed.

Mr. A. W. Anderson, General Chairman: I am sure that FAO will give the most serious consideration to what Mr. Drost has said. Fortunately the FAO Conference meets next month in Rome, and I am sure that the requests made at this Conference for consideration of these various matters, as the establishment of Committees, will come up in a very short time and will be acted upon in the Fisheries Panel at that Conference. Since any Committee formed here would be an unofficial one, the actual establishment of Committees I think, should better be left to FAO.

DETAILED INDEX

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