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FLUCTUATIONS IN THE GREAT FISHERIES OF NORTHERN EUROPE

VIEWED IN THE LIGHT OF BIOLOGICAL RESEARCH

BY

JOHAN HJORT

WITH 3 PLATES

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FLUCTUATIONS IN THE GREAT FISHERIES OF NORTHERN EUROPE

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INTRODUCTION

Fluctuations in the yield a characteristic feature of all great fisheries.

From the earliest times, a characteristic feature in all branches of the fishing industry has been the fluctuation of the respective yields from year to year. At the present time, we find the United States complaining of the failure of the mackerel fishery, while in France, a "sardine crisis" has arisen, the yield of the sardine fishery, which in 1898 amounted to over 50 million kilos, having sunk in 1899 to below 30, and in 1902 to less than 9 million kilos. The Norwegian fisheries, which more especially form the subject of the present work, have for hundreds of years experienced alternating periods of rich and poor yield. These periodical fluctuations have as a rule been of some considerable duration, a series of years of profitable fishery succeeding and succeeded by several years of dearth. Thus the term: a good (or bad) *fishery period* has become an expression of common occurrence. We may, as a preliminary, here pause to consider some examples, selected in particular from the two most important branches of the fishing industry; the cod and herring fisheries.

Norwegian Cod fisheries.

Strøm states, that in 1714 and 1715, the yield of the fishery in Søndmør, the district north of the promontory of Stat on the west coast af Norway, was so poor that the fishermen were obliged to sell their boats. In 1718, on the other hand, the yield was richer in the same degree, and remained so until 1733, when a decrease again made itself apparent. In 1736 and 1737 a rich yield was once more noted, lasting until 1740, when "all the bays along the coast were swarming with cod" which penetrated far up into the fiords. By 1760, the yield had again fallen to a very low level.

Leopold v. Buch relates that from 1799—1801, fish were abundant in Lyngen, Karlsø and Skjærvø, (Tromsø district) whereas from 1801—1807 scarcely any fish were taken.

In later years also, since the introduction of the Fishery Statistics (1866) the yield of the cod fishery has exhibited similar fluctuations. The yield of the "skrei"*) fishery varies between some thirty odd millions (in 1883,) and over 60 millions of fish (in 1912). During the later eighties and early nineties we find a long period of profitable yield. Along

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*) There being, as far as author and translator are aware, no exact English equivalent for the Norwegian word, the term "skrei" will be used throughout the work to denote such cod as have attained maturity, and are thus able to join the shoals of spawning fish, which can be taken with hook and line.

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the northernmost range of coast, that of Finmarken, where the fish taken are for the most part small (i. e. belonging to the younger year classes), the fluctuations of the fishery are particularly abrupt. Thus the statistics report a yield of 23.6 millions in 1880, while only three years later, we find the very poor total of 3.5 millions. During the last few years, from 1911—1913, the yield of the cod fishery has been unusually good.

Norwegian herring fishery.

The herring fishery exhibits perhaps even greater variation, both as regards the mature, spawning fish, the "spring herring", and the younger, immature "fat herring". The spring herring fishery, which is carried on from the Skagerak in the south to Cape Stat in the north, has, since the introduction of the statistics, exhibited enormous fluctuations. In 1866, the yield amounted to over a million hectolitres, sinking, however, so rapidly during the succeeding years, that the total catch in 1874 was 24,000 hl., in 1875 only 208 hl. In 1883, the yield was still as low as 100,000 hl., rising however, in 1884 to 262,000. The years from 1891—93 show an annual yield of over *700,000* hl., from 1894—96 less than 400,000. In 1909 a rapid increase set in, and by 1913 the statistics note a yield of no less than 1½ million hl., the highest figure ever recorded for this branch of the fishery.

The yield of the fat herring fishery (the younger, immature fish,) exhibits similar fluctuations, amounting in some years (1892, 1896, 1909) to over a million hectolitres, in others (1904 and 1905) to less than 100,000 hl. By 1907, however, it had risen again to over half a million hectolitres, and in 1909 exceeded a million.

Popular attempts to explain the fluctuations.

These great fluctuations, irregular as they must at first sight appear, have naturally for many years past occupied the minds of the population along the coast, and innumerable hypotheses and suggestions have been put forward by way of explanation. Most of these theories are, however, valueless save as indications of the state of general knowledge concerning marine biology at the periods in which they arise.

The earliest rational attempts at an explanation of the causes which give rise to these fluctuations in the fisheries naturally took as their starting point the fact that the fish were not at all times to be found in the coastal waters. On the Norwegian coast, the shoals of spawning cod and herring make their appearance with remarkable regularity in the first month of the year, often at a certain date, and remain there for only two months, or three at the outside. All attempts to capture grown herring or cod on the same grounds at other times have given entirely negative results. In the western part of the North Sea, (east of the Shetlands) the herring shoals make their appearance in June; from this time to the end of the year the locality of the fishing grounds gradually shifts southward across to the shallower waters.

The theory of migration as a cause of the fluctuations.

These facts naturally gave rise to the theory of *migrations*, which were supposed to be of great extent, nothing being known as to where the fish were to be found during a considerable part of the year, and a plausible explanation of occasional dearth was furnished by the suggestion that the fish in such poor years neglected, wholly or in part, to visit the usual grounds.

In the course of the extensive herring fishery which for hundreds of years has been carried on by Dutch and Scottish fishermen in the North Sea, it was noticed that the herring came from a northerly direction. In Norway also, it was observed that the great shoals of herring which arrived during the winter in order to spawn, came from the north-west. As Axel Boeck*) has pointed out, this fact gave rise to the idea that the herring annually migrated to the Arctic, where they remained during that part of the year in which they were not to be found in the waters nearer at hand. The well known theories advanced in England by Dott (1728) and in Germany by Johan Anderson, Burgermeister of Hamburg in 1723, to the effect that the herring annually migrated from the Arctic to the coasts of Europe and America, were generally accepted by the majority of writers in the 18th and some even in the 19th century, the same hypotheses being mentioned by Oken, Blumenbach and Cuvier, (as for instance in Cuvier's "Règne Animal", second edition, 1830).

Boeck mentions also another suggestion, put forward by the American writer Gilding, (American Philosoph. Soc. Transact., Philadelphia 1786) according to which the migrations of the herring were considered to be influenced by the declination of the sun, the fish being supposed to regulate their movements in order to avoid extremes of heat and cold. According to this writer, the field of migration of the fish embraced no less than 47 degrees of latitude, extending longitudinally from the coasts of Europe to those of America.

Probable extent of migration essentially reduced by scientific investigation.

Such theories as the foregoing with regard to the extent of these migrations have been rendered untenable by the methods applied by modern science to the study of marine biology. In the course of numerous research expeditions it has been ascertained that the area of distribution of North-European fish, including the herring and cod, is bounded on the south by a line drawn close to the south-west coast of Ireland, and that as regards the northern limit these species do not occur in the Arctic. The coastal banks in the Atlantic waters of western Europe south of the Channel have an entirely different fauna to the waters lying north of the limit above mentioned. The Atlantic Ocean has its own peculiar pelagic fauna, differing entirely from the pelagic species encountered in the waters of northern Europe. Roughly speaking, the limit of occurrence of boreal species on both sides of the Atlantic, at any rate as regards the coastal banks, may be said to coincide with the isotherm for 10° C. (Fig. 1). Of all the species which form the object of fishery in northern Europe, one only, viz. the eel, has been shown to extend its migrations across the deep waters of the open Atlantic. Future research may possibly demonstrate the existence of a similar extended sphere of movement in the case of the mackerel; for the present, however, the facts, as far as known, do not appear to favour the theory of such ocean migration.

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*) Axel Boeck. Om Silden og Sildefiskerierne; Christiania 1871.

Investigations as to the distribution of the fish in the Norwegian Sea.

With regard to the Norwegian Sea, the great expanse of water between Greenland, Iceland, the North Sea, Norway and Spitzbergen, the numerous hydrographical investigations have proved the existence of strata of cold Arctic water west of Jan Mayen, thus restricting the probable area of movement of boreal species to the waters east of there. In Fig. 2, page 7, the shaded stratum, indicating temperature over 2°, marks the area to which the horizontal and vertical movement of northern food fishes is probably restricted.

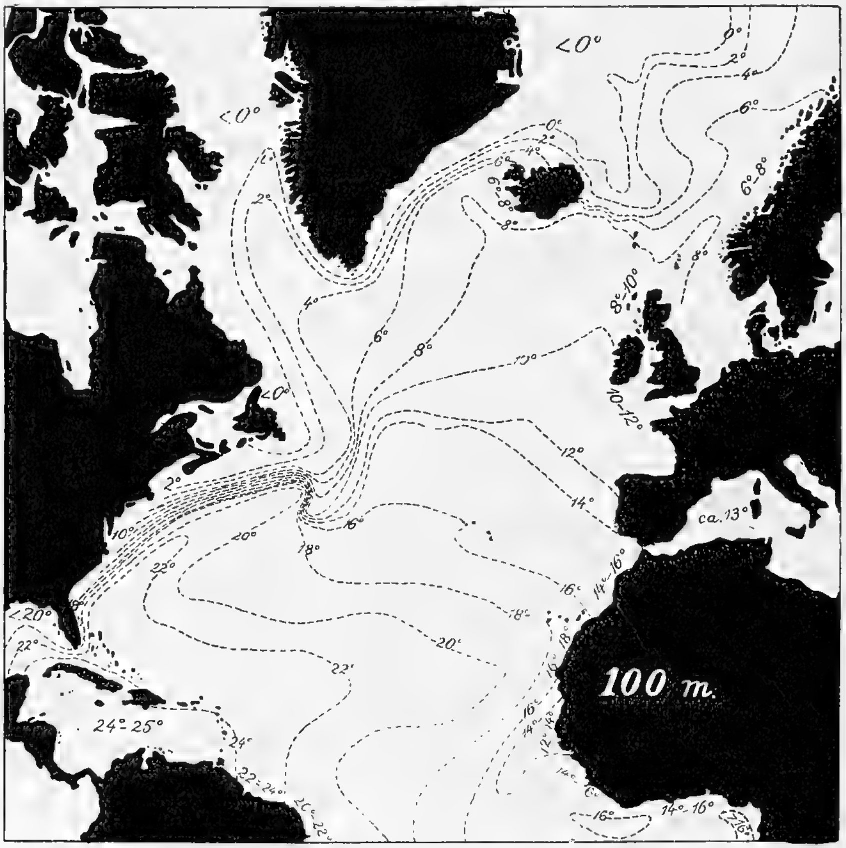

Fig. 1. Distribution of temperature in the North Atlantic at a depth of 100 metres. (Drawn by Helland-Hansen).

In the course of the Norwegian fishery investigations carried out under my supervision, I have endeavoured in various ways to discover whether any fish move out beyond the coastal banks in the temperate upper strata of the Norwegian Sea. Numerous experiments have been made with drift nets and floating lines, for the most part, however, with negative result. Such positive data as were obtained have been published in a previous work*) and will be found in Fig. 3, indicating the localities at which the

*) Johan Hjort, Norsk Havfiske II. Del, pp. 184 ff. Bergen 1905.
Murray and Hjort, The Depths of the Ocean, p. 648. London 1912.

various species were encountered. At most of these places, specimens of *Sebastes* were taken, this species being found in some considerable numbers at from 100—200 metres depth above the great depression of the Norwegian Sea. These fish are presumably to be found regularly throughout this water; the quite young larvae have also been taken there. Herring have been encountered at various places north of the North Sea Bank and the Faroe-Iceland ridge, where they were taken in drift nets at or near the surface above the deepest parts. A great number of hauls were made throughout the range from Lofoten to Jan Mayen; only in a single instance, however, were some few specimens taken. The same applies to cod, haddock, coalfish, and catfish (*Anarrhicas*). Experiments of this nature are however, by no means easy to carry out, and negative or mainly negative results are scarcely sufficient to warrant the conclusion that the species in question do not occur in any quantity in the waters investigated; there is always the possibility that the fish might occur in shoals, which it would be a matter of merest chance to encounter in so great an expanse of sea. One thing at least is certain; we have no other grounds for supposing the existence, in any considerable numbers, of coastal fish in the deeper parts of the Norwegian Sea, beyond the occurrence of *Sebastes* (throughout the greater part of the region) and herring from the North Sea slope towards the so-called "Bottlenose Ground" (north of the Faroes).

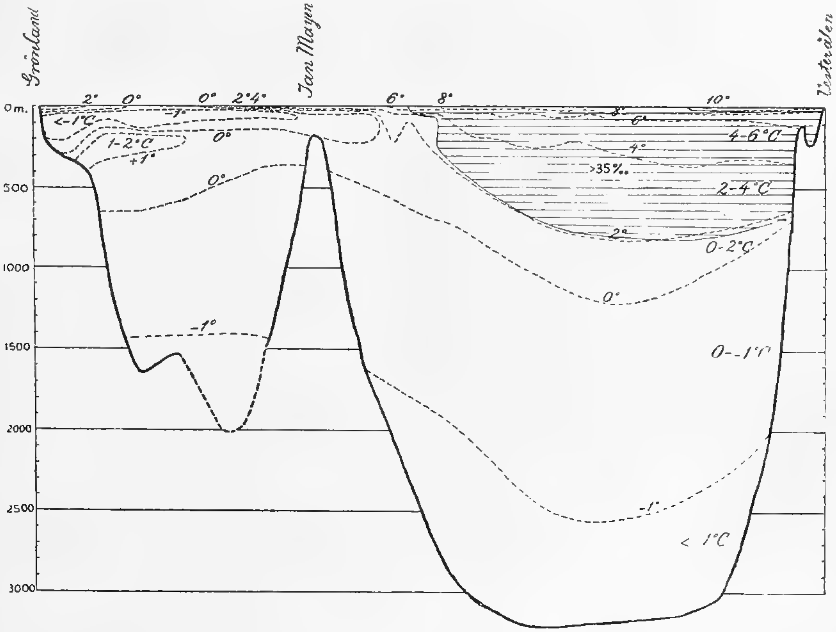

Fig. 2. Section across the Norwegian Sea from Greenland to Norway. (Drawn by HELLAND-HANSEN).

Principal species only found on the coastal banks in spawning time.

The most favourable season for investigations of this nature is the spawning time, when it it is possible to study the occurrence, not only of the fish themselves, but also of the newly spawned eggs, which are found floating over the spawning grounds. In this manner, the International Investigations have studied the spawning grounds of the cod, the plaice, and other fish, and have succeeded in showing that the area of occurrence of all the most important species is confined, in spawning time, (the principal fishing season) to the coastal banks, in many cases to certain comparatively small parts of these. The young stages also, — fish in their first years of life, — are easily caught. We have therefore a great deal of reliable material available as to the area of distribution of the fish

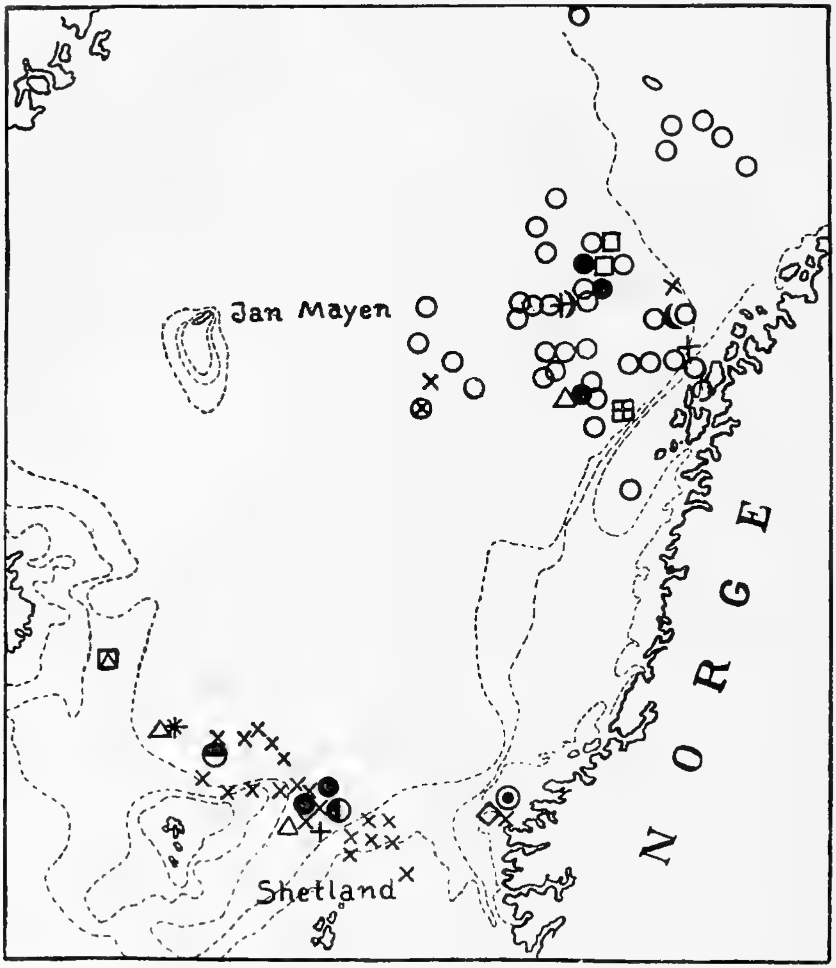

Fig. 3. Animals caught over great depths in the Norwegian Sea. The isobaths represent depths of 100, 200, and 500 fathoms.

○	*Sebastes*	⊙	*Cyclopterus*	□	Haddock
●	Cephalopoda	×	Herrings	)	*Anarrhicas*
◐	*Lamna*	+	Cod	(	Greenland shark
◒	*Acanthias*	△	*Gadus virens*	◇	Mackerel

at this period of their life, which further confirms the belief that the limits of their sphere of movement are now more or less accurately known and defined.

A considerable portion of the stock annually taken by the fishery.

The numerous marking experiments which have been carried out during the last few years have also gone far to create the impression that the stock of fish in northern waters was by no means the vague, indefinite and unlimited quantity formerly supposed. The percentage of marked fish recaptured was extremely high, and in the course of the last twenty years, scientists interested in the subject have more and more inclined to the opinion that the hauls made by the fishermen really represent a very considerable portion of the actual stock in the sea. This being granted, it is then possible, by means of *experimental hauls*, and by the study of comparatively few, but methodically collected samples, to obtain a reliable view of the stock, as for instance with regard to the relative numbers of fish of different sizes therein contained. In this manner, the first foundation for scientific study of the stock and its fluctuations was obtained.

Preliminary investigations as to the cod fishery in northern Norwegian waters, 1900—1903.

When the Norwegian research vessel "Michael Sars" was built, in 1900, the fisheries of Norway were in a highly critical position. The years immediately preceding had, from the point of view of the fishing industry, been distinctly bad, especially in the northern districts, where the population, whose existence depends almost exclusively upon the proceeds of the fishery, were in many places reduced to the direst straits. Innumerable theories and suggestions were put forward to account for the continued failure of the industry. The general opinion centred round the belief that the decrease in the yield was occasioned by the presence of the whaling vessels which at that time worked the waters to the north of the Finmark coast as far as Bear Island. It was at this period that I received instructions from the Norwegian Government to investigate, as far as possible, the causes of the diminution in the yield. I therefore commenced, in 1900, a series of cruises on board the "Michael Sars", with a view to studying the habits and occurrence of the cod in northern Norwegian waters. In the course of this work, which extended until 1903, I devoted particular attention to the study of the spawning, and the locality and movements of the fish at different stages of developement, collecting also a quantity of material to serve as basis for investigation of the composition of the stock in regard to size*). I did not, however, then succeed in arriving at any definite conclusion as to the causes of the great fluctuations in the fishery or the laws which govern the same; this was hardly to be expected in so short a time. The principal result attained in the course of the investigations was a first survey of the natural history of the cod, (*vide* Chapter III) and a recognition of the fact that future efforts towards the attainment of the end in view would need to be concentrated upon the study of the actual stock.

A serious hindrance to the progress of the work in these preliminary investigations was occasioned by my committing the error of employing the methods generally accepted

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*) Johan Hjort, Fiskeri og Hvalfangst i det nordlige Norge. Aarsberetning vedk. Norges Fiskerier, 1ste Hefte, 1903.

at the time, and drawing conclusions, from measurements of the length of the fish, as to the age of the cod, and the composition of the stock in this respect. These measurements led me to suppose that the Finmark cod were fish of rapid growth, the stock consisting of only a few year classes.

Methods of age determination adopted in the investigations.

In 1904, the German scientist, F. HEINCKE, laid before the International Council, at their meeting in Amsterdam, the results of his investigations directed towards the determination of age in the case of cod and plaice, based on a study of the bones of the fish*). In view of my own endeavours in a like direction, I naturally followed this new developement with the keenest interest. I took the earliest opportunity of becoming acquainted with Prof. HEINCKE's methods, and visited Heligoland for the purpose. Immediately on my return I endeavoured, with the valuable assistance of my then Assistants Dr. H. BROCH, Dr. K. DAHL, and Dr. D. DAMAS, to work out some practical method for age determinations on an extensive scale, embracing all the most important species of fish. The investigations carried out by Dr. DAMAS**) with regard to the cod, and those of Dr. BROCH***) and Dr. DAHL†) concerning the herring, led to the result that the scales of the fish were selected as offering the most advantageous means of ascertaining the composition of the stock in point of age.

With this end in view, a mass of material was collected during the following years, consisting of scales of cod and herring, numerous measurements also being made of fish taken at different places along the Norwegian coast. An international commission was also formed to investigate the natural history of the cod species in the North Sea. The work of dealing with the scale material was entrusted to the gentlemen above mentioned, Dr. HELLAND-HANSEN††) assisting in the work of the statistical treatment of the measurements.

The principal results of these investigations, the outcome of interested co-operation between those engaged upon the work, amounted, in brief, to a recognition of the following facts:

1) That the stock of cod and herring included a far greater number of year classes than had previously been supposed, and

2) That the relative numerical values of these year classes exhibited great fluctuations from year to year.

Representative biological or vital statistics.

These conclusions furnished a definite basis for future investigations as to the fluctuations of the fishery. In a lecture delivered at the meeting of the International Council

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*) Vide HEINCKE's reports in „Die Beteiligung Deutschlands an der Internationalen Meeresforschung“. Berlin, 1904, 1906 and 1908.

**) Contribution à la Biologie des Gadides. Rapports et Procès-verbaux Vol. X, Copenhagen 1909.

***) Norwegische Heringsuntersuchungen während der Jahre 1904—1906. Bergens Museums Aarbog 1908, Nr. 1.

†) The Scales of the Herring. Rep. Norw. Fishery and Marine Investigations, Vol. II, 1907, No. 6.

††) Statistical Research into the Biology of the Haddock and Cod in the North Sea. Rapports et Procès-Verbaux Vol. X, Copenhagen 1909.

for the Study of the Sea, in 1907*), I endeavoured to formulate this programme of work in the following words:

“To make my ideas clearer, I will proceed to draw a comparison between this Fishery Research and a science which is much more generally understood. I mean the science of Vital Statistics.

In all exposition of the science of vital statistics, there are three prominent features which attract our chief consideration: —

1. Birth-rate. 2. Age-distribution. 3. Migration. It is customary to study these questions by the help of what are called representative statistics. A certain number of individuals are selected, who are supposed to stand for the mass of the people, and attention is directed to them. We ascertain from this source their average length of life, their wanderings, their increase or decrease, and whether sickness, war, disaster, or emigration plays any appreciable part in reducing the population.

It seems at first sight a bold suggestion to propose studying the fish-supply on lines like these. A population can be counted; but who knows how many fishes are in the sea? And yet it appears to me a project big with possibility, to regard the discoveries of fishery research from a similar standpoint to what has been adopted in the science of vital statistics”.

I also took occasion to mention, in the course of the same lecture, the most important results of the investigations then already carried out, as follows:

»Of the utmost importance is the really significant fact, that our material from several banks in the North Sea clearly points towards the same numerical relations between the different year classes (as in the Skagerak). Thus on all the banks, individual fish born in the years 1902 and 1903 were in much scantier numbers than those born in 1904. This will appear from a series of curves showing the number of individuals of the various sizes from the different banks that were from time to time subjected to investigation, such as the Dogger Bank, the Great Fisher Bank, the Coast Banks and the banks in the northern portion of the North Sea.

From the copious English fishery statistics, it appears that in 1904 and 1905 fewer small haddocks were landed than in 1906, whereas the quantity of large haddocks was about the same for all three years. Our previous statements explain this, for so-called “small” haddocks are, roughly speaking, two years old, and consequently, owing to the scarcity of fish born in 1902 and 1903, extremely few small haddocks were caught in 1904—1905, while on the other hand, in 1906, numbers of haddock born in 1904 were brought to market. Thus we are now enabled to foretell some years in advance the connection between cause and effect”.

This preliminary statement, made in the summer of 1907, was followed by the full report of the Commission above referred to, published in 1909, where the points at issue were exhaustively dealt with in a comparative survey by the Commission, and in detail by Dr. Helland-Hansen as regards the question of size, and by Dr. Damas with regard to composition in point of age (*Vide* report in Vol. X. Rapports et Proc. Verb.). The

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*) Nogle Resultater av den Internationale Havforskning. Aarsberetning vedk. Norges Fiskerier, 2. Hefte. 1907.

“Some Results of the International Ocean Researches”, published by the Scottish Oceanographical Laboratory, Edinburgh, 1908.

numerous investigations as to the age of the Gadoid species, carried out with the greatest energy and skill by Dr. DAMAS, are in particular to be regarded as of the greatest importance.

The investigations carried out by the International Commission terminated abruptly with the publication of the report. This unexpected conclusion of the work I then regarded, and must still consider, as highly to be regretted. The results attained had opened up what promised to be a most fertile field for continued methodical study of one at least of the principal points in connection with the fluctuations of the fishery, viz. the varying composition of the actual stock. It was moreover evident that such studies could only be carried out by means of samples collected throughout a series of years, and treated with a view to determining the composition of the stock in point of age. I found it impossible, however, to obtain the necessary support in my endeavours to bring about the promotion of an international organisation for the study of the various races of cod and herring. I nevertheless continued to prosecute my own researches on the subject as far as opportunity permitted, partly by the collection, on a smaller scale, of material for the study of fluctuations in *the stock of cod in Norwegian coastal waters*, partly by organising the extensive collection of *herring samples, embracing the principal varieties known in northern European waters.* The former of these two projects has been greatly furthered by the Norwegian fishery investigations alone; as to the latter, the International Council has here furnished considerable means and valuable assistance.

As regards the investigations concerning the cod, during which I have had assistance from Mr. EINAR KOEFOED and Mr. OSCAR SUND, nothing has been published since the report of the International Commission; I therefore purpose to give, in the following chapters, a survey of such results as have hitherto been attained.

With regard to the herring investigations, on the other hand, various publications have appeared, some of these being by my Assistant, Mr. EINAR LEA, while some again are largely due to the valuable aid which he and others have rendered me during the past years.

Some doubt or misunderstanding having arisen in various quarters as to the methods adopted in the herring investigations*) Mr. LEA has subjected the methods in question to further careful examination in several exhaustive treatises**). The result of these has been to greatly strengthen the conviction that a study of the scales of the herring enables us not only to determine the age of the fish, but also to calculate its size at each of the different periods of growth, in accordance with the idea which from the first formed the basis of the method, viz. that the structure of the scale is in itself a record of the growth history of the fish.

In addition to this, my Assistants, Dr. K. DAHL, PAUL BJERKAN and others, and

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*) SCHNEIDER, GUIDO, Ueber die Altersbestimmungén bei Heringen nach den Zuwachszonen der Schuppen. Svenska Hydrograf-biologiska komm. Skrifter, 1910.

LEE, ROSA M., An Investigation into the methods of growth determination in fishes. Publ. de Circ. No. 63, 1912.

**) On the methods used in the Herring-Investigations. Publ. de Circ. No. 53, 1910.

A Study of the Growth of Herrings. Publ. de Circ. No. 61, 1911.

Further Studies concerning the Methods of Calculating the Growth of Herrings. Publ. de Circonstance, Nr. 66, 1913.

especially Mr. EINAR LEA have, during the years 1907—1913, carried out a great number (some score thousands) of age determinations and growth measurements of herring, partly from the coast of Norway, as also from the Atlantic, Iceland, the Faroes, the North Sea, the Skagerak and the Kattegat. Some of the results thus attained have already been published*). Among other points, it has been found that the herring exhibited similar great fluctuations in the numerical value of the different year classes to that observed in the case of the haddock in the North Sea and Skagerak (*vide supra*). Moreover, the very same year class, that of 1904, was found to be distinguished, both among the herring of the Norwegian coastal waters, and the haddock in the North Sea and Skagerak, by the very high percentage which it has furnished during the past years. The results hitherto published referred to the years 1907—1911. After a further period of two years' work, during which time definite conclusions have also been arrived at in the case of the cod investigations, I have thought it desirable to give a new survey of the results up to date. I purpose, however, in the following, to confine myself to such matter as may serve to further elucidate the problem which forms the subject of this report, viz. the fluctuations in the fisheries.

The great mass of material which has been collected, and on which the present work is based, will later be utilised for further publications, and for the discussion of other problems than that which is here principally dealt with, and to which I have devoted the greater part of my personal interest during the past years.

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*) JOHAN HJORT, Report on the Herring Investigations until January 1910; Publ. de Circ. No. 53. 1910.

JOHAN HJORT and EINAR LEA, Some Results of the International Herring Investigations 1907—1911. Publ. de Circ., No. 61, 1911.

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CHAPTER I

The Herring Stock in Norwegian coastal waters.

Norwegian Herring Fisheries.

Herring Fishery is carried on along the whole of the Norwegian coast, in the fiords, among the islands, and in the open sea off the shore. The fishermen use nets and seines, stake-nets which are anchored along the bottom or to floats, and drift nets, which are fastened together in a chain, and drift with the boat or vessel at night. The seines cut off the shoals, either along the shore (shore seines) or at some little distance from land (purse-seines). The nets used take only certain sizes of fish, according to the width of mesh, and nets with many different sizes of mesh are therefore employed, having regard to what kind of fish is expected to be caught. The seines are of fine mesh, and can frequently take all herrings down to 7 or 8 cm. in length; it is very rarely, however, that all sizes of herring are found in one and the same seine haul. This is due to the fact that the different sizes of fish move in separate shoals, apart from one another. There are thus many different kinds of herring fishery carried on in the Norwegian coastal waters, and many different "sorts" of herring are recognised, according to the size most common in the different shoals. These sorts have been known, both among the fishermen and in the trade, from time immemorial, and a great amount of care and study has been devoted to the question of dividing them according to some rational method of assortment.

The fishery statistics distinguish between four great principal groups; small herring, fat herring, large herring, and spring herring*). It is also possible to distinguish, practically speaking, between four different kinds of herring fishery, corresponding to these four classes, and differing, not only as regards the method of capture employed, but also in point of place and time of same, being carried on, for the most part, in different regions of the coastal waters, and at different periods of the year, In the year 1908, the catches of the different classes were as follows: (given in hectolitres).

	Spring Herring	Large Herring	Fat Herring	Small Herring
West Coast	613.356	....	605	47.880
Romsdal	11.500	101.320	4.990	18.151
Trøndelagen ...	....	9.628	73.852	39.320
Nordland	....	800	408.654	77.100
Tromsø district	....	9	127.500	48.100
Finmarken	....	....	....	92.580

*) As will be seen in the following, a fifth main group may also be noticed, which could be called "Norwegian North Sea herrings". These most nearly resemble the so-called "large herrings", but are taken in the eastern waters of the North Sea.

The small herring are taken, as will be seen from the above, all along the coast, but in increasing numbers farther to the north. The fat herring are taken, for by far the greater part, within the range from Trondhjemsfjord to the Tromsø district, the large herring off the coasts of the Romsdal and southern Trondhjem district, while by far the greater part of the spring herring are taken in the West Coast waters. (Fig. 4).

The proportional distribution of the yield among the different sorts as shown in the figures for 1908 may probably be taken as generally representative; fluctuations can, however, occur. The majority of fat herring may for instance be found to fall to the south, in the Trøndelagen district, or north, toward Tromsø. More than a generation ago, the large herring were taken in greatest numbers in the Nordland district, and the locality of greatest capture of spring herrings may shift southwards to the Skagerak, or northwards along the coast.

Fig. 4.

Popular classification of the different varieties.

The method of distinguishing between the four sorts of fish, which has been in use for a great number of years, is based principally upon the *size*, degree of fatness, and development of the genital organs (ovaries and milt).

The *small herring* do not exceed 19 cm. in length, the ovary or milt is, at the utmost, only visible as a thin thread below the spine; in point of fatness they are far inferior to the fat herring.

The *fat herring* vary as a rule in size from 19 to 26 cm., the genital organs of the lesser fish are very small, incipient developement being noticeable in the case of the larger. The adipose deposit however, in the flesh and round the intestines ("ister") is much more developed than in any other class of herring.

The *large herring* are superior in size, running as a rule from 27—32 cm., their genital organs are, from the autumn, in advancing developement towards maturity. This class of fish thus corresponds to that known in the North Sea fishery as "fulls". In the course of this developement the adipose deposit gradually decreases in quantity, and the fish finally pass, by imperceptible degrees, into the class of *spring herring*, which are the spawning fish. Among these latter, the ovaries are in January firm, in February and March slack, and in April entirely spent, the fish at this time being also thin and in poor condition.

Small herring and fat herring are thus immature fish, the large and spring herring being mature; it would therefore be natural to consider all four classes as representing different stages of size, developement, and age in one and the same race of fish. G. O. Sars expressed this opinion forty years ago; so deep-rooted, however, is the general idea of difference between the classes, that they are even now widely considered as being distinct species or races of fish.

The careful investigations of late years as to the size, growth, and composition with regard to age of the different classes of herring have done much to elucidate this question.

Size of the herring, and determination of age by means of measurement.

The first experiments with a view to determining the age and growth of the herring were based upon the only method at that time known, viz. the system of measurement invented by Dr. C. G. Joh. Petersen. In a sample of some hundreds of fish, the length of each individual was measured in centimetres. All the measurements taken were then arranged in order of size, whereby certain groups were obtained, and these were supposed to correspond to certain year classes. In a seine haul of small herring taken at Lofoten in March 1913, the percentage in a sample of 300 individuals for each centimetre of size was found to be as follows:

cm......	7	8	9	10	11	12	13	14	15	16
%......	2.6	28.9	23.8	12.2	3.5	2.3	11.3	10.9	4.2	0.3

Drawn as a graph, (Fig. 5) these figures give, as will be seen, a curve with double summit, representing two groups, the one between 7 and 11 cm., the other from 12 to 16 cm.

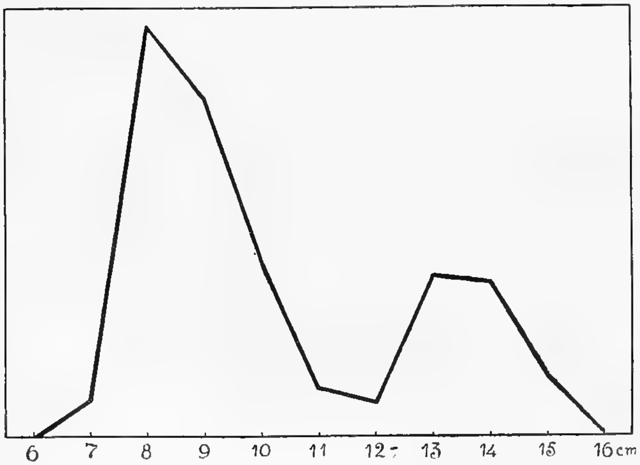
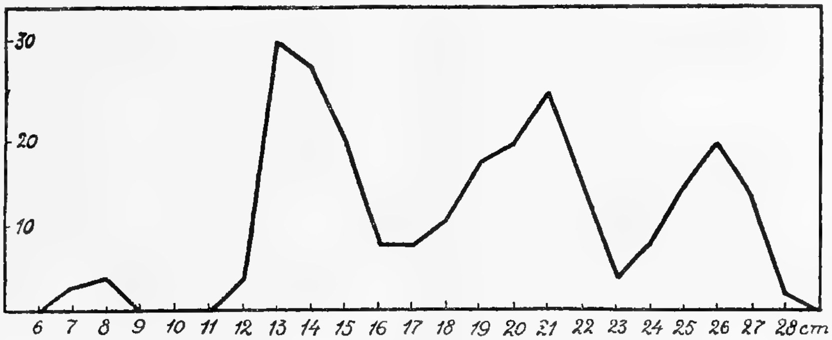


Fig. 5. Percentage of different cm. sizes in the yield of small herring. Lofoten, March 1913.

The sample being taken in March, i. e., in spawning time, the group of smaller fish would be then just one year old, the other consisting of two year old fish. Determination of age by means of the annual rings on the scales has shown this to be correct; the scales of the fish of the smaller group exhibited one winter ring, those of the larger having two. The two methods of age determination, that by measurement of length, and that by scale measurement, lead thus in this case to identical results.

In dealing with larger fish, however, greater difficulties are encountered. Fig. 6 shows a curve based on the measurements of a seine haul, taken in Nordland during the autumn of 1909, and consisting of small herring and fat herring together. As will be seen, this curve exhibits four summits or groups. The herring being taken in the autumn, and their spawning time being in the spring, one would expect to find four groups of the following ages; $^2/_3$, $1^2/_3$, $2^2/_3$ and $3^2/_3$ years. Examination of the scales, however, showed that this supposition only held good for the three first groups. Fig. 7 shows the composition with regard to age according to the results of the scale measurements. It will be seen that the three first groups consisted, roughly speaking, of fish of $^2/_3$, $1^2/_3$, and $2^2/_3$ years, whereas the fourth group exhibited no fewer than three different year classes, viz; $3^2/_3$, $4^2/_3$ and $5^2/_3$ year fish.

From the table of sizes of the small herring taken at Lofoten, and from Figs. 6 and 7, it will be seen that the growth of the herring varies greatly for different individuals of the same year class. The method of age determination by measurement fails, therefore, when dealing with older fish, the variation in growth in the older year classes being so great as to exhibit a difference in age of one, two, or three years between fish of the same size*).



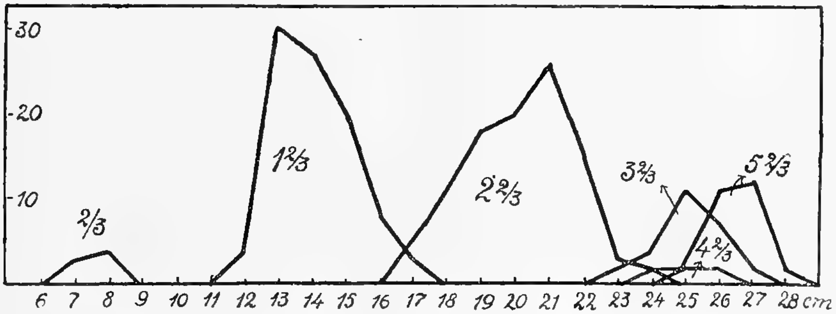


Fig. 6. Sample of small herring and fat herring from North Coast of Norway, autumn, 1909. Arranged in cm. groups. (Lea).

Fig. 7. Same sample as in Fig. 6; individuals of different year classes arranged in cm. groups according to age determination.
$1^2/_3$ denotes the curve for fish of $1^2/_3$ years old (Lea).

With so great a variation in size between the different individuals it is evident that the task of determining the *average* growth or rate of growth of the herring demands a great deal of work, and presents very considerable difficulties. These last are still further increased if it is desired to ascertain, not merely the average growth for a single

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*) Previous investigations, based solely upon measurement, have thus exhibited considerable errors in determining the age of the fish. This applies also, unfortunately, to my own first preliminary investigations in this respect.

year, but for all years, and not only for a certain part of the coast, but for its whole extent. Investigation has shown that the rate of growth varies in different years and in different waters, there being a difference, for instance, between West Coast and Nordland fish in this respect. A further difficulty, moreover, is in particular presented by the fact that the herring exhibit a tendency to move in shoals consisting of approximately the same sizes. It thus frequently happens that the small individuals of a year class keep to younger year classes, (e. g. in the fat herring shoals), while the larger specimens of the same year class associate themselves with older fish, (e. g. large herring and spring herring). An examination of all the individuals of one year class in a certain shoal will thus give a more or less correct average for that year class as represented in the shoal in question, but not for the year class as a whole.

For purposes of closer study of the growth of the herring, another method is therefore employed.

The Scales of the herring as a means of determining the age and growth of the fish.

As already mentioned, it is possible, from the scales of the herring not only to calculate the age of the fish, but also, by examination of the graphical view exhibited by the growth rings, to determine how much the fish has grown in the different periods of growth. If therefore, we draw a picture of a scale, enlarged to such a degree as to make the distance between the centre of the so-called basal line to the edge of the scale equal to the length of the fish (see Fig. 10) then the distances to the different winter rings will immediately show the size of the fish during each winter of its life.

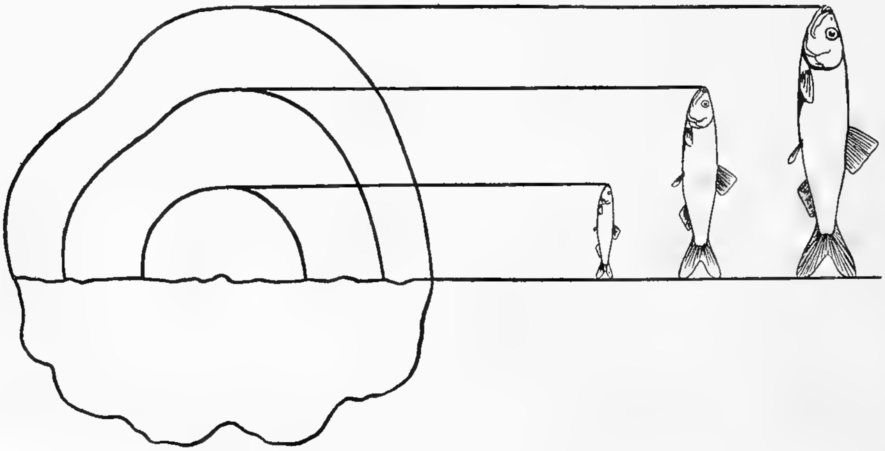

Fig. 10. Growth zones of herring scales compared with size of fish.

In order to avoid the arduous work of drawing the scales thus enlarged, a labour-saving method is employed, as follows: With the aid of a prism, the microscopic picture is thrown on to a piece of paper on the table beside the microscope. On this picture, a slip of paper is laid, upon which are marked off the different distances from the centre

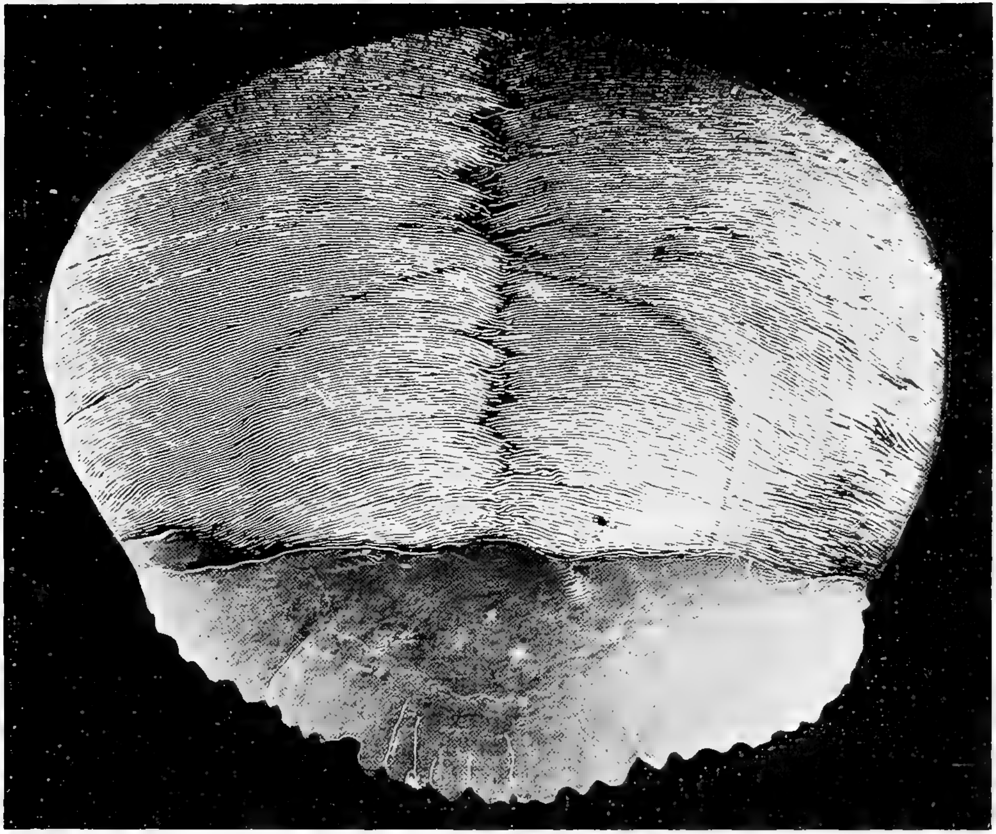

Fig. 8. Herring scale with 1 winter ring (LEA phot.).

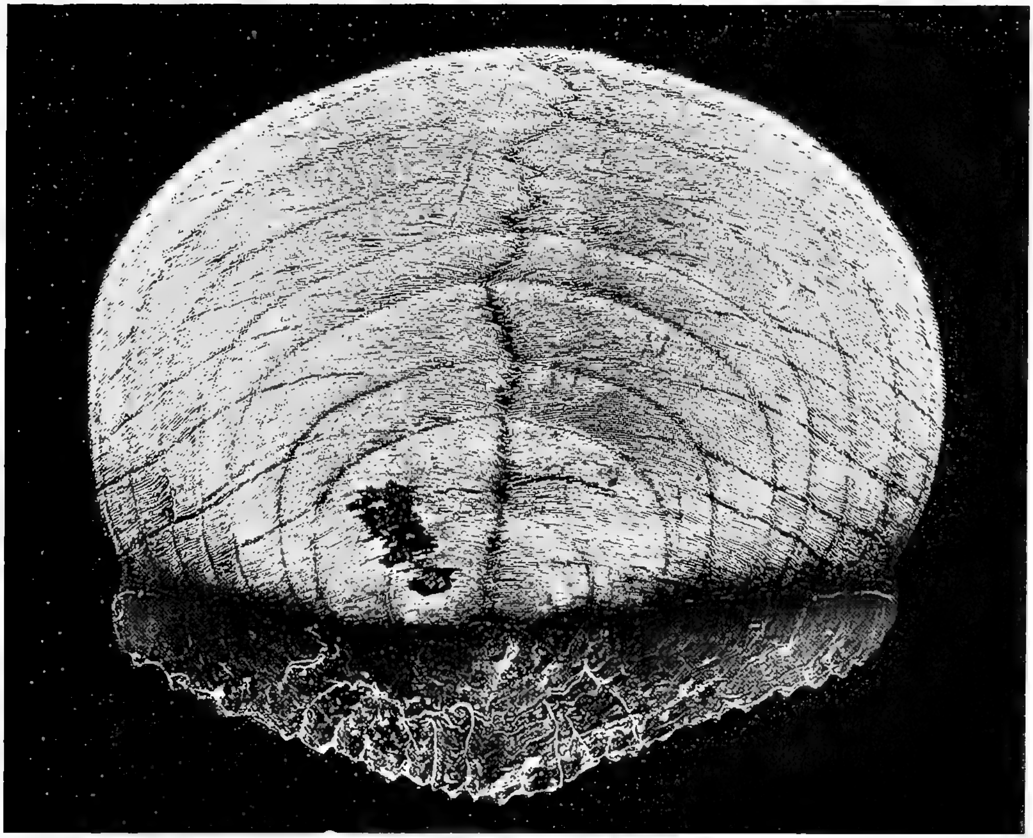

Fig. 9. Herring scale with 8 winter rings inside the edge (Lea phot.).

of the basal line to the annual rings, (see Fig. 11, V, v_1, and v_2). By means of an apparatus, it is then easy to calculate the length of the fish during the different winters*).

If we now examine, in this manner, a large number of herrings of a year class of old, grown fish from the spawning shoals (spring herring) these being so old that we may suppose all the individuals of the year class to have joined the shoal, there is every probability of obtaining at any rate an approximate picture of the average growth. Experience would also appear to indicate that the spawning shoals contain herrings which have passed their growth at various parts of the coast, which would render the resulting average as representative as possible.

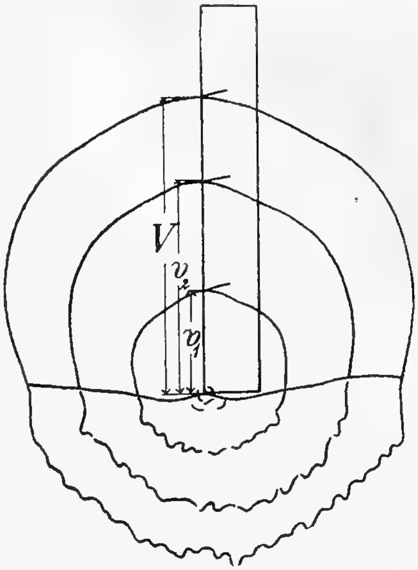

Fig. 11.

Average size of the herring at different ages.

In a sample of spring herring, examined in 1909, a group of ten year old fish was found, i. e. of individuals spawned in 1899. According to the measurements, the average growth of these fish had been as follows:

At the age of

1 year	8.8 cm.	6 years	28.6 cm.
2 years	12.7 »	7 »	30.1 »
3 »	18.1 »	8 »	31.1 »
4 »	22.3 »	9 »	31.8 »
5 »	26.3 »	10 »	32.4 »

These figures thus express the average size of the spring herrings spawned in 1899 for each winter of their life. We will here consider them as giving the averages for the size of the different age classes in winter. The mean values for summer and autumn will of course be between the figures for the previous winter and those for that following.

Growth at different seasons of the year.

Lea**) has carried out some interesting investigations regarding the growth of herrings at different seasons of the year. His method consisted in measuring, during 16 consecutive months, a large number of individuals of a year class which at the time of commencing investigations was about two years old. He thus obtained figures expressing the average *increment* of growth for each month in the third year of life. The results of his measurements are given in Fig. 12. From this it will be seen that growth took place only in the months from April to September. From October to the end of March there was no increase at all, which fact also explains the narrowness of the winter rings, and their sharply defined contrast to the remainder of the scale. The growth was most

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*) Vide Publ. de Circ. No. 53, p. 37.

**) Einar Lea: A Study on the Growth of Herrings. Publ. de Circ. No. 61. Copenhagen 1911.

rapid during the period from May to July, the curves of growth being correspondingly steeper here*). The two year old herring have thus approximately the same length in the autumn as the three year old fish in April.

We will now consider the composition with regard to size and age as exhibited by the investigation of some samples of the different classes of herring. It must, however, continually be borne in mind that the sizes and average sizes in a certain shoal may be widely divergent from the above-mentioned mean figures for the whole year classes.

The small herring and fishery for same.

Small herring are found from year to year in great numbers along the coast; in 1911 the total yield was no less than 700,000 hl. These small herrings are used for bait, for canning, and for the manufacture of oil.

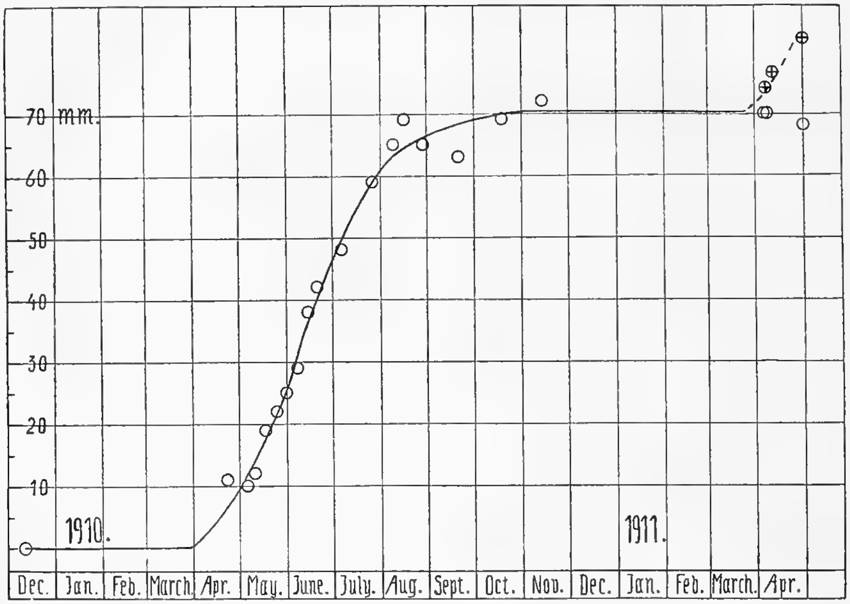

Fig. 12. Diagram illustrating the average increment (t_3) of the herrings between Dec. 1909 and May 1911. The broken curve denotes increment in the 4th growth period of the herrings (t_4) (Lea)

As the herring spawn in the spring, (March, April) it will be readily understood that the fry during their first summer are too small to be taken with the implements employed by the fishermen. Not until late autumn and winter, when they are $^2/_3$ to $^3/_4$ year old, do those which have had most rapid growth reach a size of 7 to 8 cm. in length, when they can no longer pass through the mesh of the herring seines. There is then a very distinct difference in size between these fish and those of the year class immediately preceding, (see Fig. 5). The fishermen therefore distinguish between these two groups, and give them different names; the herring of $^2/_3$, $^3/_4$ or one year of age, measuring 7—10 or 11 cm. in length, are known on the West Coast as "musse", and on the North Coast as "kril". The fish of the preceding year class, or rather, those of $1\frac{1}{2}$, $1^2/_3$,

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*) This may be otherwise in other waters. Lea's investigations apply to the West Coast.

1¾ or 2 years of age are generally known as "bladsild", and have, as long as they bear this name, a length of 12—15 or 16 cm. The largest of the "bladsild", or those in the transition stage between these and the fat herrings, fish of 16—19 cm. in length, are often used as "skjæresild" and form, as it were, a separate group, consisting partly of the larger 1¾ or two year fish, and partly of the smaller 2¾ or three year olds.

We have seen, in Fig. 5, the sizes for the two groups of "kril", and "bladsild" as taken in the seine hauls at Lofoten in March 1913. The former consisted for the most part of fish 8 or 9 cm. long; the latter being principally 13—14 cm. in length.

As noticed above, the growth of a new year does not commence until the end of April or beginning of May, and the whole growth for the year is completed in the course of some few months. During May or June, therefore, a great number of the then 1¼ year old fish become "bladsild", whereas others, of more retarded growth, are still to be reckoned as "kril". In the course of the autumn, however, by far the greater part of the "kril" from the spring pass into the "bladsild" stage, while of the 2⅔ year fish, a great number have gone over to the "fat herring" class, the lower size limit of which may be taken as about 19 cm.

Thus the small herring consist of fish between 8 and 19 cm. in length; a size corresponding, for the most part, to the first two years of life.

These two year classes, "kril" and "bladsild", often move in separate shoals, each class keeping to itself, and often in shoals consisting only of these two classes together; now and again, however, either or both may be found together with the fat herring. Only exceptionally do they occur in shoals of full grown fish. As to the reason why these youngest year classes should thus move sometimes separately and at other times together, nothing is known. An elucidation of this problem in the natural history of the herring would be of value, also from a practical point of view.

The yield of the small herring fishery varies greatly. It amounted in 1904 to 107,000, in 1911 to 701,000 hectolitres. It is also generally observed that the size of the small herring varies from year to year, the yield one year consisting chiefly of "kril", and the next mainly of "bladsild". We shall return to this point later on.

The fat herring and fishery for same.

When the herring reach a size of 19 or 20 cm., large deposits of fat begin to form in the muscles and round the intestines. This is especially noticeable in summer and autumn, and the fish remain in this condition until the genital organs begin to develope, and the fish are nearing maturity. This adipose deposit is mostly observed in fish of 19 to 26 or 27 cm., and fish of these sizes are therefore known as "fat herring".

These fish vary greatly in size from year to year. This is very distinctly evident in three samples from Nordland, all taken with the seine in August, one in 1907, another in 1908, and the third in 1909. The following table shows the percentage in each sample of the different sizes, at centimetre intervals.

	19	20	21	22	23	24	25	26	27	28	29	30
1907 . .	1.0	20.6	28.9	25.7	14.4	5.2	2.1	2.1	. .	. .	. .	. .
1908 . .	. .	8	8	19	23	24	8	6	2	1	1	. .
1909 . .	. .	. .	. .	1.3	8.7	23.0	30.0	20.0	10.5	4.2	1.6	0.5

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These figures have been used for the graphical representation (percentage curve) in Fig. 13, the fully drawn lines. In the 1907 sample, the sizes fall between 19 and 26 cm., by far the greatest percentage being for the sizes 20, 21, and 22 cm. The average size for the whole sample is 21.6 cm. The sample from 1908 shows greatest percentages at 22—24 cm., the average for the whole being 23.2 cm., while in that from 1909, the mass of individuals will be found between 24—26 cm. with an average for the whole of 25.2 cm.

A comparison of these three samples shows a distinct increase in size during the period from 1907—1909. Theoretically, this may be explained in either of the two following ways: the fish may have grown differently in the three years, or the three samples may have consisted of fish of different ages. We will therefore consider the composition of the samples with regard to age, as seen in the following table.

	2 years	3 years	4 years	5 years	6 years	7 years
1907 ..	38.4	61.5	....	0.2	....	....
1908 ..	34.1	8.3	57.6	....	....	....
1909 ..	4.3	34.8	12.5	46.2	2.1	0.2

From this table, and from the graph based on the figures (Fig. 14) it will be seen, that the 1907 sample consisted of two and three year old fish, the 1908 sample of two and four year olds, and the 1909 sample of three and five year old fish. The composition with regard to age exhibits thus a so extraordinary variation as to warrant our considering it as the only reason for the difference in average size exhibited by the samples. This is even more evident if we consider the composition of the samples, not from the point of view of the *ages* represented, but from that of the percentages in which the different years (year classes) appear. Presented in tabular form, this is as follows:

	Year class	1907	1906	1905	1904	1903	1902	1901
1907 ..	....	....	....	38.4	61.5	....	0.2	....
1908 ..	....	....	34.1	8.3	57.6	....	....	....
1909 ..	....	4.3	34.8	12.5	46.2	2.1	0.2	....

Year class 1904 among fat herring.

The table above exhibits the peculiarity, that the year class 1904 has in all three samples furnished an exceedingly large number of individuals. It is thus evident, that this rich year class, which in the autumn of 1907 was $2^2/_3$ years old, in autumn 1908 $3^2/_3$, and in autumn 1909 $4^2/_3$, is the principal cause of the great difference in the composition of the three samples. This is also clearly indicated by the dotted curves (Fig. 13), showing the distribution, in point of size, of the individuals belonging to the year class 1904 in the samples for the three years. It is natural that these (dotted) curves should agree so well with the curves of percentage of all individuals in the samples (the full line curves) since the year class 1904 furnished so great a percentage of the samples in all three years.

Examination of these samples thus leads us to two conclusions:

1) The difference in the composition of the samples in point of size is due to the fact that they were of different composition with regard to age.

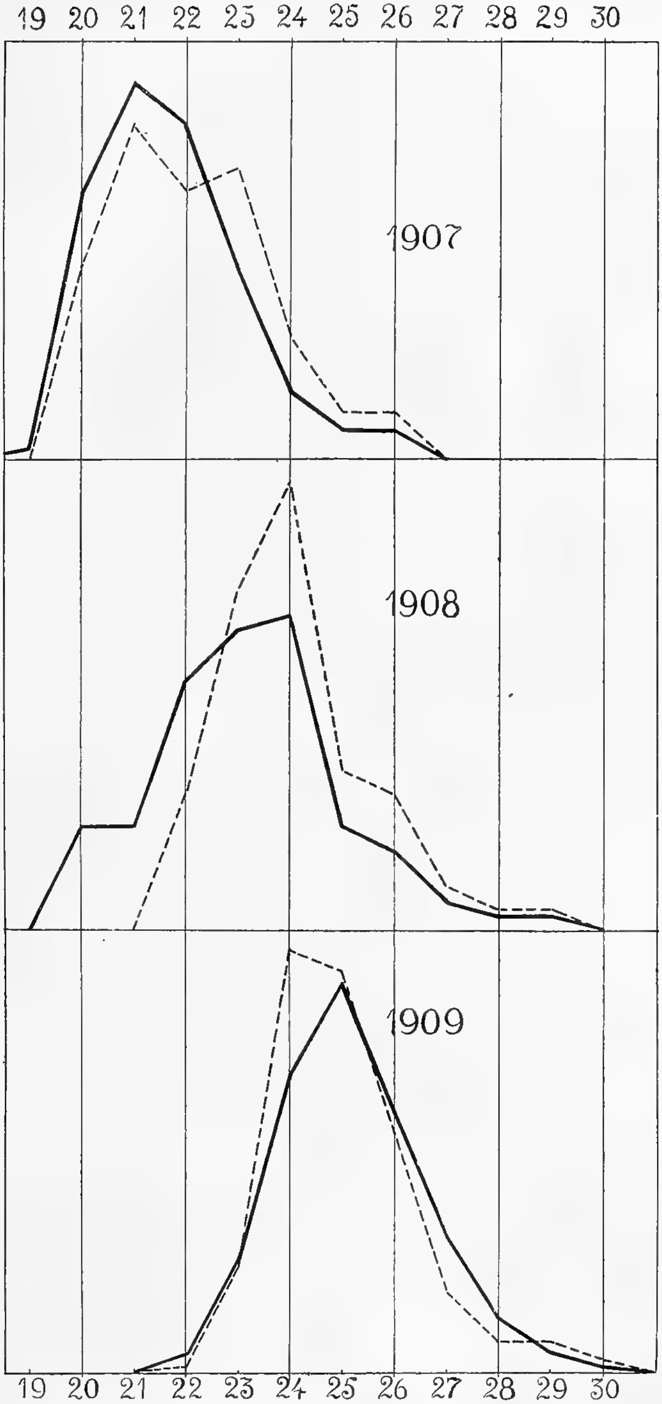

Fig. 13. Seine-caught fat herring, taken in Nordland in August, 1907—1909.
—— Composition in point of size of whole sample.
- - - - Composition in point of size of 1904 year class.
(Percentage curves).

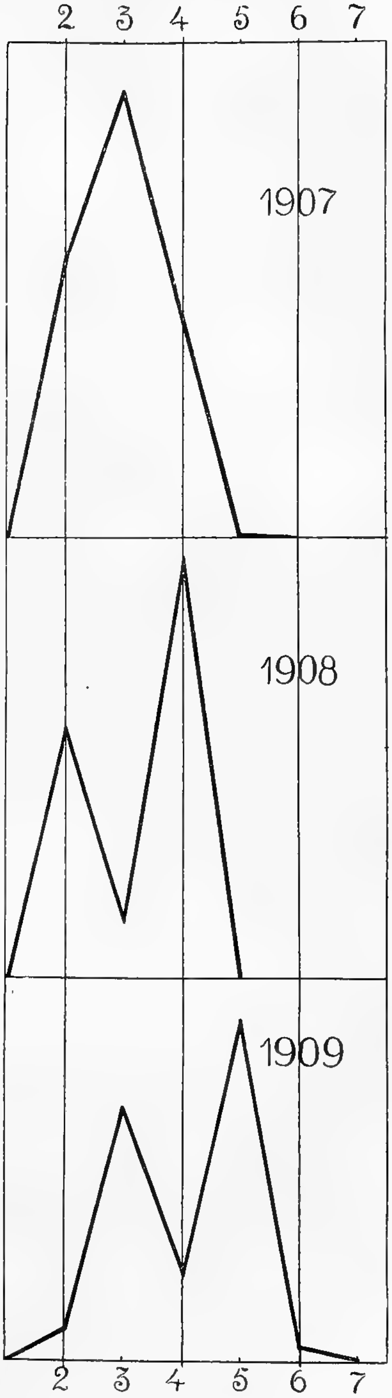

Fig. 14. Same samples as in Fig. 13. Composition in point of age.

2) The difference in the composition of the samples with regard to age is due to the fact that the numbers of the year classes varied, and especially to the circumstance that one year class, that dating from 1904, was far more numerously represented than the others.

The very important question now arises, whether these results should be considered as due to fortuitous conditions in the three samples, or to natural variation in the stock of the fat herring as a whole. Can we, from these observations, deduce a general law? It is evident, that only *experience*, obtained by the examination of many samples and covering several years, can enable us to answer this question, and, since the point is of fundamental importance for comprehension of the composition with regard to age and size, and of the fluctuations in the herring fishery, I will endeavour to show what conclusions may be drawn from the material at present available.

The samples of fat herring examined in the years 1907—1909 were as follows*):

	No. of samples	No. of specimens therein contained
1907....	12	2383
1908....	8	2398
1909....	3	1958
Total...	23	6739

In 16 of these 23 samples, the year class 1904 was found to be represented by a percentage of over 40. In spite of this, however, the average percentage for the year class in all the samples is only as follows:

in 1907, 51.3 %, in 1908, 37.8, in 1909, 16.9.

A comparison of all the different samples clearly shows to what this is due. Several samples are found to contain a large admixture of small herring, the $1^2/_3$ and $2^2/_3$ year fish, which are entirely lacking in other samples. Of the $1^2/_3$ year fish, a single sample contained 91.9 %. In 1908 there were in one sample 93.9, in another only 3.6 %, of the $2^2/_3$ year fish. Far more certain results could have been obtained by taking out all the younger fish, but as the question of the movement of the younger year classes in shoals is as yet only imperfectly investigated and understood, I prefer not to make any attempt in this direction. We will instead proceed to consider the composition in point of age and size of the older classes of fish, the large herring and the spring herring.

Year class 1904 among large herring and spring herring.

As regards the large herring, figures are available for the years 1909—1913; in the case of the spring herring, from 1907—1913. The *average* percentages of the 1904 class for all samples from these years are given in the table below, in which, for the sake of convenience, I have also included the mean figures for fat herring in the years 1907—1910.

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*) The results of the age determinations in each individual sample will be found in the tables on pp. 31—34 in Publ. de Circ. No. 61, Copenhagen 1911.

% 1904	in 1907	1908	1909	1910	1911	1912	1913
Among fat herring	51.3	37.8	16.9	4.5	0	0	0
» large »	7.7	51.6	48.8	59.6	46.0	52.5	58.6
» spring »	1.6	34.8	43.7	77.3	70.0	64.3	64.7

The year class 1904 was, as here shown, extremely numerous in most of the samples of fat herring, (over 40 %) up to 1909 inclusive. In 1910, the year class is only poorly represented, and then disappears entirely from the shoals of the fat herring. At the same time, we find that from 1907—1910, the year class 1904 is continually increasing among the large and spring herring. In 1910 and 1911 it reaches, among the latter, the very high percentage of 77.3 and 70.0, and even in 1912 and 1913 it is over 64 %.

It may now be of interest to consider, first of all, the *composition in point of size* of the spring herring in the years when the year class 1904 had disappeared from among the fat herring, and had become so numerous in the spring shoals. For this purpose four samples from the northern spring herring district, taken in 1910—1913, have been selected.

	Percentage for sizes in cm.											Average size for whole sample in cm.	Average size for all individuals of year class 1904
	26	27	28	29	30	31	32	33	34	36	37		
1910......	5.4	14.2	26.1	32.5	14·9	2.7	2.7	1.4	..	..	..	28.6	28.4
1911......	..	1.3	6.8	28.2	35.2	14.7	7.9	3.7	0.8	0.8	0.3	30.0	29.7
1912.	..	1.0	2.2	33.5	33.5	27.8	11.4	5.2	1.2	0.3	0.3	30.5	30.3
1913......	..	..	..	3.4	9.5	50.2	26.4	8.7	1.2	..	..	31·1	31.3

Fig. 15 gives a graphical representation of the figures here shown. The full line curves show the percentages in point of size for the whole samples, the dotted curves those of the year class 1904. It will be immediately seen that a distinct increase in the size of the spring herring took place in 1910—1913, while at the same time an increase in the size of the individuals belonging to year class 1904 is also apparent. In the four samples, the year class 1904 furnished the following percentages of each:

1910	78.0
1911	71.2
1912	61.6
1913	70.2.

With these high percentages in view, it would seem very natural to consider the excellent agreement of the increase in size of the whole sample of spring herring with the increase in size of the year class 1904 as due to the fact that this year class has been a determining factor in the size of the whole sample.

A full and complete view of the position of the year class in the samples can, however, only be obtained by considering together the average percentages for all year classes in the samples examined. This will be found in the following table, which shows the

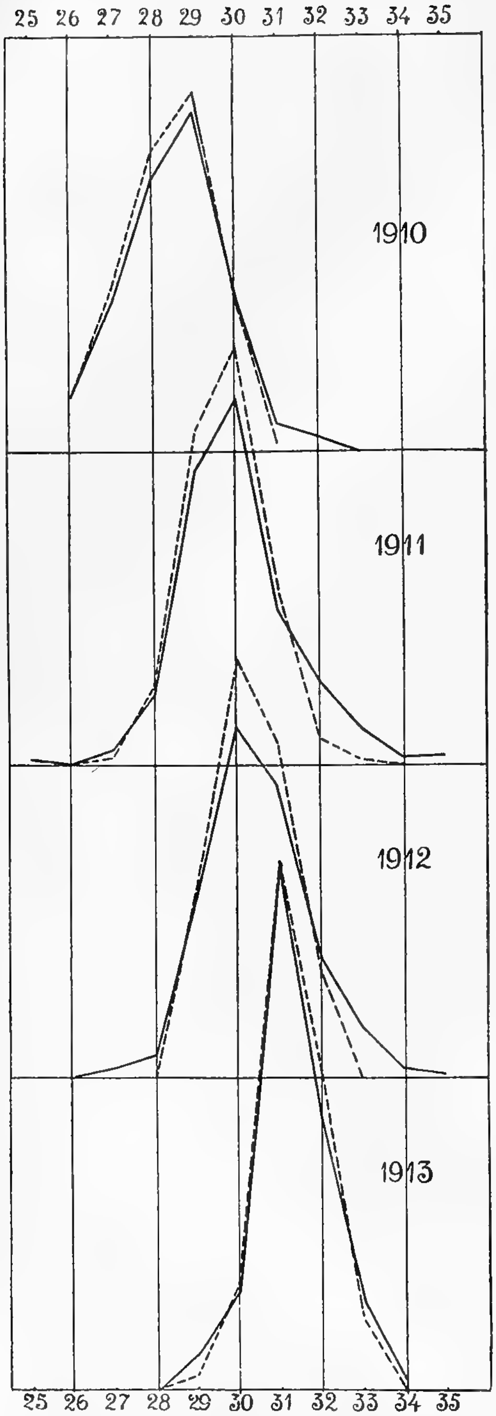

Fig. 15. Composition in point of size of spring herring.
— whole sample. - - - 1904 year class.

composition in point of age of the spring herring for each of the years from 1907—1913. It will be seen that spring herring are found from 3 to 18 years of age; those between 4 and 10 years old are, however, the only ones present in any considerable numbers (over 17 %).

Age of Norwegian Spring Herring in the years 1907—1913.

The representation of each year class is given in percentages.

Year classes	3	4	5	6	7	8	9	10	11
1907.....	**1.6**	22.2	18.5	14.8	12.6	19.4	3.4	2.3	1.7
1908.....	..	**34.8**	12.2	11.6	11.1	8.5	14.4	1.9	1.1
1909.....	..	0.4	**43.7**	11.9	4.1	4.8	6.7	17.6	3.3
1910.....	..	1.2	9·9	**77.3**	6.7	1.0	0.4	1.1	2.0
1911.....	..	0.6	4.1	17.3	**70.0**	5.5	1.5	0.6	0.5
1912.....	..	1.6	3.1	3.9	14.5	**64.3**	6.4	1.6	1.2
1913.....	0.1	0.7	2.2	3.4	4.8	13.3	**64.7**	5.1	1.2

Year classes	12	13	14	15	16	17	18	19	20
1907.....	2.2	0.9	0.5	..	..	..	..	..	..
1908.....	1.5	1.5	0.6	0.3	0.1	0.1	..	..	..
1909.....	2.6	1.6	2,3	0.4	0.2	0.4	0.2	..	..
1910.....	..	..	..	..	..	..	..	..	..
1911.....	0.1	..	..	..	..	..	..	..	..
1912.....	1.2	1.5	0·6	0.1	..	0.1	..	..	..
1913.....	1.2	0.5	0.2	0.2	..	..	..	..	..

The figures in the table will be found graphically represented in Fig. 16, which shows very clearly how this rich year class (here indicated by the strongly marked summit of the curve) gradually increases in age from 1908, when it was four years old, to 1913, when it was nine. All the other year classes must have been, at least *comparatively*, far poorer in these years. There is, however, one exception. It will be seen from the table, that in 1907 the number of eight year old fish (year class 1899) was 19.4 %: this year class is represented in 1908 and 1909 by

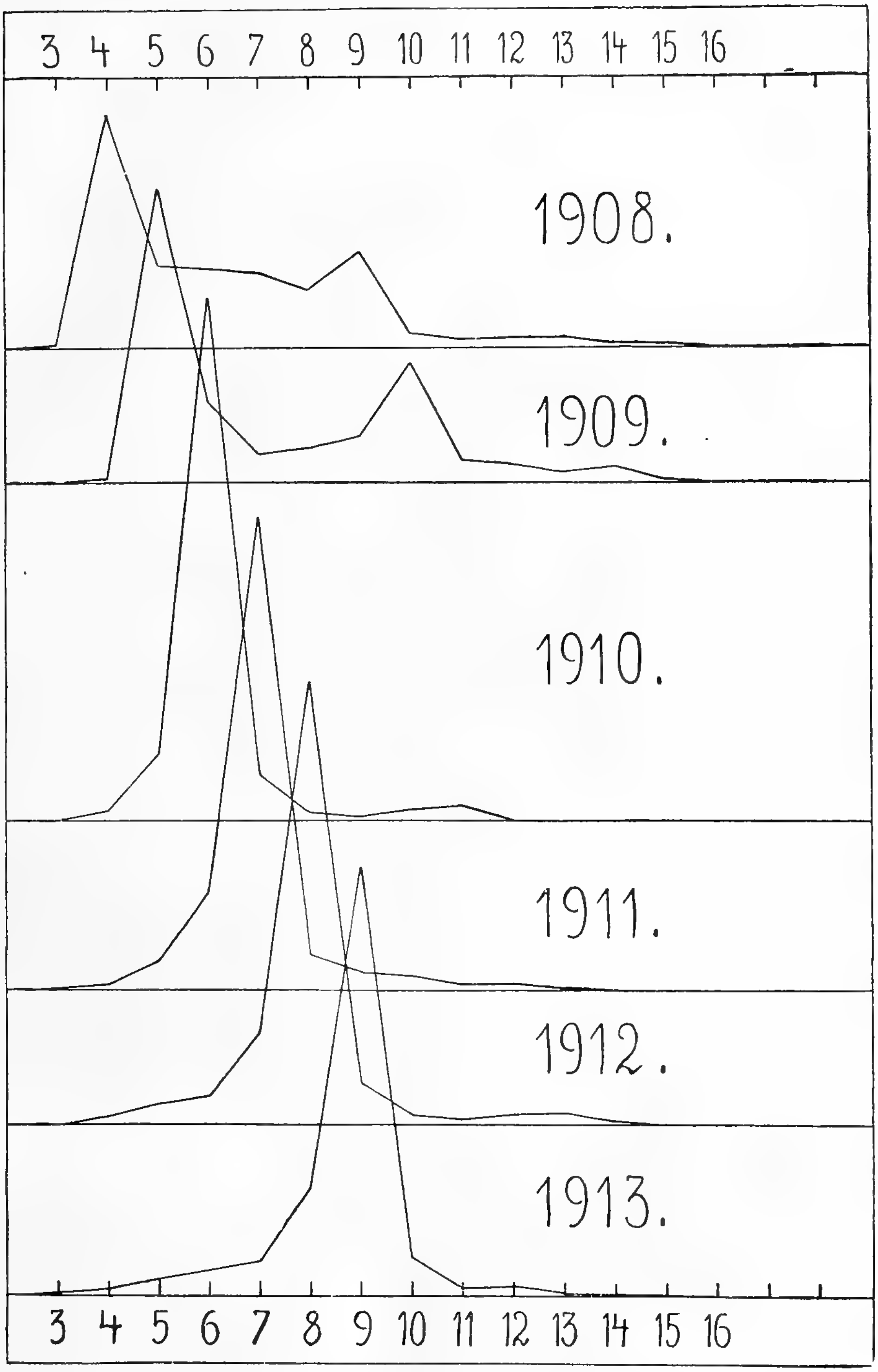

Fig. 16. Composition in point of age of spring herring, 1908—1913.
4 = 4 years old (scales showing 4 winter rings).

14.4 % and 17.6 %, and may earlier have been very numerous. The figure shows two distinct summits for this year class, in 1908 and 1909; it is of especial interest as being the only rich year class of the disappearance of which the material gives us any information. In the last year in which this year class was present in considerable numbers, (1909) it was 10 years old.

The investigations as to the average composition in point of age of the large and spring herring thus strongly support the conclusions arrived at from the study of the fat herring, viz; that a single year class has played a very great part in the stock of herring during the past years, and it would seem difficult to believe that so many facts, all tending in the same direction, should be due to mere accidental circumstances in the samples examined, rather than to general conditions applying to the whole of the stock.

Comparison of different samples as a means of checking results.

In dealing with a question of so great importance, however, the available material should naturally be utilised to the greatest possible extent for the elucidation of the problem. We will therefore, as regards the large and spring herring, proceed to consider the different samples separately, and not merely from the point of view of average results. Such consideration of the samples affords a clearer view, not only of the accuracy of the average results, but also as to how many and how large samples are required in order to give an idea of the composition in point of age and size of the stock. This latter point is of the greatest importance, not least from a practical point of view. I have therefore shown, in the following table, the results of age deter-

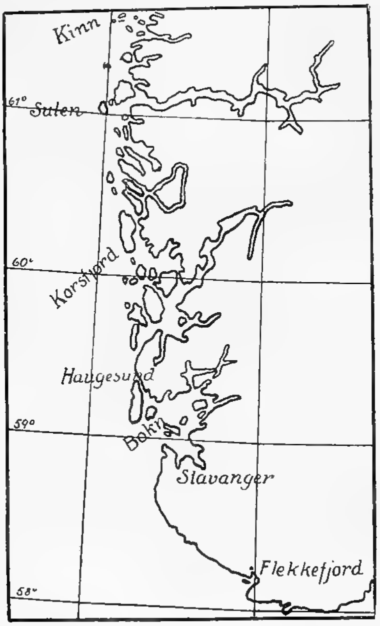

Fig. 17. Spring herring district.

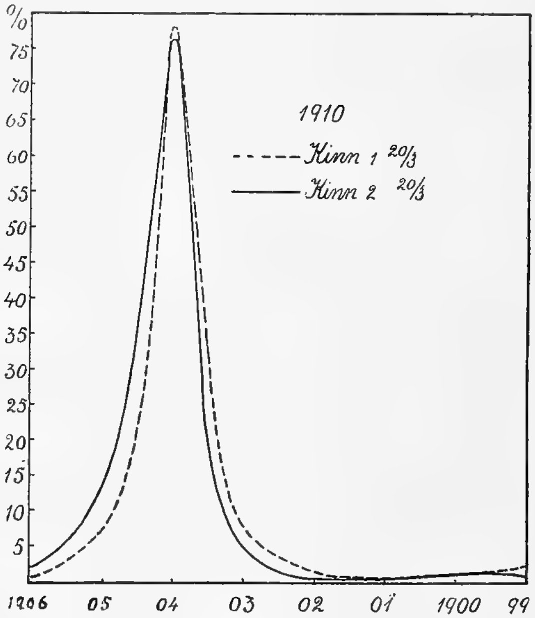

Fig. 18. Spring herring samples 1910. Composition in point of age.

mination investigations for the year class 1904 in all the samples of spring herring examined during the years 1907—1913. The table shows, as above, the percentage of the year class in the whole sample, in addition to which, the place and time of capture are also noted. The table includes 19 samples in all, embracing a total of 7,092 fish. The chart Fig. 17 will serve to better locate the place of capture.

Percentage of individuals belonging to year class 1904 in the samples of spring herring for the years 1907—1913.

No. of sample	Year of capture	Month	Place of capture	No. of specimens examined	% of year class 1904
1	1907	March	Bømmelø	375	2.1
2	—	—	Gjeitung	275	1.1
3	—	—	Espevær	274	1.5
4	1908	February	Føina	881	15.9
5	—	April	Korsfjord	549	65.2
6	1909	February	Kalvaag	200	46.5
7	—	March	Kalvaag	368	42.2
8	1910	March	Kinn	295	78.0
9	—	—	Kinn	199	76.4
10	1911	January	Korsfjord	303	70.2
11	—	February	Haugesund	380	68.7
12	—	April	Nordre distrikt	361	71.2
13	1912	March	Boku	376	64.6
14	—	—	Flekkefjord	259	55.6
15	—	—	Haakelsund	310	61.6
16	—	April	Askevold	297	75.4
17	1913	March	Flekkefjord	329	60.5
18	—	April	Korsfjord	225	70.2
19	—	—	Yttre Sulen	336	63.4

Total, in 19 samples, 7,092 individuals.

In studying this table, the samples for each year of capture must naturally be compared one with another. It will then be seen, that for each year, with the exception of 1908, a most remarkable agreement is apparent. A graphical representation of the figures for the four years 1910—1913 shows the percentage for composition in point of age of each single sample; the four figures 18—21 give the samples for each year of capture separately, for purposes of comparison. It will be seen at a glance that the composition in point of age for all of these years reveals the most accurate agreement between the different samples. In 1913, for instance, a sample was taken at Flekkefjord, one at Korsfjord, and one at Yttre Sulen, each consisting of 200 to 300 fish. The distance between Flekkefjord and Yttre Sulen is over 200 miles, and shoals of spawning spring herring were found throughout the whole of this range. The fact that such small samples, taken at such a distance apart, should exhibit so great similarity as regards composition in point of age, can only be regarded as marvellous. The only possible explanation seems to be, that the shoals were in reality perfectly homogeneous in this respect; that the samples examined were thus representative of the stock as a whole,

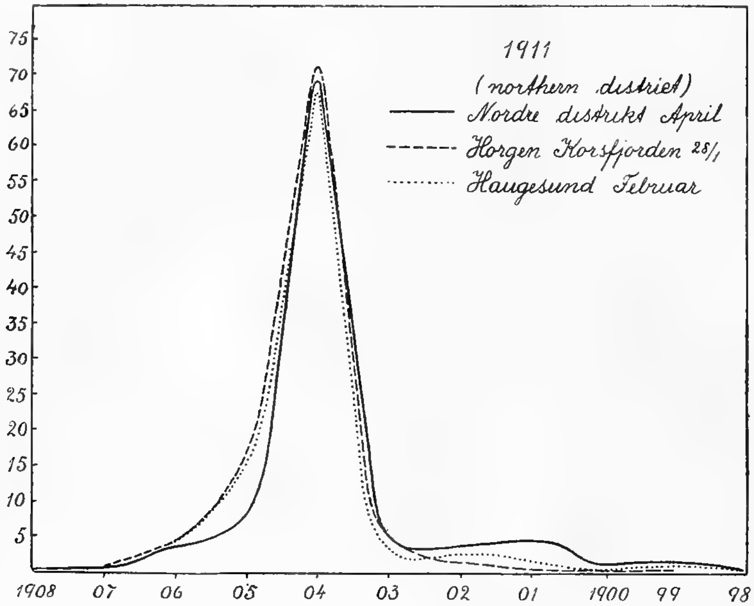

Fig. 19. Spring herring samples 1911. Composition in point of age.

and that the method of investigation here employed really affords a means of obtaining accurate information as to the composition in point of age of the whole stock.

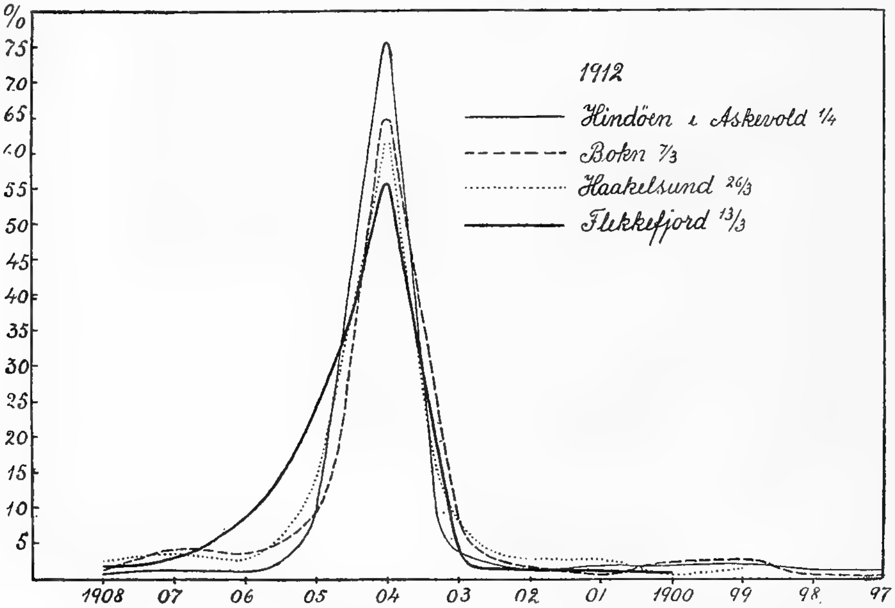

Fig. 20. Spring herring samples 1912. Composition in point of age.

From the tables already published*), it will be seen that a corresponding agreement is noticeable between the different samples for the other age classes, and for the composition, in point of age, of the large herring. Only a single example need be mentioned here, viz, the samples of large herring examined in 1907. These were, in part, extremely small, down to only 23 in one sample. In spite of this however, the rich year class 1899 already mentioned was found to present the following percentages: 30.8, 39.2, 27.9, 44, 35.3, 43.0, 36.0, 40.0, 48.0, 42.8, 23.7, 33.7, 35.5, Two of these samples contained over 100 individuals, these showed percentages of 36.0 and 35.5.

From the foregoing, it would appear legitimate to draw the following conclusions:

While the agreement between the single samples of fat herring from the same year was, on the whole, generally good, great variations occurred here and there, owing to the fact that the admixture of small herring in the samples was inconstant, the individual year classes apparently moving sometimes in separate shoals, at others in mixed shoals. In spite of this, however, it proved possible, by observation of the fat herring samples above, to deduce the probability of that regularity which the study of the samples of large and spring herring so strongly confirms. In other words, the great variation in composition from year to year appears to be due to the presence of certain rich year classes; in the case of the samples examined, the year class 1904. As regards the large and spring herring, the greatest agreement is noticeable between the different samples examined in the same year. The mature, full grown fish thus appear to be so fairly mixed, that examination of even few and small samples suffices to give a correct view of the composition of the stock with regard to age in a certain year.

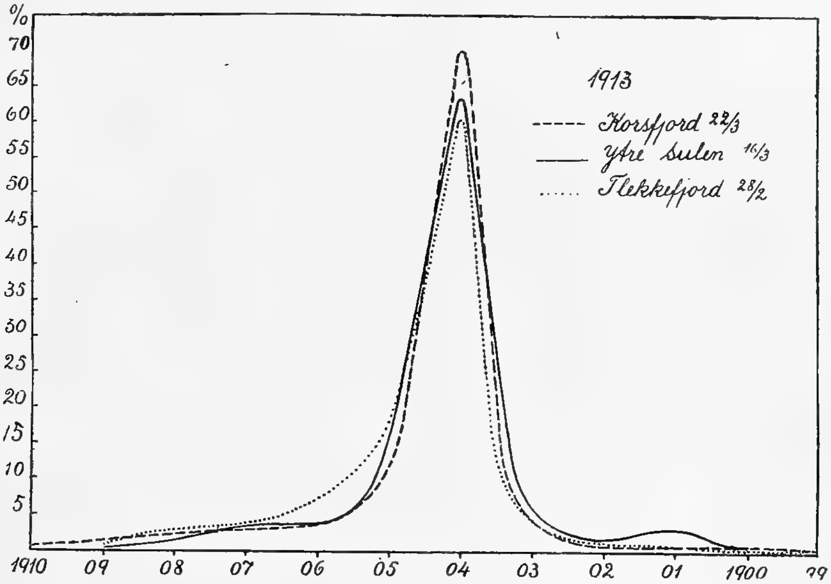

Fig. 21. Spring herring samples 1913. Composition in point of age.

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*) Vide Publ. de Circ. No. 61 pp. 32—34, Copenhagen 1911.

Recruiting of the spawning shoals from those of the fat herring.

The table on p. 29, showing the composition, in point of age, of the different samples of spring herring, reveals one great discrepancy, viz. between the two samples from 1908. The February sample contained 15.9, that of April 65.2 % of the 1904 year class. This fact will however, be explained if we compare the samples from 1907 on the one hand, and those from 1909 on the other. The composition in point of age of these samples will be found in Fig. 22. In 1907, the spring herring contained only 1—

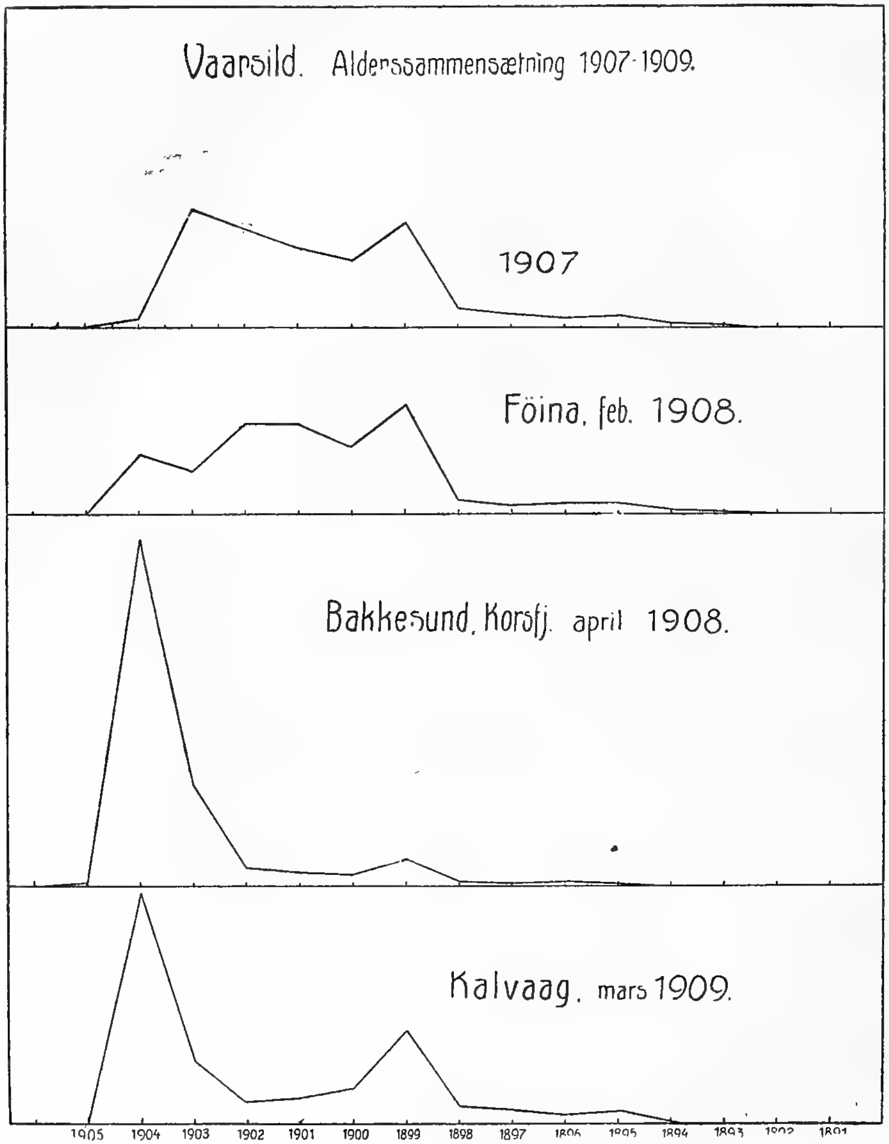

Fig. 22. Composition in point of age of spring herring for the years 1907—1909.

2 % of the year class 1904, in 1909, over 40 %. A great *immigration to the spring herring shoals from those of the fat herring* must therefore have taken place in the meantime. This occurred during the spring fishery of 1908, which explains the paucity of these fish in the early (February) catch, and the great contrast presented by the later (April) hauls. The immigration is not however, restricted to this period; it continues, and not until 1910 do we find the highest percentage (77.3) among the spring herring, (*vide* Table p. 26). This agrees with the fact that the fat herring samples, at any rate up to the summer of 1909 inclusive, contained large percentages of the 1904 year class, whereas in 1910 this year class had almost entirely disappeared from the fat shoals.

A far closer comprehension of this emigration from the fat herring shoals and corresponding immigration to the shoals of large and spring fish is furnished by an interesting observation made by Lea, which he describes as follows: "A very large part of the rich 1904 year class have lived, during their first years, in northern Norwegian waters, and it appears that most of them, in 1906 (their third year of life) exhibited an unusually poor increment of growth. The scales, which furnish, as it were, a graphical illustration of the growth, reveal this most distinctly. If we observe the scale marked *b* in Fig. 23 we find that the distance between the second and third winter rings is remarkably small. For purposes of comparison, another scale, marked *a*, is shown, illustrating the manner in which the winter rings are generally found to lie.

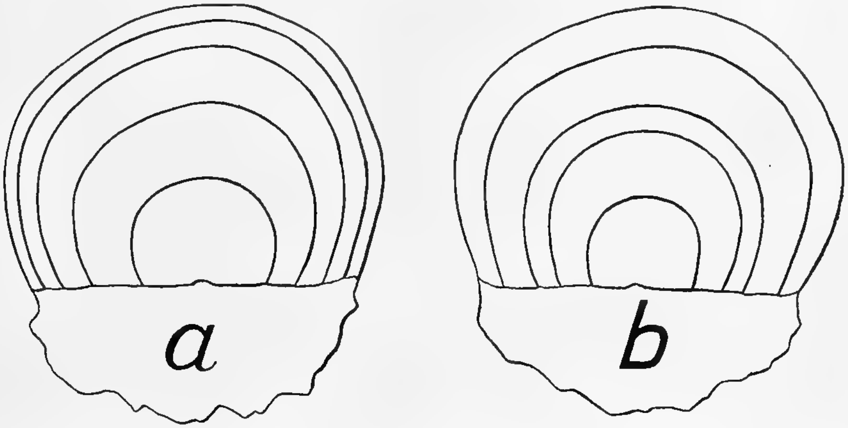

Fig. 23. Scales of two five year old herring from the North Coast of Norway; *a*, normal growth, *b*, "marked" fish (Lea).

"*Most of the herrings from the northern Norwegian waters exhibited scales as that marked b.* The only reasonable explanation of this would seem to be that these fish in 1906 (their third year of life) must have lived under conditions unfavourable to their growth. The theory of a racial phenomenon is here untenable, since the fact is only apparent in those of the Norwegian herrings which occurred in northern Norwegian waters in 1906.

"The peculiar appearance of these scales enables us to distinguish them from others, and the presence in a sample of a large number of herrings having such scales indicates more or less certainly that one has to deal with fish which have lived in northern Norwegian waters. The scales thus serve as a kind of certificate of origin, legible even when the fish are encountered in waters far distant from those of the northern coasts of Norway. In other words, it is possible to study the migrations of these fish in the same manner as when dealing with specimens marked and set free for purposes of investigation. Whereas the scientist, however, may mark his thousands of fish, and possibly recapture some few hundred, nature has here marked millions, and millions may be caught. During the ten years 1907—1911, the occurrence of these "marked" fish has been closely studied, and their migrations may be traced, more or less acurrately, as in Fig. 24.

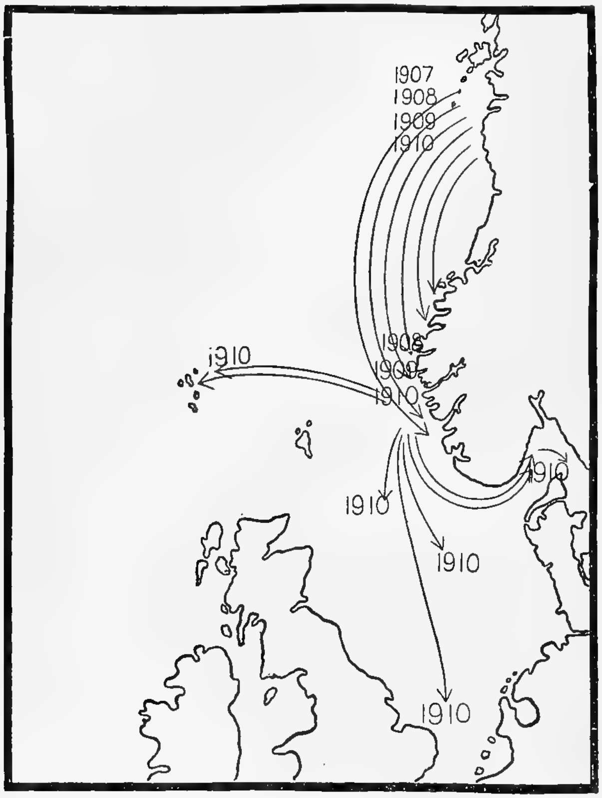

Fig. 24. Migrations of the »marked« herring. (Lea).

"Moving from the northern Norwegian waters, they have passed southward in great numbers, to find a spawning place off the west coast, encountering here fish which had grown up in more southerly waters, and spreading, together with these, westward to the Faroes, and eastward to the Skagerak. Some few individuals have gone even farther, penetrating into the Kattegat, and the southern part of the North Sea, where they have been encountered in small numbers among the herring having their habitat there. None of these fish are now to be found in the northern Norwegian waters, but farther south they still occur in numbers, and their appearance and migrations may be further studied".

It will be seen from the chart (Fig. 24) that in 1908, the emigrant Nordland herring began to make their appearance among the large herring off the coast of the Romsdal district, while in 1910, they were present in the spring herring shoals. This exactly corresponds to a great emigration of Nordland fat herring in 1909 and immigration among the spring herring in 1910, which, as we have seen in the foregoing, is strongly suggested by the composition in point of age of the two classes.

Closer study of this phenomenon enables us moreover, to calculate the percentage furnished later on by the original Nordland fat herring contingent, when mature, among the shoals of large and spring fish*).

In a sample of large herring, 47 % of the year class 1904 were found to be marked fish. As the earlier fat herring samples from Nordland revealed the fact that only $^2/_3$ of the year class were marked, it is necessary to increase the percentage of 47 %

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*) Vide Hjort and Lea. Publ. de Circ. No. 61.

by one-half, i. e. 24, making 71 % of the large fish originate from Nordland fat herring. In a similar manner, the percentage for the spring herring was found to be 48. This indicates that the spring herring shoals had recruited from fish of more southerly origin to a greater degree than the large herring. Investigations as to the growth of the spring herring also show that a part of these must have grown faster than the Nordland fish, maturing at an earlier age. Although the 1904 year class furnished so great a percentage of the spring herring both in 1908 and 1909, none of them were found to be marked. Not until 1910 did the marked Nordland herring make their appearanec among the spring shoals.

In the south-western part of the Norwegian coastal waters, the herring mature at an age of 3 (though very rarely), 4, or 5 years, whereas in the northern waters maturity is only reached by any considerable number at an age of 5 or 6. It is thus extremely natural that the percentage of the 1904 year class in the spring shoals should have increased up to 1910 (when the fish were 6 years old). As will be seen from Fig. 24, a sample from the Faroes, examined in 1910, containing 51 % of the 1904 year class, was found to include marked fish, whereas samples from the same waters taken in 1908 and 1909 revealed only a minimal quantity (less than 1 ‰) of the 1904 class. *These fish spawned in Faroe waters in 1910.* As to how far any of them may later have joined the Norwegian spring shoals, nothing is known.

Recapitulation. Sketch of the natural history of the herring.

It may now perhaps not be out of place to give a rough outline of the life history of the herring in Norwegian coastal waters.

The spawning shoals of spring herring, which are taken in West Coast waters, form a stock of very variable age and size. The youngest fish reaching maturity are three years old; these are, however very few in number. Of those fish which grow up in the southern waters, many join the spring shoals at an age of four years, the majority, however, probably a year later, whereas those of northern origin do not enter the spring class in any considerable numbers until they are six years old. The average size and age of the shoals vary according to the numbers of the years classes represented. We may therefore find small (young) spring fish with an average length of 27 or 28 cm., and larger (older) ones with an average length of 31, 32, and even 33 cm. Previous experience (year class 1899) seems to indicate that the spring herring do not, in any great numbers, reach a higher age than 10 years; the present material, however, clearly shows that the number of years here taken into consideration is too small to permit of our formulating any definite opinion as to this. Further investigations will here be necessary, and it will be not least interesting to observe how soon the 1904 year class will die out, i. e. what percentage it will form of the stock of spring fish during the next few years.

The young fry are carried northward along the coast by the current. (The chart in Fig. 25 may here be used for comparison). They spread as if sown all along the extensive range of coast, and everywhere some small fish develope, beyond doubt mostly in the northern waters. In the autumn, when these small fry are 8—10 cm. long, and $^2/_3$ year old, or in the winter, at the age of about one year, when they are called "musse" or "kril", they begin to make their appearance in the seines. Next spring they begin to grow again, in May, and soon become "bladsild" (12—15 cm. long). Most of them remain during the following winter at this length, some, however, grow faster. During their third year, some at least of the year classes begin to associate themselves with the fat herring, and for the next two or three years, according to locality, they belong to the fat shoals.

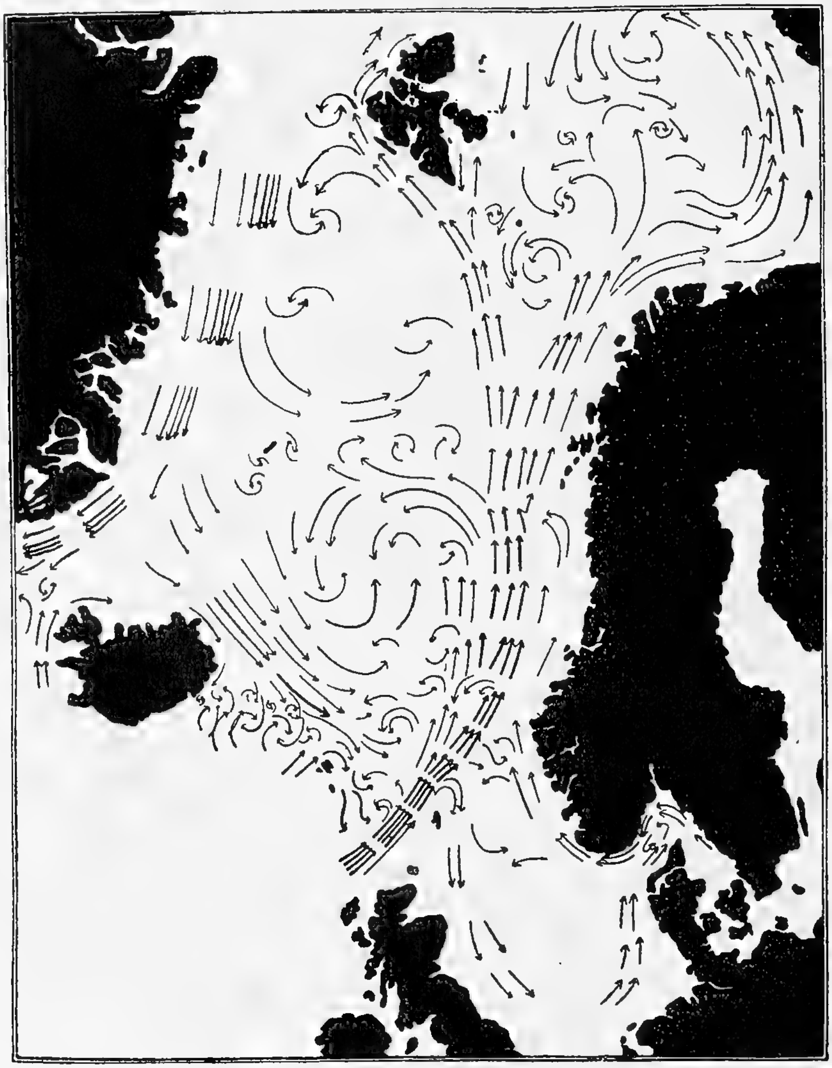


Fig. 25. The Currents of the Norwegian Sea. From Helland-Hansen and Nansen.

At an age of 4, 5, or 6 years they separate from these, in the autumn, when the genital organs are beginning to develope; they are then "large" and in the following spring become "spring herring". At this time they undertake migrations of greater or lesser extent, moving southwards along the coast, in a direction contrary to that in in which they as young fish were passively carried by the current.

A study of the natural history of the herring in Norwegian coastal waters thus leads us to the conclusion that the life-cycle of the herring is limited to a more or less restricted area of sea, and that these waters have a common race or stock of herring. True, individuals may, as we have seen, exhibit peculiarities of growth according to locality, as for instance in southern or more northerly waters; these variations in growth must, however, at any rate for the present, be considered as due to the influence of extraneous natural conditions having no permanent hereditary effects. It would seem highly probable that the young of fish which have grown up off the west coast of Norway can be carried by the current up to the North Coast waters, and there grow up under the same natural conditions, and at the same rate, as the indigenous Nordland fish. How far this also applies to the more distinctly localised shoals which are found in some of the fiords, Trondhjemsfjord, Lysefjord, etc., is yet an open question, the solution of which, while presenting features of biological interest, is hardly likely to influence the great general law, that the race of herring in the Norwegian coastal waters forms, on the whole, a single independent stock.

As will be seen in the following chapter, the full-grown herring make periodical migrations between the spawning times, moving out into the North Sea and the Norwegian Sea; it has already been noticed, in the foregoing, that they may penetrate as far as to the Faroes, and they may possibly even find their way to the sea north of these islands, the southern Bottlenose Grounds. During the course of these migrations, they frequently mix with herring of other races, (the Shetland herring); as far as is known, however, it would seem fairly certain that the very great majority return to the Norwegian coastal waters on the approach of the next spawning season.

The fluctuations of the herring fishery.

It now remains to be seen how far these scientific results serve to elucidate the problem of fluctuations in the great herring fisheries, and the question naturally arises whether any relation can be shown to exist between the varying composition with regard to age of the samples examined, and the variations in the hauls made by the fishermen.

It is obvious, that no such relation need, as a matter of fact, exist. We may well imagine that the yield of a certain fishery could be poor, even though one year class might be far more numerous than other still poorer year classes, while a highly profitable fishery may be based upon the capture of fish belonging to several year classes, each of which is represented in about the same proportion. Only by experience of the natural conditions which govern these phenomena can we obtain information of any value in this regard; we will therefore proceed to examine the facts which have been ascertained as to the hauls made by the fishermen, as given in the fishery reports and statistics.

In the Norwegian fishing industry, great interest has for a long time been evinced as to the collection of information dealing with the size of the herring and cod. The necessity of this is obvious, when taking into consideration the great variation in the sizes due to the fluctuations in the composition with regard to age. These practical observations have not, however, been based on measurement of the length of the herring, as in the foregoing, but on collection of statements as to their *weight*, and on the basis of long experience of the fluctuations in the weight of the fish, a system of assortment has arisen, embracing certain size groups (weight groups), which have gradually become so generally known, that certain designations have been applied to the classes thus distinguished, as "Merchant's fish" or "Mark I", "Medium fish" or "Mark 2" etc. During the fat herring fishery, the telegrams reporting on the "quality" of the fish indicate this in terms such as "mainly Mark 2 fish" and similar expressions. It is thus very natural that a great deal of experience has in course of time been obtained as to the fluctuations in the occurrence of these different "marks", and it is a well known fact in the Norwegian fishing industry, that the fat herring fishery may in one year be distinguished by Mark 2 fish, in another by Mark 5, etc. These facts agree so thoroughly with our data previously noted as to the fluctuations in composition of the stock with regard to age and size, that it may well be worth while to more closely consider the relation between the age of the herring, their length, weight, and position in the scale of the old sorting method. The table above gives a comparison on these lines as regards the small herring and fat herring, and we may here find a good deal of useful positive information. It will be noticed that the "kril"; one year old fish, of 8—11 cm. in length, weigh from 3.6 to 6 gr. and run thus from about 150 to 300 per kg. according to size, or 15,000 to 30,000 per barrel (100 kg.).

Small herring and fat herring, North Coast.

Average age of seine hauls	Length in cm.	Weight in gr.	No. pr. kg	No. pr. 4 kg.	No. pr. 100 kg.	Classes	
First year of life	8	3.6	280	1120	28000	Kril	Small herring
	9	3.7	270	1080	27000		
	10	4.4	223	672	22300		
	11	6.0	166	564	16600		
Second year of life	12	7.5	133	534	13300	Bladsild	
	13	10.0	100	400	10000		
	14	12.5	80	320	8000		
	15	18	55	220	5500		
	16	25	40	160	4000		
	17	29	34	136	3400	Skjæresild	
$1^2/_3$	18	35	29	116	2900		
	19	41	24	96	2400		
$2^2/_3$	20	51	20	80	2000	C. Mk. 7	Fat herring
	21	58	17	68	1700	MC. Mk. 6	
	22	71	14	56	1400	M. Mk. 5	
$3^2/_3$	23	81	12	48	1200	MK. Mk. 4	
	24	100	10	40	1000		
	25	110	9	36	900	K. Mk. 3	
$4^2/_3$	26	125	8	32	800	KK. Mk. 2	
$5^2/_3$	27	162	6	24	600	KKK. Mk. 1	
$6^2/_3$	28	192	5	20	500	KKKK.	
	29	206	4	16	400	KKKKK.	

The "bladsild" increase very rapidly in weight; the larger specimens already weigh 25 gr. or only 40 per kg., the "skjæresild" average only 25—30 to the kg.

Assortment of fat herring.

The fat herring are divided for trade purposes into no less than nine different marks, embracing together fish of from 2—7 years of age, 19—29 cm. in length, and from 50 to about 200 gr. weight. The smallest average therefore as many as 20 to the kg., the largest, which are, however, very rare, 4—5. The sizes most frequently occurring are those between the so-called Mark 5 and Mark 1 or 2. Mark 5 fish are about 22 cm. long, and weigh about 70 gr., averaging 14 to the kg. Marks 1 and 2 include fish of 26—27 cm. in length, weighing 110—125 gr. or 6—8 per kg.

It is a well known fact that the yield in one year may consist almost exclusively of Mark 4 and 5, in another of Mark 2 and 3, which is sufficient proof that the practical industry recognises great fluctuations in point of size, although it has not been known to be due to variations in the year classes. It would also be difficult for men engaged in the practical industry to discover this, since the different individuals of the year classes vary so greatly in size that no one year class corresponds to any distinct mark, but each embraces several mark groups. We therefore find, in most cases, that the statements in the fishery reports indicate several groups, e. g. "Mark 2—4", without indicating the percentage of each. It is thus only possible to obtain approximate information with regard to size from the fishery telegrams for the years 1906—1909, nor can the statements given be expressed in figures, as for instance in a calculation of the average sort for each year. Thus roughly, however, it was not difficult to see, on perusing the telegrams, that the yield of 1906 contained many Mark 6 fish, that of 1907 Mark 5, and that of 1908 Mark 3—4, while in 1909, many Mark 1, 2 and 3 fish were noted. A cargo of herring from Ejdsfjorden in September 1908 thus showed:

Mark 2	Mark 3	Mark 4	
50	200	1250	barrels.

Two cargoes from Nordland, in 1909 showed:

Mark 1	Mark 2	Mark 3	Mark 4	Mark 5	
400	500	500	200	...	barrels.
190	607	636	470	88	

Fluctuations in the fat herring fishery.

It is thus beyond doubt that a marked increase in the weight of fat herring took place in the years 1907—1909, as was also the case with the samples scientifically investigated. Moreover, the character of the increase was such as to agree very well with the supposition that it was principally due to those fish which in 1907 were three years old, and in 1909 five.

According to the Fishery Statistics, the following quantities (given in hectolitres) of fat herring were taken in the Nordland district in the years 1903—1910:

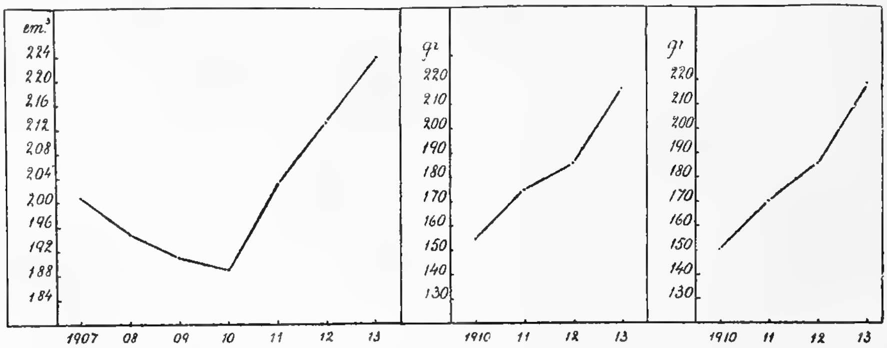
1903....	261,274	1907....	157,515
1904....	61,853	1908....	408,654
1905....	8,359	1909....	883,772
1906....	27,359	1910....	413,595

In the years 1904—1906 the yield of the fishery was, as will be seen, unusually low. In 1907 an increase began, continuing through 1908 and 1909, and culminating in the last named year. These figures agree very well with the supposition that there has been a rich year class in the North Coast waters which was especially noticeable in the years 1908 and 1909. It also agrees with the fact that the two previous year classes, 1902 and 1903, were very poor; these would otherwise have been most prominent in the yield of the years 1905 and 1906.

Fluctuations in the weight of spring herring.

The large and spring herring are not classified under the same marks as the fat herring. During the fishery, the telegrams state how many herring go to a "barrel measure" (150 litres) and in the salt fish trade it is generally stated how many herring go to make up a weight of four kg. The table above shows a comparison of the relative length and weight of large and spring herrings. The large herring are, as will be seen, heavier at the same length than the spring fish, being fatter than these last; the difference is,

Length in cm.	Large herring				Spring herring			
	Average weight in gr.	No. pr. kg.	No. pr. 4 kg.	No. pr. 100 kg.	Average weight in gr.	No. pr. kg.	No. pr. 4 kg.	No. pr. 100 kg.
27	..	..	..	..	130	7.7	30.8	770
28	163	6.1	24.4	610	147	7	28	700
29	169	6	24	600	163	6	24	600
30	187	5.2	20.8	520	183	5.5	22	550
31	199	5	20	500	190	5.3	21	530
32	213	4.7	18.8	470	211	4.7	19	470
33	250	4	16	400	229	4.4	18	440
34	..	..	..	..	258	4	16	400



1. 2. 3.

Fig. 26. Average volume and weight of spring herring in different years.

1. Average volume (in cm.³) of spring herring, according to statements of the fishery authorities.
2. — weight (gr.) of samples scientifically investigated.
3. — — — of fish of 1904 year class in these samples.

however, not very great. The smallest of these full-grown herrings weigh about 150 gr. or somewhat over 6 per kg., the largest about 250 gr. or 4 per kg.

It is very interesting to compare these statements as to the average size of the spring herring during late years with the mean values found for the samples scientifically examined, both as regards the samples as a whole and especially for the individuals of the 1904 year class. A comparison on these lines is given in Fig. 26.

On the extreme left is shown a curve (1) for the average volume of the herring (in cubic cm.) for the years 1907—1913*). It will be seen that the volume of the fish sank in the years 1907—1910, rising again to its highest figure in 1913. Farther to the right will be found the average weights for the samples (2) and the year class 1904 (3) in the years 1910—1913. These exhibit a rise which is perfectly parallel with the curve to the left.

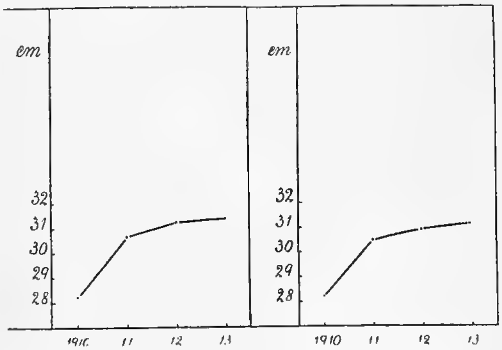


Fig. 27. Average length (cm.) of all individuals in the sample from 1910—1913 (1) and of fish of the 1904 year class in the same (2).

Fig. 27 shows the average length for all individuals in the samples (1) and in the 1904 year class during the years 1910—1913 (see also Fig. 15).

In the case of the spring herring also, the statements as to the fishermen's hauls agree entirely with the figures for the samples examined.

Fluctuations in the yield of the spring herring fishery.

The fishery statistics give the following figures expressing the yield of the spring herring fishery for the years 1904—1913 in hectolitres:

1904....	528,000	1909....	772,000
1905....	633,000	1910....	982,000
1906....	775,000	1911....	1.054,000
1907....	979,000	1912....	937,000
1908....	625,000	1913....	1.500,000

These columns reveal a distinct increase for the years 1909—1913, and it would also here appear to be evident that the yield of the fishery has been exceptionally rich from the time when the year class 1904 began to play a prominent part. We thus find, both in the fat herring fishery and that of the spring fish, similar evidences of an increase dating from the time when the year class 1904 began to make their presence felt among the stock. This is very distinctly noticeable in a graphical representation of the statements of the fishery statistics, both for the fat herring and the spring herring yields, Fig. 28.

We cannot, however, in this case attach the fullest value to these statistics, as they indicate the amount of the yield in hectolitres, and not in number of fish, and, owing

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*) These figures have been obtained by calculating the average of the statements as to how many fish were reckoned per barrel measure in the different years.

to the great variation in the size of the individuals, a hectolitre will in one year represent a far greater number of fish than in another. We know however, the size of the herring for the last few years, and it has therefore been possible to calculate the number of herrings taken in the years 1907—1913, both as for spring herring on the whole and also as for the 1904 year class among the spring shoals. The result of this calculation will be found in the following table, and in the graph shown in Fig. 29

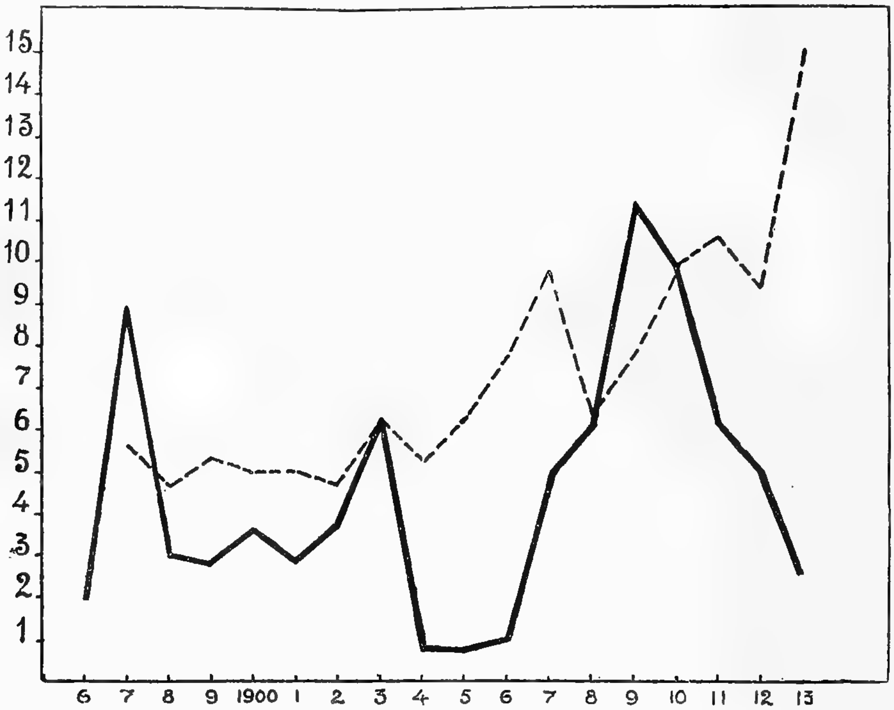

Fig. 28. Yield of the fat herring and spring herring fisheries for the years 1896—1913.
—— Fat herring. - - - Spring herring. 15 = 1,500,000 hectolitres.

No. of millions of herring taken in the years 1907—1913.

Fish of all ages		Year class 1904
1907....	440	7
1908....	321	112
1909....	403	177
1910....	518	400
1911....	519	363
1912....	440	283
1913....	671	434
1907—1913....	3312	1776

From this we see that altogether more than half of all the spring herring taken during these seven years belonged to the 1904 year class. The figures and the graph show the increase in the number of individuals in the years 1907—1910, at the time when the immigration from the fat herring shoals took place. After that, the yield varies considerably. We may certainly say that the fishery since 1910 has been rich and extensive, and that the year class has in all years exhibited such a degree of wealth as even to warrant the anticipation, in one year, of a good yield in the next. There is however, no full and complete agreement with what one might expect to find, from the percentages for the year class in the samples examined. According to these, the greatest number of individuals should have been taken in 1910, when the percentage was 77.0, and later somewhat less. This discrepancy can evidently only be explained by the supposition that the catches in these years have not made up the same percentage (percentage of fish caught) of the whole stock. In order to understand the fluctuations of the fishery, it is therefore evidently highly necessary to be acquainted with the variations of the year classes; it must, however, continually be borne in mind that other conditions may also play an important part

Many factors may of course be found to account for the fact that the proportion of the stock taken in the course of the fishery varies from year to year. We have first of all the factors upon which the whole industry depends, viz. weather conditions and ruling prices. In addition to this, the movements of the fish will also be of great importance. In some years, the fish move at so great a depth as to render it difficult for the fishermen to reach them. In others, it must be supposed that the stock, for instance, of spring herring, seek other waters than those where the fishermen have assembled to await their arrival.

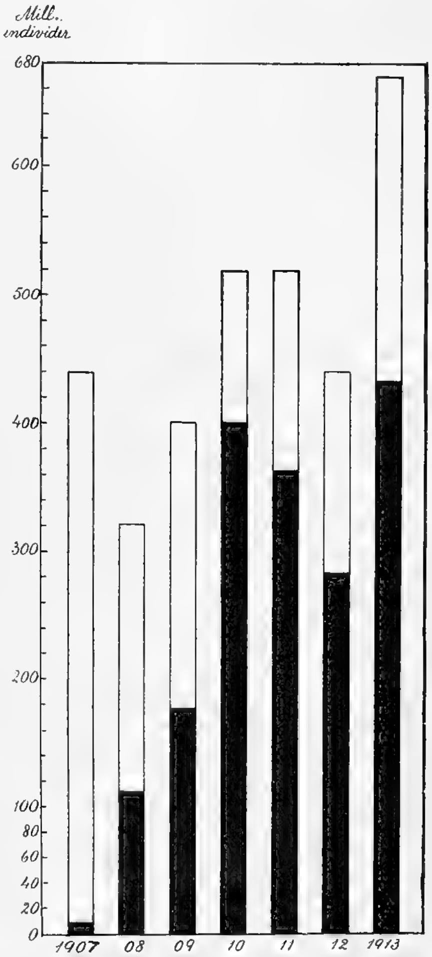

Fig. 29. Yield of spring herring for the years 1907—1913, in millions of fish. The black columns represent 1904 year class.

As already mentioned, spawning herring were taken in 1910 on the Faroe banks; these fish undoubtedly belonged to the Norwegian spring stock.

In 1903, K. Dahl*) carried out some fishing experiments for cod ("skrei") on the so-called Haltenbank (between $64^1/_2$° and 65° N. Lat.). He encountered here an exten-

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*) Undersøkelser over skreibanker paa strækningen Trænen—Kristianssund. Aarsberetn. vedk. Norges fiskerier. Bergen 1904.

sive spawning of spring herring, and found spawning herring in the stomach of the coalfish, while the sea was full of newly spawned herring larvae.

In the years 1866 to 1874, the large herring fishery was carried on to a very great extent on the North Coast, and there is no doubt that in these years spawning took place farther to the north than usual.

As will be seen in the following chapter, shoals of spent spring herring are found as early as May on the North Sea Banks: it is therefore natural to enquire whether part of the spring stock possibly spawn, in certain years, on the banks of the North Sea. This is a question of long standing, discussed already by Axel Boeck. It has happened, in the history of the herring fishery, that the fat herring yield has been good for a long period of years, while that of the spring herring has been extremely poor. It is a difficult and unsatisfactory task to study the facts of periods so far removed, when the observations made were few and far from accurate; we may yet learn from this that for a full and entire comprehension of the fluctuations in the herring fishery, extensive and manifold investigations are required. As regards the period investigated of late years, it may at least be said that the investigations with regard to age alone have largely contributed towards the elucidation of the fluctuations in the Norwegian herring fishery, and although there may yet be many other phases to explain, — to which we shall return later on — it must be presumed that these age investigations will in the future be of increasing importance, the increase being in proportion to the degree in which a more highly developed fishing industry is applied to the whole of that region of sea in which the herring move.

CHAPTER II

The Stock of Herring in the North Sea and Skagerak.

The Herring fishery in the North Sea. Yield.

According to the international "Bulletin Statistique", the quantities of herring landed in the different North Sea countries in the years 1903 and 1909 were, (in kilogrammes) as follows:

	1903	1909
Norway	49.136.154	90.207.820
Denmark	101.737	149.776
Germany	19.989.447	39.250.257
Holland	100.675.413	88.466.920
Belgium	....	1.255.600
England	148.014.487	217.970.456
Scotland	181.193.288	192.228.114
Total...	499.110.526	629.528.943

The value of the yield amounted in 1909 to 86 million shillings, or about 45.4 % of the total value of all the North Sea fishery.

The participation of the various countries in the herring fishery of the North Sea exhibits differences, not only in the amount of the yield, but also in the methods employed. From Norway, very little open sea fishing is carried on; only in the autumn does some drift net fishery take place on the Viking bank, due west of Bergen. The great mass of the yield cited in the above table as for Norway applies to the Norwegian spring herring fishery, which is exclusively coast fishing. In all other North Sea countries, the coast fishery plays a comparatively insignificant part. Herring are taken along the coast everywhere; in the Scottish firths, in English and German bays, the mouths of rivers, and in the Zuyder Zee, but in small quantities. The true North Sea herring fishery of all these countries is carried on in open sea, on the North Sea banks, with drift net or trawl. The fishermen have in many ways adapted their methods in the most economical manner according to the conditions which prevail in their respective countries. Along the coasts of England and Scotland, where the great shoals of herring move close to the shore, it pays to fish from small vessels, and to bring the catch fresh to market each day. The German, Dutch, and Belgian fishermen, who have farther to go to the fishing grounds, are obliged to make long voyages of five to six weeks' duration, and salt their catches on board. It is nowise within my sphere, however, to describe these different methods of fishing; it must only be borne in mind, in consideration of the following, that all catches made in this great North Sea fishery are made either with the drift net or with the trawl. Until a few years ago, the drift nets were the only implements of importance, and even in 1912, the herring taken with the trawl amounted to only 4.4 $^0/_0$ of the total yield. By far the greatest numbers are thus taken with the drift net; the equipment, as regards these implements, is also enormous. In the Scottish fishery statistics for 1910 we find that the total area of the nets in use in that year amounted to no less than 119,626,340 square yards.

Drift nets and trawl.

These drift nets have, in the course of long experience, been adapted to the capture of such sizes of herring as are generally found in greatest numbers on certain fishing grounds. The size of the mesh is therefore not everywhere the same.

The English fishery investigations have carried out extensive observations as to the relation, in point of size and maturity, between the drift net hauls and trawl catches of herring. Fig. 30 shows the results of these investigations, which are based upon a very large amount of material, between 15 and 16,000 herrings having been measured. The full line curve shows the size of the trawl-caught fish, the dotted curve that of those taken with the drift net. (The curves show, for both groups, what percentages lie below each of the centimetre sizes marked on the abscissa). It will be noticed that the difference between the two catches is very slight. Comparison of the degree of maturity in the two groups also revealed considerable similarity, with the exception of the spent fish, which did not appear in the trawl catches at all. (On the bottom?)

Drift net fishing has been carried on in the North Sea for several hundred years, and an extensive literature exists dealing with the interesting history of this fishery and all the important observations which have been made in course of time by the hun-

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dreds of thousands of fishermen engaged in the industry. One of the earliest points noted — an experience which must have cost innumerable fruitless experiments, with enormous effort and expense, — is the fact that the drift nets working the different parts of the North Sea only take herring at certain definite times of the year. The herring fishery is everywhere restricted to a short season, which varies for the different banks of the North Sea; it is, however, sufficiently regular to permit of a rough determination as to where the fish are to be found in the different months of the year.

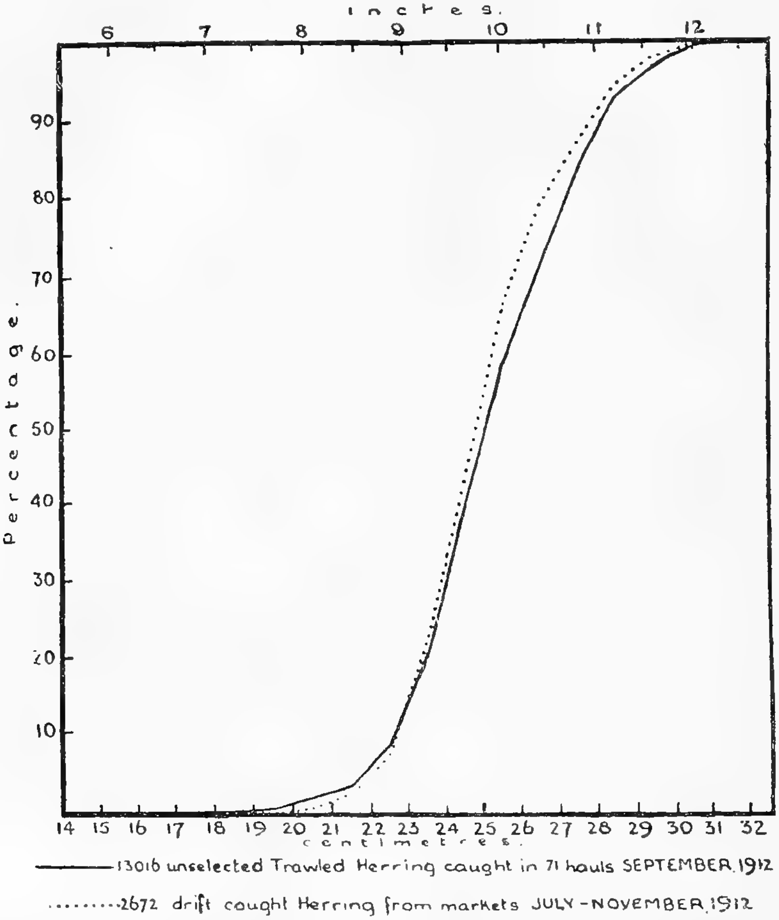

Fig. 30. Herring from East Coast of England 1912; percentage of fish below each cm. size.

Seasonal variation of the fishery.

H. M. Kyle*) has performed the extremely valuable task of carefully collecting information as to the fishing grounds and quantity of fish caught for each month in the year, expressing his results in a series of monthly charts for the year 1903. These give the best description of the course of the herring fishery in the North Sea. According to Kyle's information, the fishing is, during the first three months of the year, carried

*) Bulletin Statistique des Pêches Maritimes, Vol. I, Copenhagen, 1906.

on exclusively along the coast, in bays or fiords. The only *great* fishery at this time of year is the Norwegian spring herring fishery, which is carried on especially in March—April, and the Bohuslän fishery in January.

The months from May to August form the season for the great Scottish and northern English fishery; May for the west and north-west coast of Scotland, June—July for the Shetland Isles and the east coast of Scotland, and August also for the coast of northern England.

For the last four months of the year, the herring fishery is for the most part restricted to the southern waters of the North Sea: in September from the Tyne to the Dogger Bank, in October from the Dogger to Lowestoft and Yarmouth, and in November and December between the coasts of England and Holland.

Following the successive appearance of the fish from the Shetlands southward, the fishermen shift from one fishing ground to another. It would be very natural, from this occurrence of the herring, to deduce a great migration from the ocean north of the North Sea southward to the shallower waters of the banks in its southern part; a theory, which, as we have seen, is of very ancient origin.

Difference of opinion as to the migrations and race of the herring.

In course of time, however, as more extensive experience was obtained, many doubts and differences of opinion arose concerning this migration theory. The fishermen noticed that the herring were not everywhere of the same "sort"; that different sizes and "qualities" appeared at different times and in different parts of the North Sea. This led many to conclude that there were in the North Sea a great number of different local *races* of herring, each with a very restricted area of movement, and that the peculiar seasonal occurrence was only due to the fact that the fish, during the period of developement of the genital organs, congregate in denser shoals, rendering fishery profitable. Between these two extreme opinions, that of a great general migration and that of a number of local races, various other theories have arisen, and there exists a great number of works dealing with the different hypotheses.

Scientific works on the subject have also, ever since the time of LINNÉ, distinguished between different races or varieties of herring; there has, however, as LILLJEBORG observes, always been a difficulty in classifying them according to definite and constant characteristics. LINNÉ, in his "Fauna Suecica", distinguishes between two varieties, α and β; the first he designates *harengus*, or herring in the true meaning of the term, the second *membras* or "Strømning"; the herring of the Baltic. It is very natural that Swedish investigators should be well acquainted with the difference between the herring of different waters, since the coast line from the Gulf of Bothnia in the north round to Bohuslän presents opportunities of studying herring living under extremely different conditions. Sweden has therefore also furnished most valuable contributions to the natural history of this fish. Thus NILSSON, in his "Scandinavisk Fauna" of 1855, divides the races of herring as follows:

1) The ocean form, including a) Norwegian spring herring and b) Gøteborg or Bohus herring.

2) North Sea coastal water forms, a) Kulla herring, and b) Norwegian summer or autumn fish.

3) Baltic forms, including the "Strømning".

Numerous writers, in Sweden and in all other North Sea countries, have taken part in the discussion concerning these races. It will be of no interest here to consider the earlier literature on the subject, as the characteristics laid down by the various writers differ in reality only slightly from those which the fishermen have been able to observe with their own methods of investigation. An important point in the discussion, both among fishermen and scientists, has been the question as to whether the herring were winter spawning or summer spawning. After long controversy as to whether the individual herring only spawned once a year, and in such case, only in winter or only in summer, or whether each fish was able, for instance, to spawn once every eighteen months, the majority of opinions gradually centred about the following theory: All round the North Sea there exist a number of local varieties or races, which live close to the coast, in bays or fiords. These are winter spawning fish. The great shoals which form the object of the true North Sea herring fishery belong to a particular race of herring, spawning in summer and autumn: these are the ocean herring of the North Sea. Of other oceanic varieties, the Iceland and Norwegian herring are the most important; these are, however, spring spawning, and differ widely from the true North Sea fish.

In the earlier scientific literature on the subject we find several attempts at a sharper distinction between the races by means of measurements and figures. Thus NILSSON has already attempted to calculate different physical dimensions in proportion to the total length for several races of herring, and to compare these proportions as between the different races. He calculates, in the case of the ocean herring (*forma oceanica*) that the longitudinal diameter of the eye amounts to $^1/_{22}$—$^1/_{20}$ of the total length (to base of tail fin) whereas the corresponding figures for the coast herring (Skjærgaardssild; *forma taeniensis*) are only $^1/_{17}$—$^1/_{16}$.

This method of distinguishing between different races by measurement of the dimensions of the body has, as is generally known, played an especially important part in the study of the races of mankind (anthropometry) and the attempts which have been made to find some arithmetical expression of such minor racial peculiarities as lie at or beyond the limit of immediate visual perception, or are subject to so great a degree of variation that extensive observations are necessary in order to discover the average and characteristic for each separate race.

It is to HEINCKE*) that the credit is due for first applying to the study of the herring all those principles and methods which have gradually been discovered for the study of mankind.

The term "race" (family or tribe) is taken by HEINCKE as meaning a number of individuals living under the same external conditions, together propagating their kind, and standing therefore in more or less close relation to each other. The idea of a *race* is based upon that of an ideal *type*. All the separate individuals diverge from this type both as regards each single quality and also as to the combination, in each case, of all qualities appertaining to the type. The very idea of a type presupposes a certain degree of variation in the individuals and their qualities, the type being the *average*, or *mean* of all the different individual, varying qualities.

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*) See for instance HEINCKE: Naturgeschichte des Herings. Geschichte der Heringsforschung. Abhandlungen des deutschen Seefischerei Vereins. Band II. Berlin 1898.

HEINCKE's method is therefore to examine the individuals with regard to all, or a large number of their qualities, and to find an arithmetical expression for a combination of these. In this way, the individuals of one and the same race will naturally group themselves about the same type (the mean of the race), and individuals of different races be separated, owing to the grouping of their qualities about different means. (Metode der kombinierten Merkmale).

Working on this basis, HEINCKE has examined the variation of a great number of qualities in thousands of herring from different localities. Of the qualities in question, some are constant, i. e, independent of the age and growth of the fish; to these belong the number of vertebrae, of keel scales, and of fin rays. All these factors are invariable from that point in the life of the herring when the organs in question have arrived at developement; or from the transition of the larva to the young fish stage. By far the greater number of the qualities which HEINCKE has examined have, however, been found to vary with age and growth. At the time when HEINCKE carried out his investigations, no method of determining the age of the herring was known; he was therefore unable to make comparisons between individuals of equal age with full certainty of accuracy. As HEINCKE himself points out, only a part of the investigations made can therefore be regarded as sufficiently stringent. He was also unable to obtain so great an amount of material as he could have wished. His task was therefore principally to draw up a *method* of race investigation, in which he has certainly succeeded, and to employ the same, at any rate as regards the larger groups of the herring races.

HEINCKE's investigations led him to the firm conviction that several different races of herring can with certainty be distinguished, differing in many respects one from another. As a general rule, those races which live far apart, or rather, under widely differing external conditions, are found to exhibit greater variation than those which live together.

Heincke's classification of the races of herring.

On the basis of all his investigations, HEINCKE has drawn up a system, of which we may notice the following features.

1) *Northern ocean herring;* spawn near the coasts in winter or spring, but move during summer in the open sea.

Large fish, over 30 cm. when full grown. Large number of vertebrae, over 57 on an average. Short head and tail. May be divided into two groups:

a) *Iceland herring*, having remarkably large eyes, short skull and fairly long tail, in contrast to

b) *Norwegian herring*, which have small eyes and short tail.

2) *Coast-herring.* These are always winter spawning; they live in the immediate neighbourhood of the coast, spawning in brackish or estuary water. Their physical peculiarities exhibit greater variety for different localities than is the case with the ocean herring.

The head is blunt, longer, and with a more strongly developed snout than in the ocean form. The width of skull is small, these being long skulled fish. The body is short and compressed, head and tail however, being long (long tailed fish). They may be divided into several minor groups:

a) Coast herring of the northern waters of the North Sea and the Skagerak. Exhibit considerable resemblance to the Norwegian spring herring.
b) Coast herring of the southern waters of the North Sea, the Kattegat, and the Western Baltic. These are smaller, (less than 25 cm.) with fewer vertebrae.
c) Spring herring from Rügen.

3) *Ocean herring of the North Sea Banks*, inhabiting the open sea from the coasts of England and Scotland across the whole of the North Sea, through the Skagerak and Kattegat, and in to the Western Baltic. In summer and autumn they move to seek spawning grounds on the sandy and stony banks which rise from the depths of the sea at some distance from land.

These have all a medium number of vertebrae, (56.5—55.5) a large number of keel scales behind the ventral fins (15—14 average) these scales being highly developed. They are broad skulled fish, with long body but short tail (short tailed fish).

a) The northern bank herring belong to the northern waters of the North Sea, Skagerak, and Kattegat. To these must be reckoned first of all the great race of herring which forms the object of the Shetland, Scottish, and North of England fishery; in addition, also those herring which spawn on the Jutland Bank and are taken in great numbers in winter off the coast of Bohuslän. No. of vertebrae 56.5, body long, head, and especially tail, short.
b) The southern bank herring. Closely related to the foregoing, differing essentially by a larger number of keel scales between the ventral fin and anal aperture, and greater breadth of head. The group includes the herring south of the Dogger Bank.

This system represents in many ways a very high degree of progress, based as it is upon investigations carried out according to a clear and critical method, from which definite arithmetical values may be obtained for distinction between the different forms.

Mixture of Races in the North Sea.

We have seen in the foregoing, that HEINCKE had arrived at a clear understanding of these races or types, by investigation of a large number of individuals, the average characteristics of which presented a distinct view of the racial peculiarities. It is however, obvious, that such a method of investigation must presuppose the samples as "pure", i. e. consisting of individuals of the same race. If samples containing a mixture of specimens belonging to two or more races are treated statistically as one, then the results obtained will naturally be valueless or misleading. Now the different races in the North Sea frequently occur in unmixed shoals; they are, however, also often found mingled together. Samples of such shoals will then also be mixed, and only by *sorting the samples* will it be possible to separate the different races one from another for individual examination. Such sorting can also be carried out according to HEINCKE's method; one can, as HEINCKE points out, instead of examining a large number of individuals, examine a large number of features in some few specimens, or even in a single one. Such investigation is, however, an extremely lengthy and difficult task; it is therefore of the greatest importance to ascertain whether it may not be possible, when once a comprehension of the races has been obtained, to discover some more easily discernible *distinctive marks* by which to determine to which race the single individuals belong, and properly sort the mixed samples. Such a system can, in many cases at least, be found in the study of the degree of maturity exhibited by the genital organs, and where this in itself is not sufficient, a combined observation of the size of the fish, its degree of maturity, type of growth, and age, will go far to attain the desired object. These investigations are essentially easier, and therefore permit of extensive examination of specimens and samples, which is naturally a necessity if one desires not only to solve the zoological problem of distinction between the different forms, but also to follow the natural geographical distribution of the same, with the natural history of the different races in certain areas of sea. Such investigations will, of course, in their results, arrive at the same object as the more anatomical racial study, showing, for instance, as we have seen in the previous chapter in the case of the Norwegian coast herring, the natural area of migration of a race. On the basis of such investigations, also, one arrives at the question of variation in the migrations and size of the stock, which is of especial importance in dealing with the problem of fluctuations in the fishery.

The investigations which we shall here especially consider have been particularly directed towards this end. As will be seen from the following, greater difficulties have been encountered in the North Sea than in the Norwegian waters; the investigations have not been carried on for so long a period of time, and can therefore not present so definite results. They serve however, at least to point the way for future investigations of the same nature. I will now briefly state the most important results which have been obtained.

Mixture of races in the northernmost part of the North Sea.

At the conclusion of the last and commencement of the present century, some few Norwegian fishermen began to take part in the herring fishery on the North Sea Banks; they worked, however, grounds which are only rarely and to a slight extent fished by other nations, viz. along the so-called "Revkant", or 100 fathom curve, which forms the boundary between the North Sea Banks and the Norwegian Channel. There is in particular one small bank near the Revkant, called the Viking Bank, due west of Bergen, and this bank formed the true fishing ground of the Norwegian fishermen.

The catch which these fishermen brought to land exhibited great variation in "quality", being now fat, early "fulls", now far advanced fulls, sometimes spent fish, and at other times a mixture of all sorts. Investigations in the Fishery Laboratory very soon convinced me that these hauls must consist partly of Shetland herring, partly of fish belonging to the Norwegian race, and I endeavoured to test this by means of fishing experiments carried out in the northern part of the North Sea, and by subjecting the fish to close study, both according to the method laid down by HEINCKE and also other and simpler methods, especially size and degree of maturity*).

These experiments will be referred to again in a later chapter, as they contribute

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*) See Norske Havfiske, II Del, p. 310 ff. and Laurits Devold og Johan Hjort: Norsk Sildefiske i Nordsjøen. Norsk Fiskeritidende. 1906.

largely to the elucidation of the migrations of the herring. It will here suffice to mention that it proved possible to determine, that the herring along the hundred fathom curve consist for the most part of Norwegian fish, with occasional admixture of Shetland herring, which as a rule keep to the west of the bank. Fig. 31 shows the fishing grounds where one of the larger series of experiments was made, in 1905. The herring here were found, when taken in on the bank, Stations 3—16, in the autumn (August-November) for the most part in *spent* condition, whereas the herring on the Revkant, Stations 17—36, exhibited genitals in a far less developed state of maturity. Even late in the autumn, for instance at the end of October, the ovaries were found to be at stage III*). The first group belong to the summer spawning Shetland herring, the last to the Norwegian spring spawning fish.

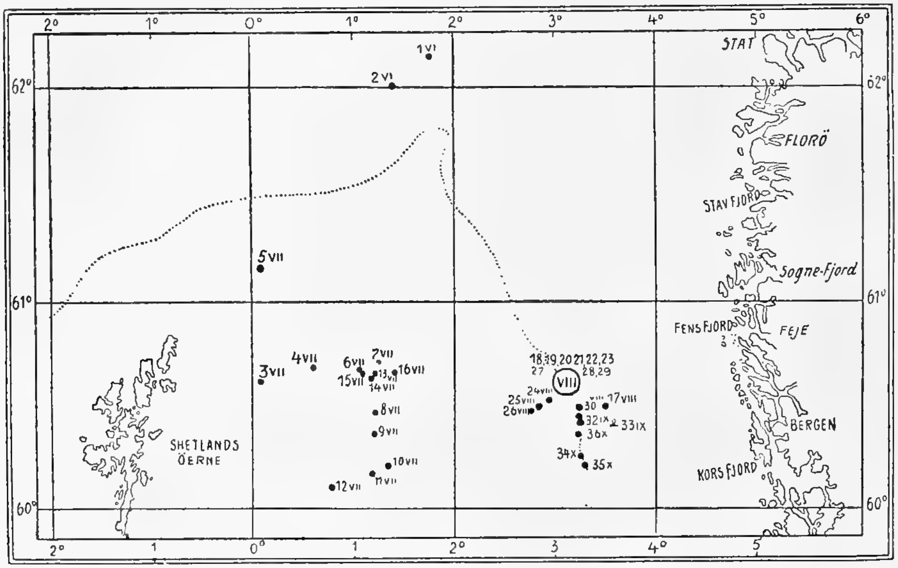

Fig. 31. Grounds worked by the cutter "Fridtjof", 1905.

The study of herring from the Dogger Bank and Skagerak also furnished considerable information as to the composition of the samples; it appeared, however, very desirable to check these results by comparison with Heincke's methods of investigation.

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*) As regards maturity, the following 7 stages have been fixed, chiefly on the basis of a suggestion made by Heincke.

Stage I. Immature fish which have never spawned, with very small genitals immediately below the spinal column. The female exhibits claret coloured, torpedo-shaped ovaries about 2—3 cm. long and 2—3 mm. thick. No. eggs visible to the naked eye. The male has whitish or greyish brown knife-shaped testicles, 2—3 cm. long and 2—3 mm. broad.

Stage II includes both immature fish with genitals beginning to develope, and spent fish with genitals beginning to prepare for a new spawning. Ovaries somewhat more than half the length of the abdominal cavity, about 1 cm. in diameter. Eggs small, but visible to the naked eye. Testicles of the male are whitish, with some blood-red spots, and of the same size as the ovaries.

Stage III. Genitals thicker, or swollen, occupying about the half of the whole abdominal cavity.

Stage IV. Genitals occupy $^2/_3$ of the abdominal cavity. Eggs not yet transparent; milt white and swollen.

Such examination was therefore commenced at the Laboratory by Broch, who has examined numerous samples from the Norwegian coastal waters and from the different parts of the North Sea.

Broch's investigations as to mixture of races.

Broch's*) investigations in regard to race confirmed on the whole the results arrived at by Heincke. Broch found, as did Heincke, a distinct racial difference between the ocean herring of the North Sea Banks (Shetland, Dogger, and Bohus herring) and the ocean herring off the Norwegian coast, (spring, large, and fat herring).

As regards the North Sea herring, Broch's investigations furnish, as he himself points out, but little new information; in the case of the Norwegian coast herring, however, he is able to make far more definite statements, having had an essentially greater quantity of material at his disposal than Heincke. Broch points out first of all with certainty, that the greater part of the herring in Norwegian coastal waters belong to one and the same race, corresponding in all essentials to the marks of racial distinction described by Heincke. He also points out that there exist in different fiords, as for instance Trondhjemsfjord, local races, small spring spawning fish, which may perhaps be compared with Heincke's coast forms (see above).

Broch then examined the mixed samples from the north-eastern part of the North Sea, sorting the samples according to the degree of developement of the genital organs. The samples from the Viking Bank, already mentioned**) as taken at the end of October and beginning of November 1905, were thus found to consist of two groups, one having genitals at Stages II and III, or approaching the stage of the "full" herring, the other group exhibiting genitals in a state of exhaustion (spent fish). Investigations as to the racial characteristics, (number of vertebrae, number of the first closed haemal arches, number of keel scales between the base of the ventral fin and the anal aperture, length of head and cranium etc.) distinctly indicated that these spent fish agreed in every respect with the summer or autumn spawning Shetland herring, while the other group resembled in all essentials the racial character of the Norwegian spring herring. Thus further proof was furnished of the fact that the two great races of ocean herring in the northern part of the North Sea meet and mix together, and that it is possible, at

Stage V. Genitals occupy the whole of the abdominal cavity. Ovaries contain some large transparent eggs; milt white, but not yet loose.

Stage VI. Milt and roe loose.

Stage VII. Spent. Ovaries slack with some few eggs still remaining. Testicles blood-red.

It is evident that the above, like any other description of stages in a developement, cannot exactly fit every possible case which may occur. This difficulty however, may be met by noting the two stages between which the case in question is found to lie, as I—II, III—IV, etc.

As regards degree of fatness, four stages are recognised.

0	practically no fat.
1	some fat.
+	moderately fat.
m	very fat.

*) Norwegische Heringsuntersuchungen während der Jahre 1904—1906. Bergens Museums Aarbog, 1908, No. 1.

**) Vide Broch, l. c. Tables II, III and IV.

least at certain times, to distinguish one from another in a sample merely by observation of the degree of maturity exhibited by the genital organs.

As mentioned in the introduction, Broch found in the scales of the herring an excellent means of determining the age of the fish, and his very first investigations showed that the different races exhibit different growth, and that individuals of equal size belonging to different races may differ greatly in point of age.

International studies as to age and growth.

These principles have been subjected to far closer investigation and consideration in the course of the more extensive and systematic international herring investigations, and these have confirmed, in increasing degree, the fact that the rate and manner of growth exhibit peculiar characteristic features in the different races. Some score thousand fish from different waters have been measured according to the methods described in the previous chapter, and calculations made as to the size of the individuals at the different periods of growth through which they have passed, thus furnishing a very large number (nearly a million) of figures for calculation of the average growth of the herring in different regions*).

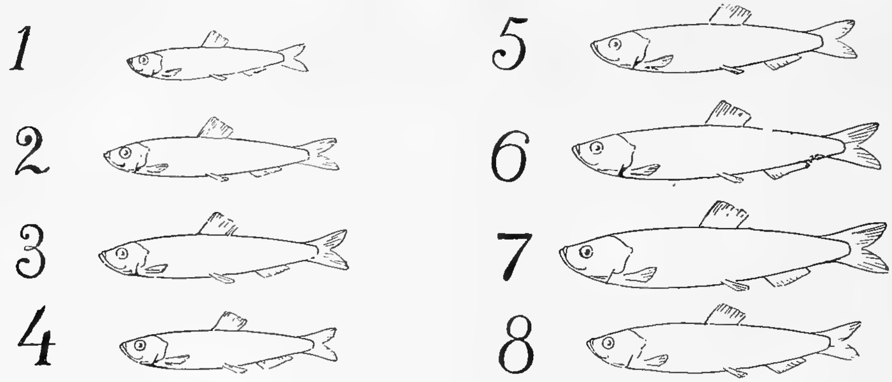

Fig. 32. Eight herring of equal age (4 years) from

1. White Sea.
2. Lysefjorden (West Norway).
3. Zuyder Zee.
4. East Coast of Sweden.
5. Western part of North Sea.
6. Atlantic Ocean.
7. Iceland.
8. West Coast of Norway (Spring herring).

Some examples will show what can be attained by such investigations.

*) K. Dahl has in his paper "The Scales of the Herring" (Report on Norwegian Fishery and Marine Investigations, Vol. II, 1907) suggested that the first winter ring may, in the case of autumn spawning herring, be formed, not in their first winter but in the second, when the fish are $1^1/_4$, $1^1/_3$ or perhaps even $1^1/_2$ years old. He bases this theory partly on the fact of having found the first growth zone to be far larger in the case of autumn spawning than in that of spring spawning fish, and partly on having encountered, on the Jutland Bank in winter, small herring of 4 cm. in length without any scale covering at all. This question has hardly been finally solved as yet, and a study of the smallest herring (especially in winter) in the North Sea countries adjacent to the spawning grounds of the autumn spawning fish will probably be necessary. It should therefore be continually borne in mind, in consideration of the following, that the age of autumn spawning fish may have been fixed some months too low.

Fig. 32 shows eight fish, all of equal age, viz. 4 years, but from different localities. All are drawn to the same scale and in the size representing the average for their respective localities. The drawings for this and the following figure are taken from two plates prepared by **Lea** for the Copenhagen Exhibition in 1912.

1) White Sea, 2) Lysefjord (western Norway), 3) Zuyder Zee, 4) East coast of Sweden, 5) Western North Sea, 6) Atlantic, 7) Iceland, 8) Norwegian spring herring.

The four races on the left (1—4) have their origin in closed waters, whereas the four on the right (5—8) were taken in open sea (North Sea, Arctic Ocean, Atlantic Ocean). It will at once be seen that the herring from the closed waters are smaller than fish of the same age from more open waters.

Precisely the same impression is obtained on examination of the scales, as shown in Fig. 33.

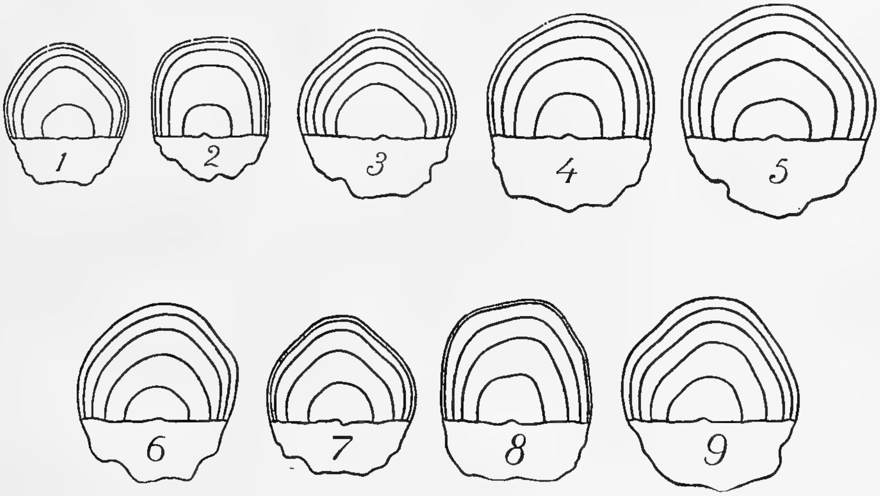

Fig. 33. Normal scales of 5 year old herring from

1. Lysefjorden. 2. Zuyder Zee. 3. Kattegat.
4. Faeroes. 5. Iceland. 6. Norway (Spring herring).
7. Western part of North Sea. 8. Atlantic Ocean. 9. Shetlands.

1) Lysefjord, 2) Zuyder Zee, 3) Kattegat, 4) Faroes, 5) Iceland, 6) Spring herring, 7) Western North Sea, 8) Atlantic, 9) Shetlands.

These scales illustrate the average growth of five year old herring from the localities in question. The scales are drawn in proportion to the size of the fish, while the distances between the different winter rings show how they have grown from year to year.

A glance at the figure will show that the study of the scales furnishes information not only as to the different size of the grown fish in different waters, but also as to entirely different manners of growth in the periods embraced. Some have grown poorly until the formation of the first winter ring (1 and 2), others better (3). Some have grown well in their first years, but poorly later on (7 and 8) while others exhibit very satisfactory growth even in their fifth year (5, 6 and 9). The growth can thus exhibit so considerable variations, that it is frequently possible, in the case of a loose scale, to determine to what fish it belongs, even though other sorts may have been taken in the same haul.

In an earlier sketch of the international herring investigations, Lea and the present writer*) showed how the figures on which the construction of such average or standard scales (Fig. 33) is based, can also be utilised for drawing curves of variation for the growth of the herring during different periods, (length of the fish at the age of one year l_1, increment in second year t_2, third t_3, etc.). Moreover, it is also possible to ascertain from such curves how far a sample consists of fish which are homogeneous in point of growth, or contains several different *growth-types.*

Heincke has previously pointed out that a single feature may in many cases suffice to distinguish one race from another; this necessitates, however, examination of a large number of individuals. In all probalibity, the study of the growth will be found to furnish the most practical means of distinguishing between the various races of herring which are found to mix in the North Sea. The greatest efforts are therefore being devoted to the treatment of the large number of growth measurements obtained from the North Sea samples examined. This important task has been undertaken by Lea, and it is to be hoped that the result may form an excellent basis for future closer acquaintance with the races and rates of growth of the herring in different parts of the North Sea. By this means, valuable light will in course of time be thrown upon the biologically interesting question as to the influence of the different natural conditions in this complicated region upon the individual growth of the fish and their hereditary characteristics.

Geographical distribution of the different age groups.

It is however, also of great importance for the study of the natural history of the herring, and thus for the question of race, to investigate *the geographical occurrence of the different age groups*, or *the composition with regard to age of the herring in different parts of the North Sea.* In order to understand the area of distribution of a race it is naturally not sufficient to be able to fix the limits of migration for certain stages, as for instance, the spawning shoals. Not until we have ascertained where all the different stages are to be found is it possible to determine the extent of the area of distribution of the race, and define the geographical limits which separate one race from another. If, for instance, a certain water is found to contain only older fish, this fact alone is sufficient to indicate that the race there represented must have a far more extended area of migration. Thus we have in the foregoing seen that in Norwegian waters, the grown herring are found principally in the southern part, the immature fish chiefly in the northern regions. No investigations on this point have as yet been carried out with regard to the North Sea.

If we examine the drift net hauls made by the fishermen in the North Sea, it will soon be observed that these consist pre-eminently of grown, mature fish. I have already**) made numerous investigations on this point. It appeared for instance, that five steam drifters fishing in the North Sea from the end of May to the beginning of December, with a total catch of 14,962 barrels, obtained

715	barrels	or	about	4.8	%	fat herring
14.389	—	»	»	91.4	»	fulls, and
573	—	»	»	3.8	»	spent fish.

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*) Some results of the International Herring Investigations. 1907—1911, Publ. de Circ. No. 61.

**) Norsk Havfiske, II. Del, p. 310 ff.

The fishing was carried on off the west coast of Scotland, at the Shetlands, in the waters north of and on the Dogger Bank, and southward towards the coast of Holland. Only off the west coast of Scotland and the Shetlands were any fat herring (matjes) caught, the catches otherwise consisting entirely of grown fish with large roes and milt, or spawning and spent fish.

A study of the samples collected from the fishermen's drift net hauls gives an exactly similar result. These samples show the length of each individual fish in cm., the sex, and degree of maturity of the genital organs*). In addition to this, the age of each individual, and size at all different periods of growth, (l_1, t_2, t_3, etc.)**) have been determined on the basis of the scales collected.

Only in the waters west of Scotland and round the Shetland Isles are immature fish found early in the season, and in the autumn, some few samples from the southern half of the North Sea may be found to contain a greater or lesser admixture of immature fish.

As regards age, by far the most part of the fish are over three years old; in the great open sea fishery carried on in the northern half of the North Sea, the rule seems also to be that the three year old fish are slightly represented in the samples. (See Table p. 63).

Distribution of the youngest year classes.

The drift nets of the North Sea fleet are thus evidently adapted to the capture of grown herring, and other implements must be used if it is desired to obtain information as to the distribution of the younger, immature age classes.

Such investigations have not previously been made in the open waters of the North Sea. Information is to hand from the different countries bordering on the North Sea as to the occurrence of small herring along the coasts, and these fish have also in many places been measured and described, as for instance in Scotland, (Firth of Forth, Moray Firth), England (Plymouth) Holland, Germany, and Denmark. No closer investigation of their subsequent growth and habitat has, however, been made. It is also a matter of great difficulty to study these conditions on the open coasts of the North Sea, the services of a steamer and the employment of many kinds of implements being required.

The question appeared to me however, to be of the utmost importance for the study of the natural history of the herring in the North Sea. I therefore made, in 1912, several cruises in the North Sea with the "Michael Sars" exclusively for the purpose of studying the distribution of the younger stages of herring, my Assistants, E. Kofoed and E. Lea, accompanying me. The cruises were carried out in June —July, and October—November, in order to compare the conditions prevailing in summer with those of autumn. The implements used were a fine-meshed trawl of the same construction as those employed by the Swedish fishermen, and a fleet of drift net composed of a series of nets of greatly varying width of mesh.

The drift nets used were as follows:

a) Sprat net.	Width of mesh (from knot to knot)........	1 cm.
b) —	—	1.2 »

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*) See note p. 52—53.

**) Examples will be found in Publ. de Circ. No. 53, pp. 139—159.

c) "Loddegarn" (as used for *Mallotus*)	(from knot to knot)....	1.3	cm.
d) Nordland fat herring net	—	2.1	»
e) —	—	2.2	»
f) —	—	2.5	»
g) Large herring net	—	3.1	»

These implements were found to be well suited to the purpose of the investigations. The trawl took all sizes of herring and sprat down to about 10 cm. in length, smaller sizes only occasionally and in quite small numbers. The drift nets took all sizes down to 7—8 cm. It is evident, however, that the hauls made with these nets cannot, at any rate in the case of the drift net, claim to be *representative* of the stock on the grounds. Although I believe the sizes of net selected to be suitable for the capture of the different size groups present in the North Sea in summer, there will no doubt have been individuals on the grounds which could not be taken in the nets. Still less can the hauls be considered as representative of the stock in regard to its composition in point of size, or for the *quantitative occurrence of the different sizes.* The obtaining of such representative hauls is a far more difficult task than that which I had set before me at the commencement of the investigations, viz, *to obtain a first survey of the localities in which the different sizes of herring occur in the North Sea as a whole.*

In the chart shown in Fig. 34 an attempt has been made indicate the results obtained by these investigations. The chart is only intended to illustrate the catches of younger fish, the three smallest groups. By 0 group I understand, as stated in the explanation of the figure, herrings whose scales have as yet no winter ring. Groups I and II are those with one and two winter rings respectively. (The investigations were, as already mentioned, carried out in summer and autumn)*).

The chart shows depth lines indicating 400, 200, 80 and 40 metres depth. Each of the stations where the fine-meshed trawl was used is marked with a dot, those where the drift net was employed being indicated by a cross.

At the negative stations, i. e. those where no fish of the three youngest groups, (0—II) were taken, a circle has been drawn about the dot or cross, and the experiments made during autumn, (October—November) are shown by a partial thickening of the circle.

At all the positive stations a square has been drawn, one side being thickened for autumn investigations, in addition to which, a figure indicates the size group there found, 0—II naturally to mean that all three groups were present. The chart contains no statements as to the size of the hauls, or the quantitative occurrence of the size groups.

The first conclusion at which we arrive on consideration of this chart is that all stations north of the 80 metre line are entirely negative. In the northernmost part of the North Sea, or at depths of over 80 metres, no herring of the smallest sizes were thus taken. The only exception is perhaps the Skagerak or the Jutland Bank, where fish of both I and II groups were at least taken close by, on or immediately beyond the 80 metre line.

In the waters between the 80 metre line and the coast, several positive stations will be observed. These form, moreover, a distinct series, in such a manner that the the

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*) See note p. 54.

smallest *0 or I groups are found nearest to land, and in summer only quite close to the shore, or between the 40 metre line and the coast.*

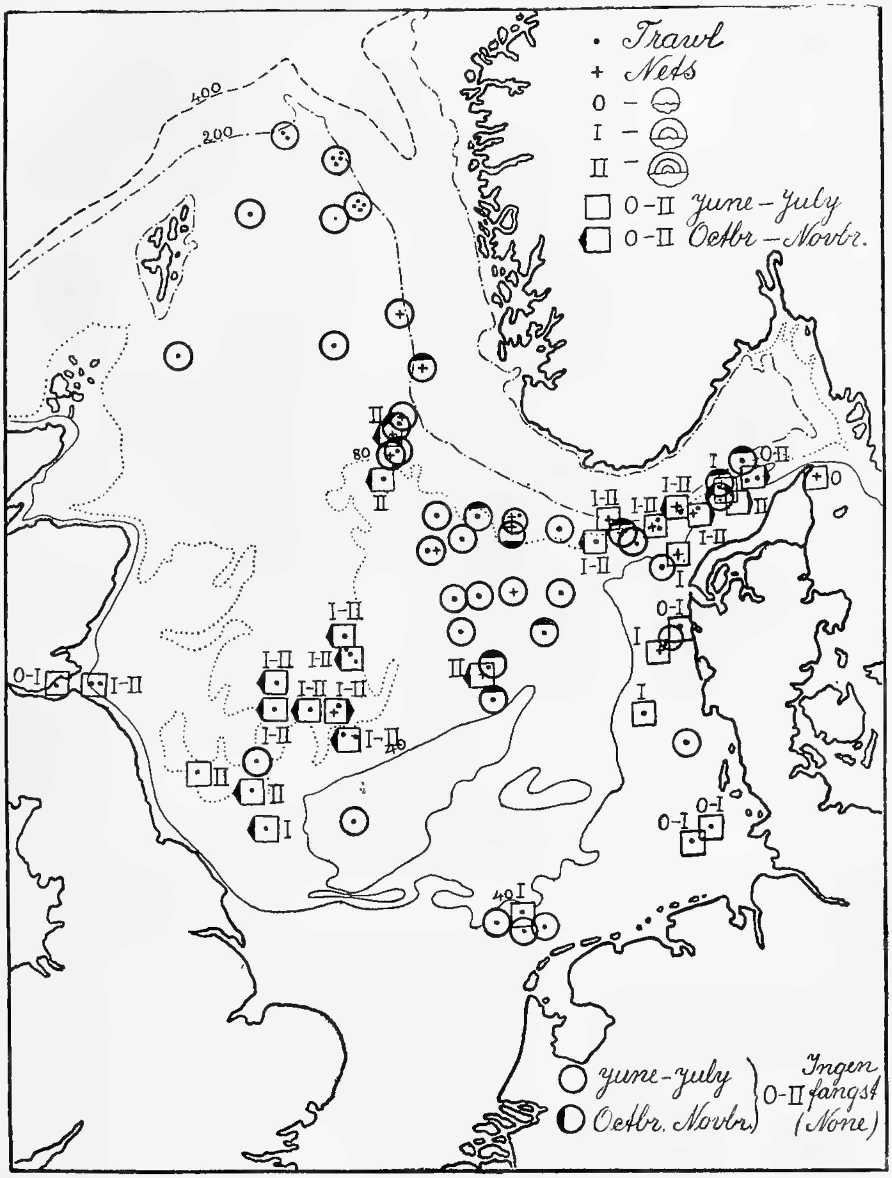

Fig. 34. Distribution of the youngest year classes in the North Sea.

The 0 group, for the capture of which the implements were not prepared, and which I regard as a more or less accidental component of the hauls, evidently occurs nearest the coast. Group I was found in summer at about 20 metres depth at almost every spot where hauls were made, from the coast of Holland up to the Skaw. On the English and Scottish coasts, the 40 metre line runs for the most part so close in to land that I was unable to make any hauls there, except in the Firth of Forth, (permission being courteously granted me by the Scottish Fishery Board). In autumn, group I is encountered farther out from land, and at greater depths; it then includes also considerably larger fish.

Group II was hardly ever taken nearer to land than the 40 metre line; its area thus appears to be between the 40 and 80 metre limits, or on the edge of the 80—100 metre depth.

It would hardly be justifiable to attach any superlative importance to these attempts at determining the occurrence of the groups, at any rate, as a general and permanent solution of the problem of the distribution of young herring in the North Sea. It should however, be permissible to conclude from these investigations that the younger stages of the herring, like the corresponding stages of many other important fish, are chiefly to be found at lesser depths; i. e. in the shallower waters of the Banks, and more or less close to land. This was also the point which I regarded as of primary importance.

Comparison of the distribution of the youngest year classes with the currents in the North Sea.

In considering the herring of the Norwegian coastal waters, we have seen that the young fish are carried by the current far away from the spawning grounds, and spread in the direction of the current northwards along the coast. It would seem reasonable to suppose that somewhat similar conditions prevail in the North Sea. Judging from the available information as to the currents of this water, it would seem that a strong current sets southward from the north coast of Scotland and the Shetland Isles, towards the Dogger Bank and the German Bight, and thence again through the Skagerak towards the coasts of Sweden and Norway. The well known and excellent experiments with drift bottles carried out by Dr. Fulton give a very good illustration of this, (see Fig. 35) and would appear to agree directly with the results given above as to the occurrence of the younger stages of herring. In consideration of the question, it should, however, always be borne in mind that quantities of young herring occur along the whole range of the east coasts of England and Scotland, and that the waters to the north and northwest of Scotland are also particularly rich in young herring of different sizes. Fishery is even carried on here in the spring, for the young fat herring (matjes).

Taking all this into consideration, it would appear desirable that also the younger stages be made the subject of investigation as regards their race and growth, in the same manner as the spawning shoals. For a comprehension of the geographical areas of distribution of the different races it is naturally of particular importance to ascertain whether the young herring encountered along the coast include the young of both coast and ocean forms, whether the young stages of Shetland herring also grow up in the southern waters of the North Sea, or only near the coasts of Scotland and the Shetland Isles. Innumerable interesting results will doubtless be arrived at on these points in course of time; for the present, we must in all probability suppose that roughly speaking, the southern part of the North Sea is one of the largest and most important growth centres for the young of the great spawning shoals of ocean herring in the North Sea. The enormous numerical superiority of the ocean form as compared with the coast varieties

Fig. 35. Results of Dr. Fulton's Drift bottle Experiments in the North Sea.

should in itself suffice to warrant the supposition that the young of the former race make up a considerable portion of the total of young stages found in the North Sea and Skagerak.

Composition in point of age of herring shoals of older age classes. Difficulty of investigation.

It will be sufficiently evident from the foregoing that an elucidation of the important question as to the *composition in point of age of the herring stock in the North Sea* is a task which presents grave difficulties. There are in the North Sea several races, the areas of developement of which are as yet but little known. We still lack certain information as to the rate of growth of the different races, there is for instance some doubt as to whether the first winter ring is formed in the first or second winter in the case of the autumn spawning fish. There is also the purely practical difficulty that the hauls made by the fishermen are carried out with drift nets, which do not furnish samples entirely representative of the actual stock, the younger stages partly escaping. To this must doubtless be added the fact which plays so great a part in the Norwegian waters, viz, that the occurrence of the younger year classes exhibits considerable variation, these making their appearance sometimes separately, and sometimes mixed, thus causing great fluctuation in samples from the same locality.

We are thus still far from being able to finally solve the problem of composition with regard to age in the North Sea; further preparatory work is required. It is however a question whether it may not already be worth while, for the sake of a preliminary survey, to consider some of the many sides of this great question. It would then be natural to select for consideration the samples dealt with from the shoals of older spawning or mature fish, and endeavour to ascertain how far it may be possible here, as in the case of the Norwegian herring, to find some regularity in the composition with regard to age of the samples.

We have seen in the foregoing, that observation of the size of the fish, and the degree of development of their genital organs, formed a means by which it was possible, not only to distinguish between two samples, one consisting of autumn spawning Shetland herring, and the other of spring spawning Norwegian fish, but also to sort out, from a mixed sample, the individuals belonging to each of these two races. It is probable, that this will be possible to an even greater degree if we take into consideration, not only the size and degree of maturity of the fish, but also the age of each individual, and the average size of the different year classes in the samples. A knowledge of the general results of HEINCKE's race investigations will also here furnish valuable assistance.

In the table on page 63 will be found some specimens of the many sample sexamined in 1911. The samples have been dealt with from the point of view of composition with regard to age, (percentage of year classes) average length for each year class in the sample, and maturity. I have here to thank Mr. PAUL BJERKAN for his kind assistance in dealing with these samples.

Different types ot composition in point of age.

Samples 1 and 2 are taken from the north-eastern part of the North Sea (Viking Bank). The maturity of the genital organs indicated that most of the fish were spring spawning. The May sample (No. 1) revealed genitals recently spent and regenerating, the September sample being a mixture, with genitals in varying degrees of development towards the large herring stage. These must thus be fish belonging to the Norwegian race. The September sample contained, however, some few specimens of spent autumn spawning fish.

North Sea Herring.

All samples but one from 1911.

Samples		Year classes (Number of individuals percent.)											Year classes (Average length in cm.)											Quality
		1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	
Type I from Rev-kanten	[1]) 15th May 61° 4′ N. L. 2° 37′ E. G.	..	..	..	9.3	14.0	41.9	16.3	4.7	9.3	2.3	2.3	..	..	..	30.0	30.8	30.3	30.1	30.5	30.0	31.0	32.0	All Norwegian spring herring, regenerating sexual organs (Stage II).
	[2]) 30th Sept. 60° 21′ N. L. 2° 33′ E. G.	..	..	1.1	7.6	18.5	40.2	15.2	7.6	4.3	..	2.2[1])	..	..	29.0	29.9	30.8	30.7	30.6	30.7	31.0	..	33.0[2])	84.5 % Norwegian spring herring in Stage II—IV („storsild"). 15.5 % Summer spawners, spents (Stage VII).
Type II	[3]) 29th Aug. Shetland 60° 32′ N. L. 0° 8′ E. G.	..	2.5	4.2	16.8	10.1	20.2	20.2	13.4	10.1	1.7	0.8	..	27.3	28.4	29.6	29.6	30.4	30.8	30.6	30.9	30.5	32.0	Summer spawners. spawning and spents (Stages IV—VII. Some (6 %) Spring spawners in Stage II.
	[4]) 11th Sept. DoggerBank 54° 8′ N. L. 2° 15′ E. G.	1.0	6.2	15.1	37.2	23.3	9.0	4.6	2.5	0.3	0.8	..	23.5	25.2	25.9	26.6	26.9	27.2	27.8	28.0	29.0	28.0	..	Most individuals spawning in late autumn "Doggerbank herring". (Stages III—V and some VII).
	[5]) 20th July Jutland Bank	1.1	2.6	8.0	31.0	21.9	21.9	8.0	3.3	1.8	0.4	..	25.0	25.7	26.4	26.9	27.2	27.7	27.6	27.7	27.8	29.0	..	Autumn spawners (Stages II—IV). Some (ca. 2½ %) fat-herring (Stage I).
	(1910) [6]) 10th Febr. W. from Pater-nosterskjær Kattegat.	..	..	11.7	29.5	24.8	12.6	12.4	4.7	2.3	0.9	0.5[3])	..	..	24.3	25.4	25.9	26.4	27.2	27.7	28.3	27.9	28.0[4])	Ca. 46 % spents, Autumn spawners (Stages VII—II).[5]). Ca. 47 % fat herring (Stages I and II)[6]) Ca. 7 % Spring herring, developing sexual organs (Stages III—VI).
Type III	[7]) 27th May N. Shields 55° 0′ N. L. 0° 35′ W. G.	6.4	52.6	24.3	11.5	2.6	2.6	..	..	..	..	..	22.0	22.9	24.5	25.7	26.0	26.5	..	..	..	..	..	Ca. 40 % Spring spawners, spents (Stage VII). Ca. 60 % fat herring (Stages I—II).

[1]) 1898 1.1 1897 1.1 1895 1.1 — [2]) 1898 32.0 1897 32.0 1895 32.0. — [3]) 1898 0.2 1897 0.2. — [4]) 1898 28.0 1897 28.0. — [5]) Meagre. — [6]) Fat.

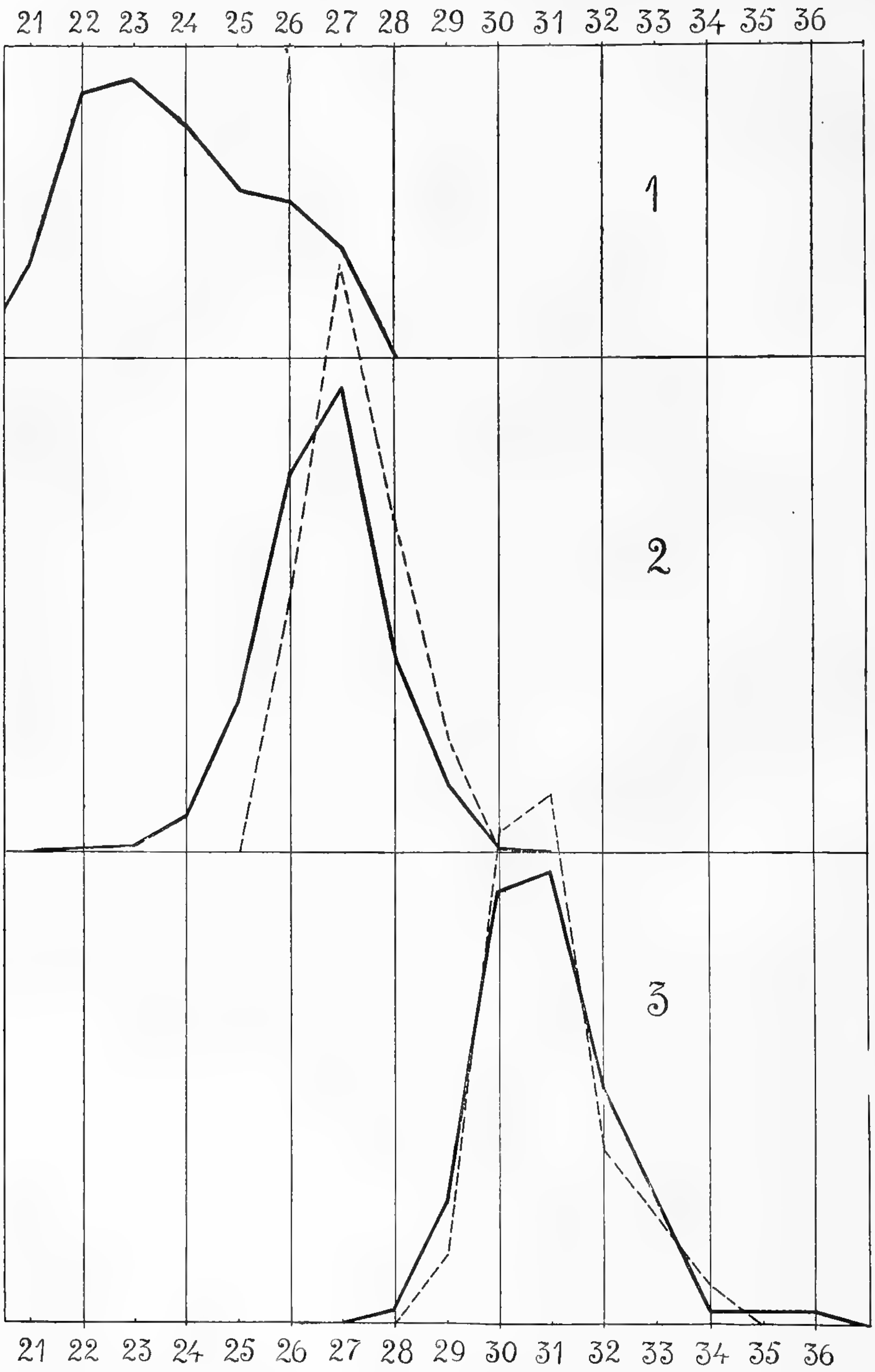

Fig. 36. Composition in point of size (%. of cm.-groups) of 3 samples from the North Sea. —— of all individuals in the samples. - - - - of individuals of 1904 year class in these samples.

If we consider the average sizes of the year classes, we find very high figures, the great majority being over 30 cm. They are thus large herring, which also agrees with the supposition that they belong to the Norwegian race.

The composition with regard to age here shows that a single year class (1904) is very strongly represented, amounting to over 40 %. Here also we find great similarity with the large herring and spring herring in 1911.

Samples 3—6 consisted chiefly of summer or autumn spawning fish, 3 and 6 contained a proportion of spring spawning individuals, while 5 included some young fat herring.

Examination of the average size of the year classes shows (with the exception of the mixed sample No. 3) much lower figures than in Nos. 1 and 2; the composition is here entirely different. The 1904 year class is much less strongly represented; the year classes 1906 and 1905, on the other hand, play a far more important part, 1906 in particular amounting in Nos. 4—6 to 30 % or more.

All these samples were taken within the area where Heincke's autumn spawning ocean fish occur, in the waters about the Shetlands, the Dogger Bank, the Jutland Bank, and Bohuslän.

Finally, we have in No. 7 a sample of much smaller fish, 22—26.5 cm., from the English coast. These are a mixture of spring spawning fish (coast herring) and young fat herring. The composition shows great predominance of the 1908 year class, (which in May 1911 shows three winter rings); the 1907 year-class, however, is also strongly represented.

If we compare all the samples together, it is immediately noticeable that they contain three different types, distinguished by peculiarities in the average size of the year classes, season of spawning, and composition in point of age.

Figs. 36 and 37 show examples of the *composition, as to size and age*, of each of these types, samples 2, 4 and 7 having been selected as representative.

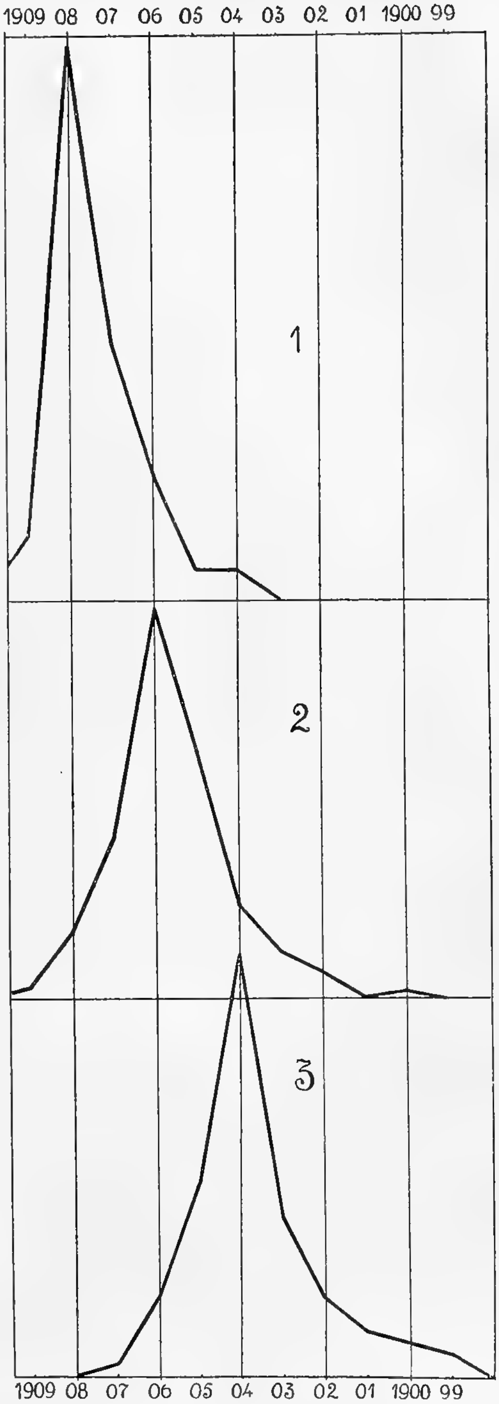

Fig. 37. Composition in point of age of same samples as in Fig. 36.

Fig. 36 shows the composition in point of size. In the sample from the east coast of England (7) two groups are slightly indicated, one about 23 and one about 26 cm. This presumably corresponds to the mixed composition of the sample, consisting of fat herring and spring spawners, (coast herring). The Dogger Bank sample (4) shows a distinct maximum at 27 cm., that of the Viking Bank fish (2) at 31 cm.

In like manner, Fig. 37 indicates a maximum for the English coast sample (7) of the year class 1908, that from the Dogger Bank (4) of 1906, and that from the Viking Bank (2) of 1904. That this difference in composition with regard to age does not alone determine the difference in size will be seen from the dotted curves in Fig. 36. These curves show the variations in size for the year class 1904 among the Dogger Bank and Viking Bank fish: it will be seen that the individuals from 1904 were far larger among the Norwegian coast herring than among the Dogger Bank fish, (which is also evident from the average sizes for the year class as shown in the table). The Dogger Bank fish therefore consisted, in 1911, of smaller individuals, both absolutely and in relation to age.

Numerical relation of the year classes in different parts of the North Sea.

From this it would seem that we may hope, even with the present material and with simpler methods, to obtain a view of the composition in point of age of the spawning or grown shoals of herring in the North Sea. In the charts Fig. 38—40 therefore, a number of the results from the age determinations of the 1911 samples have been given. The charts have been drawn up with a view to separately representing the numerical value of the year classes in all the samples examined. All stations have therefore been marked on a chart of the North Sea, a circle being drawn at each with radius according to the percentage of the year class as represented in the sample taken there. Thus the chart in Fig. 38 gives a graphical illustration of the percentage of the 1904 year class in the North Sea samples from 1911. Fig. 39 shows the same for 1906, and Fig. 40 for 1908. These three year classes, 1904, 1906 and 1908 were, it will be remembered, the most prominent in the three different types of composition with regard to age given above.

In the chart for 1904 year class, Fig. 38, we find large circles along the 200 metre line in the northern and north-eastern part of the North Sea; in on the banks, however, the values are everywhere small, decreasing southwards, except for August—September, when we find somewhat larger circles (10—20 %) on the Dogger Bank.

The chart for 1906 on the other hand, shows very small circles along the 200 metre line, and larger, (20—40 %) from the Shetlands southward along the east coast of Scotland and England and on the Jutland Bank. As we shall see later on, similar conditions prevailed on the coast of Bohuslän. In the immediate vicinity of the coasts, however, somewhat smaller circles will be noticed, as for instance off the coasts of Scotland and England.

The chart for 1908 shows only very small values in the north-eastern part of the North Sea, all, with one exception, being less than 10 %. Nearer the Shetlands they are somewhat larger, while in the southern part of the North Sea they amount to over 50 %.

A comparison of the three charts seems to indicate:

1) That in the study of age composition also, it is possible to follow the migration of the Norwegian herring out to the edge of the banks in the North Sea, and here to

observe how these fish, when not too strongly mixed with the Shetland race, preserve their peculiar composition in this respect. Thus in 1911 there was a single predominant year class (1904) as we have seen in the foregoing chapter.

1911 [1904]

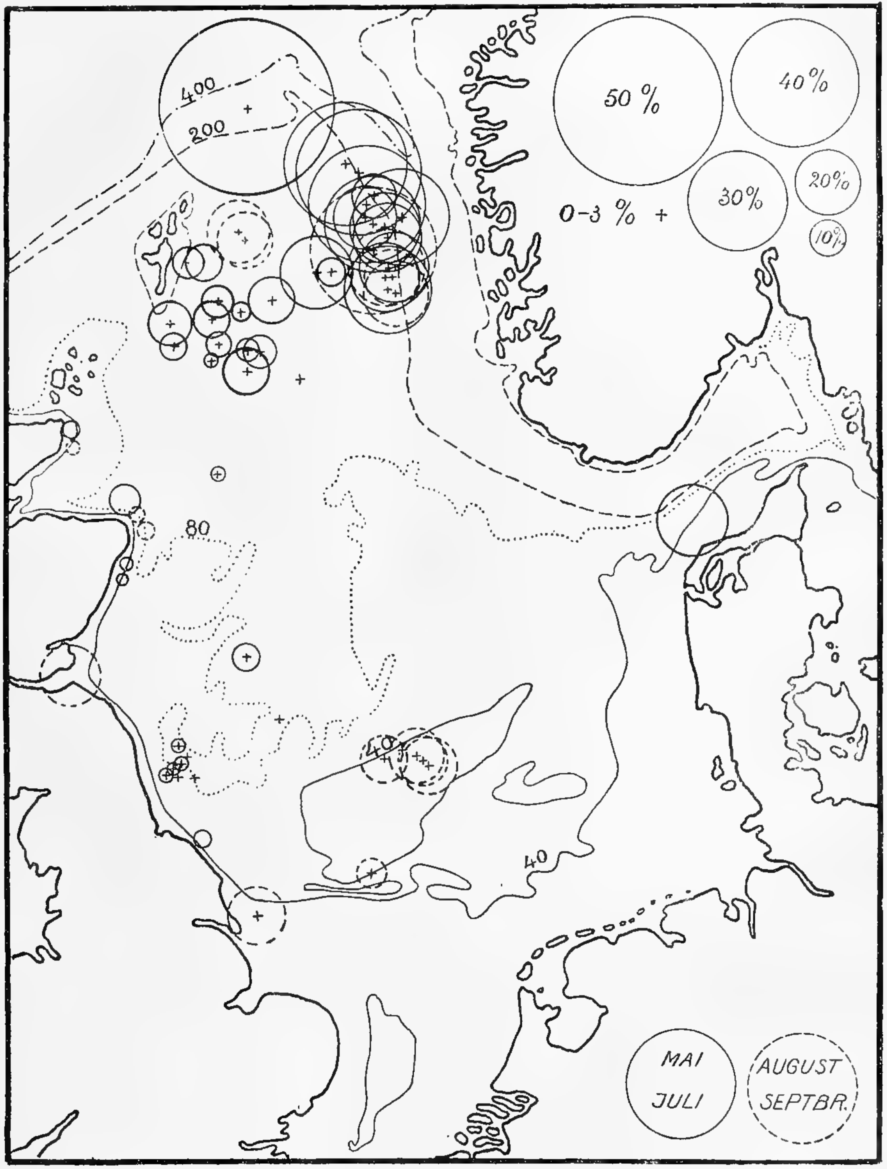

Fig. 38. Percentage of fish of 1904 year class in certain samples from the North Sea (1911).

2) That the autumn spawning ocean herring exhibit, from Shetland to the Dogger, on the Jutland Bank, and off the coast of Bohuslän, the same distinct peculiarity as regards the 1906 year class, and the table on page 63 as well as closer observation of the

different samples, further shows a similarity, not only as regards this year class alone, but for composition in point of age on the whole, throughout this great area.

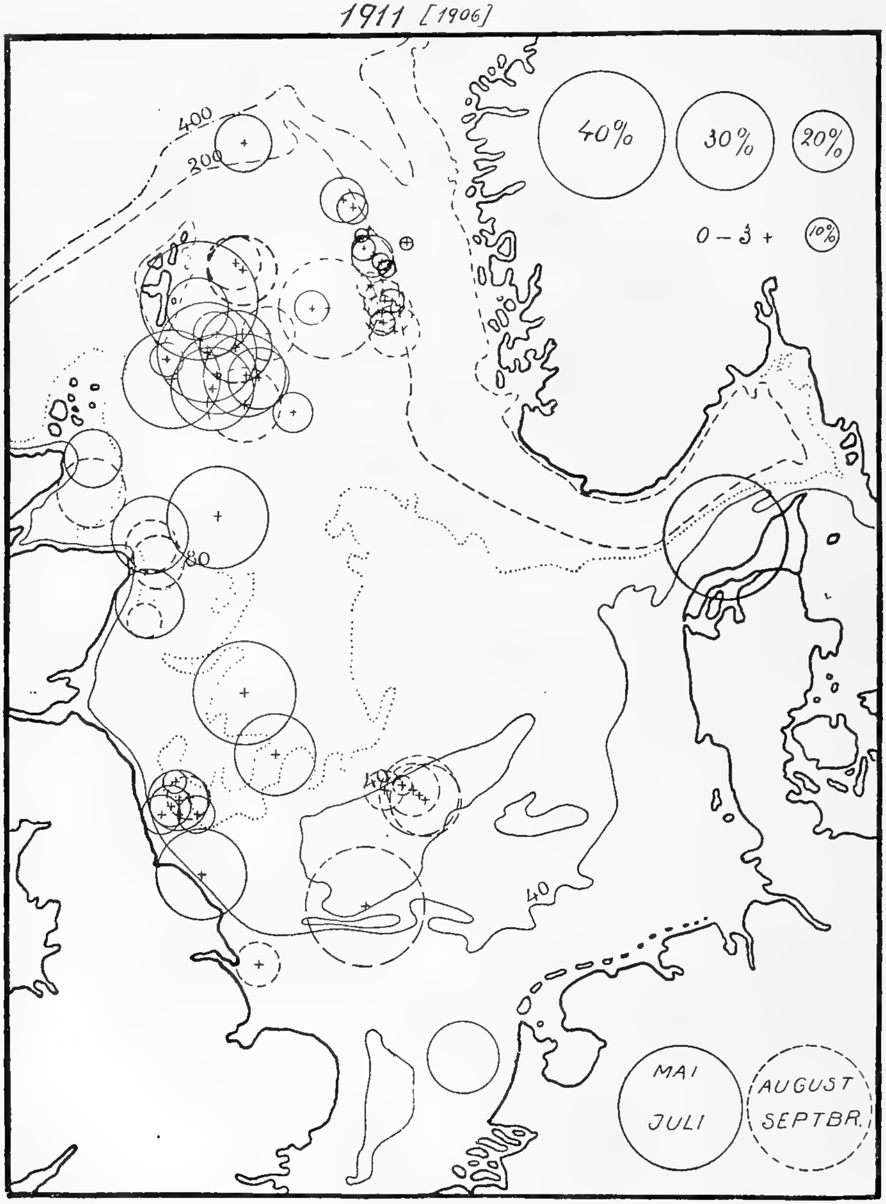

Fig. 39. Percentage of fish of 1906 year class in certain samples from the North Sea (1911).

3) That these two races, the autumn spawning North Sea herring and the spring spawning Norwegian fish thus had, in 1911, an entirely different composition in point of age, with different predominant year classes. In the case of the summer or autumn

spawning fish, however, no single year class was found to be so strongly represented as among the Norwegian herring.

1911 [1908]

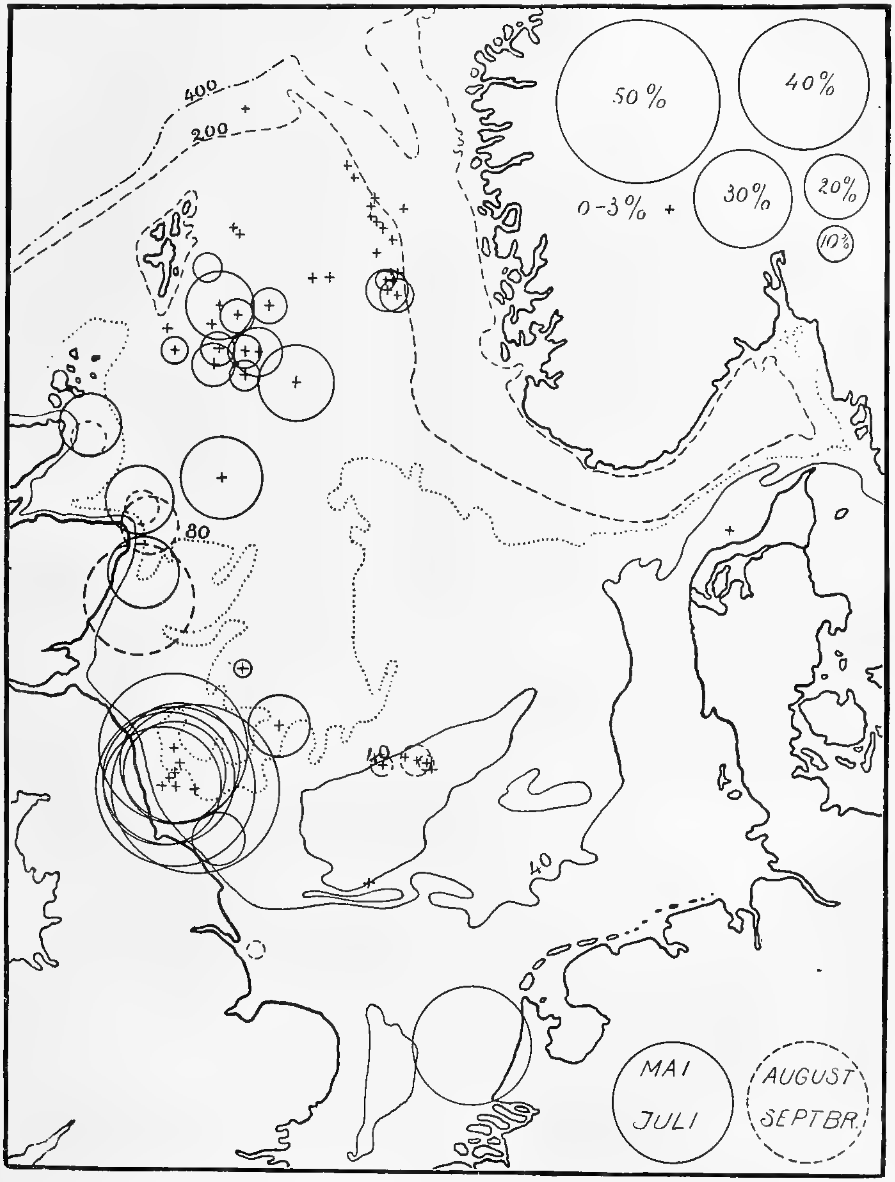

Fig. 40. Percentage of fish of 1908 year class in certain samples from the North Sea (1911).

4) That these samples also show the younger herring, year class 1908, as occurring chiefly in the southern part of the North Sea, near the coasts,

Age of Herring. Skagerak and Kattegat.

(The representation of each year class in percentages).

1910.

Samples	Year classes																Quality
	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	
Norwegian spring herring $^{20}/_{3}$	..	..	..	..	1.2	9.9	77.3	6.7	1.0	0.4	1.2	2.0	..	..	..	..	Norwegian Spring herring. (Spawning and spents, stages III to VII).
1. *Risør* $^{14}/_{1}$	..	..	..	4.8	44.5	12.5	19.4	3.4	3.4	1.9	3.4	2.8	1.9	1.6	0.6	0.3	Ca. 55 % Norwegian spring herring developing, sexual organs. (Stages III—V). Ca. 11 % fat herring. (Stage I). Ca. 34 % autumn spawners regenerating. (Stage II).
2. 22 miles NNW from *Hirtshals* $^{28}/_{7}$	..	..	66.1	32.0	1.1	0.4	..	0.2	..	..	..	..	0.2	..	..	..	97 % fat herring. (Stages I and II). 3 % autumn spawners. (Stages III—IV).
3. 9—10 miles W from *Paternoster* $^{10}/_{2}$	..	..	..	11.7	29.5	24.8	12.6	12.4	4.7	2.3	0.9	0.5	0.2	0.2	..	..	Ca. 46 % spents (autumn spawners, stages VII—II). Ca. 47 % fat herring. (Stages I—II). Ca. 7 % Norwegian spring herring. (Stages III—VI).
4. 13 miles W from *Vinga* $^{12}/_{1}$	..	..	..	10.0	21.5	23.1	14.9	11.6	7.3	4.2	3.2	2.0	0.9	1.1	0.2	..	Sample like 3, but no component of spring herring.
5. 5 miles W from *Vinga* $^{7}/_{9}$	..	..	14.8	32.8	33.2	4.4	4.4	6.5	1.7	0.4	0.4	0.9	0.4	..	..	..	Ca. 43 % fat herring. (Stages I—II). Ca. 56 % autumn spawners developing sexual organs. (Stages II—IV). 1 % spents. (Stage VII).
6. Fladen—Kobbergrunden $^{15}/_{10}$	..	..	19.7	25.3	27.5	5.3	8.1	10.1	1.3	1.3	1.0	0.5	..	..	..	..	Sample like 5, but more individuals in stages IV—VII.
7. 2 miles W from Tistlarne $^{16}/_{12}$	..	0.3	4.4	4.7	20.3	11.5	13.5	20.6	6.6	5.2	6.9	4.4	1.7	..	..	..	Mostly spents and regenerating. (Stages VII and II). Some fat herring. (Stage I).

1911.

Samples	Year-class																Quality
	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	
Norwegian spring herring	..	..	..	0.6	4.1	17.3	70.0	5.5	1.5	0.6	0.5	0.1	..	..	..	..	
8. *Langesund*, Autumn	..	16.4	75.4	7.5	..	0.3	0.3	..	..	..	..	..	..	..	..	..	Fat herring (stages I—II) and some spring herring developing sexual organs. (Stages II—IV).
9. *Jutland Bank* $^{20}/_{7}$	..	1.1	2.6	8.0	31.0	21.9	21.9	8.0	3.3	1.8	0.4	..	..	..	..	..	Autumn spawners. (Stages II—IV). Some (ca. 2½ %) fat herring in stage I.
10. 14 miles W from *Marstrand* Febr.	..	..	9.7	18.3	14.3	18.9	12.1	12.1	5.9	4.6	2.2	1.3	0.3	..	0.3	..	Fat herring (Stage I) and autumn spawners, spents and regenerating. Stages VII and II).
11. 9. miles W from *Winga* $^{4}/_{2}$	..	..	0.4	10.4	13.6	16.0	13.6	18.4	12.8	9.6	4.4	0.8	..	..	..	..	Sample like 10
12. SW fr. *Marstrand* $^{18}/_{8}$ 57°45′N.L., 11°6′E.G.	4.2	19.2	44.7	19.2	10.6	..	2.1	..	..	..	..	..	..	..	..	..	Fat herring (Stages I—II), some autumn spawners developing sexual organs. (Stages III—IV).
13. Warberg $^{31}/_{8}$	3.1	34.0	34.3	15.2	9.8	1.0	1.8	0.3	0.5	..	..	..	..	..	..	..	Sample like 12, spawners in more advanced stages.
14. Anholt $^{7}/_{10}$	..	12.7	24.0	25.7	22.8	7.7	1.7	3.1	1.4	0.5	..	..	0.3	..	..	..	Sample like 12 and 13. some (ca. 1 %) spents.

Skagerak and Kattegat.

Turning now to a consideration of the herring in the *Skagerak*, we find that the conditions are here even more complicated. We find in the Skagerak the Norwegian herring, the autumn spawning ocean herring of the North Sea Banks, local spring spawning coast herring, and also, in the Kattegat and the Belts, probably a distinct autumn spawning variety. Such complicated mixtures as may here arise are hardly to be properly sorted out in all cases save by extensive study of the race and growth. Some general features may, however, be indicated, even with the methods hitherto employed.

The table on page 70 shows the composition in point of age, and the degree of maturity of the genital organs for a number of samples taken in the years 1910 and 1911. The chart Fig. 41 shows where the samples were taken.

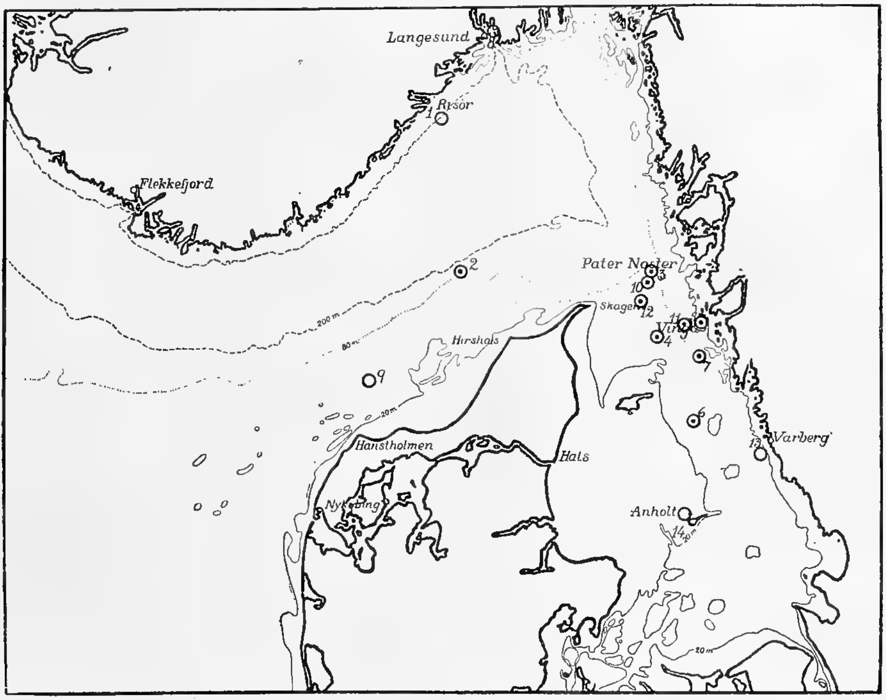

Fig. 41. Skagerak and Kattegat, showing locality of capture of the samples noted in the table on p. 70.

The Norwegian spring herring showed, as already mentioned, in 1910 and 1911, over 70 % of the 1904 year class. In the Skagerak, however, these appeared only as a more or less faint admixture among the other varieties, as for instance at Risør (sample 1) and Bohuslän (No. 3).

The autumn spawning ocean fish of the North Sea Banks, especially those spawning in the south-eastern corner of the North Sea and the Skagerak, move in the winter, as HEINCKE has shown, in to the Skagerak. Samples 3 and 4 from February and January 1910 exhibit a composition in point of age which strongly resembles that of the autumn spawning North Sea fish. The same applies to the sample from the Jutland Bank, July

1911 (No. 9). These three samples, (3, 4 and 9) thus support Heincke's theory, viz, that the Bohus herring (spents) consist in winter of fish which have spawned in the autumn in the North Sea, especially on the Jutland Bank. The samples from Bohuslän, February 1911 (10 and 11), on the other hand, reveal so strong an admixture of fat herring that the composition in point of age is thereby altered.

Autumn spawning fish are also found in the Kattegat in the autumn, samples 5, 6, 7 from 1910 and 12, 13, 14 from 1911. These fish doubtless differ considerably from the autumn herring of the North Sea, and should probably be regarded as a local race belonging chiefly to the Kattegat.

Fat herring occur, as will be seen, in considerable quantities everywhere throughout the Skagerak and Kattegat; at Risør and Langesund on the Norwegian side of the Skagerak (samples 1 and 8) on the Jutland Bank (2 and 9) and in most of the samples from Bohuslän and the Kattegat.

The samples thus confirm the idea that the Skagerak and Kattegat have a mixed stock of herring, consisting of immigrant ocean herring, both spring spawning Norwegian fish and especially autumn spawning North Sea fish; autumn spawning Kattegat herring; probably spring spawning coast herring; and, in addition, a large number of young fat herring.

The Skagerak and Kattegat form nurseries for great numbers of herring; the great fisheries, however, are based upon the large shoals of ocean fish which spawn in the autumn out in the North Sea, moving in during the winter towards the coast of Bohuslän. Similar large immigrations — of spring spawning Norwegian ocean herring — most probably take place in certain years, along the Norwegian coast of the Skagerak towards the mouth of the Christiania Fiord, and the northern part of the Bohuslän coast.

Variations in age composition from year to year.

We have hitherto only considered the age composition of the North Sea herring for a single year. It is evident, however, that a comparison of several years in this respect, as in the case of the Norwegian herring, is necessary in order to discover the characteristic regularity in the *average composition* of the stock, and in the *variations* of this composition. The international herring investigations in the North Sea are af comparatively recent date; for the years 1910—1912 however, I am in a position to state the results of the investigation of samples from the Shetland and Lowestoft districts.

Fig. 42 shows the composition in point of age of five samples from Shetland waters, viz.

1) 19 July 1910.
2) Winter 1910—1911.
3) May 1911.
4) June 1911.
5) July 1911.

The two uppermost figures for July 1910 and the following winter show a fairly equable representation of the year classes 1903, 1904 and 1905. From May 1911 to

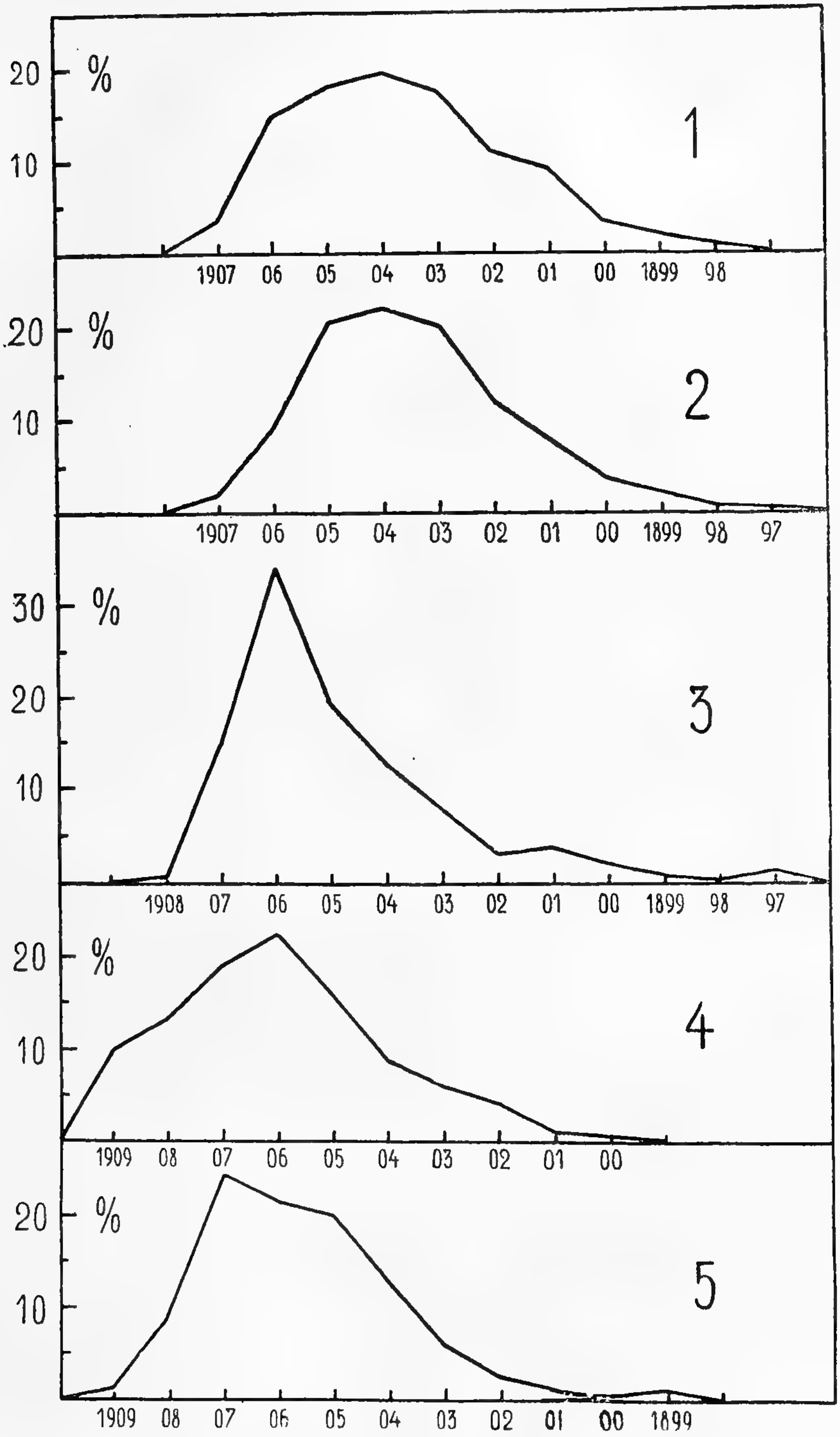

Fig. 42. Composition in point of age of herring samples from Shetlands.
1. July 1910. 2. Winter 1910—1911. 3. May 1911. 4. June 1911. 5. July 1911.

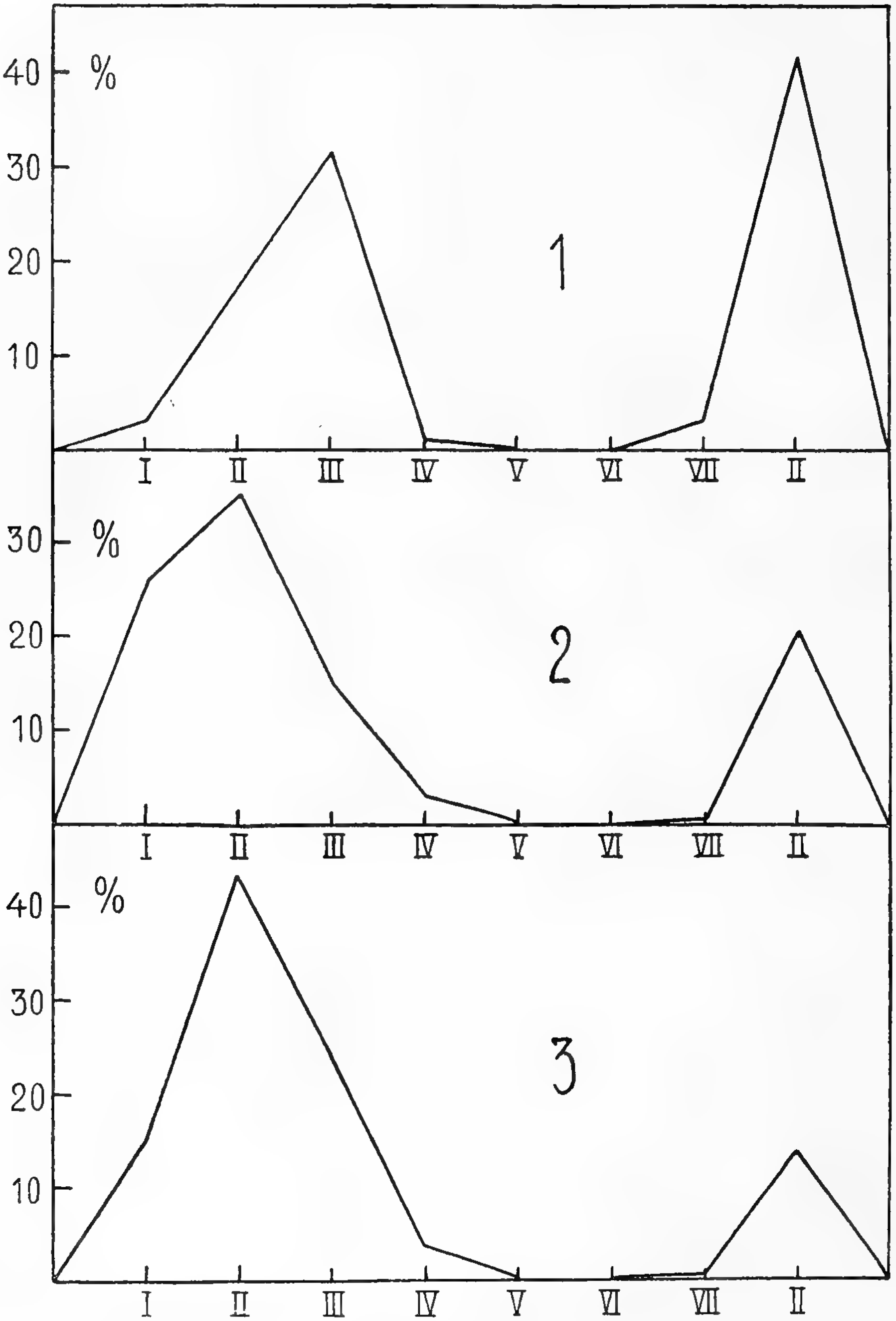

Fig. 43. Percentage of different stages of maturity in herring samples from the Shetlands, 1911.
1. May. 2. June. 3. July.
(Stage II divided into two groups: very fat (left) little fat (right). The last are spent fish).

July of the same year, a great alteration took place in the composition, May showing great quantities of fish of the 1906 year class, June and July of 1907. This can only be explained as due to an immigration of new (younger) individuals. It is therefore

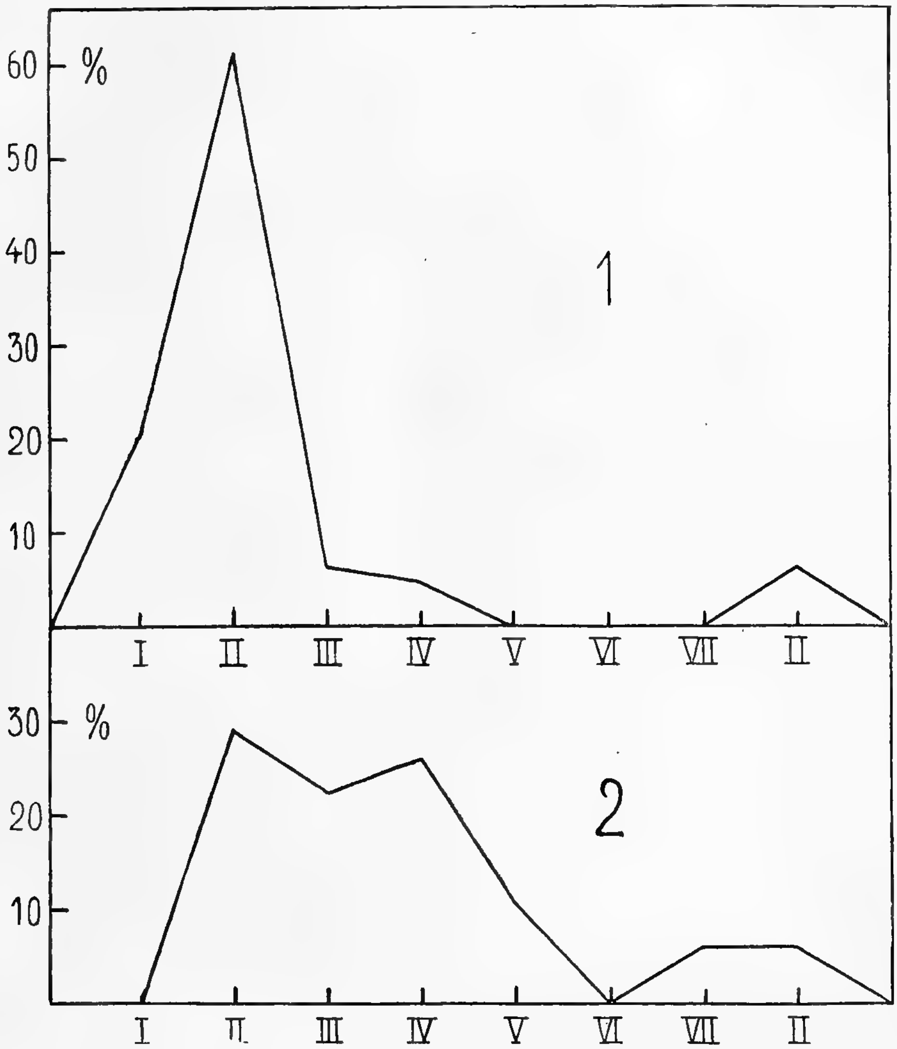

Fig. 44. Percentage of different stages of maturity in herring samples from the Shetlands, 1912.
1. June. 2. July.
Stage II, see note to preceding figure.

particularly interesting to consider the maturity of these 1911 fish: an illustration of this factor will be found in Fig. 43.

In May there was a large percentage of spent fish, as well as a large group of individuals with genitals at stage III, i. e. preparing to spawn., (called "large herring" in the Norwegian fishery). In June and July the number of the spent fish in the samples

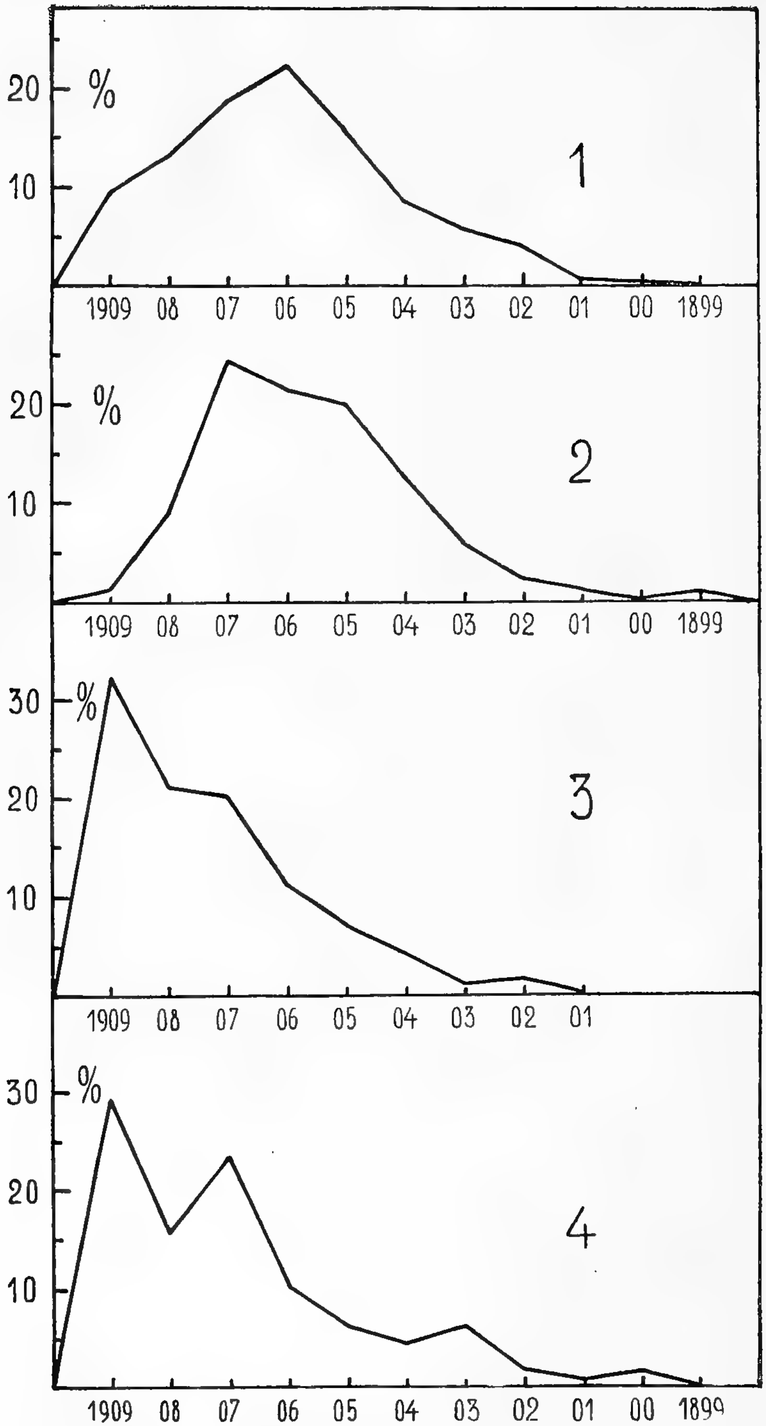

Fig. 45. Composition in point of age of 4 herring samples from the Shetlands.
1. June 1911. 2. July 1911. 3. June 1912. 4. July 1912.

decreases, that of the fat herring (Stages I and II) increasing. *The change from May to July must therefore be due to an immigration of fat herring.*

In order to discover whether this is to be regarded as a fact peculiar to the year 1911 or as a phenomenon of common occurrence, we will now compare the maturity

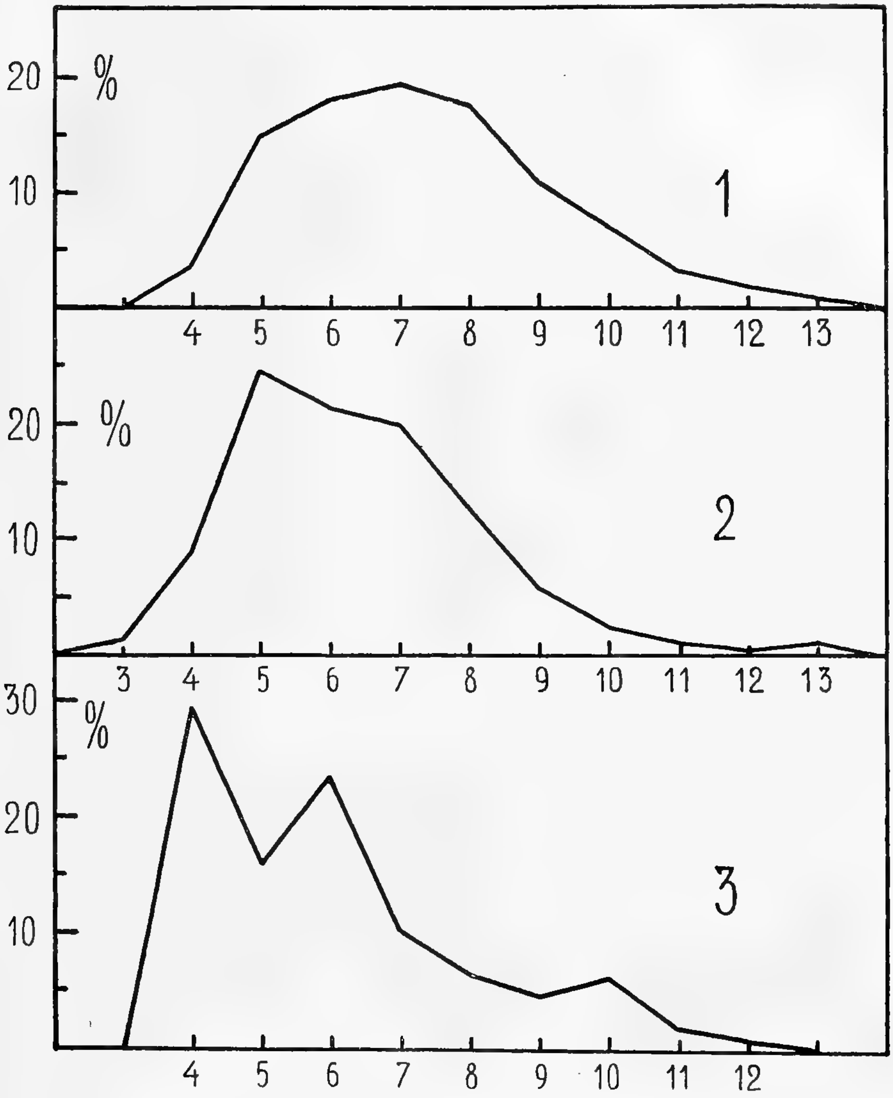

Fig. 46. Composition in point of age of three herring samples from the Shetlands.
1. July 1910. 2. July 1911. 3. July 1912.

and composition in point of age of the Shetland herring for the months of June and July in 1911 and 1912. Fig. 44 shows the maturity in June and July 1912. If we compare this with Fig. 43, we find that there was in both years a large amount of fat herring present, most in 1912. Each of the two years exhibits great similarity between the two summer months, but a comparison of the one year with the other reveals a very great difference.

We will then compare the composition in point of age for the two summer months of 1911 and 1912. (See Fig. 45). In this respect also the samples for each year agree very well together, great difference being, however, apparent between those of one year and those of the other.

In 1911, the year classes 1905, 1906 and 1907 were most strongly represented. In 1912 however, there were *comparatively* far fewer of the year classes 1905 and 1906, whereas the year classes 1907, 1908 and 1909 were very predominant. Of these again, 1907 and 1909 appear to have played the most important part, 1908 being both in 1911 and 1912 less numerously represented.

As there thus appears to be a similarity between the summer samples of the same year, we will proceed to compare the composition in point of age for the month of July in the years 1910, 1911 and 1912, considering, not the age classes, but the age of the fish. (See Fig. 46).

In these three years, 1910—1912, we find a great decrease in the average age of the herring, the older individuals being comparatively far less numerous than the younger, the four year old fish in 1911, and the three and five year olds in 1912.

Theoretically, this may be explained in two ways, either as due to the death or emigration of the older fish, or to the immigration of a large number of new, younger individuals. We have seen, from the year 1910, that the composition in point of age of the Shetland herring may be marked by large quantities of older fish, 5—7 years; it would therefore seem reasonable to suppose that in 1911 and 1912 large numbers of younger fish occurred, in particular of the 1907, 1908 and 1909 year classes.

From the Lowestoft district, we have analyses of three samples from the years 1910—1912, the 1910 sample taken in October, those for 1911 and 1912 in November. The following tables show the degree of maturity of the fish in these samples, and the degree of fatness; it will be noticed that in all three cases, the samples consisted almost exclusively of grown fish, with genital organs highly developed, and little or no fat.

Lowestoft herring: percentage of fish at different stages of maturity.

Stage of developement of genital organs	I	II	III	IV	V	VI	VII	Stage II, with no or little fat
17. X. 1910	..	..	..	3.9	96.1	..	..	..
13. XI. 1911	0.2	1.0	0.2	35.6	59.4	..	..	3.6
14. XI. 1912	2.0	1.4	3.7	29.8	52.2	0.4	8.2	2.3

Lowestoft herring: percentage of fish at different degrees of fatness.

Quantity of fat	Very fat	Moderately fat	Slightly fat	No fat
17. X. 1910	..	..	1.2	98.8
13. XI. 1911	1.2	3.2	7.0	88.8
14. XI. 1912	1.5	4.9	6.5	87.1

We have thus to deal with fish approaching maturity, and about to spawn in the near future. The composition with regard to age will be seen from Fig. 47. In 1910, the majority of the fish belonged to the year classes 1907—1905, some however, being still older, from 1905 and 1904. In 1911, the 1908 year class is predominant, as is also the case in 1912. *We thus find here, as in the case of the Shetland samples, a great difference in the composition with regard to age between the years 1910 and 1911. In 1911 and 1912, the herring shoals were mainly composed of great quantities of young fish of recent year classes, especially those of 1908 and 1909.* Other samples from northern waters (Tynemouth) exhibit a similar numerical predominance of the 1909 year class.

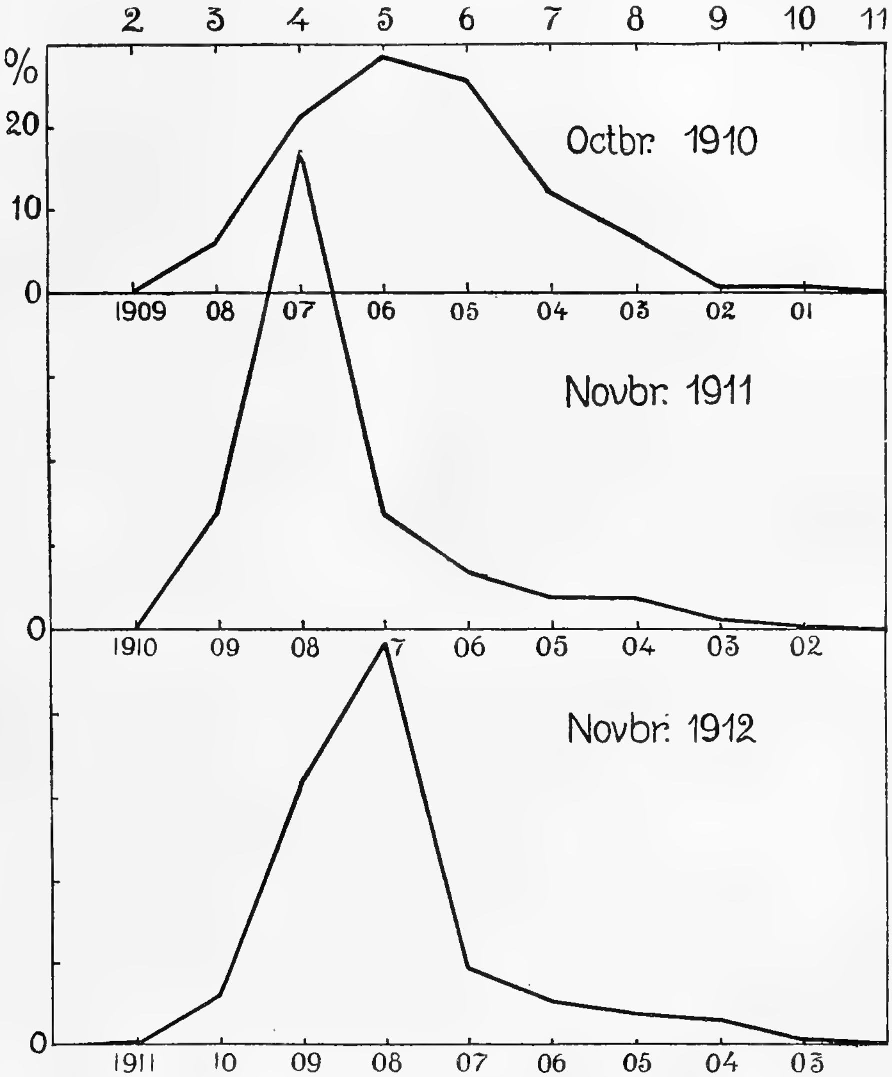

Fig. 47. Composition in point of age of three samples of herring from Lowestoft, taken in the autumn of 1910, 1911 and 1912 respectively.

If we now endeavour to make a comparison with the results of the fishery statistics, we notice the interesting fact that these years, 1911 and 1912 (as well as 1913) showed an unusually rich yield in the fishery off the coasts of Great Britain. (See Fig. 48, drawn from the statements of the English fishery statistics). The supposition that the year classes 1907, 1908 and 1909, especially that of 1908, should have been particularly rich in the case of the Lowestoft material, is thus also confirmed by the results of the fishery.

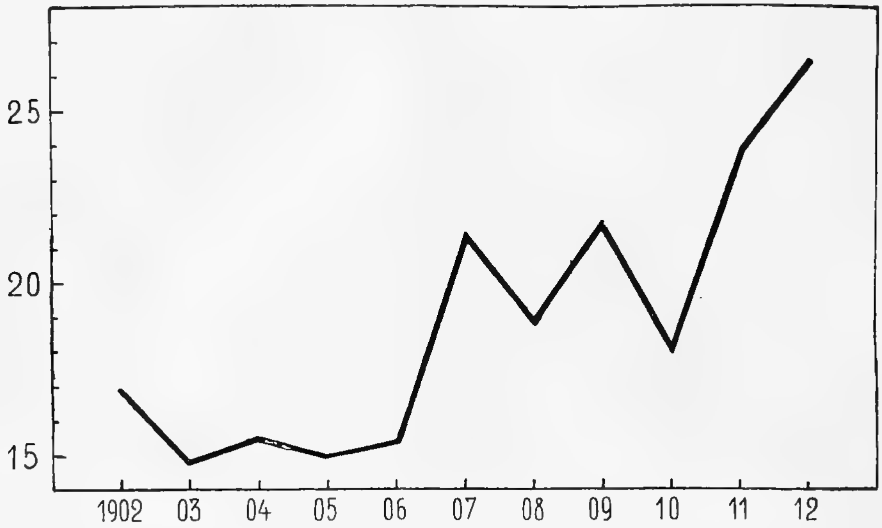

Fig. 48. Landings of North Sea herring on the East Coast of England for the years 1902—1912. In millions of kg.

Occurrence of the rich year classes concurrent with rich yield in the fisheries (in 1911 and 1912).

It would appear legitimate, from the foregoing, to draw the following conclusions:

The Shetland stock contains a large admixture of fat herring, herring with genitals maturing, and partly spent fish.

The fat herring immigrate into these waters in the summer, causing an alteration in the composition with regard to age.

Spring samples (May—June) hardly furnish any accurate basis for conclusions as to the composition of the stock in summer.

Future investigations should be directed towards a study of the seasonal variations, immigration and emigration.

In spite of the necessity of extensive investigations, the material at hand would yet appear to indicate a basis for determination of the composition in point of age for the single year. Thus we found that there was a distinct difference in this respect between the years 1910, 1911 and 1912, this being occasioned by a great immigration of young fish in 1911 and 1912. This appearance of new year classes on the fishing grounds seems to have coincided with the increase noted in the fishery yield.

A more detailed description of the whole of the available material as to composition in point of age, and quality, of the North Sea hauls will shortly be published by Mr. Paul Bjerkan.

If we compare these results with the composition in point of age of the Norwegian race of herring, we find this similarity, that both races exhibit some remarkably rich year classes, not however, in both cases from the same year. There is probably also this point of difference, that the richness of these year classes is more pronounced in the case of the Norwegian race than in that of the North Sea fish. The fluctuations in the herring fishery of the North Sea are therefore slighter than in that of the Norwegian waters.

This is, however, a point for future investigations to further examine and test.

CHAPTER III

The cod, its spawning, migrations and size.

Geographical distribution of the Gadoid species.

Of all the fish which live and move upon the sea floor, (bottom fish) the Gadoid species are the most important from the point of view of the fishing industry. The present writer has, in an earlier paper*), compiled a survey, based upon the international statistics, of the yield in all the countries of northern Europe within the whole expanse of water from the Barents Sea to the coasts of Portugal and Morocco, for the year 1906. The total yield of bottom fish for the whole of the great area embraced amounted in this year to 973,484 tons, of which no less than 81 % belonged to the cod family, next in point of importance being the flatfish (Pleuronectidae) with 11 %. The respective yields of the remaining genera were comparitively small. Of the Gadoids again, the most important is the cod, as will be seen from the following table.

Cod	44.1 %
Coalfish	3.3 »
Haddock	25.0 »
Pollack	0.1 »
Whiting	2.4 »
Hake	2.2 »
Ling	2.9 »
Tusk	1.0 »

These percentages apply, as already mentioned, to the whole of the region from the Barents Sea to Morocco. If we compare the various waters therein included, we find, from the statements of the statistics, that the importance of these species differs greatly in the different waters. This will be seen from the following table, showing the

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*) John Murray and Johan Hjort, The Depths of the Ocean. Chap. VIII. Fishes from the Sea Bottom, pp. 441—442.

proportion of each of the most important species to the whole yield of each separate water.

	Cod	Coalfish	Haddock	Ling	Tusk	Hake
	%	%	%	%	%	%
Barents Sea	29.4	...	17.7	...	...	...
Norway N. of Stat	81.1	6.0	2.9	3.1	2.9	...
Iceland	59.6	3.9	20.8	2.4	0.1	...
Faeroes	47.7	3.0	29.9	2.2	0.7	...
North Sea	18.8	1.3	45.1	2.5	0.3	0.5
N. W. of Great Britain	19.7	9.5	23.6	9.7	0.7	2.6
S. W. - — —	4.4	0.6	5.4	3.1	...	31.7
Bay of Biscay	...	...	0.8	0.7	...	65.2
Portugal and Morocco	...	...	4.1	0.5	...	41.0
All waters	44.1	3.3	25.0	2.9	1.0	2.2

According to this table, there is no region in which the cod plays so great a part as in the Norwegian coastal water. This single species here amounts to over 80 % of all bottom fish taken. In Iceland and Faeroe waters also, the cod is an extremely important item; in the North Sea, the percentage falls below 20 %, while west of Great Britain it decreases rapidly to nil. South-west of Great Britain lies the southern limit of distribution of the cod. Considerable similarity in this latter respect is exhibited by the coalfish, ling and tusk, which, like the cod itself, are pre-eminently Norwegian Sea fish.

The haddock is of most importance in the North Sea, where it furnishes something approaching half of the total yield in bottom fish; it is found, however, in great quantities farther north, especially in the Barents Sea. The fact that it is not caught in quantities in Norwegian waters is due, as I have endeavoured to show in the work above mentioned, partly to the nature of the bottom, and partly to trade considerations.

The hake is a more southerly form, being met with first in the North Sea, and occurring in greatest numbers in the warmer water of the Atlantic coast of Europe.

This peculiar distribution of the different species would seem to coincide with a certain constant difference in the temperature of the water; in evidence of this may be adduced the fact that the fish on the eastern and western sides of the Atlantic live under corresponding conditions in this respect. From the chart, Fig. 1, it will be seen, that the line of 10° C. at 100 metres depth may be drawn on the eastern side off the south-west coast of Ireland, whereas on the American side it goes much farther south. The area of most frequent occurrence of the cod falls between the 6° and 8° isotherms, the prevailing temperature off the coasts of southern Iceland, at the Faroes, on the Newfoundland Banks, and off the coasts of the northern states of America.

The American statistics give the following catches of cod, haddock, and coalfish, in 1906 (in cwts.):

	Cod	Haddock	Coalfish
Northern States	40.000	21.000	7.900
Central —	1.400	200	50
Southern —	0	0	0

It would thus appear that a similar regularity prevails in the distribution of these species on the western to that noted on the eastern side of the Atlantic.

Norwegian Cod Fisheries.

The Norwegian fishery statistics distinguish between the catches of two kinds of cod; the "skrei" or mature cod, and "cod other than skrei". Both groups vary greatly in size, and in their relation one to another, as will easily be seen from the following table for the years 1908 and 1911. The skrei are noted as for number of fish, the other group in kg.

District	Skrei (no. of fish)		Cod other than skrei (kg.)	
	1908	1911	1908	1911
Skagerak........	10 000	15 300	1 086 300	1 811 760
West Coast......	1 240 000	1 152 700	1 585 883	1 234 505
Romsdal.........	8 326 500	6 708 000	654 850	572 918
Trøndelagen......	4 074 500	4 505 600	1 609 036	982 540
Nordland........	16 947 700	18 259 600	3 366 989	4 047 184
Tromsø..........	2 027 300	1 188 600	1 468 000	915 090
Finmarken.......	2 183 100	1 432 800	44 067 015	98 652 036
In all...	34 809 100	33 262 600	53 833 564	108 216 033

The two largest skrei districts are, as will be seen, Romsdal and Nordland. South of Romsdal the catch is as a rule but small; now and again, however, (as in 1913) large quantities may exceptionally be taken farther south, towards Bergen. North of the Nordland district again, the skrei fishery also decreases, which fact is not so clearly shown in the above table, the figures for Finmarken including under skrei the cod taken in winter, of which in reality only a part are actually mature (*vide infra*). The group "cod other than skrei" embraces several different elements. In the fiords of the Skagerak coast, small sized cod are taken all the year round. In the winter, mature cod are also taken; these are, however, not included in the statistics as skrei, partly owing to the peculiar nature of the fishery and partly to the small size of the fish. Large cod are taken in summer and autumn by deep sea fishing boats from Romsdal, working out on the banks. This branch of the fishery furnishes the greater part of the catch entered for this district as "cod other than skrei". The same applies more or less to all the northern districts, including Tromsø; cod of different sizes are, however, also taken among the islands and in the fiords.

The northernmost district, Finmarken, shows a dominating majority of the group "cod other than skrei"; in 1908 over 80 %, in 1911 over 90 %. The Finmark fish, as will be seen later on, vary greatly in size.

The skrei are, as already mentioned, noted according to number of fish, the remainder in kg. As the sizes in both groups vary greatly, it is extremely difficult to arrive at any comparison between them, in point of quantity. Taking the average weight of the skrei as 2.7 kg. (gutted weight) as has long been the custom in the statistics, we find that the yield of this group in 1908 far exceeded that of the other cod, whereas in 1911 a far greater quantity of other cod were taken than of skrei. This at once suggests the existence of far-reaching natural conditions, which may well be regarded as exercising an important influence on the fluctuations of the industry.

Fig. 49.

The skrei fisheries.

Of the various cod fisheries, the skrei fishing is the oldest and most important, extending as far back as the history of the country, while the developement of the fishing industry has affected this branch more than any other. In the course of centuries therefore, a great amount of experience has been gained as to the skrei and its spawning. During the long period of time when no charts were in existence (down to about the beginning of the 19th century) the whole skrei fishery was based upon ancient tradition indicating certain fixed grounds, the locality of which was marked by the so-called "med". This was a particular point at sea, determined by cross-bearings on land, as a rule from small islands or rocks, to the inland heights in the background. The individual fisherman's knowledge of such localities would naturally be very limited, and the fishery restricted to small areas. The difficulty was moreover further increased by the extreme irregularity of the depth, the sea floor, like the land adjoning, exhibiting a formation of alternating ridges and valleys. If we examine the accompanying chart of one of the most important skrei districts, from Lofoten to Tromsø, we find a series of quite small banks, divided by deep channels.

Fig. 49 shows six such banks, marked I—VI, where skrei fishing has, at certain times, at least, been carried on. On these grounds, the cod assemble in spawning time in dense shoals concentrated within a very small area, and it is thus natural that the general idea of certain spawning places should have existed from very ancient times.

Old skrei grounds.

Prof. Amund Helland has collected information as to the old "med" or skrei grounds, obtaining the same from men having local knowledge of the spots in their immediate district. From Romsdal he obtained bearings of 158 such grounds; from one man 6, from others 10, 12, 33, up to as many as 50. By the courtesy of Prof. Helland I have been enabled to publish, in a former work, a chart indicating the position of some of these; several will be found marked on Fig. 50.

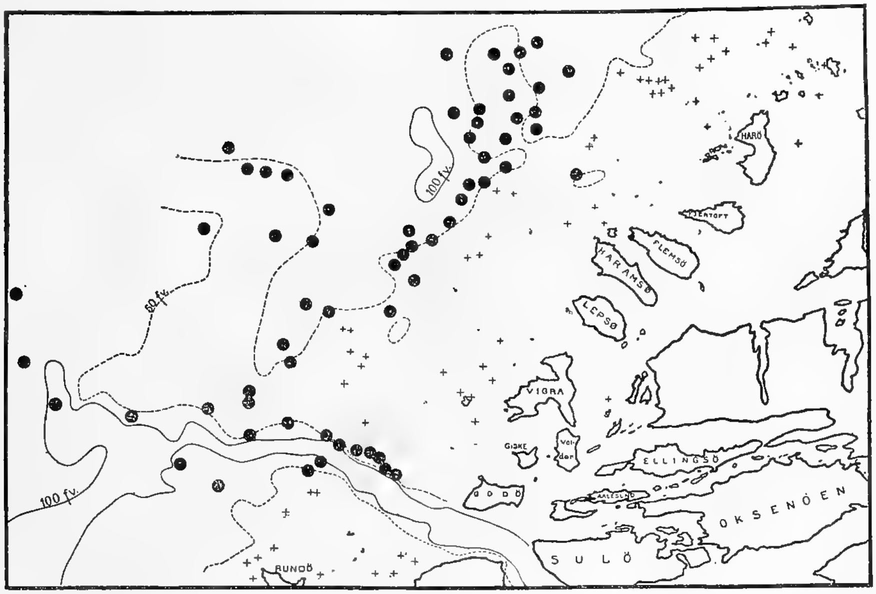

Fig. 50. Old skrei grounds outside Søndmør. From information collected by A. Helland.

If we compare the position of these fishing grounds with the depth curves, we find that they follow more or less closely the 50 fathom line, which may be said to roughly indicate the skrei grounds all along the northern range of coast from Stat to Finmarken. Fishing may, however, be carried on now in deeper, now in shallower water, from the shore to over 100 fathoms.

Distribution of the floating eggs.

During a cruise to the skrei banks in the northern Norwegian waters in 1901, I noticed that the floating eggs of the cod were confined to a distinctly limited area of occurrence. They were found immediately over the small skrei banks, whereas in the channels between, scarcely any eggs were observed. By towing a silk net of 1 metre diameter for some minutes at the surface of the water, I found at the spots marked I II, III and VI in Fig. 49, thousands of eggs, whereas in the deep channel between the banks, and in the sea outside, few or none were found.

Similar investigations were made in 1906 from the "Michael Sars" on the Romsdal banks. Dr. Damas, who treated the material obtained, has noted the catches made on the chart shown in Fig. 51. Here also the occurrence of eggs in any quantity is restricted to very small areas; some few miles away, the figures are very low. If we compare the occurrence of the eggs with the depth curves, we find that the large quantities were observed along the 50 fathom line, so that a great similarity will be noticed between Fig. 50 and Fig. 51, the one showing the position of the skrei grounds according to the old tradition current among the fishermen, the other indicating the actual occurrence of recently spawned eggs.

Fig. 51. No. of fish eggs, (chiefly cod) taken during the skrei season (March—April) 1907, at the surface of the water, by horizontal hauls of 5 min. duration with a net of 1 metre diameter (Damas).

Some doubt has arisen in certain quarters as to the value of these results. The German scientist Hensen*) even goes so far as to doubt whether definite spawning grounds can be said to exist at all, being of opinion that the fish spawn promiscuously wherever they happen to be, and that nothing in the nature of spawning migration ever takes place, nor any assembly of the fish in certain spots for the purposes of spawning. It is easy to understand the formulation of such a theory in the case of investigators dealing with waters having more or less level bottom and no very prominent banks;

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*) Das Leben im Ocean nach Zählungen seiner Bewohner. Erg. d. Plankton-Exp. Bd. V. 1911.

an investigation of the Norwegian waters would, however, in all probability have led to a revision of opinion. The investigators could scarcely entertain any doubt as to the efficacy of the method employed in the Norwegian investigations for collection of eggs, viz. the towing of silk nets at the surface of the water. In the Norwegian waters, where, as we have seen, the difference in the quantity of eggs on the banks, as compared with the water above the deeper parts, is so exceptionally marked, even this simple method is sufficiently efficacious for the purpose. The object of the Norwegian egg investigations was to determine where the eggs were to be found; not to ascertain the exact numbers in which they occurred. A fully *quantitative* investigation would naturally be a far greater and more difficult task, and Hensen and other investigators are doubtless right in opining that such can only be carried out by means of vertical hauls, made from the bottom to the surface in such a manner as to search the whole mass of water between.

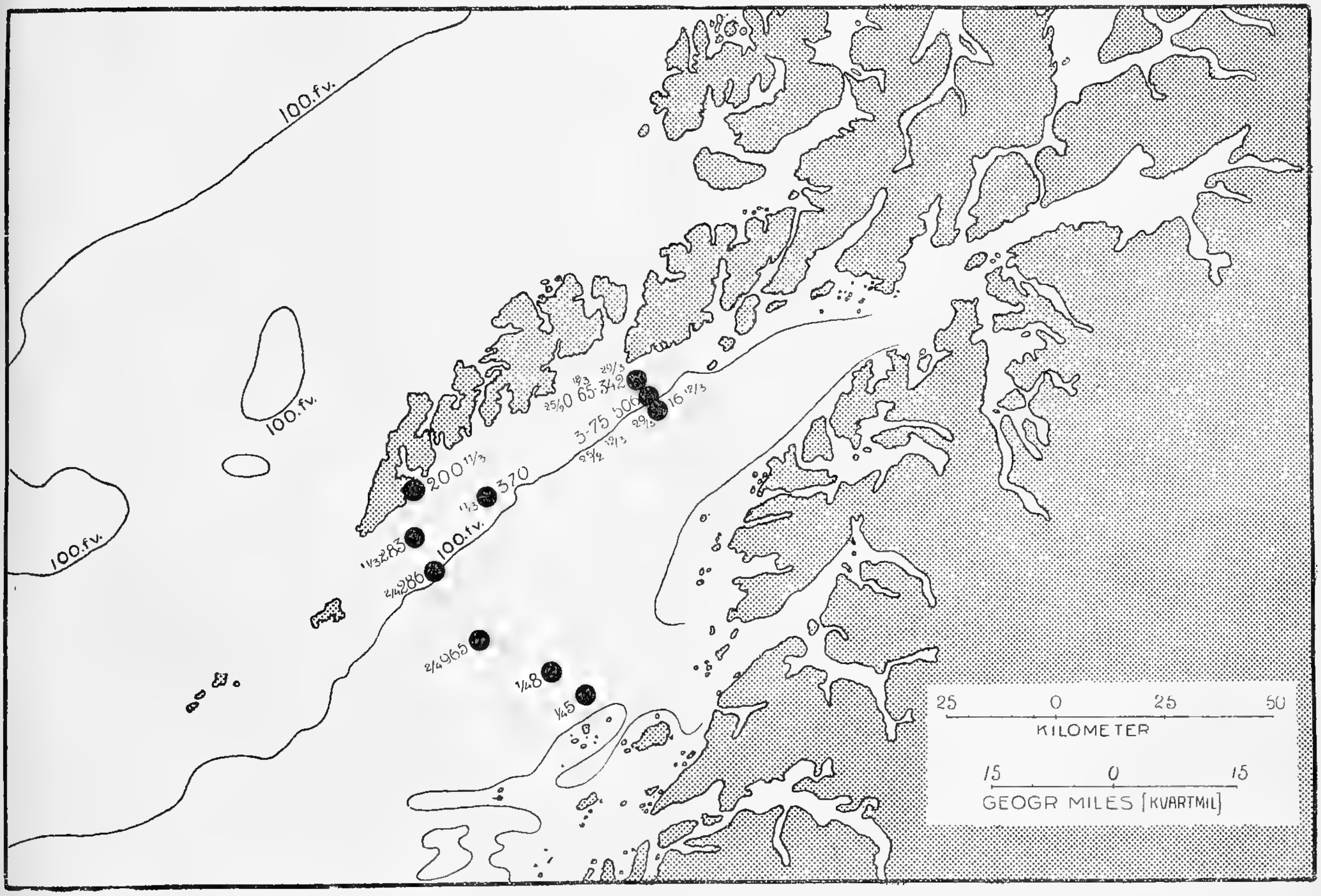

Fig. 52. No. of fish eggs (chiefly cod) pr. sq. metre surface, taken by vertical hauls during the period from 25. Feb.—2. April 1913. Dates indicated in the figure.

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Egg investigations off Lofoten, in 1913.

Having occasion to again investigate the occurrence of eggs on the Lofoten banks, I made a series of hauls, not only in the manner described by Hensen, but also, in part, with the net constructed by him. The catches, which consisted almost exclusively of cod eggs, were counted, and the number of eggs per square metre surface calculated. Several cruises were made, the same spots being investigated several times. A number of the results obtained will be found in Figs. 52 and 53. Fig. 52 shows the hauls from 25th February to 2nd April, Fig. 53 those made later in April. The date and number of eggs are noted for each station. The first vertical hauls were made from East Lofoten, from Henningsvær out over the bank to the edge (100 fathom line) on the 25th February. No eggs, or only very few (3) were found in these hauls (Fig. 52). During the first half of March the number of eggs from East Lofoten increased somewhat, (65, 75) more, however, being found on the western side, where hauls made on the 11th March

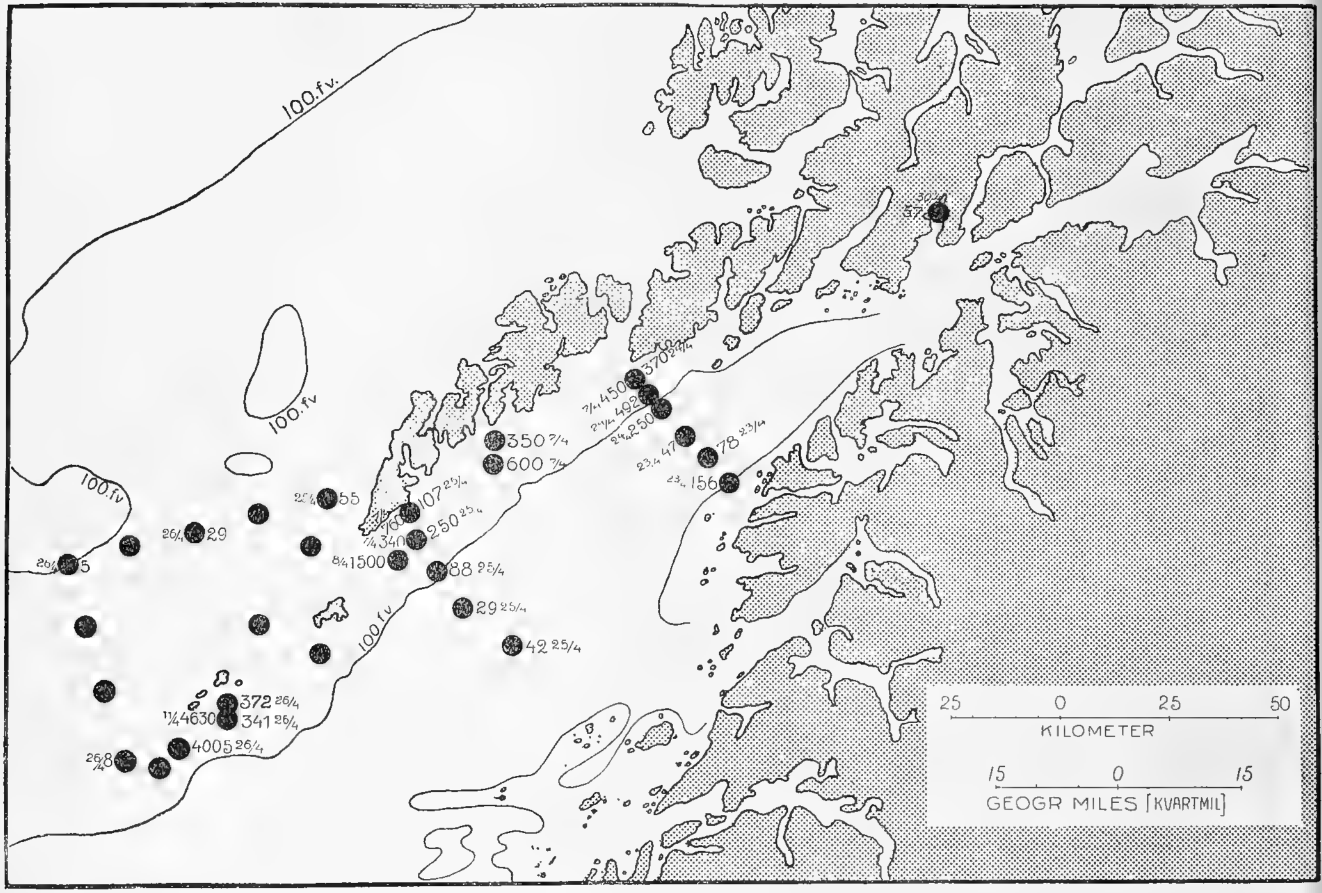

Fig. 53. No. of fish eggs, (chiefly cod) pr. sq. metre surface taken by vertical hauls in April 1913. Dates indicated in the figure.

showed between 200 and 400 eggs per haul. In the latter part of April, the catches near the edge from East Lofoten amounted to over 500.

In April, eggs were found on the eastern Lofoten bank to the number of 4—500 per square metre surface, while farther to the west, the occurrence was in places very considerable, thus off Lofotodden, 1,500 eggs. The greatest catches were made at Røst, where at one place, on the 11th April, 4,630 eggs per sq. m. surface were found.

It will be noticed that the occurrence is here extremely irregular. On the 26th April, 4,005 eggs per sq. m. were taken at a single haul at one station south-south-west of Røst, while some few miles away only 8 eggs were found. This would certainly appear to confirm the theory as to the existence of certain limited spawning grounds, which theory was moreover, still further supported by observation of the fishery. On the occasion of the investigations at Røst on the 11th April, the number of implements set out in the sea immediately adjacent was so great that it appeared impossible to make a vertical haul on the fishing ground itself. In order to avoid damaging the fishermen's gear, we were obliged to make our vertical haul at a distance of a mile from the small area where the mass of fishermen were at work. The results of these investigations therefore confirm, in a very high degree, the conclusion previously arrived at, viz., that the shoals of cod and their newly spawned eggs are, during and immediatly after spawning time, restricted to small areas. These areas lie, as we have seen, exclusively inside the banks, that is, between the land and the 100 fathom limit. Of all the hauls made in deeper water, out in the middle of Vestfjorden, only one can show any large number of eggs, viz, that of the 2nd April, (Fig. 52) where they amounted to 965 per sq. m. of surface. This occurrence in such numbers here I can only explain as due to the eggs having been carried out from the bank by the current.

Another distinct example of eggs drifting with the current may also be mentioned (Fig. 53). On the 11th of April, the number of eggs per sq. m. taken near Røst was 4,630, whereas on the 26th of April, at the same place, it was only 341. The fishery had in the meantime shifted some miles in a south-westerly direction, to where the figure shows 4,005 eggs, and it must be supposed that the great quantity of eggs had during this period become distributed over a larger area. On both days, however, (the 11th and 26th April) the eggs were found in great quantities exactly at those spots where the most intense fishery was in progress. Indeed, as regards the Lofoten fishery as a whole, it may be said that the greater quantity of eggs found in the western part of the fiord as compared with the occurrence in the eastern waters coincides with the fact that the fishery during this year was richer in the former than in the latter.

International investigations as to the spawning places of the cod.

The results of the first investigations (in 1901) as to the restricted occurrence of the cod eggs naturally led to the conclusion that the eggs might serve as a basis for determining the position of the spawning shoals. I therefore, in the year immediately following, suggested to the International Council that endeavours should be made to chart, upon a co-operative basis, the whole spawning area in northern European waters, the method of proceeding being to note the spot in which newly spawned cod eggs were found. This proposal, which was supported in particular by Heincke and Hoek, led to the undertaking of very extensive investigations, in which the Danish, Dutch, German and Norwegian vessels especially took part, the results being subsequently published in an exhaustive report, containing also excellent papers by Dr. Damas and Dr. Joh. Schmidt*).

The results of this important work are of great interest in many respects, and will doubtless serve as the basis for future consideration of the stock and its fluctuations. They show, first of all, that the spawning grounds of the cod are everywhere restricted to the banks near the coast . (*Vide* chart Fig. 54, which gives a survey of the spawning grounds of the cod in northern European waters). We have seen from the statistics,

Fig. 54. Spawning region of the cod *(Gadus callarias)*. The broken line gives the extreme western limits of the area in which pelagic fry have been found off the coast of Norway.
L = Littoral Bottom Stages. B = Bottom Stage of the 0-group.

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*) Rapport sur les travaux de la Commission A.
Rapports et Procès-Verbaux, Vol. X, Copenhagen 1909.

that the catches of large cod cease near the south-west coast of Ireland; this coast also marks the limit of occurrence of the newly spawned eggs. Round the coasts of Great Britain and in the North Sea, the cod spawn chiefly at depths between 20 and 80 metres; nowhere, however, were so great quantities of eggs encountered as in the Norwegian Sea. In Iceland waters, the spawning is, according to the excellent Danish investigations, restricted to the south and west coasts; at the Faroes, it takes place all round the islands.

On the Norwegian coast of the Norwegian Sea. it would appear that there exists one unbroken range of spawning grounds as far as Sørø in the western part of Finmarken. East of this island, or east of its western coast, the cod spawn only in small numbers, as is clearly shown, both by the results of the egg investigations and also by the statements of the statistics with regard to the quantity of roe taken by the fishery, which ceases at Sørø. We have thus here reached the northern limit of the cod spawning grounds. I had occasion to notice this fact during my cruise in 1901, and recognising the importance of the question, I understook a cruise during the present year off the coast of Finmarken, where I made numerous hauls. These gave precisely the same result as in 1901, showing the spawning to be very slight. Only a very few eggs were taken in the hauls, and in conversation with local merchants I learned that only a few barrels of roe had been salted during the winter from the large quantities of fish obtained east of Sørø.

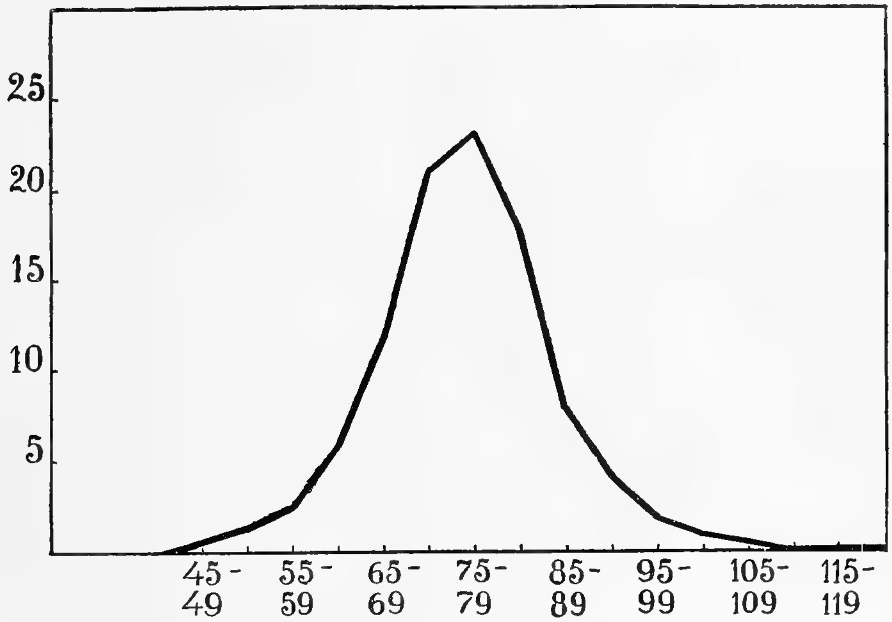

Fig. 55. Percentage of the different size groups (5 cm. groups) among 19,790 skrei measured in different years.

Size of the skrei.

As regards the size of the skrei, investigations have been made by measurement of large samples from 1902, 1903, 1905, 1906, 1907 and 1913. During some of these years, samples were collected from different places along the coast, with the object of obtaining material for comparison of the growth of the cod in different parts of the coastal waters. It will here, however, suffice to mention the samples from and including Lofoten to the north.

In all the samples taken, the fish were measured from snout to tip of tail, correctly to the nearest cm. (75.5—76.4 = 76 cm). The sizes in each sample are arranged in groups for each 5 cm., thus the lengths from 60—64 cm. form one group. In all the following tables and figures, the number of individuals falling to each group is stated as a percentage of the total number of fish in the sample.

During the six mentioned years, the total number of skrei measured was 19,790; a quantity which should suffice to give some prospect of obtaining, by comparison of the measurements as a whole, a view of the limits of size of the skrei and the average or normal composition in this respect. A graphical representation has therefore been given (Fig. 55) of the numerical values of the different size groups (in percentages) in all the samples, taken together as one. (See also the following table, last line).

Skrei. Percentage of 5-cm. groups.

	Under 50	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	105—109	110—114	115—119	Over 120	Average length
1902	0.1	0.7	2.8	10.9	17.3	21.2	18.4	13.3	7.0	4.9	1.6	0.8	1.2	..	..	..	74.9
1903	0.7	2.3	5.7	13.6	19.1	25.2	13.5	10.1	4.8	2.6	1.6	0.7	0.2	..	..	..	71.8
1905	1.2	3.8	3.8	4.4	17.1	27.9	17.7	12.7	4.4	3.8	1.9	1.3	..	..	..	..	73.5
1906	..	..	..	..	2.8	20.4	41.2	23.7	7.3	2.8	1.2	0.4	..	..	..	..	79.2
1907	..	0.05	0.05	0.5	1.6	10.6	26.6	34.4	18.0	6.6	1.1	0.2	0.3	..	..	..	81.1
1913	0.5	0.4	1.2	5.3	14.3	21.5	22.3	13.9	7.0	4.5	3.9	2.6	1.6	0.6	0.2	0.2	77.6
All years..	0.5	1.2	2.3	5.8	12.0	21.1	23.3	18.0	8.1	4.2	1.9	1.0	0.6	0.1	0.03	0.03	76.4

It will be seen that the lowest limit size for skrei falls about the 50—54 group, the highest at 100—104 cm. Both smaller and larger (up to even 140 cm) fish are known; beyond the limits named, however no single 5 cm. group amounts to even 1 % of the whole. The following figures will give an idea of the distribution of the sizes.

Under 65 cm.	Between 65 and 84 cm.	Over 85 cm.
9.8 %	74.4 %	16 %

Nearly three quarters of the whole number of individuals are thus found to fall between the sizes of 65 and 84 cm., one tenth being under 65 and one sixth over 84 cm. The highest single percentage is that of the 75—79 cm. group (23.3 %) and *the average size for the whole number is 76.4 cm.*

Comparison of various skrei samples.

A comparison of the different samples from one and the same year is of great importance as a test of the reliability of our method. We have a number of good samples from 1913, measured partly by Mr. Oscar Sund, partly by Capt. Rönnestad, and partly by the present writer. These include material from East and West Lofoten, and from Røst. Figs. 56—59 give a graphical representation of the composition of each of the samples, these percentages being arranged for each of the three areas of the Vestfjord, while in a special figure the averages for the three areas are compared. With the exception of three (small) samples from Svolvær and Østnesfjord, all these samples compare very well together, as do also the average sizes for the samples. The three mentioned samples from Østnesfjord and Svolvær all included large fish, the averages being 81.3, 84.2, and 84 cm. The averages for all the others were considerably lower, as will be seen from the following.

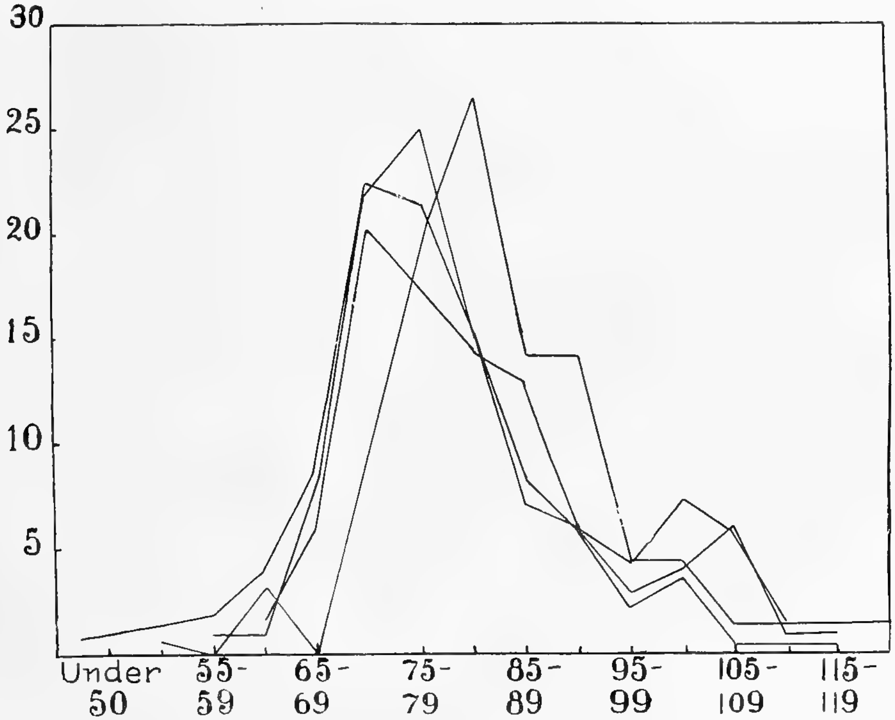

Fig. 56. Composition in point of size of 4 samples of skrei from East Lofoten, measured during the skrei season in 1913.

East Lofoten (Henningsvær) 76.8.
West Lofoten, (Reine, Sørvaagen, Moskenes) 75.7, 74.2, 76.4, 76.1, 76.5.
Røst, 77.0, 77.5, 75.8.

The greatest difference between the averages is that between 74.2 and 77.5, or 3.3 cm. The average of all those samples was 76.2, the variation in the different samples being slight; (+ 0.2, + 0.3 + 0.6 + 0.8 and + 1.3 cm.: ÷ 0.1, ÷ 0.4, ÷ 0.5, ÷ 2.0 cm.). Thus it must be agreed that the samples for the whole range from Henningsvær to Røst exhibit great similarity, and we are probably justified in regarding the three samples from Høla and Østnesfiord as exceptions, the more so, as the Lofoten reports frequently make mention of the fact that the fishery here is generally distinguished by the especially great quantity of large fish. This is more noticeable in some years than in others. Among the years considered, 1903 presents features of particular interest. We will therefore examine the measurements for this year, and especially those from the three localities investigated, viz. Svendsgrunden (the bank marked II in the chart Fig. 49). Røst, and Vestfjorden (West Lofoten). Fig. 60 gives an idea of the size of the skrei at these places in 1903; it will at once be noticed that there is a great difference between the three samples. In that from Svendsgrunden, the majority of the fish are under 70 cm., and almost the whole of the sample falls below the figure stated above as the average size, viz. 76.4 cm. The sample from Røst is larger than the Svendsgrunden sample, but smaller than that from Lofoten; all three, however, exhibit an average below the normal, the figures being 66.1, 72.8 and 74.2 cm. Comparing these, we may say that roughly speaking, the number of small fish increases from Vestfjorden out towards Røst, and still more farther out towards the northern bank. I may here observe that I shall attempt, in the following, to explain this as due to a great immigration in this year of small fish from the most northerly waters joining the skrei shoals and that the difference between the samples therefore was greater in 1903 than is usually the case.

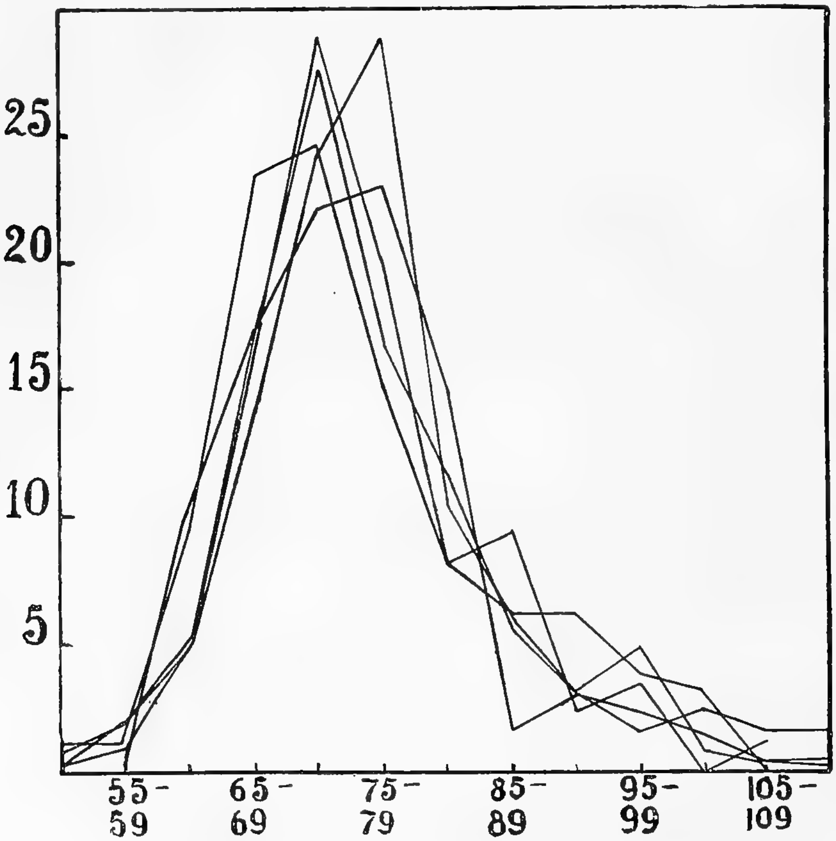

Fig. 57. Composition in point of size of 5 samples of skrei from West Lofoten, measured during the skrei season in 1913.

From these results it would seem, in my opinion, that it should be possible to form an accurate view of the stock of skrei in a more restricted area; in the case of more extended regions, however, the composition in point of size may — in any case in some years — exhibit considerable variations. It is evident that it will be necessary in the future to investigate the stock of skrei at different localities in order to ascertain how the size varies from one place to another; only by means of such investigations, pursued throughout a considerable period of time, will it be possible to determine with any great degree of accuracy, the size of the stock in separate years. Until this has been done, all observations will of necessity be of a provisional character, and limited value. It is however, a point of great interest to examine how great the differences have been between the various years, according to the material at present available. I have therefore shown, in the table on p. 92 and in Fig. 61, the results of all the measurements, taking all the samples for each separate year as one. Finally, the table also shows the averages for all samples, referred to above, (see last line, and Fig. 55). A comparison of the different years reveals great differences in several respects. The average size for all fish measured was, in 1903, 71.8 cm., as against 81.1 in 1907. The fact that the difference in the average sizes (for all samples) for two separate years can amount to between 9 and 10 cm. is of the utmost importance, when

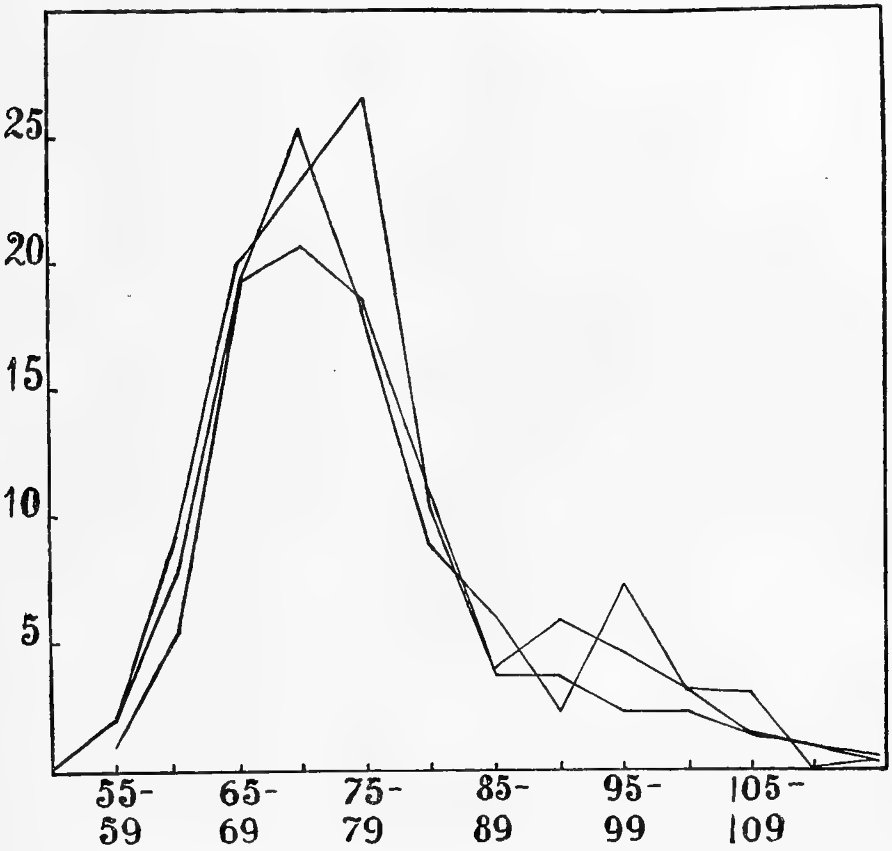

Fig. 58. Composition in point of size of 3 samples of skrei from Røst, measured during the skrei season in 1913.

we remember that three quarters of the whole stock of skrei lie within a size field of only 20 cm. in extent. In 1913, the averages both for the whole sample and for the separate groups approach very nearly the average for all years. In 1902, 1903 and 1905, the size of the skrei was below, in 1906 and 1907 above the average. The individual groups likewise exhibit great variation from year to year. Thus the group 65—69 cm. was represented in 1903 by 19.1 %, in 1907 only 1.6 %. In 1906 and 1907, the total number of individuals under 70 cm. was less than 3 %, in 1902 over 30, and in 1903 over 40 %. A glance at the figure will show, that the years 1902, 1903, 1905 and 1913 have their majority to the left, 1906 and 1907 to the right of the central group, 75—79 cm., within which the average for all years together is situate. In 1902 and 1903 the individuals are widely distributed throughout a number of groups, whereas in 1906 and 1907 we find them highly concentrated about a few groups, with especially high percentages, and some greatly dominating sizes.

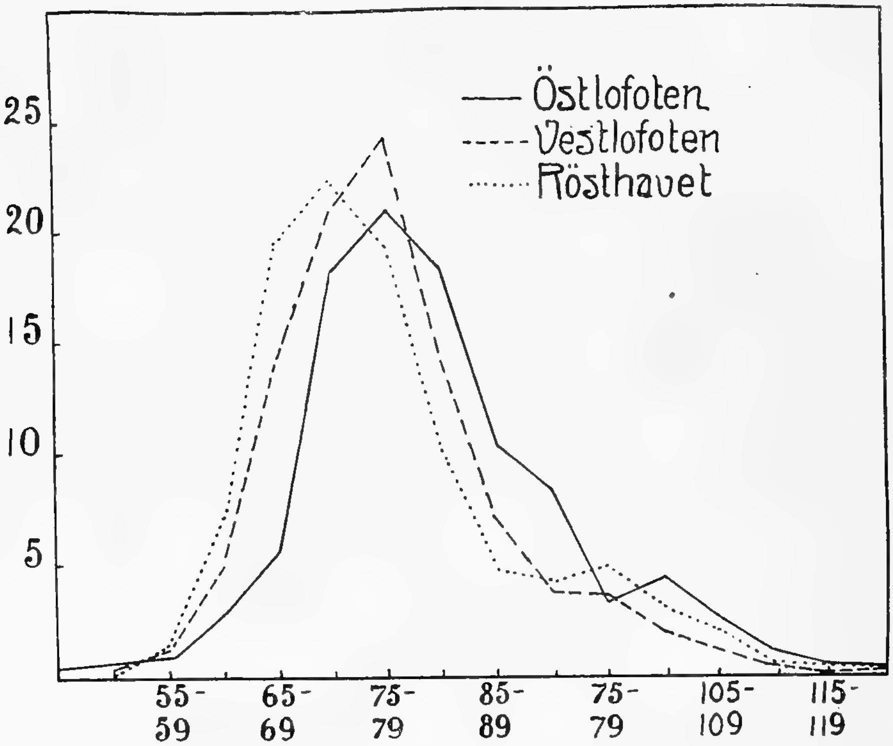

Fig. 59. Average composition in point of size of all samples from the three districts in 1913.

Throughout the whole of the period 1902—1913, there seems to have been some definite process at work; a regular movement of the centre of size. Thus we find that from 1902 to 1903 the size decreases, the average falling from 74.9 to 71.8. An increase is then apparent, from 1903 to 1907, the average rising from 71.8 to 81.1, and finally, from 1907 to 1913, again a decrease. We shall in the following frequently have occasion to refer to these very important fluctuations in the size of the skrei.

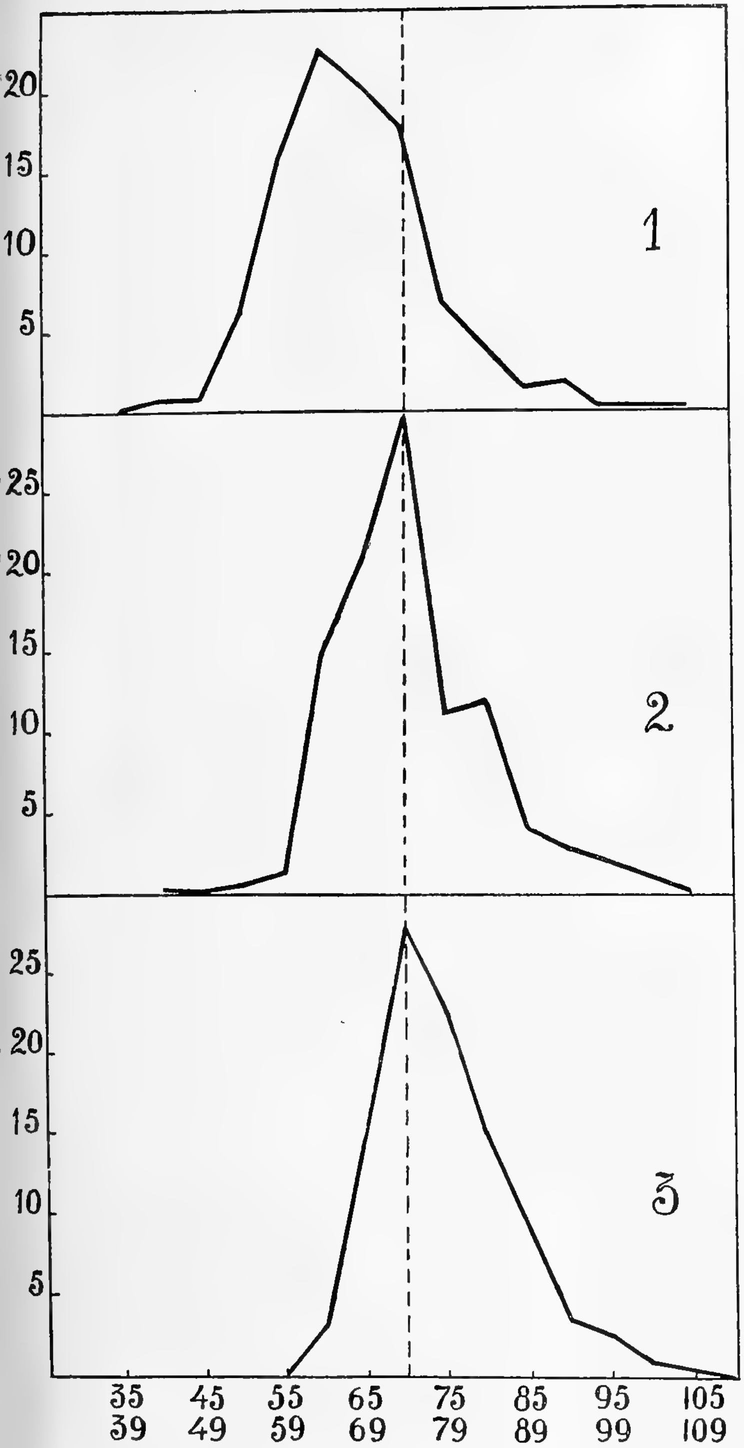

Fig. 60. Composition in point of size of skrei samples, all from March 1903.
1. Svendsgrunden. 2. Røst. 3. West Lofoten.

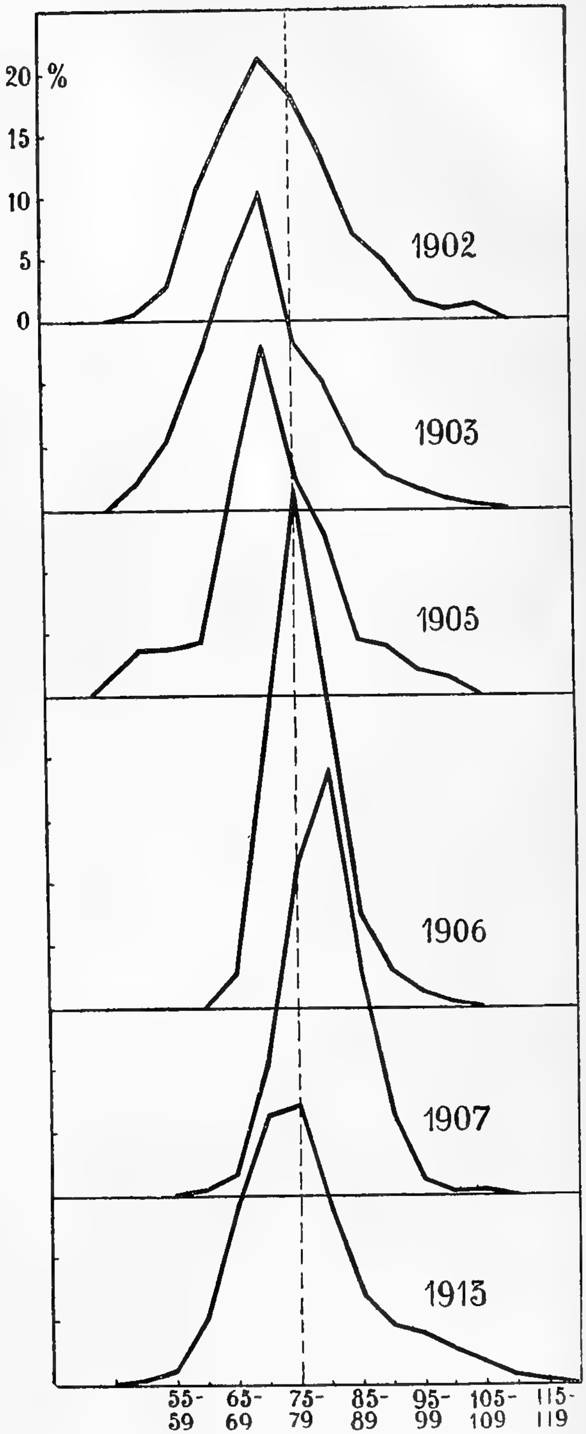

Fig. 61. Average composition in point of size of skrei samples from different years. (For corresponding figures, see table p. 92).

Migrations of the skrei.

The skrei do not as a rule appear on the spawning banks until the end of January or some time in February; by the end of April they have disappeared. If long-lines or other implements are set out on these banks outside the recognised season, as for instance, in summer, a single cod or so may now and then be taken, but no more. It is thus natural that discussion should from ancient times have been rife as to whence the cod come and whither they go. Scientific fishery investigations have also endeavoured in various ways to furnish some solution of the question, and I will here briefly refer to some of the facts which have been ascertained. First of all, the marking experiments carried out during the present year. During my preparations for these experiments and in the course of the work itself, I received valuable assistance from Mr. Oscar Sund, Capt. Thor Iversen and Capt. P. Rönnestad. The difficulty of the task had been apparent from the first, and no previous marking experiments had thus been carried out with regard to large spawning skrei, although, as will be seen later on, something had been done in this respect in the case of younger stages of cod. The difficulty lay in the fact that the skrei on the northern grounds often keep to deep water, 100 fathoms or more, and may thus easily die when brought to the surface. A well boat was therefore employed, in which the fish could be kept until their vitality was beyond doubt. The mark used consisted of double silver buttons, with a pin of silver wire, and was fixed to one of the bones of the gill cover, (Fig. 62) bored for the purpose with a sharp tool. The whole process of marking lasted less than one minute for each fish. One of the greatest incidental difficulties was the necessity of fishing from the well boat, in order that the fish might at once be placed in the well, and it was frequently no easy matter to fish in company with the dories and other boats on the fishing grounds. In the Lofoten waters, the fish were found at from 60 to 120, chiefly perhaps 80—90 fathoms depth; off the coast of Finmarken between 40—140, and here also most frequently at 80—90 fathoms.

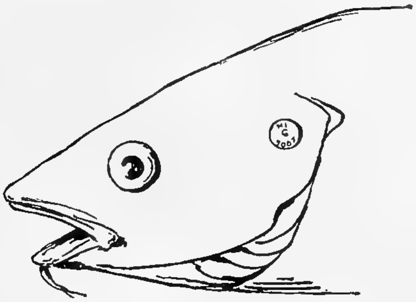

Fig. 62. Head of cod, with mark.

In all, 70,400 hooks were set in the Lofoten water, 5,234 cod being taken, of which, however, only 2,400 were considered fit to be marked.

Off the coast of Finmarken 91,400 hooks were set, 5,451 fish taken, and 1,955 marked.

The total number of cod marked was thus 4,355. Up to time of writing, November 1913, about 400 — or 9.2 % — have been recaptured.

The table on p. 99 gives a survey of the composition in point of size of:

1) All skrei measured at Lofoten 1913, in all 3,616.
2) All skrei marked at Lofoten.
3) All marked skrei recaptured at Lofoten.
4) All cod marked off the coast of Finmarken.
5) All recaptured cod from Finmarken.

It will first of all be noticed that the marked fish, both from Lofoten and Finmarken, are, in point of size, very near the average of all the measurements made at Lofoten

Samples				Percentage for each 5 cm. group															
		No. of fish	Average length in cm.	Under 50	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	105—109	110—114	115—119	Over 119
Lofoten March—April	All 12 samples...	3616	77.6	0.5	0.4	1.2	5.3	14.3	21.2	22.3	13.0	7.0	4.5	4.0	2.6	1.6	0.6	0.2	0.2
	Total marked...	2400	76.8	0.7	0.5	1.6	5.2	16.0	22.7	22.4	12.6	6.5	3.9	3.7	2.2	1.2	0.4	0.2	0.2
	Total recaptured	279	77.3	1.1	..	0.7	3.9	12.2	22.2	26.5	16.4	6.8	3.6	3.6	1.1	1.1	0.4	0.4	..
Finmarken May—June	Total marked...	1955	73.4	0.9	2.9	4.9	10.4	17.5	20.5	18.5	9.2	7.0	4.0	2.0	0.9	0.9	0.3	0.1	0.05
	Total recaptured	121	77.1	..	1.7	1.7	6.6	8.3	23.1	20.7	10.7	10.7	8.3	4.1	2.5	0.8	..	0.8	..

in 1913. It must therefore be presumed that the marked fish were in this respect representative of the Lofoten skrei in that year. It is also probable that the marked cod from Finmarken corresponded very closely in size to the actual stock present in those waters in May and early June 1913. As we have seen, the Finmark fish agree very closely in size with the Lofoten stock this year, so much so, that they must be presumed to form part of the same stock, a theory which is further supported by other facts.

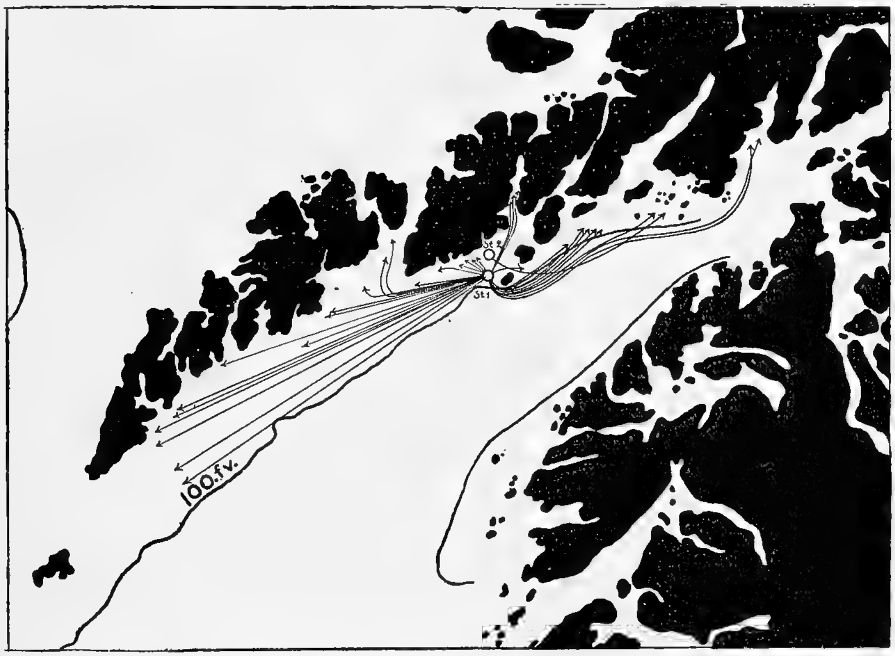

Fig. 63. Movements of 31 out of 100 skrei marked on 1st March 1913, being the number recaptured up to 16th April.

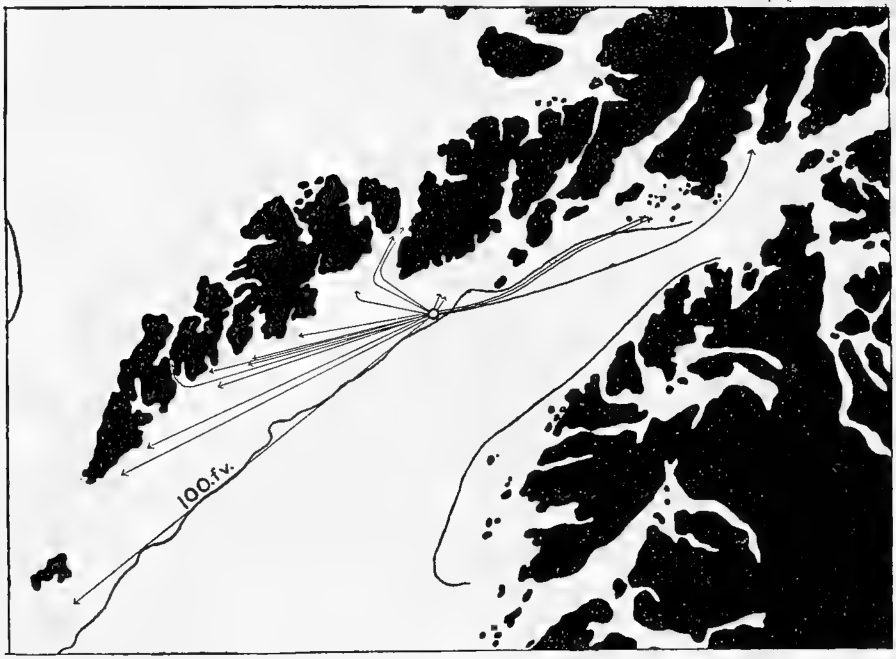

Fig. 64. Movements of 17 out of 63 skrei marked on 17th March, being the number recaptured up to 21st April.

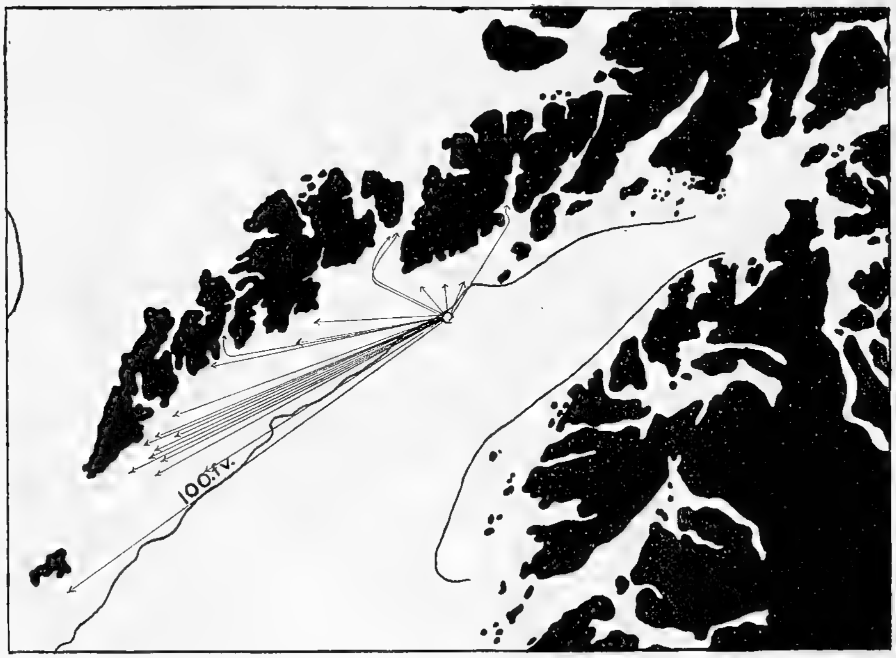

Fig. 65. Movements of 22 out of 86 skrei marked on the 17th March, being the number subsequently recaptured.

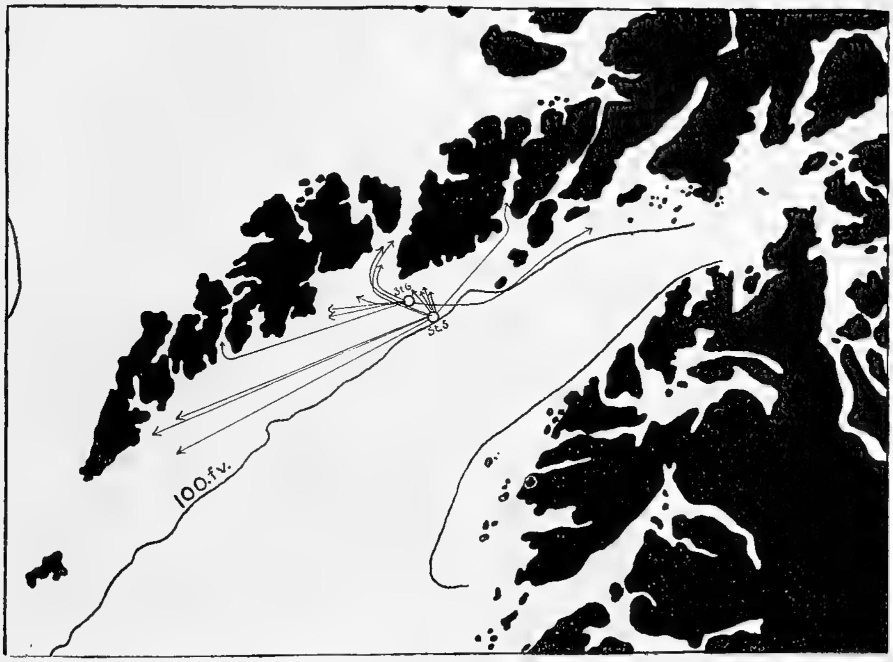

Fig. 66. Movements of 16 out of 72 skrei marked at two spots on the 17th March, being the number recaptured in April.

Fig. 67. Movements of 94 out of 508 skrei marked on the 1st April, of which 90 recaptured in April, 3 in May, and 1 in June.

It is very interesting to note how closely the recaptured fish agree, as regards their composition in point of size, with those set free. The average size of the fish set free at Lofoten was 76.8, that of the fish recaptured 77.3 cm., the average of all fish measured being 77.6. As regards Finmarken, the average size of the freed fish was 73.4, of those recaptured 77.1 cm. There is a slight tendency towards a higher proportion of recaptures among the larger fish than among the smaller; taken on the whole, however, the similarity in point of size between the fish set free and those recaptured, appears remarkably great. From this it may safely be concluded that the present material should be able to furnish some information as to the natural history of the cod.

Fig. 68. Movements of 71 out of 460 skrei marked on the 1st April, of which 67 recaptured in April, 3 in May, and 1 in July.

The marking experiments were commenced in East Lofoten on the 1st March, when 100 skrei were returned to the water, part at one place and part at another (Fig. 63). The figure shows how these fish have spread eastward and westward over the Lofoten bank; east to Kanstadfjorden and west to Moskenes. Of these 100 fish, 23 were recaptured as early as March; up to the 16th April inclusive, 31 had been retaken, since then however, no more have come to hand.

On the 17th March, 63 fish were set free off Henningsvær, of which 17 were recaptured by 21st April inclusive, none since (Fig. 64). On the same date, 86 fish were set free at the edge of the bank, of which 21 had been retaken by the end of April, one being found later, on the 20th of July, in Østnesfjorden (Fig. 65). On the same date, also, at two other stations, (Fig. 66) 47 and 25, of which 16 recaptured in April.

On the 1st of April, 508 fish were set free on the bank outside Reine, of which 90 were recaptured during the same month, three in May, and one in June (Fig. 67). On the same date, 460 fish were set free at the edge of the bank outside Reine, of which 67 were retaken in April, three in May and one in July; 71 in all (Fig. 68).

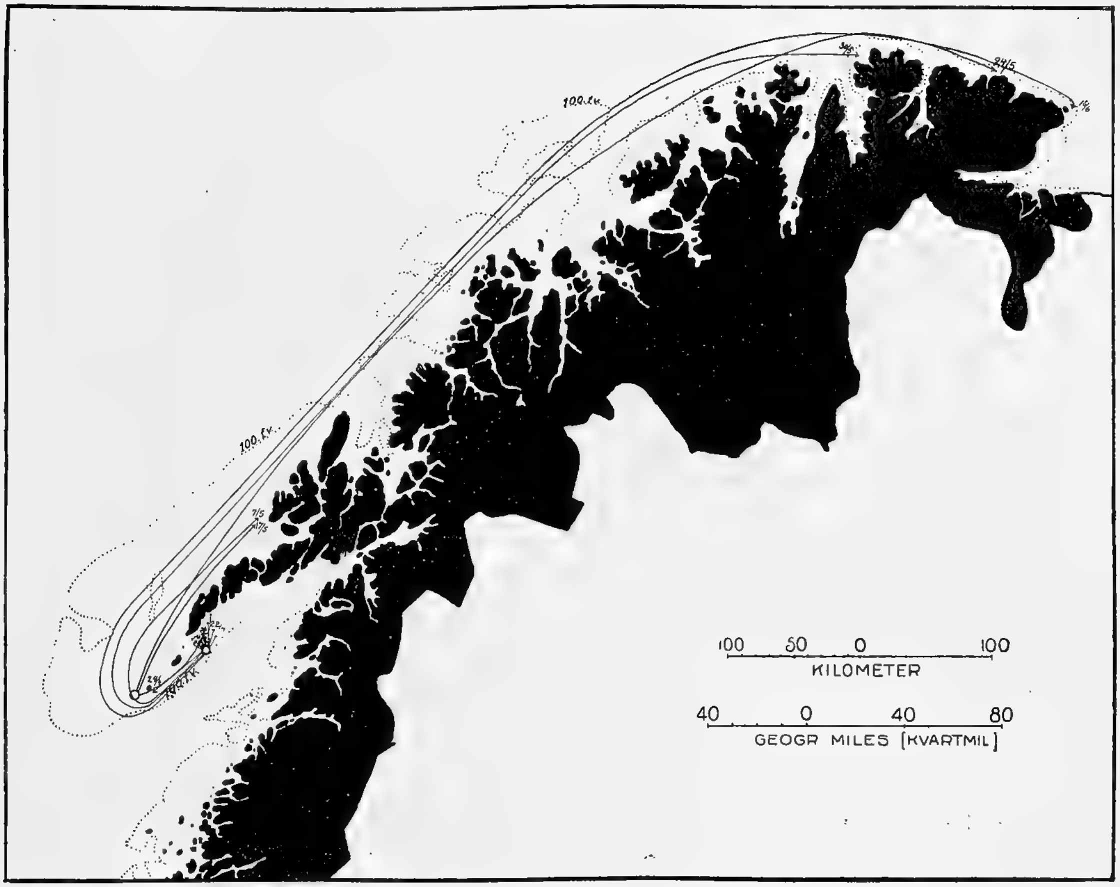

Fig. 69. Examples of long migrations made by grown cod marked at Lofoten (Moskenes, Røst) end of April 1913, and recaptured off the Finmark coast end of May or early June the same year. Dates of marking and recapture indicated.

On the 8th April, 378 fish were set free off Moskenes, of which the following were recaptured (Fig. 69).

Lofoten, April, 20 fish.
Lofoten, May, 3 fish.
Vesteraalen, May, 1 fish.
Finmarken (Skjötningsberghavet) 30 May, 1 fish.
Finmarken (Vardø) 16 June, 1 fish; in all, 26 fish.

On the 18th and 28th April, 733 fish in all were set free off Røst, of which the following were recaptured (Fig. 69).

Off Reine (Lofoten) 1 fish, (22 April).
Vesteraalen 1 » (17 May).
Finmarken (Baadsfjord) 1 fish (24 May).

Percentage of fish recaptured.

We will first of all consider the numbers of the fish set free and recaptured, as shown in the following table.

Date	Place	No. of fish marked	No. of fish recaptured	% of marked fish recaptured	
1 March	Høla off Svolvær	100	31	31	East Lofoten 26.8 %
17 —	Bank, Henningsvær	63	17	27	
17 —	Edge of bank, —	86	22	26	
17 —	Bank, —	72	16	22	
1 April	Bank, Reine	508	94	18.5	West Lofoten 14.1 %
1 —	Edge of bank, Reine	460	70	15.2	
8 —	Moskenes	378	26	7	
18, 28 —	Røsthavet	733	3	0.4	
March—April		2400	279	11.6	

For *East Lofoten*, the percentage of skrei recaptured varies, as will be seen, from 22 to 31, averaging 26.8 %. *More than every fourth fish was here recaptured.*

For *West Lofoten*, the percentage of recaptures off Reine was between 15 and 18½; average of all three samples 14.1 %, or *about every seventh fish.* From Røst, only 0.4 % were recaptured, the percentage of *all recaptures* being thus reduced to 11.6 %.

In comparing these percentages for the different parts of the Lofoten waters, however, it must be borne in mind that the experiments were not all carried out simultaneously. The East Lofoten fish were set free in March, those from West Lofoten during the first half of April, and those from Røst in the latter part of that month. The fishing season was thus farther advanced when the western fish were marked and freed, their chances of escape being thus proportionally increased. The Røst markings were carried out during the last few days of the fishing season, so that the probability of recapture was here particularly slight. In considering the percentage of recaptures, it is also necessary to remember that in all probability, not all the fish recaptured were reported to the authorities. In several cases, the silver mark was first discovered on the dried head. Moreover, a number of the marked fish may have died in the meantime. Inasmuch as it is possible, therefore, to draw any conclusions from the number of fish recaptured, we may probably accept the results of the experiments along the range from Høla to Reine during the period from 1st March to 1st April, according to which, *every fourth or fifth specimen was recaptured.*

Migrations.

If we then proceed to consider the information at hand with regard to the movements of the fish, we find, especially from the East Lofoten experiments, that the fish spread eastward and westward over the bank. Starting from Høla in East Lofoten, some have moved to Moskenes, others to Kanstadsfjorden on the east, and similarly also from Henningsvær. From here a number also moved to Værø and Røst. In the western Lofoten waters, the fishery was particularly intense about the beginning of

April, and most of the fish were taken on the spot; we have, however, instances of some specimens having gone as far as Værø and Røst, to Vesteraalen and Finmarken. And from Røst, some of the fish moved to West Lofoten, to Vesteraalen, and Finmarken.

The most interesting cases are unquestionably those of the three specimens which had made their way to Finmarken. Two of these were set free at Moskenes on the 8th of April, and retaken, one in Skjøtningsberghavet on the 30th of May, the other near Vardø, (off Hornøen) on the 16th of June. The third was set free at Røst on the 18th of April, and retaken on the 24th of May near Baadsfjord in the eastern part of Finmarken. The lengths of these three fish were 89, 95 and 102 cm. We have thus entirely reliable proof that the skrei *can*, in the course of 5—6 weeks, cover the distance from Lofoten to East Finmarken, a journey of between 800 and 900 km.

Comparative size of skrei and Finmark fish in 1913.

The further investigations carried out in 1913 show, moreover, that the number of fish following this route was not restricted to some few individuals. First of all may be mentioned the great similarity in the composition in point of size noted this year between the skrei and the Finmark fish. We have already seen, in the table on p. 99, that the size of the fish measured and marked at Lofoten corresponded very closely indeed with that of the Finmark specimens marked. The fish marked in this latter water in May and June were taken at many different places between the North Cape (Honningsvaag) and Vardø, just as the marked Lofoten fish were found all the way from East Lofoten to Røst, in spite of which, all the samples together exhibit the similarity shown by the figures in the table. It is particularly interesting to compare the composition in point of size of two samples, one examined at Røst on the 14th of April, the other at Honningsvaag (Finmarken) on the 6th of May, the times and places here corresponding very closely to the marking and recapture of the specimens. The respective composition of the two samples is therefore given in tabular form below.

Composition in point of size.

	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	Over 105
Røst 14. VI.	...	1.0	8.7	20.8	22.2	22.7	9.7	3.9	3.9	2.4	1.9	2.9
Honningsvaag. 6. V....	0.5	4.5	10.5	21.5	22.5	22.5	12.0	5.0	1.0	...	...	...

There is this point of difference between the two samples, that the Finmark samples shows a somewhat greater admixture of small fish under 65 cm. (15.5 %, as against 9.7 in the sample from Røst) while on the other hand, the large fish are fewer in number. If we consider, however, the three groups most numerously represented, those from 65 to 79 cm., we are forced to admit that the similarity here is as great as could well be expected between two samples, even had they been taken at one and the same locality. The Finmark fish moreover, exhibited every sign of being spent, the ovaries being small; there is therefore little doubt that the great majority of the fish were skrei, which had made their way to Finmarken after having spawned on the banks farther to the west and south.

Marking experiments in Finmarken in 1913.

It was thus evident, that the marking experiments carried out in Finmarken in 1913 were in reality to be regarded as a continuation of the investigations as to the migration of the skrei, since the Finmark fish marked in this year were, as a matter of fact, spent skrei. We will therefore proceed to consider the results of these experiments. During the period from 12th May to 27th June, there were marked, as mentioned above, in all 1,955 cod, taken along a range of the Finmark coast from Honningsvaag to Kiberg (Varangerfjord), most of them being marked between Berlevaag and Baadsfjord, in the eastern part of the water. The total number retaken was 121, or about 6.2 %. In the two figures, 70 and 71, will be found a number of examples of the migrations of the marked fish from Finmarken. The main direction is eastward along the coast of Finmarken (Fig. 70) and farther along the Murman coast (Fig. 71). It is thus finally proved, that *the spent skrei seek first the coast of Finmarken and then the Murman coast, and that the fishery in both these places has for its object the same stock which spawns on the Norwegian skrei banks.* The rapid movement of these fish must be regarded as at any rate a partial explanation of the fact that the percentage of recaptures here was so much lower than that of the Lofoten fish.

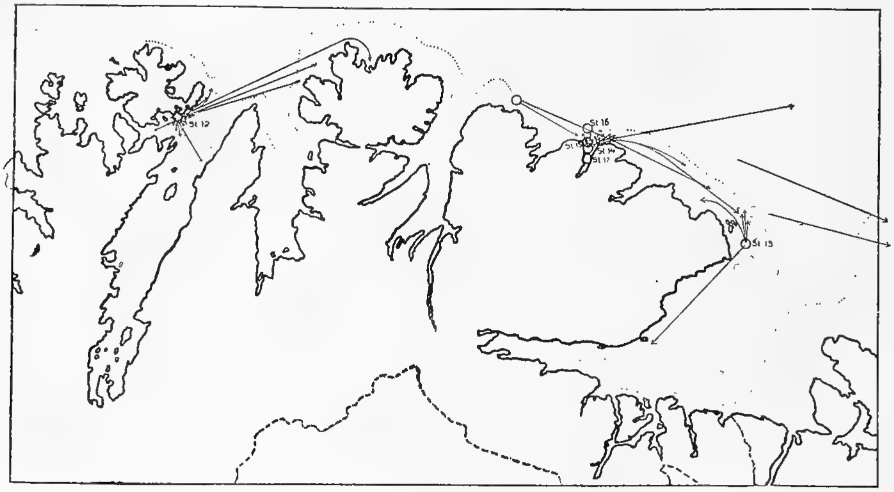

Fig. 70. Marking experiments, Finmarken 1913.

These results had long been anticipated. Thus the Russian expedition under KNIPOWITSCH carried out, in 1898 and 1900, fishing experiments north of the Murman coast, and discovered that a movement took place eastwards along this range. In 1902, K. DAHL made some fishing experiments from the "Skolpen" off the coast of Finmarken, and was likewise able to note an increase in the size of the cod evidently due to the immigration of skrei from the west. As we shall see later on, many similar instances are known.

Other instances of migration noted.

All this however, by no means proves that all the skrei follow this route. I have already in an earlier work*) made mention of the fact that the fishing industry of the

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*) Fiskeri og Hvalfangst.

Barents Sea presents many cases of large cod frequently being found in the northern part of this water, thus for instance off the coast of Spitzbergen, Bear Island, and up towards the edge of the ice. Prof. G. O. Sars has, in his record of the "Norske Nordhavs" expedition, described how he encountered on the 15th August 1878 a very rich fishery for large cod near the Norwegian Islands (N. W. point of Spitzbergen, near 80° lat.), the fish "differing in no way from the bank cod taken on our coasts. Although they were of very fair size, some even unusually large, and scarcely inferior to the largest Lofoten skrei, no roe or milt was found in any of them". As all the cod were large, no small fish being found, Sars concluded that they did not belong to Spitzbergen, but must have come from the south, and belonged to the same stock as those spawning for instance near Lofoten. This fishery was carried on especially at the close of the 70's and in the early 80's, but then ceased. In the course of a cruise which I made in 1901

Fig. 71. Migrations of cod from Finmarken to the Murman Coast, 1913.

to Spitzbergen I did not succeed in catching a single cod. At Bear Island also, the occurrence varies greatly. In 1900 I found no cod there; in 1901 however, successful fishing experiments were carried out on the edge of the bank, cod of between 72 and 120 cm. being taken. In 1900, the temperature on the bank was ÷1.5, in 1901, between 1° and 2°. I have in course of time obtained a great deal of information from sealers as to the occurrence of large cod in the whole of the water between Bear Island and Novaya Zemlya; these occurrences were, however, generally regarded as due to the accidental presence of quickly moving fish, which are continually changing their position, and thus difficult to locate, the encountering of such shoals being largely a matter of chance.

Finally, skrei are also found outside the regular season on the banks off the coasts of the Tromsø and North Coast districts, more especially, perhaps, out towards the edge of the banks. The numerous fishing experiments already made have shown occasional occurrence of large fish in summer on all the banks of the northernmost part of the Norwegian coast. Not only on the banks and out towards the edge, but even beyond, above the great Arctic deep, some few wandering large cod have been encountered in summer. (See also chart, Fig. 3, Introduction).

Thus the skrei shoals, after spawning, distribute themselves over the sea banks, northward and eastward along the coast over the banks of the Barents Sea. From these localities they must again move back next winter, when roe and milt begin to develope, southward and westward to the skrei banks. We then again encounter great migrations, but in the opposite direction.

Younger stages of cod.

The skrei are the grown, mature fish, all large enough to be taken with hook and line, and as most of the skrei here dealt with were captured in this manner, the samples examined may be considered as a representative selection of the actual stock. Investigation of the size composition of the skrei shoals is therefore a much simpler matter than in the case of the younger, immature stages, which do not congregate, as do the skrei, at certain spots, and with all sizes mixed together. Among the many different sizes, from the young fry up to the stage immediately proceding maturity, we find several groups, differing either in biological respects or in regard to habitat and manner of life. It is therefore impossible to obtain, in a single sample, any sufficiently representative selection to permit of immediate conclusions as to the composition of the mass. It is necessary to take many samples from different shoals of fish at different places, endeavouring to combine the ideas obtained so as to form, as it were, a composite picture. Moreover, it is in some respects impossible to find any standard by which to judge of the respective quantitative values of the different groups, even though it may be possible to accurately determine the composition in point of size of each separate group.

As regards the northern Norwegian waters, if we desire to study the habitat and life history of the younger stages, it is necessary to commence with the very earliest stages, i. e. the newly spawned eggs, which, as we have seen, are to be found in the water immediately above the spawning shoals, on the skrei banks. We have also seen how these newly spawned eggs are transported, at a very early stage, from place to place by the movement of the water. During the period of developement, therefore, to the larva and young fry stages, their locality is constantly shifting, and the area of distribution of the whole mass of fry is soon found to lie within geographical limits entirely distinct from those of the spawning grounds. It was natural that the fishery investigations should attempt an examination of these passive movements of the various stages of developement, since the study of this question might well be expected to furnish,

Fig. 72. Extreme limits of distribution of the youngest stages of cod
I. Newly spawned eggs.
II. Larvæ and small fry, June.
III. Young fish, Aug.—September 1900.

inter alia, an explanation of one of the principal points in the life history of the cod, as well as in the fishery for same, viz. the fact that the young cod are found in greatest numbers off the coasts of the northernmost districts, where little or no spawning takes place.

Passive movements and distribution of the young cod.

I therefore endeavoured, during the cruises made with the "Michael Sars" in 1900 and 1901, to investigate the distribution of the larvae and small fish, which was done by towing large nets of 6—8 ft. diameter at the surface of the water. These experiments also showed that the young larvae and fry may be taken many miles from the spot where they were spawned. The results obtained on board the "Michael Sars" in this respect will be found in Fig. 72. The curve marked I shows the distribution of the eggs, II the uttermost limits for the young fish of some few centimetres' length, in June and July 1901, curve III indicating the occurrence of young fish some inches long in August—September 1900. The young fry are thus carried, sometimes for hundreds of miles, being sown, as it were, over the banks off the northern coast of Norway, and especially in the Barents Sea, where they may be taken the following year in fine meshed trawls on the bottom. As in the case of the herring, this drift follows the direction of the current, (Fig. 25) and the northern coastal waters thus become the natural habitat of the younger stages. It should, however, also be borne in mind that great numbers of small fish, both herring and cod, also grow up all round the coast. These young fish live under widely different external conditions in the different localities. Those nearest the coast itself spend their early years, the first especially, in shallow water, where temperature and other conditions vary greatly from place to place along the extensive range.

Distribution of the youngest bottom stages.

During the cruises made by the "Michael Sars" in 1901, a fine-meshed trawl was employed, and at several places, off Bear Island, east of Vardø, and in the Varangerfjord, small cod of between 10 and 30 cm. length were taken. Similar results have been obtained on other occasions, and although the observations thus made are far from being as numerous as might be wished, they yet suffice to show that small cod, from the very earliest bottom stages upward, are to be found widely distributed throughout great parts of the Barents Sea. A point of particular importance in considering the stock of cod in northern waters is the fact that even these very young stages are found at so great depths as 100—200 fathoms, which renders it possible that their area of distribution may embrace the whole of the great Barents Sea. This mode of life is very different from that customary in more southerly regions, where the younger stages live as a rule in shallow water. The same difference in the depths at which the fish occur in northern, as opposed to southern waters, also applies to other species besides the cod. Thus trawling for plaice is often successfully carried on in the Barents Sea at a depth of over 100 fathoms, whereas in the North Sea, the stock of plaice is almost exclusively restricted to the shallower waters, at depths of less than 30 fathoms.

The catches hitherto made are sufficient to demonstrate the fact that the composition in point of size of the young cod differs from year to year. This may be seen from the following record of hauls made with the fine-meshed trawl on board the "Michael Sars".

Trawl Catches. Percentage of 5 cm. groups.

	10—14	15—19	20—24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64	65—69	70—74
Bear Island, Aug. 1905	0.01	64.0	13.6	7.2	8.0	4.7	2.1	0.4	..	..	..	..	..
Cape Kanin Bank, Aug. 1907 .	..	..	5.4	34.3	32.1	18.0	8.0	1.1	0.8	0.4	..	..	..
Varangerfj., June 1913	40	3	2	4	8	10	13	9	2	5	1	2	1

During August 1905, the mass of the trawl catches made off Bear Island consisted of fish between 15 and 19 cm. long. In August 1907, the hauls made in the eastern part of the Barents Sea were mainly composed of young cod between 25 and 34 cm. long. In 1913 however, we again find a great quantity of quite small fish (10—14 cm.), the catches here, however, also including many specimens belonging to the 40—44 cm. group. As will be seen later, this difference in the respective composition of the catches can scarcely have been accidental, but must rather be considered as due to great fluctuations in the average size of the stock, and as the older and larger groups recruit from these small fish, it is of great importance to note the existence, even at this early stage, of fluctuations in the relative frequency of the different sizes.

Not until they have reached a length of some 40 cm. do the cod begin to be taken by the fishermen's lines, for which reason no information is available as to the younger stages save that obtained by scientific investigations. As to their migrations also, little is known; no marking experiments have ever been carried out with cod of less than 40 cm. length, either in the Barents Sea or the Finmark waters. Marking experiments with young cod have, however, been carried out to a considerable extent elsewhere.

Marking of small cod.

Dr. JOHS. SCHMIDT has made marking experiments with a number of young cod in the Iceland and Faroe waters. In the former*), two series of experiments resulted in the recapture of only 8.4 and 1.6 % of the marked fish, the migrations indicated being of small extent. In the latter water however**), where some 4—5,000 cod were marked during the years 1909—1912, an extremely large proportion was retaken. Of 800 fish marked in 1909, no less than 485, or over 60 %, were recaptured, and this very close to the spot where they had been set free.

In the North Sea, marking experiments with small cod under 40 cm. have been carried out by the German fishery investigations, especially from Heligoland. Of the fish here marked, 76.5 % were recaptured at the places where they were freed. WEIGOLD, in his description***) of the experiments, is of opinion that about half of the fish marked were retaken at exactly the same spot.

*) Marking experiments on Plaice and Cod in Icelandic waters. Meddel. fra Kommissionen for Havundersøgelser, København 1902.

**) Command. C. F. Drechsel: The International Investigation of the Sea, its results and practical objects. København 1912.

***) Die deutschen Versuche mit gezeichneten Dorschen. 1. Bericht. Arb. der deutschen wiss. Kommission für die internationale Meeresforschung 1913.

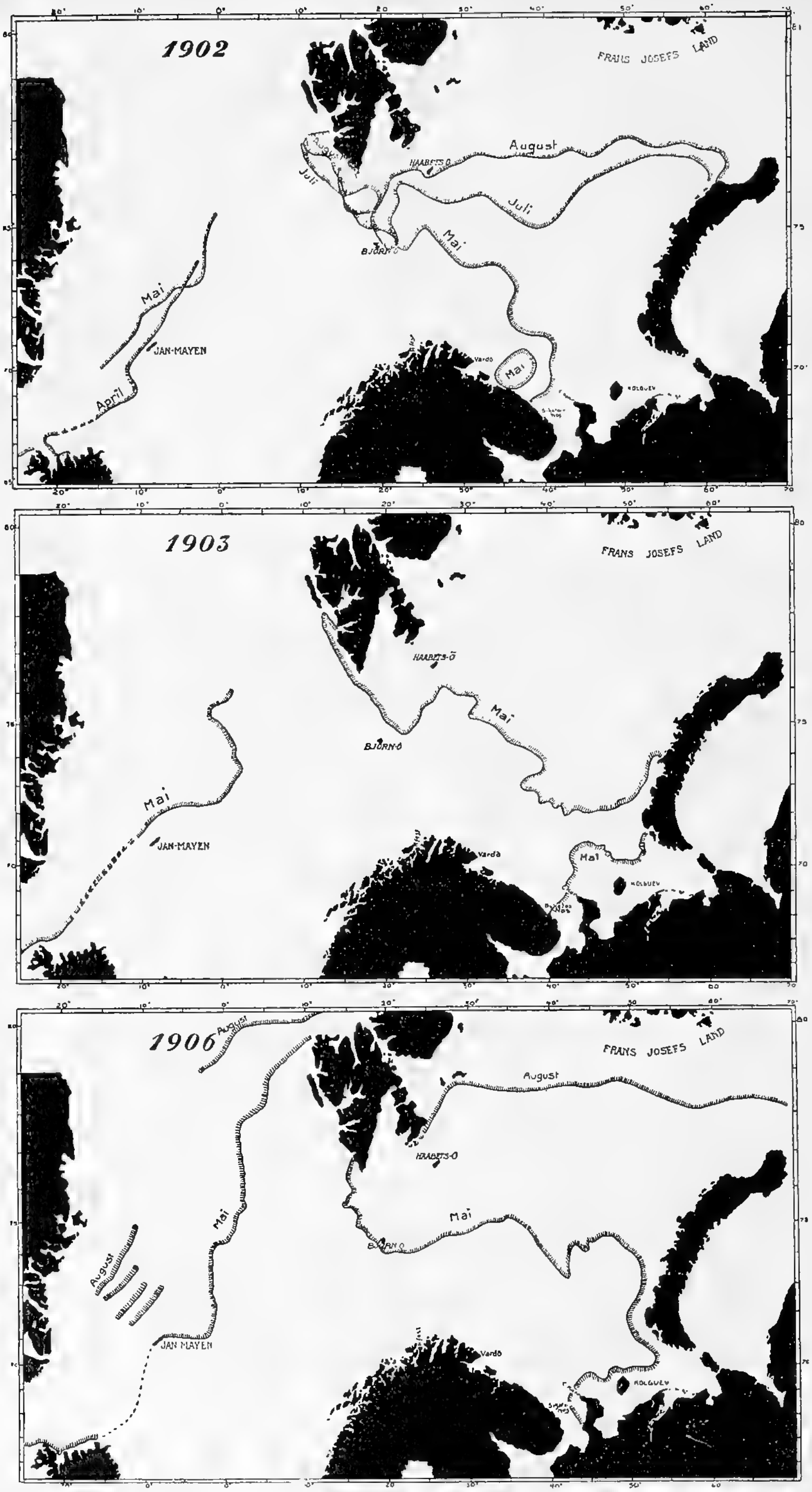

Fig. 73. Ice Boundaries from the Charts of the Danish Meteorological Office.

Similar experiments have also occasionally been made in Norway with the smaller sizes of cod, and with similar results. K. Dahl has thus marked cod in the fiords on the coast of the Skagerak, the recaptured fish being found to have made only small migrations.

From this we may suppose that the youngest stages of cod also in the Finmark waters keep within a more or less restricted area. Their locality during the first years of life will thus depend on where they have been carried by the current at the time when they first reach the bottom on the great level floor of the Barents Sea. Closer study of the distribution of the young stages within the limits of this submarine plain is one of the important subjects for investigation presented by the Barents Sea. It is at any rate certain, that they are to be found off Bear Island in the North, Cape Kanin in the east, and the Murman and Finmark coasts to the south. And there is little room for doubt that most of them have their origin in the spawning which takes place on the Norwegian skrei banks.

Finmark codling, “Loddefisk”.

As to the size of the fish at the time of commencing migration, nothing is known as yet; it is, however, reasonable to suppose, that this takes place when they become “loddefisk”*) and that the fish from this time onwards lead a wandering life. Their area of movement is still however, doubtless restricted to the Barents Sea, and it is scarcely likely that they penetrate west of Finmarken before the time arrives when they are ready to join the spawning shoals on their way to the skrei banks.

Within the limits of the Barents Sea, it is probable that they move, like the skrei, northwards and east in summer and autumn; westward and south, i. e. towards the coast of Finmarken, in the winter or spring. Their occurrence here, so close in to land as to permit of their frequently being taken in the fjords or from the shore, is doubtless largely due to the presence of the capelan.

The capelan *(mallotus villosus)* is an Arctic fish, known from the coasts of Labrador, Newfoundland, Greenland, Iceland, and the Barents Sea. It occurs on the coast of Finmarken only in the spring, spawning in March and April on banks and in bays close to the shore. During the summer, it keeps to the northern waters of the Barents Sea. The cod taken on the Bear Island Bank in July 1901 were found to contain quantities of this fish, and the Norwegian sealers report frequent observations of its occurrence in the northern part of the Barents Sea, during summer as far up as Novaya Zemlya and Franz Josefs Land. The capelan is found especially near the ice limit, which frequently serves as an indication of its locality, (*vide* charts fig. 73 of ice limits, as also one previously published by the present writer showing the occurrence of capelan during summer)**).

Migrations of capelan shoals towards the Finmark coast.

When the enormous shoals of capelan leave their northern quarters in winter, and move towards the Finmark and Murman coasts, they draw after them the shoals of

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*) »Loddefisk« is the local name for codling following the capelan, or *mallotus* (»lodde«) and taken by long lines in Finmark waters.

**) Fiskeri og Hvalfangst. Bergen, 1903.

cod encountered on the way, the latter pursuing and greedily devouring them. I have found between twenty and thirty of these fish in the stomach of a single cod. Among their other enemies are the fin-whales and certain Arctic birds, so that the shoals with their pursuers can be observed at a great distance. I had occasion to observe this combined movement of capelan, cod, and birds, in 1901, when I encountered them far to the east of Finmarken before any had as yet appeared on the coast, so that there was no doubt of the fact that migration was taking place. The presence of the capelan could be discerned by shooting the birds or capturing the cod which had devoured them. The fishermen of the Murman and Finmark coasts have naturally acquired considerable experience as to this immigration, on which the early fishery in Finmarken so largely depends. During their landward progress in February, March and April, the capelan are as a rule pursued by cod of smaller size, the skrei being for the most part far distant from the Barents Sea at the time, spawning on the skrei banks away to the west. As to the locality in which the fish approach the shore, this is probably dependent on various factors, as for instance, the earlier prevailing conditions with regard to ice and temperature of the water farther to the north and east in the Barents Sea, and the state of the water near the coast itself. The fish make land sometimes in the east, sometimes in the west. Men acquainted with the waters assert that when there are quantities of capelan near Bear Island, then the fishery is better in the west; when the capelan congregate chiefly in the eastern part of the Barents Sea, then there is better fishing on the eastern part of the Finmark coast.

It is thus evident, that the Finmark stock consists in reality of two component parts, the "loddefisk" and the "skrei", each of which approaches the coast from a different quarter. It will readily be understood that the fluctuations in the composition of these two elements, and their varying locality of occurrence, combine to render the stock in the Finmark waters a highly complicated whole. And it will immediately be seen that the fishery in a certain year may at first, say in March-April, consist exclusively of small cod, until the mass of the skrei arrive from the west, in May, June, or July. Or the reverse may be the case, the skrei being the more important all through the season.

Size of the Finmark fish.

For several years, material has been collected as to the Finmark fish, especially by means of measurement, some 9,000 fish in all having been measured. The investigations embrace the years 1901, 1902, 1905, 1906, 1909 and 1913.

Commencing, as in the case of the skrei, with all the measurements as a whole, we find the figures shown in the table on p. 115 and Fig. 74.

The figure includes, for purposes of comparison, a curve indicating the composition in point of size of the skrei as shown in Fig. 55 already referred to.

As against this, the corresponding curve for the Finmark fish will be found considerably more elongated in form, and contains a far higher percentage of younger stages. This is clearly shown by the following figures.

	Under 65 cm.	Over 65 cm.
Finmark Fish....	52.7 %	47.2 %
Skrei	9.8 -	90.2 -

Cod. Finmarken. Percentage of 5-cm. groups.

	Under 40	40—44	45—49	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	105—109	110—114	115—119	120—124	125—129	130—134	Average length
1901	2.7	5.7	14.5	16.6	20.8	15.1	8.8	7.1	3.2	4.0	0.6	0.2	0.4	. .	0.2	. .	. .	. .	. .	. .	58.2
1902	. .	. .	2.8	2.8	15.6	22.9	7.4	24.8	12.8	6.4	0.9	0.9	0.9	1.8	. .	. .	. .	. .	. .	. .	68.1
1905	3.4	5.8	8.7	10.4	9.6	6.2	6.5	8.7	10.6	7.7	5.0	4.6	3.7	2.8	2.2	4.1	. .	. .	. .	. .	69.6
1906	1.2	1 2	3.6	10.0	9.0	7.7	12.4	6.5	15.4	10.0	5.9	5.3	. .	3.0	3.6	3.0	1.2	. .	0.6	0.6	73.4
1907	5.2	12.1	11.3	18.3	16.4	11.3	8.0	6.5	5.2	3.2	1.8	0.4	0.2	0,1	. .	. .	. .	. .	. .	. .	57.1
1909	0.3	1.9	4.7	11.5	34.0	28.0	10.5	4.2	1.2	1.6	0.9	1.3	. .	. .	. .	. .	. .	. .	. .	. .	60.1
1913	. .	. .	0.9	2.9	4.9	10.4	17.5	20.5	18.5	9.2	7.0	4.0	2.0	0.9	0.9	0.3	0.1	0.05	. .	. .	73.5
All years	1.8	3.8	6.6	10 3	15.7	14.5	10.1	11.2	9.6	6.0	3 2	2.4	1.0	1.2	1.0	1.1	0.2	0.01	0.09	0.09	65.7

More than half the Finmark fish were, in the years in question, under 65 cm. The smallest specimens in the samples belonged to the 25—29 cm. group, but as these were very few in number, all groups under 40 cm., which together do not amount to more than 1.8 %, have in the table been taken as one. All groups under 50 cm. together amount to 12.2 %; from and including 50 to 80 cm. all groups are more or less evenly represented, showing a percentage of between 10 and 16. Within this field, however, the curve exhibits a distinct division, with two maxima, and it will be noticed that the limit between

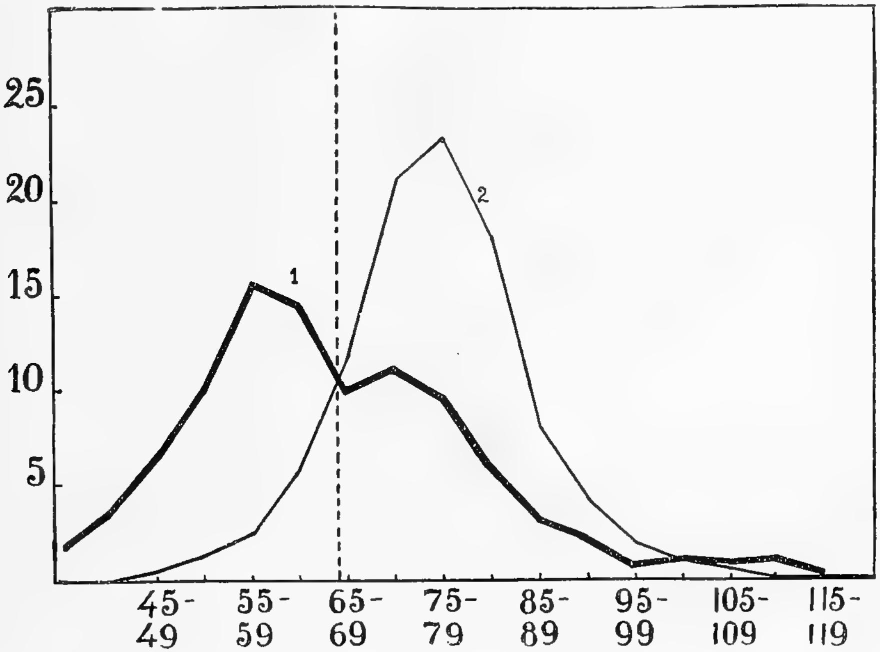

Fig. 74. Curve 1 shows the composition in point of size (percentage) of 9,000 Finmark fish measured in 1901, 1903, 1905, 1906, 1909 and 1913.
Curve 2 is that already given in Fig. 55, showing composition in point of size of the skrei.

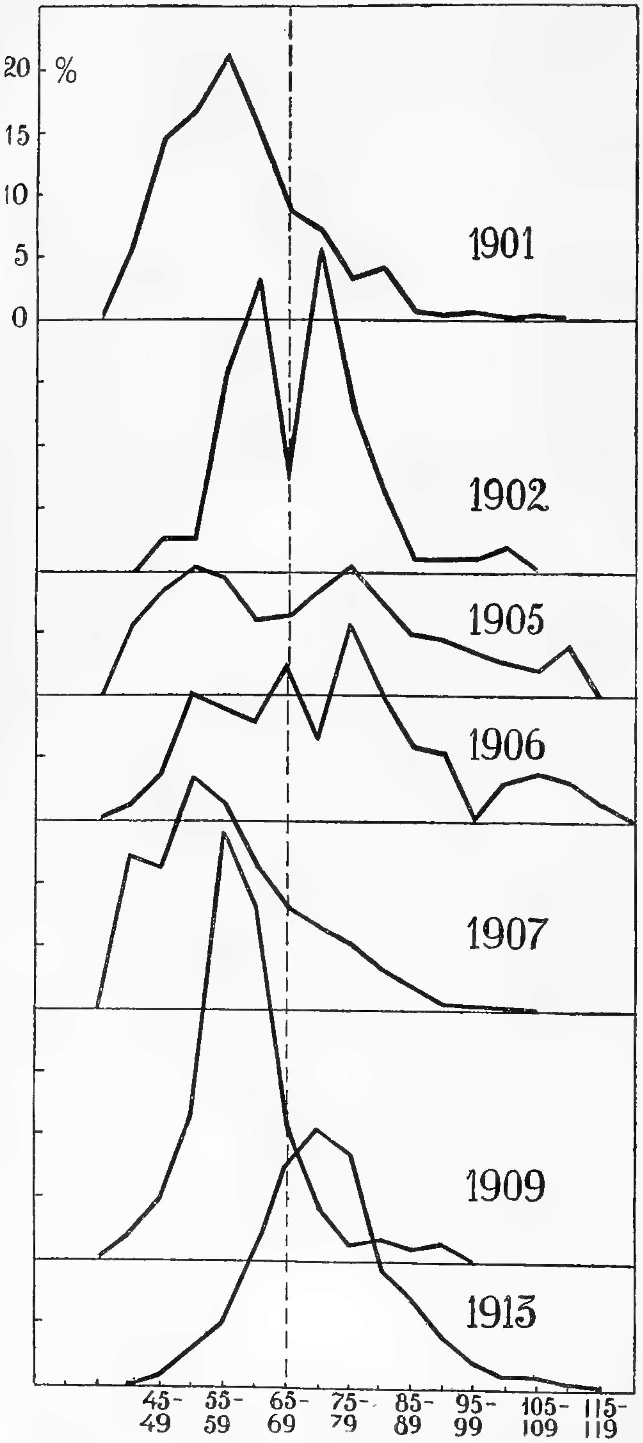

Fig. 75. Composition in point of size of the Finmark fish in different years.

these falls nearly at the point of intersection of the two curves. This also indicates that the Finmark stock consists of two parts, the *skrei group* or mature fish, and the immature individuals. For the sake of convenience, we may in the following refer to those two groups of Finmark fish as the *loddefisk group* and the *skrei group* respectively, fixing the dividing limit at 65 cm. length*). This limit does not, as will be seen from the skrei curve, exactly coincide with the dividing line between mature and immature fish; there are also doubtless some skrei among the loddefisk; it is however, difficult to find any better definition, as any attempt at such must of necessity be of an arbitrary nature.

Size of the Finmark fish in different years.

The table on p. 115 shows the size of the Finmark fish in the different years as far as known. This being a point of considerable importance, I have also added, (Fig. 75) a graphical representation of the same, while the following little table will serve to give a rough survey of the more salient features, including as it does the relative numbers of the larger groups. The tables and the figure reveal considerable fluctuations in the size of the Finmark fish from year to year, both as regards the averages and also within the

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*) In the following figures this limit is marked by a dotted vertical line, which for the sake of convenience is placed at the 65—69 cm. group in stead of a little to the left of same.

separate groups. The averages for all years show approximately the same number of loddefisk and skrei. The former is, in three of the years, represented by over 70 % (in one over 80 %), the skrei also, in one year, amounting to over 80 %.

	Loddefisk (under 65 cm.)			Skrei (over 65 cm.)		
	Under 50 cm.	50—64 cm.	All under 65 cm.	All over 65 cm.	65—79 cm.	Over 80 cm.
1901	22.9	52.5	75.4	24.3	19.1	5.2
1902	2.8	41.3	44.1	55.9	45.0	10.9
1905	17.9	26.2	44.1	55.9	25.8	30.1
1906	6.0	26.7	32.7	67.5	34.3	33.2
1907	28.6	46.0	74.6	25.4	19.7	5.7
1909	6.9	73.5	80.4	19.7	15.9	3.8
1913	0.9	18.2	19.1	81.0	56.5	24.5
All years . .	12.2	40.5	52.7	47.2	30.9	16.3

Within the loddefisk group again, I have distinguished a special subdivision, that of fish under 50 cm., varying in different years from 0.9 to 28.6 %. The corresponding field of variation for the groups from 50 to 64 cm. lies between 18.2 and 73.5 %.

If we now proceed to consider the different years *in chronological order*, we notice that the series begins in 1901 with a high percentage of loddefisk and a low percentage of skrei. Thence up to 1906 inclusive, the percentage of the former decreases, that of the skrei, on the other hand, increasing. From 1906 to 1909 we find a new increase in the percentage of loddefisk, with a corresponding decrease on the part of the skrei; from 1909 to 1913 the reverse is the case.

It is evident that these extremely complicated conditions must be due to various factors. The following possibilities immediately suggest themselves: an immigration of small fish into the shoals of the loddefisk, an emigration of Finmark fish joining the shoals of skrei, a movement of skrei from the spawning banks to Finmark waters. Each of these various points must be separately studied and elucidated. Before proceeding to further discussion of these fluctuations, however, we may glance at some typical variations in point of size within one and the same year, thereafter, by observation of the age and growth of the fish, endeavouring to ascertain how soon one group can pass into another.

Variation in size of the Finmark fish in one and the same year.

We have previously referred to the fact that the Finmark stock must be regarded as consisting of two component parts, the loddefisk and the skrei. If we now compare, not only the average size of the Finmark fish as exhibited by the total of samples for a single year, but also the different samples one with another, we find that these are not invariably "mixed"; some of them are "pure" samples of one or other of the two components. This we might almost have deduced already from the table on p. 115. And we now find, that both cases may arise, either an early arrival of the loddefisk (during the first part of the season) the skrei making their appearance later on, or an exclusive predominance of the skrei in spring, the others delaying their arrival until well on in the summer. Of these, the former case is the more common. The skrei are on the spawning grounds in March and April, when the loddefisk arrive, and it would seem that the time of their appearance on the Finmark coast is subject to considerable variation. It may, however, happen, as already mentioned, that the fish arrive as early as the latter part of April, no loddefisk being then present in the Finmark waters.

The years 1902, 1905 and 1913 give several examples of this. In 1902 and 1905, the skrei did not appear until well on in summer, in 1913 they were the first to arrive. Both instances are clearly shown by the composition in point of size of the samples collected at different times: for convenience of comparison, a graphical illustration of the variations in the three years is given in Figs. 76 and 77. The years 1902 and 1905 show, during June, a high percentage of the younger year classes among the Finmark fish; a decrease took place, however, in the course of the summer. Thus the proportion of cod under 65 cm. was during these years as follows:

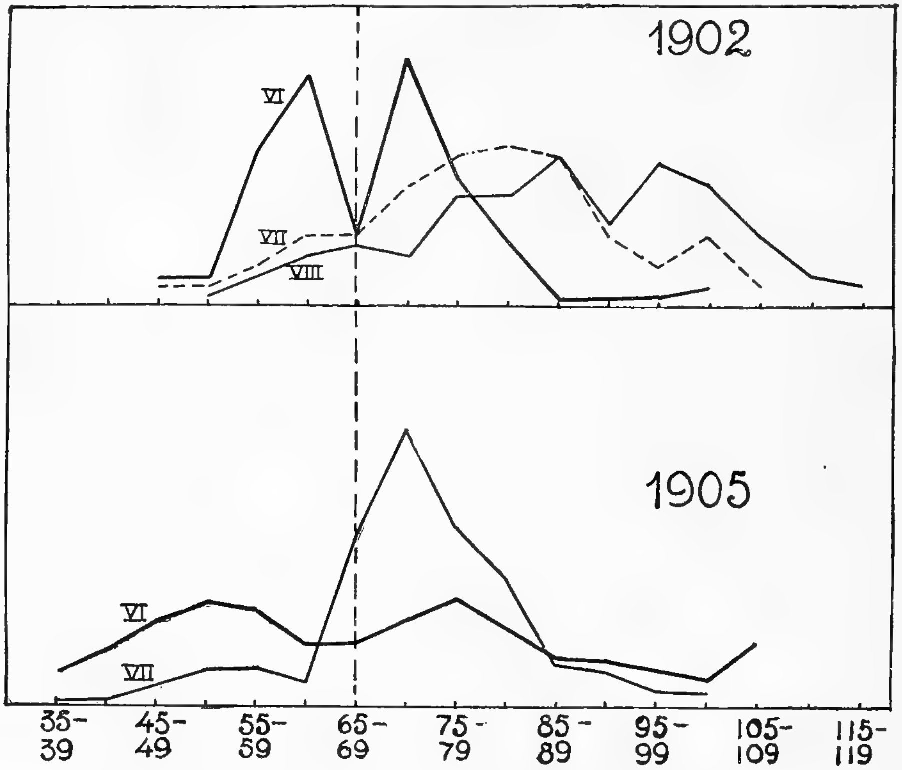

Fig. 76. Different samples of Finmark fish from the years 1902 and 1905.
VI = June. VIII = August.

	1902	1905
June.......	44.1 %	54.1 %
July	15 %	13.2 %
August.....	6 %	....

We therefore find, in August 1902 and July 1905 "pure" skrei samples among the Finmark fish, and Dr. K. Dahl, who made the investigations in Finmarken in 1902, expresses the opinion that the summer samples from here exhibit great similarity in point of size to the skrei samples from the same year.

In 1913, as we have seen, the Finmark fish at the beginning of May exactly resembled the skrei in this respect. We may here refer to what has previously been said as to the similarity between the two samples from Røst and Honningsvaag The resemblance was so great, that both fishermen and merchants in 1913 declared that there were only skrei to be found in Finmark waters. Where then, were the loddefisk at this time? By a mere chance, I happened to obtain some information as to this. An English trawler put into Vardø, after having worked several different grounds far to the east, along the Murman coast, and the master of the vessel declared that the cod there were of smaller

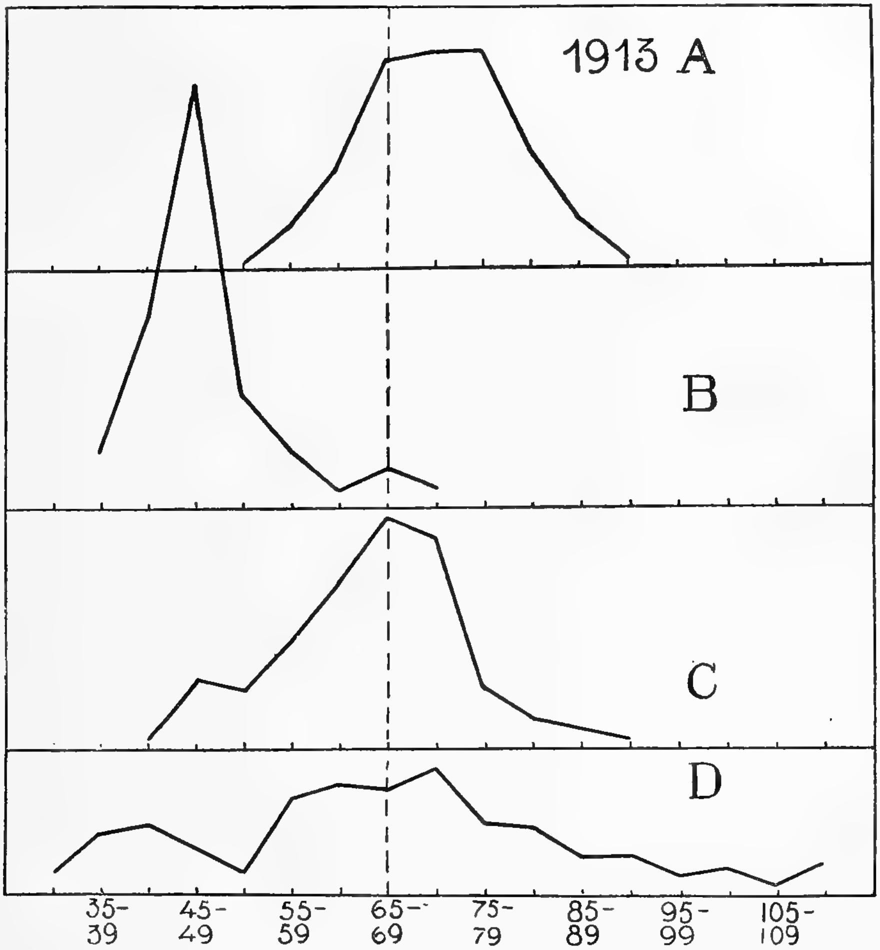

Fig. 77. Samples of cod from the Barents Sea, 1913.
A. Finmarken, May. B. Murman Coast, May. C. and D. Finmarken, June.

size, exhibiting samples in proof. He further agreed, at my request, to take with him two practised men, who were able, during the latter part of May, to measure samples from 24 different trawling catches. These samples, taken as a whole, showed a mixture of large and small fish; at some of the stations, however, unmixed samples of small fish were found. This will be seen from the following:

Trawl Catches, Murman Coast. May 1913.

		Under 40	40—44	45—49	50—54	55—59	60—64	Over 65
Station 16.....	Least mixed	8.2	27.8	33.0	17.5	5.2	3.0	5.2
— 14.....		6.3	29.1	31.6	10.1	7.6	7.6	7.6
— 24.....		6.0	20.0	44.0	12.0	6.0	4.0	8.0
— 11.....	Moderately mixed	7.8	27.1	22.5	12.7	10.0	8.8	10.8
— 22.....		2.1	23.2	22.1	14.7	12.6	9.5	15.8
— 12.....		4.8	30.5	21.9	11.4	5.7	7.6	18.0
— 17.....	Most mixed	5.2	9.3	7.2	8.2	24.8	16.5	28.9
— 19.....		3.0	11.0	15.0	12.0	14.0	7.0	38.0
24 stations....	Average	7.5	17.4	19.7	12.7	11.2	8.9	22.4

This table shows a series of eight trawling stations, arranged in order of increasing proportion of skrei over 65 cm. The six first stations exhibit very similar results, with a predominance of small cod between 40 and 50 cm. These must be presumed to represent the younger, immature portion of the stock, present in the waters off the Murman coast in May. Not all the young fish, however, are here included, as the smallest sizes would not be taken in an English trawl, and, as we have already seen in the case of my own trawling experiments in the Varangerfjord, there were then, at about the same time, a great quantity also of quite small fish, of 10—14 cm. in length. Judging from this, and from the figures for the above six stations, the predominant sizes of immature fish here present in the spring of 1913 would be the groups 10—14, 40—44, and 45—49 cm. This is exactly what is shown by the hauls made in the Varangerfjord, although the percentages for the groups about 40—45 cm. appear small, on account of the large number of fish of 10—14 cm.

Hauls made with fine-meshed trawl. Varangerfjord 5—6 June 1913:

10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Over 65
40	3	2	4	8	10	*13*	9	2	5	1	3

We find, therefore, that the composition of these small cod is very irregular, with very low percentages for the sizes lying between the 10—14 and 40 cm. groups, as also for those between 50 and 65 cm. In May, the skrei were still but poorly represented in the samples from the Murman coast. The average for all the 24 stations is 22.4 %, whereas the corresponding figure for the Finmark waters at the same time is about 85 %. In some of the hauls made by this trawler, the skrei only amounted to about 5 %. If we now compare this with the results of the marking experiments, we obtain a good idea of the successive eastward movements of the skrei up to the time when the Murman coast fishery begins, later on in the summer.

A movement of small fish in the opposite direction, from the eastern waters to the Finmark coast, must, however, have taken place during the summer of 1913. This will be clearly seen from Fig. 77. I have here drawn four curves, indicating:

1) Size of the Finmark fish in May, with about 85 % skrei.
2) Size of the fish in one of the trawl catches (St. 24) on the Murman coast in May.
3) and 4) Sizes of the Finmark fish later on in June.

On comparing these curves, we find that the composition of the Finmark fish in June exhibits distinctly different percentages from those for the beginning of May, a greater number of small fish being present. The curve is also more elongated in form; there are no specially predominant single groups, as in May. This is, in my opinion, partly due to an emigration of skrei moving eastward, and partly to an immigration of loddefisk moving west. Later on in June, the fishery decreased in intensity, there being fewer fish on the grounds, which may to some extent account for the fact that the less numerously represented groups, both of large and small fish, now begin to play a more important part in the composition of the whole. That an immigration had taken place, was however, apparent to anyone having occasion to observe the fish by thousands at this time. The change made itself apparent suddenly, out in deep water (150 fathoms) where, as the fishermen said, a new shoal had arrived. These fish were, however, far from equal to those previously present. One might naturally have expected to encounter, among these new arrivals, a composition in size similar to that evident in the trawling catches on the Murman coast in May. A slight indication of this is also shown by curve 4, (Fig. 77); this group could not, however, play so important a part among the Finmark fish as in the trawl catches, the method of capture alone would render this impossible. The trawl would doubtless take most of the fish between 40—50 cm.; cod of 40 cm. however, are, as we have seen, of no great importance in the line fishery of Finmarken.

In the Barents Sea, the water layers and the fish shift east and west. It is probable that in 1913 a distinct eastward movement took place earlier in the year than is usually the case; at the beginning of May also, the temperature of the upper two hundred metres, as far east as Vardø, was very high, about 4°.

In order to obtain better idea as to the movements of the cod from one shoal to another, we must now proceed to consider the age and growth of the fish.

CHAPTER IV

The stock of Cod; its composition with regard to age.

Age and growth of the cod.

The earliest attempts at determining the age of cod were based upon numerous measurements, grouped according to size (C. G. Joh. Petersen). The results obtained by this method were, as in the case of the herring, satisfactory as far as the younger stages were concerned, but proved unreliable in the case of the older fish, exactly as we have seen in Chap. I when dealing with herring, the older year classes melting one into another without any distinct limit between (*vide* Chap. I, Figs. 5—7). Not until the introduction of the method of studying otoliths, bones, and scales was it found possible to arrive at accurate determinations of age for the individual fish, and thus obtain reliable information as to the general composition in point of age.

Damas' scale investigations.

The first extensive investigations based on examination of the scales of the cod were carried out by Dr. Damas*), who gives a detailed description of the progress of the method. Damas describes the scale of the cod as follows: "The scale of the gadoids, when strongly magnified, is found to be composed of polygonal elements, which may be styled, in the terminology applied to the structure of trees, as cells. In order to avoid any erroneous idea as to the morphological value of these, we may call them small polygonal plates ("plaquettes polygonales"). They are arranged in rows, at once radially and concentrically situated, in more or less regular design, each having a sharp edge. This gives rise to a number of concentric edges, the plates being divided by radial and concentric furrows".

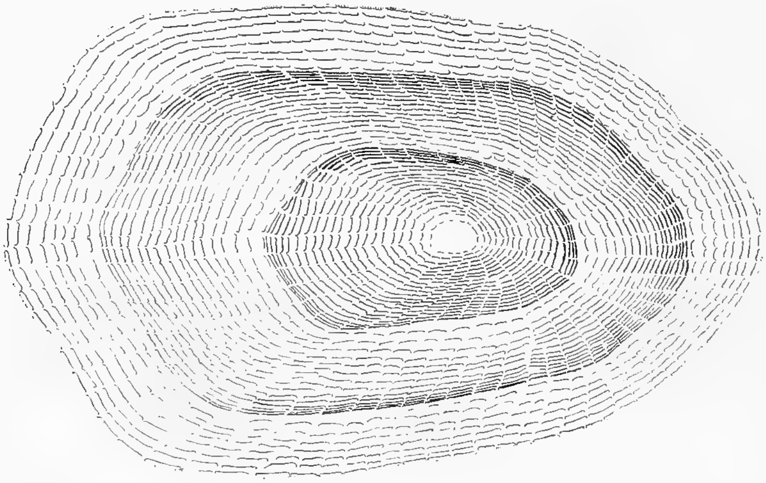

Fig. 78. Scale of a coalfish, 2½ years old and 30 cm. long, taken in Nordland, 1907.

From Fig. 78 it will be seen that the size of these small plates varies greatly. The innermost ones are large, but soon become highly compressed, then suddenly widening out again. Between the most contracted plates and the adjacent larger ones, a sharply defined line is seen. The resulting formation is a series of alternating zones of broad and narrow plates: the figure shows three of the former and two of the latter. Examination of the scales at different times of the year has revealed the fact that the large plates are formed in summer, the narrow in winter. According to Stuart Thompson,

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*) loc. cit.

the broad plates represent rapid, the narrow ones slower growth, the growth of the scale being in proportion to that of the fish. We can thus, by means of the scales, observe the growth which has taken place in the course of a year, the greater, rapid summer growth, and the lesser, slow increase in winter. Slightly magnified, the zones corresponding to the winter's growth appear as rings, called *winter rings.*

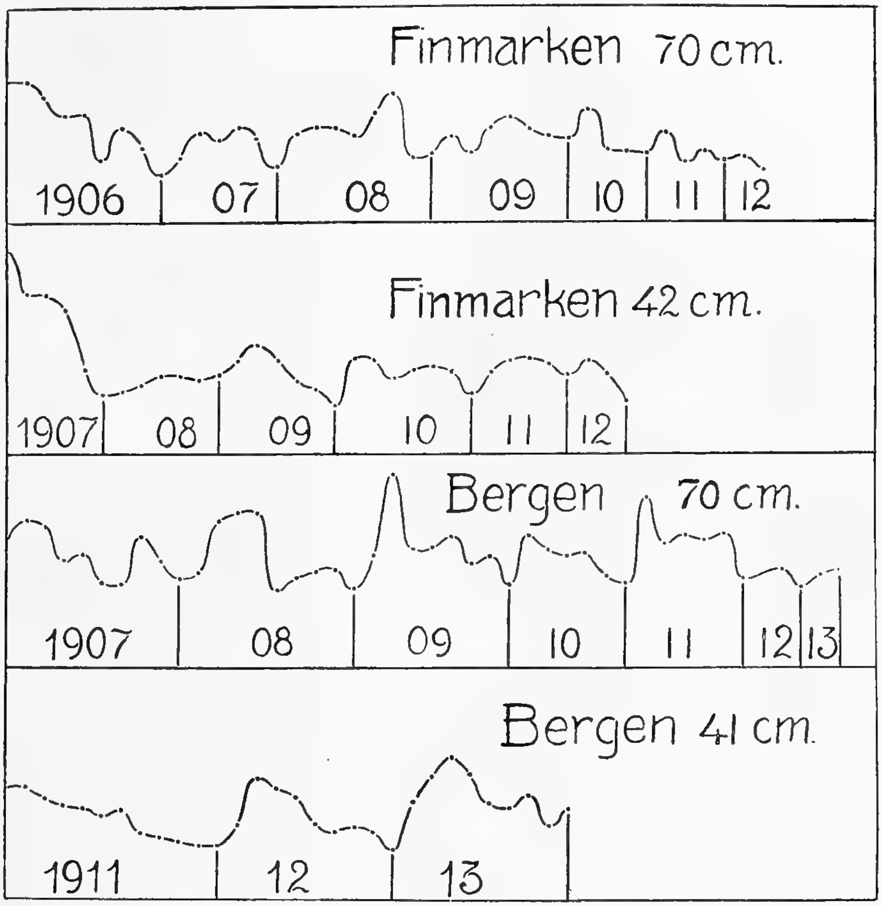

Fig. 79. Graphical view of size of plates on the scales of 4 cod, 2 from Finmarken and 2 from Bergen (vide text).

Fig. 79 gives a graphical representation of the varying size of the plates, from the centre to the periphery of the scale, in four skrei, two from Finmarken and two from Bergen. The vertical distance from a point on the curve to the abscissa indicates the width of the plates, magnified 300 times. The summits of the curves thus indicate periods of rapid growth, the hollows between them representing periods of slow growth, the deepest hollows corresponding to the winters. The two specimens from Finmarken exhibit, on the whole, a slower growth than those from Bergen.

The number of these indicates the age of the fish, while a study of the size of the zones themselves shows the nature of the growth. By examining the scales of fish taken at different times of the year and in different waters, the relation of the growth to the external natural conditions associated with different seasons and localities may be ascertained.

Acting on these principles, Damas made a great number of observations in different waters as to the age and growth of various species of cod, discovering considerable dissimilarity in the latter respect. In the North Sea, the growth of the cod was found to be rapid and even, while the skrei of the Lofoten banks exhibited a slower growth, in which a very distinct periodicity was noticeable. Between these, various intermediate classes are found, as also between the cod having their habitat near the open sea, and those of the fiords.

The influence of the season of year upon the growth was found to differ greatly in different waters. In the Skagerak, haddock with ovaries in a mature state have been taken in July (K. Dahl), the edges of the scales showing "winter growth". In the Barents Sea, outside the mouth of the white Sea, the "summer growth" had not begun in August.

Examples of different growth in different waters.

Fig. 83 shows scales of four cod, all of about the same size, 27—31 cm., from different parts of the Norwegian coastal waters, F. from Fredrikstad, (Christiania Fiord), B. from Bergen, H. Helgeland (Nordland) and V. Vardø (Finmarken). The scales of the cod from the southern waters show only one winter ring inside the edge, those of the northern fish having two. If we calculate, in the manner employed in the case of the herring, the size of these fish at the different periods of growth, we obtain the following results.

Growth of certain young cod from 4 places on the coast of Norway:

Place	Length	1st year's growth	2nd year's growth	3rd year's growth
Fredriksstad. F.	27 cm.	16.4 cm.	10.6 cm.	....
Bergen. B.	29 —	14.3 —	14.7 —	....
Helgeland. H.	29 —	14.7 —	9.5 —	4.8 cm.
Vardø. V............	31 —	8.3 —	10.5 —	12.2 —

Both the first and second year's growth exhibit great variation; it is particularly noticeable that the growth in these years is very slight in the case of the northernmost specimen, from Vardø. Since the scales can show so great variation, it is interesting to more closely consider the question as to whether scale investigations, also in the case of the cod, can give as reliable results as those obtained by Lea in the case of the herring, and if so, to employ the method for further investigation into the growth of the cod in different waters. Such investigations have already been commenced by Oscar Sund, who has furnished me with the following particulars as to the results hitherto obtained.

Sund's methodical investigations as the utility of the scales in the study of growth.

"The scale covering of the cod and coalfish is not quite so regular as in the case of the clupeidae, which exhibit exactly one cross row of scales to each myomer. In the

Fig. 80. Scale of coalfish with 1 winter ring.

Fig. 81. Scale of coalfish with 2 winter rings.

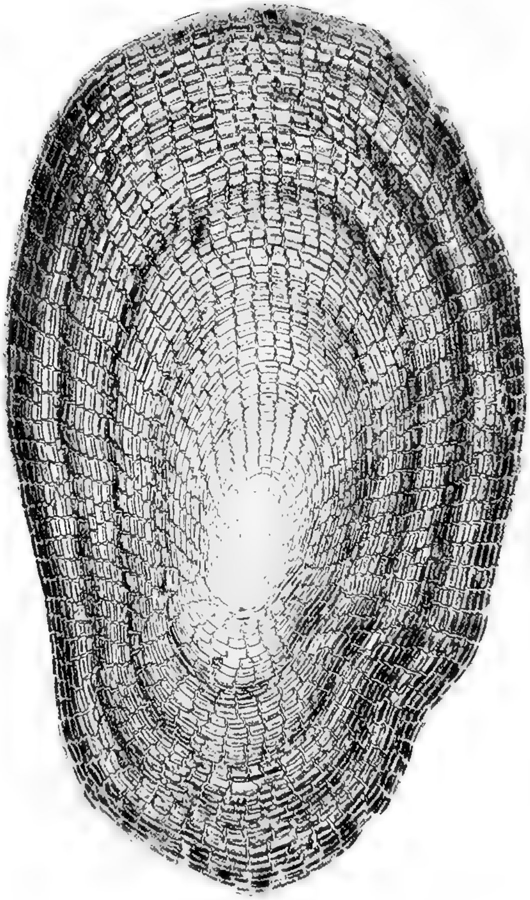

Fig. 82. Scale of cod with 5 winter rings.

Fig. 80—82 Lea phot.

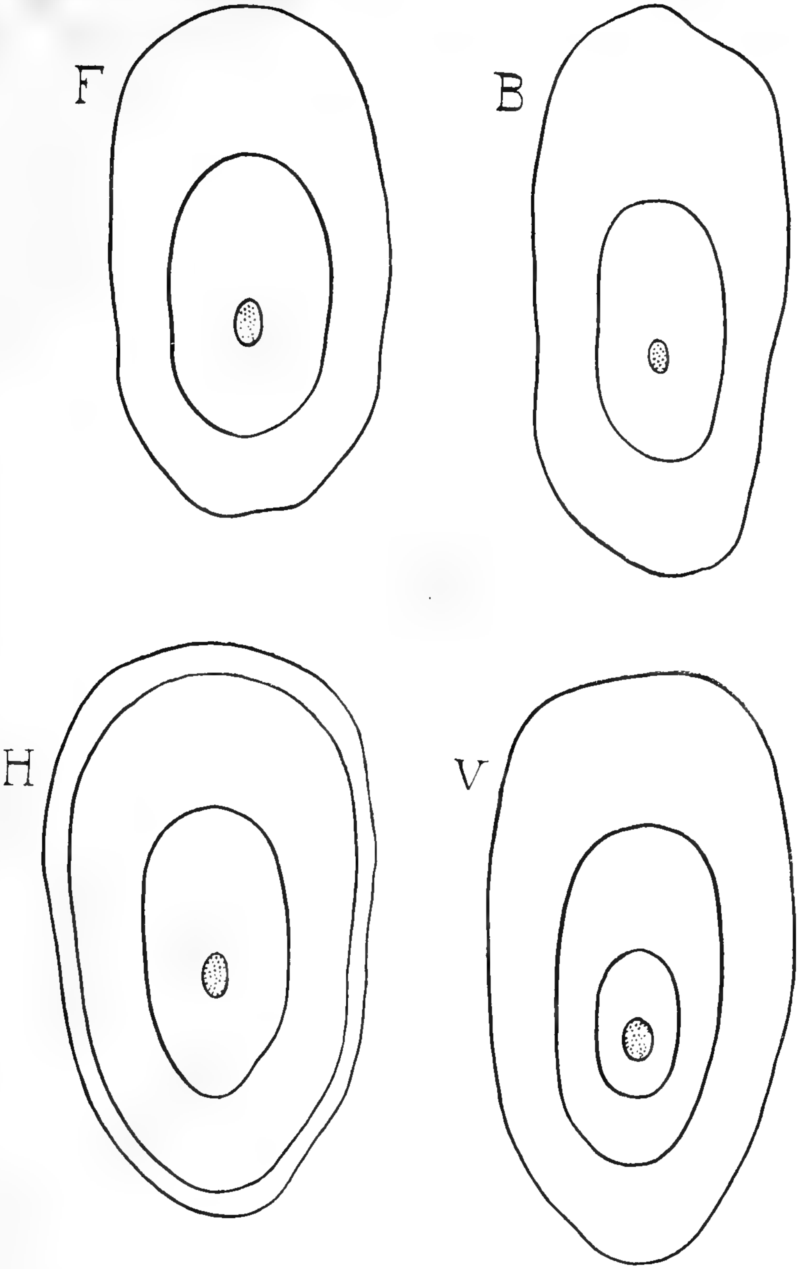

Fig. 83. Schematic illustration of scales of 4 cod from different parts of the Norwegian coast.
F. from Fredrikstad 27 cm. long. B. from Bergen 29 cm. long.
H. — Helgeland 29 — V. — Vardø 31 —

case of the two gadoids referred to, this regularity is only rudimentary, the cross rows only approximately corresponding to the vertebrae. We may, however, take it as a general rule that there are approximately three cross rows to each myomer, (the salmon species have two), a coalfish with 54 myomers having 167 scales longitudinally, and a cod with 53 myomers having 173.

"The scales are found to overlap, the greater part being embedded in the skin, only the hindmost edge reaching out to the chromatophorous epidermis. The scales within limited areas of the surface of the body are of more or less identical size and shape. Apart from these "normal" scales however, we find here and there quite small scales entirely embedded in the skin, and presumably representing supernumerary formations. These scales are quite useless for purposes of investigation, often exhibiting a different number of annual rings to that of the normal scales; it is therefore to be presumed that they are formed at very different periods in the life of the fish. They are, however, easily distinguished from the normal scales by their size and lack of pigmentation, and can therefore hardly have any misleading effect on the calculations.

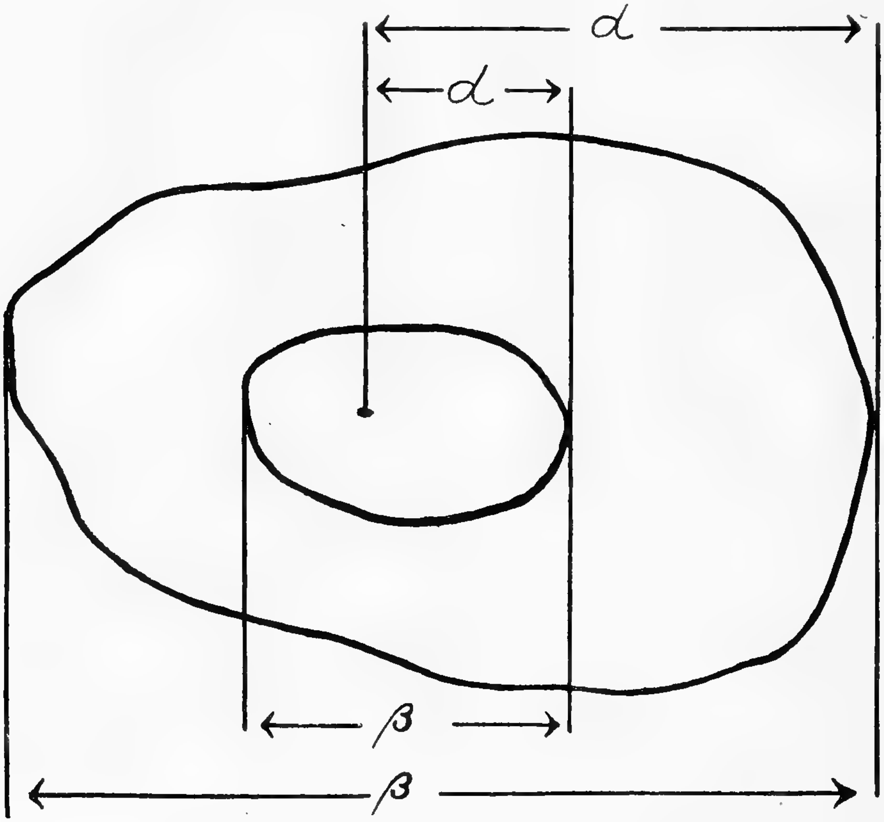

Fig. 84. Method of measuring scale dimensions (vide text).

"The normal scales are first formed, according to Damas, along the lateral line; before the first period of growth has expired, however, the scale covering is distributed over the whole of the body.

"As regards the size of the scales, both in the case of the cod and coalfish the rule applies, that they are largest in the vicinity of the lateral line, near a point opposite the fore end of the third dorsal and second anal fins. Table I shows the size of the scales in the "central" longitudinal row, from the upper corner of the gill opening to the central rays of the tail fin, with the relation of the central zone to the whole scale, which is measured in two dimensions, α and β, as shown in Fig. 84.

Table 1.

Coalfish 45.3 cm.					Cod 34.0 cm.				
Nr.	α	β	$\frac{\alpha_0}{\alpha}$	$\frac{\beta_0}{\beta}$	Nr.	α	β	$\frac{\alpha_0}{\alpha}$	$\frac{\beta_0}{\beta}$
10	...	123	...	34	45	66	122	71	68
20	...	117	...	34	50	78	128	70	71
30	...	108	...	35	55	68	118	69	67
40	...	120	...	34	60	75	125	72	69
50	...	115	...	36	65	77	139	75	70
60	...	130	...	35	70	82	145	71	68
70	...	137	...	34	75	90	153	67	66
80	...	147	...	33	80	97	171	69	68
90	...	157	...	32	85	104	171	67	69
100	...	157	...	31	90	91	162	71	75
110	...	152	...	33	95	94	162	69	69
120	...	155	...	31	100	98	163	71	67
130	...	149	...	31	105	93	160	65	67
140	...	143	...	34					
150	...	113	...	35					
160	...	79	...	32					
Average =			...	34.4	Average			69.8	68.0
Index of variation m =			...	4.7 %	Index of variation m =			3.8 %	2.4 %

From Table I, we see that the size of the scales increases and decreases somewhat irregularly backward over the central row.

"If we now consider, in the same manner, a cross row of scales from the lateral line downwards, we find the results shown in Table 2.

"As will be seen from this table, there is always the risk, in calculating the length of the fish in its first winter, of an error of up to 5 % or more, corresponding to an error of up to 8 mm., which may, in exceptional cases (1 of 360), theoretically, amount to three times this figure, or 2.4 cm.

"Even this possible error need not, however, be any serious hindrance, its influence on the average of a large number of individuals being very slight. The calculated average length of 100 fish in their first year will thus be subject to an extreme error of 0.24 cm., when the average is taken at 15 cm. And if, instead of the microscope, a projector be used, then this error, (due partly to inaccuracy of measurement and partly to irregularity of growth) will as a rule be reduced by one half.

"The *proportion* existing between the dimensions of the scale and those of the fish

Table 2.

Coalfish 45.3, 65th cross row					Cod 34.0 cm. 101st cross row				
No.	α	β	$\frac{\alpha_0}{\alpha}$	$\frac{\beta_0}{\beta}$	No.	α	β	$\frac{\alpha_0}{\alpha}$	$\frac{\beta_0}{\beta}$
1	...	146	...	33	1	93	162	70	67
2	...	145	...	33	2	89	155	67	68
3	...	140	...	35	5	87	149	69	70
4	...	145	...	37	7	86	145	71	70
5	...	148	...	34	9	73	123	67	67
6	...	147	...	35	10	74	130	69	69
7	...	140	...	35	11	78	136	72	68
8	...	147	...	33	12	76	136	72	69
9	...	147	...	33	13	79	131	71	72
10	...	139	...	33	14	69	122	72	71
11	...	143	...	31	15	73	139	73	70
12	...	147	...	32	16	66	123	70	67
Average =			...	34.6	Average =			70.25	69.0
m =		±	...	5.4 %	m =		±	2.69 %	2.39 %

now remains to be considered. Owing to lack of suitable material, it has not hitherto been possible to arrive at a final determination on this point. It may however, safely be asserted that the variations which may occur are only slight, and appear, moreover, to be partly of a regular nature. One of the causes of dissimilarity between the size of the scale and the length of the fish which we find in the herring does not arise in the case of the cod and coalfish, viz, the relative size of the scale-covered part of the body. This factor, which in the case of the herring increases until maturity is reached, exhibits no regular alteration with age in the cod and coalfish, save in the case of quite small specimens. On the other hand, the irregularity in the size of the scales renders the relation between the growth of the scale and that of the fish less distinct, when judging merely by comparison of the size of several individuals and the size of certain of their scales. The best method would be to keep fish in captivity, measuring their scales at different ages — a method which is scarcely feasible as regards the herring, but which might well, and doubtless will, be employed in the case of the cod family. Table 3 will serve to give an idea of the relation between the size of the scale and the length of the body for coalfish, Table 4 showing corresponding figures for cod. L = total length, T = length exclusive of head and tail fin, E = size of scales from the vicinity of the lateral line below the forepart of the second dorsal fin, H = size of scales from the vicinity of the lateral line below the forepart of third dorsal fin.

“The figures given in the above tables as for accuracy of the agreement between the size of the scale and length of the fish (5.5—8.3 %) correspond to those found by Lea in the case of the herring, viz: 6—7 %.”

These methodical investigations suffice to show that the scales of the cod may be used as a means to exact study of the growth of the fish; there remains the important task of investigating the growth of the cod in all the different parts of its area of distribution. It is however, evident, that we must for the present restrict ourselves to those waters which have been made the subject of special investigation during the past years,

Table 3. (Coalfish).

Nr.	L	T	$\frac{L}{T}$	E	H	$\frac{T}{E}$	$\frac{T}{H}$
1	11	79	1.43	1.15	1.20	69	66
2	122	83	.47	1.20	1.35	69	62
3	122	84	.45	1.35	1.45	62	58
4	124	87	.43	1.25	1.40	69	62
5	145	100	.45	1.50	1.65	67	61
6	148	102	.45	1.45	1.60	70	64
7	153	105	.46	1.65	1·70	64	62
8	153	105	.46	1.55	1.75	68	60
9	150	107	.40	1.55	1.65	69	65
10	160	110	.45	1.60	1.85	69	60
11	385	275	.40	4.50	5.25	61	52
12	398	278	.43	4.80	5.35	58	52
13	397	284	.40	4.30	5.15	66	55
14	412	295	.40	4.45	5.75	66	51
15	453	315	.38	...	...	..	..
16	696	494	.41	7.00	9.00	70	55
Average			1.43	...	...	66.5	59.7
m =			2.02 %	...	...	5.5 %	8.3 %

Tab. 4 (Cod).

Nr.	L	T	$\frac{L}{T}$	H	$\frac{T}{H}$
1	103	67	1.54	0.95	71
2	115	77	.49	1.10	70
3	125	84	.49	1.35	62
4	130	88	.48	1.40	63
5	145	99	.47	1.50	66
6	162	108	.50	1.75	62
7	215	143	.50	2.30	62
8	245	165	.48	2 80	59
Average			1.49	...	64.4
m =			1.3 %	...	6.2 %

and which, in consideration of the foregoing, are of most particular interest, viz, the range from Lofoten to the Barents Sea.

Growth and age of young cod.

We will first of all consider the growth of the *young cod*, which are too small to be taken by the fishermen's lines. The following table shows the results of measurements of cod from the Barents Sea.

½ year old, (August),
1¼ » » (June) and
1½ » » (August).

Percentage of the different centimetre groups.

cm.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	average cm.
½ year old..	8.	36.5	27.0	16.0	11.1	1.6	..	..	..	..	..	..	..	..	..	..	..	4.9
1¼ — ..	..	..	..	..	..	..	..	3.6	33.0	42.6	13.4	4.9	2.4	..	..	..	..	11.9
1½ — ..	..	..	..	..	..	..	..	..	..	..	..	0.2	1.5	10.2	28.2	35.5	24.3	17.9

The 1½ year old fish have not been classified by investigation as to age, and may possibly include some slightly older individuals; Damas places the average at 15.1.

In August 1907, a number of hauls were made in the Barents Sea with a fine-meshed trawl, the fish taken being chiefly 2½—4½ years old. The composition in point of size has already been given; the following table shows a *comparison between the composition of the sample in point of size and that in regard to age**).

Hauls made with fine-meshed trawl. Barents Sea 1907.

	20—24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	Total %	Average length
2½	4.9	11.8	0.8	...	...	...	...	...	17.5	21.9 cm.
3½	0.4	22.5	21.7	8.5	1.9	...	...	...	55.0	31.2 —
4½	...	...	8.7	8.7	4.2	0.4	...	...	22.0	35.0 —
5½	...	...	0.8	0.8	1.1	0.8	...	...	3.5	.....
6½	...	...	...	...	0.8	...	0.8	0.4	2.0	.....
Composition in point of size	5.3	34.3	32.0	18.0	8.0	1.2	0.8	0.4	100.0	

By comparing this table with the previous one, we find the following average sizes for different ages of small cod.

½	1¼	1½	2½	3½	4½ years.
5	11.9	15.1	21.9	31.2	35.0 cm.

This also agrees with the growth measurements undertaken by examination of the scales. An especially characteristic feature is the slow growth in the first two years.

The table further shows that there is considerable variation, not only in the composition with regard to size, but also in that in point of age, among the young cod, some year classes being richer than others. Thus we find 55 % of 3¼ year old fish, as against 17.5 and 22 of the 2¼ and 4¼ year old respectively. We have already noticed, that the catches made with the fine-meshed trawl in 1905 and 1913 consisted chiefly of *one year old fish.*

Growth and age of the loddefisk.

If we now turn to the loddefisk, we may here first of all compare the composition in point of age with that in regard to size, in a similar manner to the comparison of the small cod, selecting for the purpose a table based on a sample of 654 fish, analysed by Dr. Damas**).

The average sizes given by Damas are as follows:

Age.......	3¼	4¼	5¼	6¼	7¼	8¼	9¼	10¼ years
Length....	39.4	46	52.4	56.3	62.2	66.2	73.9	80.1 cm.

*) This table has been compiled from the same sample dealt with by Damas on p. 120 of his paper. As his results did not agree with those of my own investigations, I examined the sample again, and found that all the statements of age in the table given by Damas on p. 120 were one year too low. In the course of subsequent correspondance on the subject, Dr. Damas authorised me to state that he agrees with my view, and that an error has arisen in his table during printing.

**) l. c. p. 124—125.

Line catches. 654 cod from Finmarken June 1907.

	Under 40	40—44	45—49	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—89	Over 90	Total
$3^{1}/_{4}$	3.2	3.2	0.2	0.3	...	...	...	...	...	...	...	...	6.9
$4^{1}/_{4}$	0.2	4.4	7.6	1.5	0.2	...	...	...	...	...	...	...	13.9
$5^{1}/_{4}$	...	0.3	3.4	7.0	2.3	0.7	0.5	...	...	...	...	...	14.2
$6^{1}/_{4}$	...	0.3	0.5	7.0	7.2	3.5	1.7	0.9	0.2	...	...	...	21.3
$7^{1}/_{4}$	...	...	...	1.2	6.6	5.3	3.2	2.1	0.7	...	...	...	19.1
$8^{1}/_{4}$	...	...	...	0.5	1.5	2.1	2.1	2.3	0.6	0.5	...	...	9.6
$9^{1}/_{4}$	...	...	...	0.2	0.3	0.5	0.3	0.7	2.4	0.7	0.2	0.2	5.5
$10^{1}/_{4}$	...	...	...	...	...	...	...	0.3	2.1	2.0	1.1	0.2	5.7
$11^{1}/_{4}$	...	...	...	...	...	...	...	0.3	0.3	0.9	0.7	...	2.1
$12^{1}/_{4}$	...	...	...	...	...	...	...	...	0.2	0.3	0.5	0.2	1.2
$13^{1}/_{4}$	...	...	...	...	...	...	...	...	...	...	0.2	0.2	0.4
	3.4	8.2	11.7	17.7	18.1	12.1	7.8	6.6	6.5	4.4	2.7	0.8	100.0

Of the youngest year classes, which are represented both in the trawl catches of small fish and among the line-caught cod from Finmarken, the average sizes are highest for the latter; thus:

	3 year old	4 year old
Trawl catches	31.2	35.0
Finmark fish	39.4	46.0

The difference is naturally explained by the fact that *only the largest specimens among these younger year classes are taken with the line. These year classes therefore only partly belong to the loddefisk.* From five years of age upwards, however, most of the fish appear

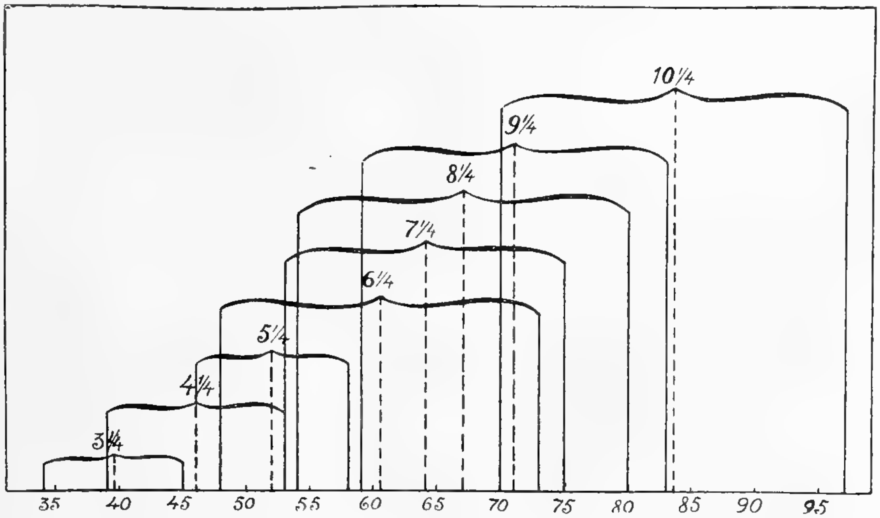

Fig. 85. Variations in size and average sizes of different year classes. The horizontal base line gives lengths in cm. $10^{1}/_{4}$ = $10^{1}/_{4}$ years old.

to belong to these, the great majority of five year old fish being over 50 cm. All the age classes exhibit great variation in point of size, as will be seen from Fig. 85, where the limits of variation and averages for the year classes are stated for the line-caught fish, according to the investigations made. A comparison of this figure with the table above will serve to further show the *composition in point of age of the different size groups.* First of all, it will be seen that no single size group entirely or even closely coincides with any single age class, there being as a rule at least two of the latter which include a great part of the individuals in a size group. Thus most of the fish of

40—44 cm. long are 3 and 4 years old
45—49 » » 4 » 5 »
50—54 » » 5 » 6 »
55—59 » » 6 » 7 »
60—64 » » 6 » 7 »

The loddefisk, or cod under 65 cm. in length, thus include the ages from 3—7 years, the skrei, those of more than 65 cm., being over 7 years old. The former class includes, however, some specimens of 8 and 9 years, the latter some few of 5 and 6 years old. The boundary line between the two will best be seen by examination of the composition of the skrei in point of age.

In the samples upon which this table is based, a characteristic feature in regard to *age* was the fact that many of the year classes were very evenly represented.

Age	4¼	5¼	6¼	7¼	8¼	years
No.	13.9	21.4	21.3	19.1	9.6	%

In regard to size, the individuals were evenly distributed among many groups, and in like manner, as regards age, belonged to many different year classes. We have already seen, in considering the size of the Finmark fish, that these do not by any means always embrace so many different sizes in more or less even proportion. At certain times, and in certain years, a single size may be far more numerously represented than the others. The material at my disposal as regards determinations of age is unfortunately not so extensive as that for measurements of length. Determinations of age are available only for the years 1907, 1909 and 1913. It is however, of particular interest to compare these three years, each of them representing a different characteristic situation. I have therefore, in Figs. 86 and 87, compared the age and size of the Finmark fish for these three years, for 1907 according to DAMAS', for 1909 and 1913 according to my own analyses.

We have already referred to the size and age composition in 1907, and pointed out the characteristic feature, that many size and age groups were here more or less evenly represented.

It is otherwise in 1909 and 1913. Both these years exhibit a *concentration* of sizes and ages about some few groups, these differing however, very greatly for the two years, as will be seen from the following.

	Principal size groups	Principal age classes
1909	50—64 cm.	5 and 6 years
1913	65—79 »	8 » 9 »

The variation in the composition as to age and size is thus seen to be as great as could possibly be imagined. The year 1909 shows great quantities of the youngest loddefisk, (the five year old fish), whereas in 1913, we find the stock almost entirely composed of skrei (8 and 9 years old).

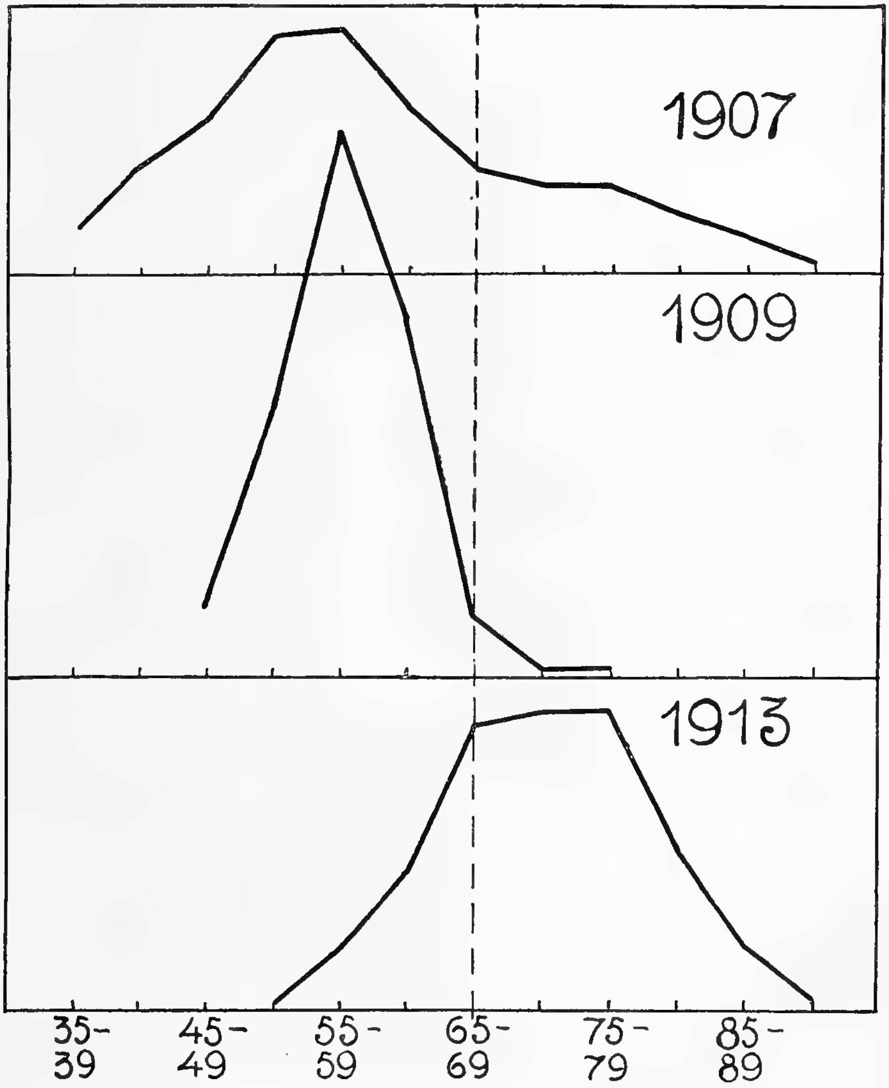

Fig. 86. Composition in point of size of Finmark fish in the years 1907, 1909 and 1913.
45 = 45 cm.

In 1913 many samples were taken, several of which I subsequently analysed. We have already noticed, when considering the varying composition in regard to size of the Finmark fish, that in May 1913 these consisted exclusively of skrei, the stock on the Murman coast being chiefly composed of small fish, whereas in June, an immigration

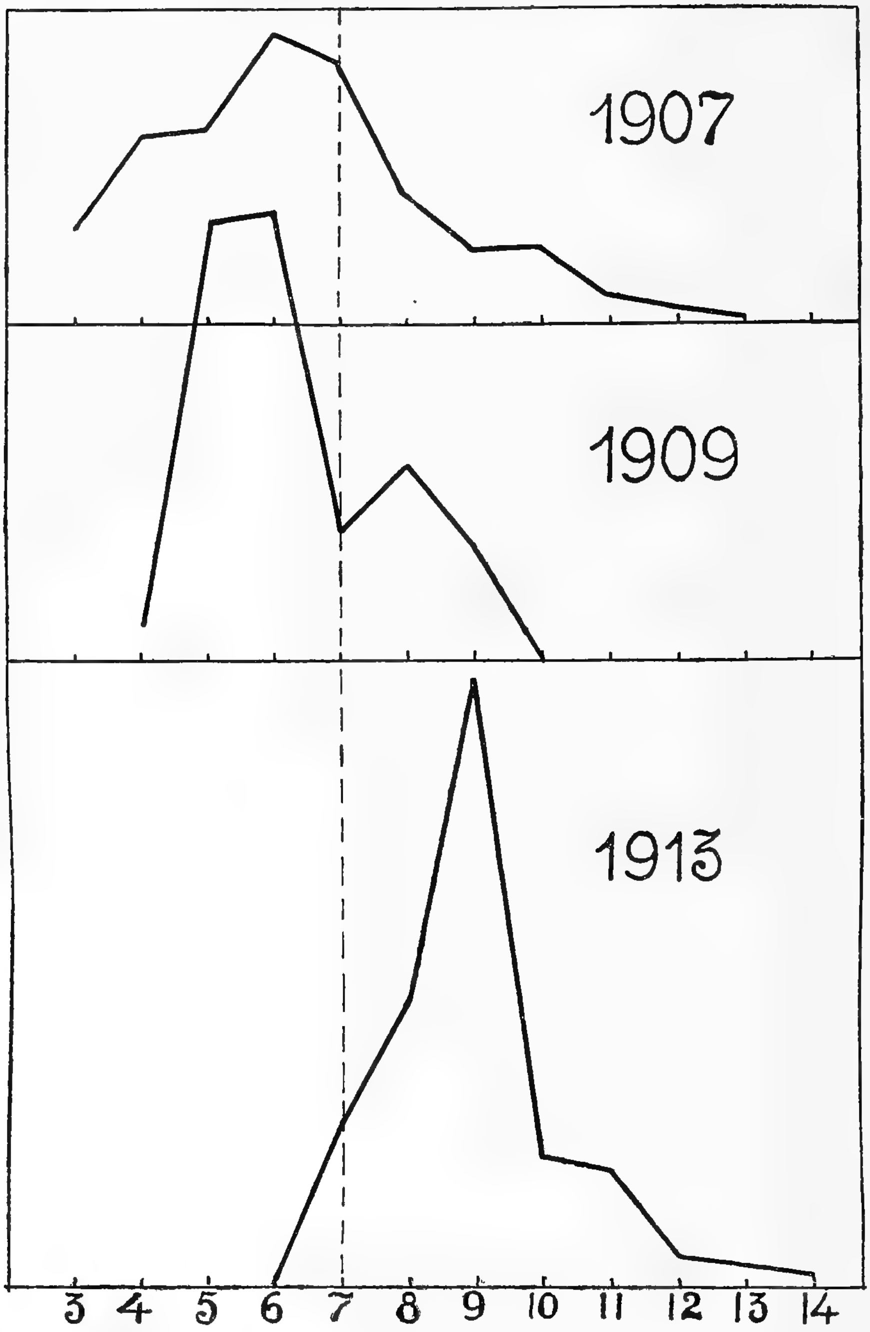

Fig. 87. Composition in point of age of Finmark fish in the years 1907, 1909 and 1913. 4 = 4 years.

of small sizes occurred on the Finmark coast, great quantities of skrei emigrating at the same time to waters farther east. The samples upon which these conclusions were based have also been analysed in regard to age: the results will be found in Fig. 88, from which a good view of the conditions may be obtained. In May 1913, the Finmark stock consisted of 8 and 9 year old fish, the latter especially amounting to 45 % (Curve 1). The stock on the Murman coast, on the other hand, was composed of 4, 5, and 6 year olds, (Curve 2) which were entirely lacking in the Finmark waters in May. In June, however, the composition in point of age for Finmarken (Curves 3 and 4) shows an admixture of younger fish, especially six year olds (16 %) which are best taken by hook and line. We thus find a distinct resemblance between the results of the investigations as to the age and size of the Finmark fish.

The investigations as to age serve also to further support the conclusion already arrived at by the study of the composition in regard to size, viz; that the Finmark fish, in May 1913, agreed exactly with the Lofoten skrei. Before going closer into this, however, some general observations as to the age and growth of the skrei may not be out of place.

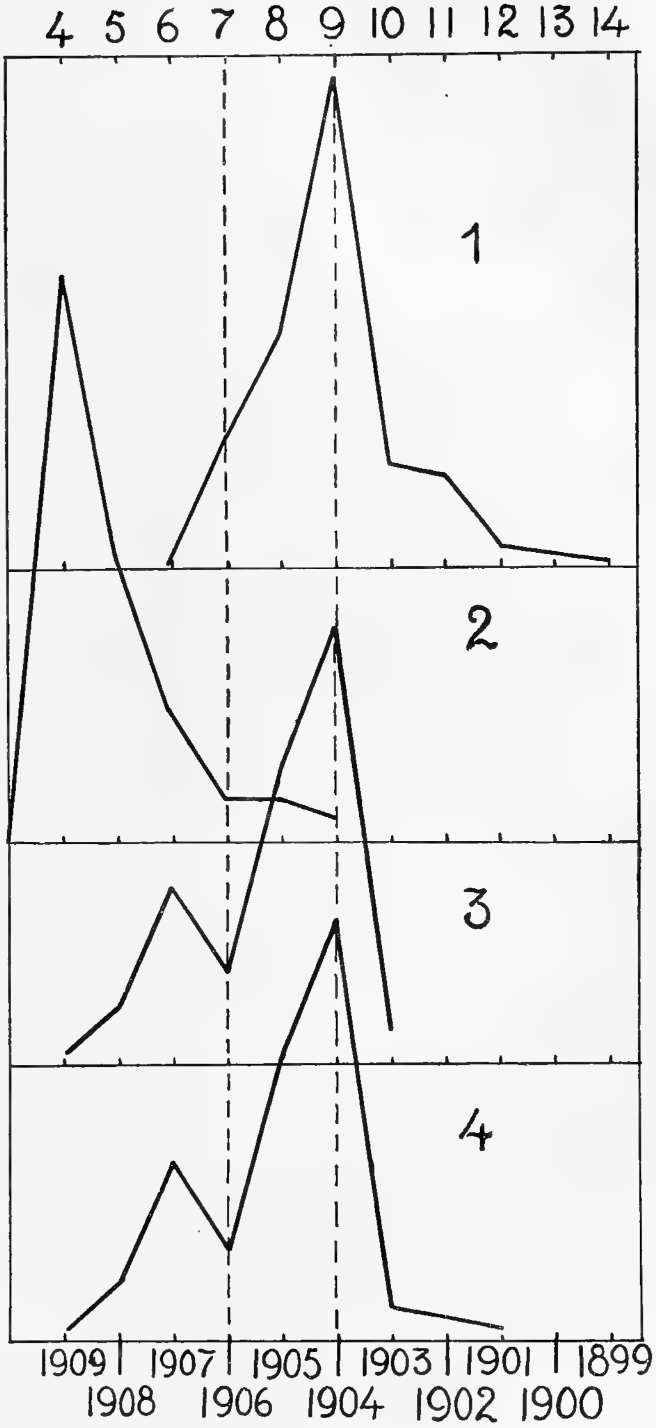

Fig. 88. Composition in point of age of cod samples from the Barents Sea in 1913. 1. Finmarken, May. 2. Murman Coast, May. 3. and 4. Finmarken, June.

Age and growth of the skrei.

As regards the age of the skrei, DAMAS mentions having examined 95 Lofoten skrei of between 53 and 71 cm. in length, of which

3 were 5 years old
6 » 6 » »
14 » 7 » »

the remainder, (72), between 7 and 12 years old, the largest, from 100 to 115 cm. in length, having a minimum age*) of 9—15 years.

An analysis of age which I made of a sample of 207 skrei taken on the 14th of April 1913 at Røst, gave the following results.

	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	105—109	Over 110	total
7 years	1.0	2.9	1.4	1.0	...	...	...	...	...	...	...	...	6.3
8 —	...	5.9	7.8	2.4	1.9	...	...	...	...	...	...	...	18.0
9 —	...	...	11.2	15.2	15.2	4.9	1.9	1.0	...	...	...	...	49.4
10 —	...	...	0.5	2.4	4.9	2.9	1.0	1.4	0.5	0.5	...	...	14.1
11 —	...	...	...	1.0	1.0	1.9	1.0	1.0	0.5	0.5	...	...	6.9
12 —	...	...	...	...	...	...	...	0.5	...	0.5	0.5	1.4	2.9
13 —	...	...	...	...	...	...	...	...	1.4	...	...	1.0	2.4
Size composition; % of total sample	1.0	8.8	20.9	22.0	23.0	9.7	3.9	3.9	2.4	1.5	0.5	2.4	100.0

This sample contained no 6 year old fish, about 82 % were between 8 and 10 years, most being 9 years old. Only a very few were over 11 years, these in all amounting to but 5.3 %. The following table shows the average sizes according to this analysis, the average figures from Damas' table also being given. As will be seen, they agree very well together, at least when taking into consideration the paucity of the material.

Average length	7 years	8 years	9 years	10 years	11 years	12 years
Acc. to table above	63.9	67.1	73.6	80.6	84.5	107.
» » Damas' table	62.2	66.2	73.9	80.1	....	....

Of skrei, the only material available for determinations of age is from the years 1906, 1907 and 1913. The analyses for 1906—7 have been made by Einar Kofoed, those for 1913 by myself. The results will be found in Figs. 89 and 90. All things considered, the samples agree very well; some difference is, however, apparent. In all the years, the great majority consisted of 8—10 year old fish; in 1906 however, the 8 year individuals were most numerous, in 1907 and 1913 the 9 year olds. These two last named years again differ one from the other, 1907 showing many 10 year fish. A comparison of the sizes for the three years exhibits very similar results; the skrei were in 1907 represented by the largest size groups.

These samples do not however, give any complete view of the composition in regard to age and size of the skrei; as will be seen from the table on p. 92, there were in certain years, e. g. 1902, 1903 and 1905, considerably more small skrei than in the years here referred to.

*) Damas points out (l. c. p. 115) that determination of age in the case of older specimens is a difficult matter, and that the figures given should be considered rather as too low than too high.

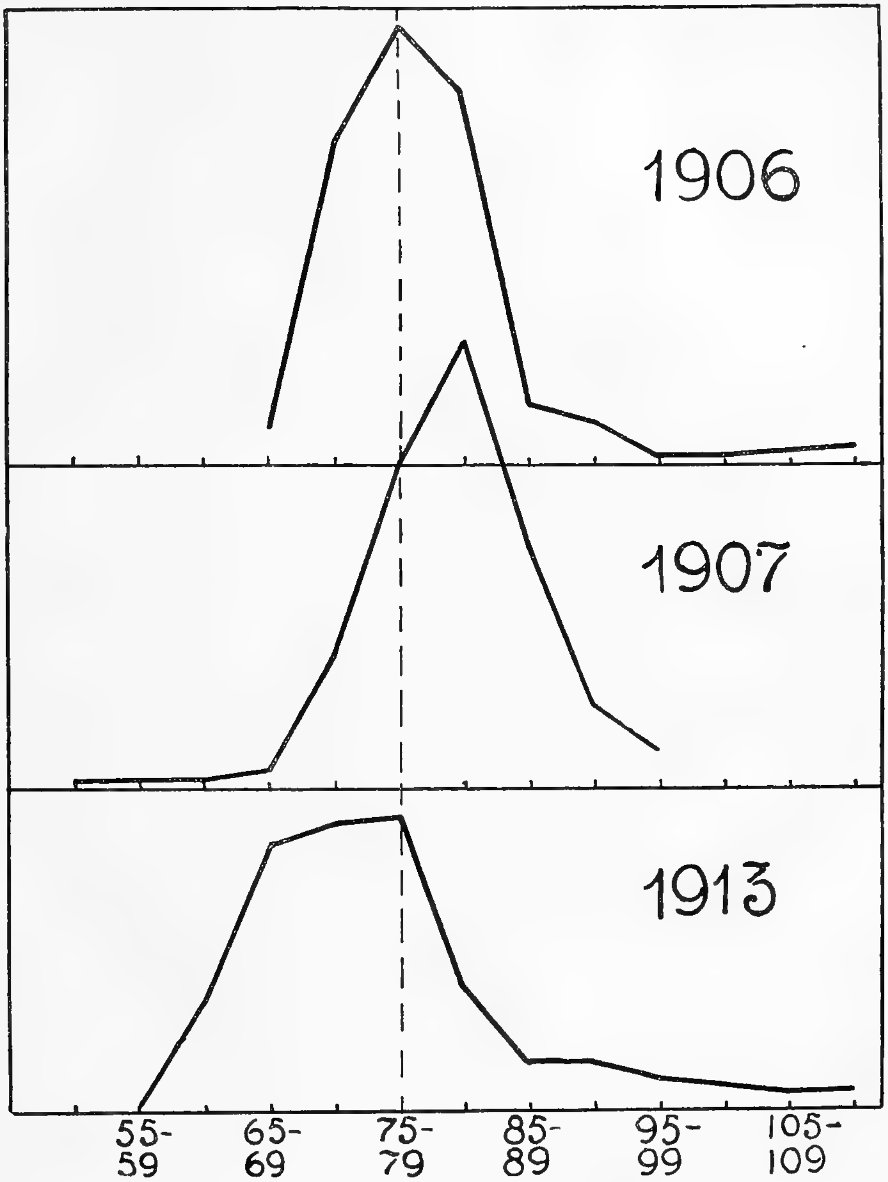

Fig. 89. Composition in point of size of skrei samples from the years 1906, 1907, and 1913.

Similarity of composition between skrei and Finmark fish in 1913.

We will now proceed to further compare the skrei and the Finmark fish in 1913. A table (p. 105) has already been given showing the composition in point of size of the two samples of { Skrei from Røst, 14th April, Finmark fish from Honningsvaag, 6th May.

Fig. 91 gives a comparative view of the size and age of these two samples. The similarity in the composition in both respects may be termed remarkable, and would appear to furnish, in the first place, valuable testimony as to the reliability of the method employed. When two samples, taken some 6—700 km. apart, exhibit so great similarity in their compsition, in spite of the fact that they contain so many size and age groups, then it is highly probable that both have been taken from, and are truly representative of, one and the same stock. This probability is, moreover, placed almost beyond doubt by the results of the marking experiments, which proved that migration from Lofoten to Finmarken took place.

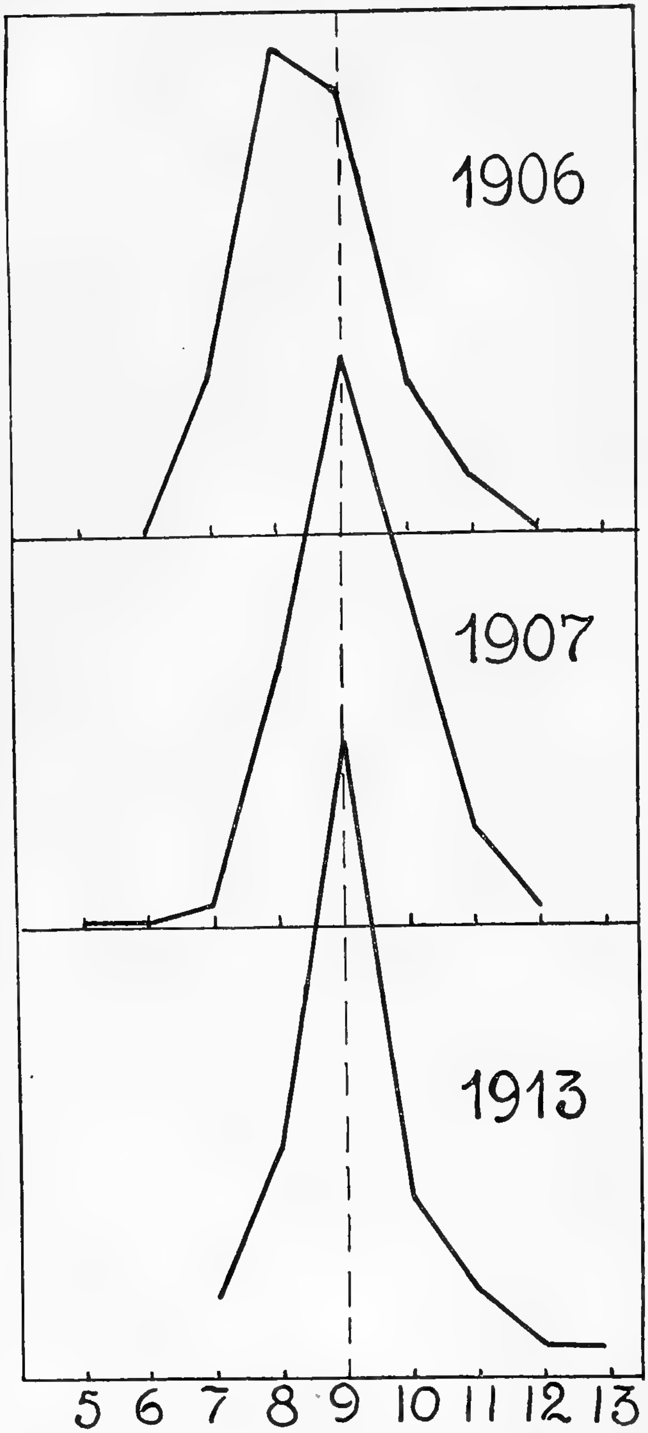

Fig. 90. Composition in point of age of skrei samples from the years 1906, 1907, and 1913.

The year class 1904.

In both the samples here referred to, the highest percentage falling to any single year class was 45 %, this being the figure for the 9 year old fish, i. e., those spawned in 1904. We thus arrive at the remarkable fact, that nearly half of both skrei and Finmark stock in 1913 were fish of the 1904 year class, the same which has played so very important a part in the herring fishery of the last few years (see Chap. I). It would thus seem as if not only in the case of the herring, but also as regards the cod, the 1904 individuals were more numerous than those of other years. Before coming to a decision as to this, however, we must first see what can be ascertained from the samples available as to this year class, and compare the results obtained with the facts indicated by the fishery statistics for these years.

Fig. 92 gives a comparative view of all the samples from which any information is to be obtained as regards the occurrence of the 1904 year class in the last few years. The figure shows the composition in point of size of the samples (the broken lines) and

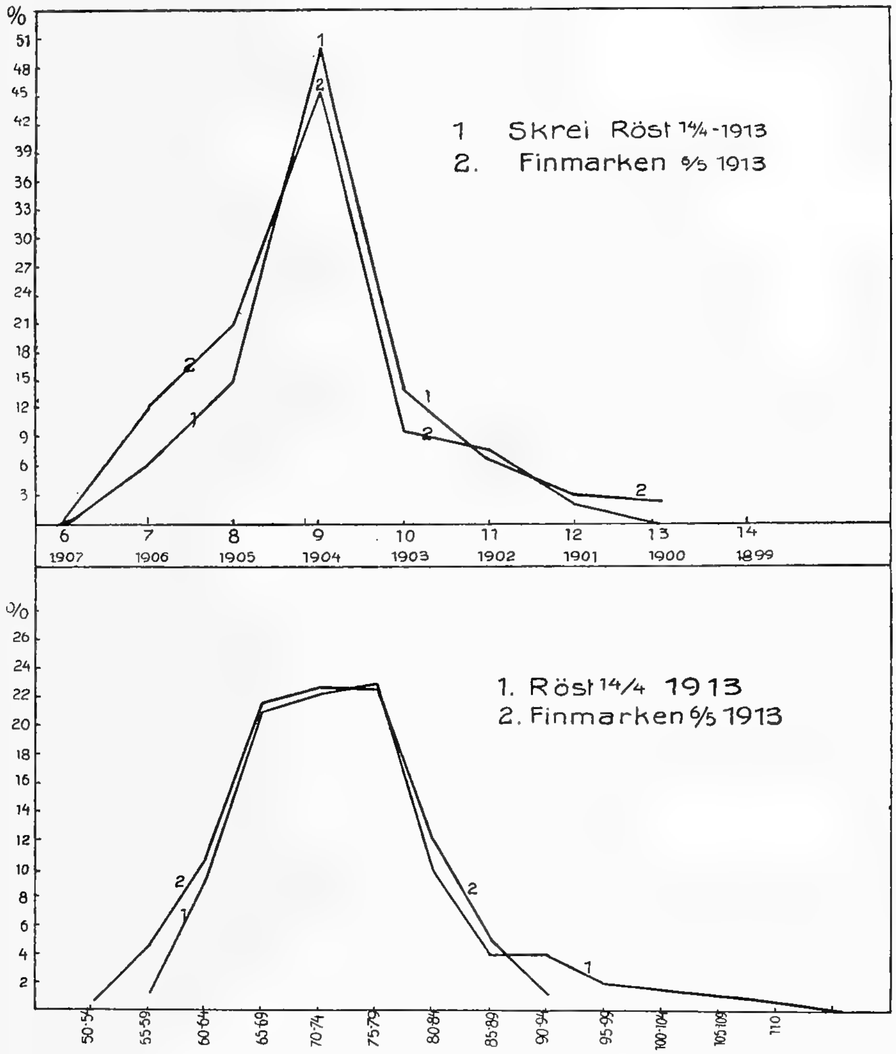

Fig. 91. Composition in point of age (uppermost) and size, of two samples from 1913.
1. Skrei from Røst, $^{14}/_{4}$. 2. Cod from Finmarken $^{6}/_{5}$.

the same for the year class in each sample, 1904, expressed in *percentage of the whole sample.*

In 1905, the fish of the 1904 year class were between one and two years old. The great quantity of small fish taken in the fine-meshed trawl, and which in August were between 15 and 19 cm. long, must have belonged to this year class. These fish amounted to 64 % of the cod taken in the trawl.

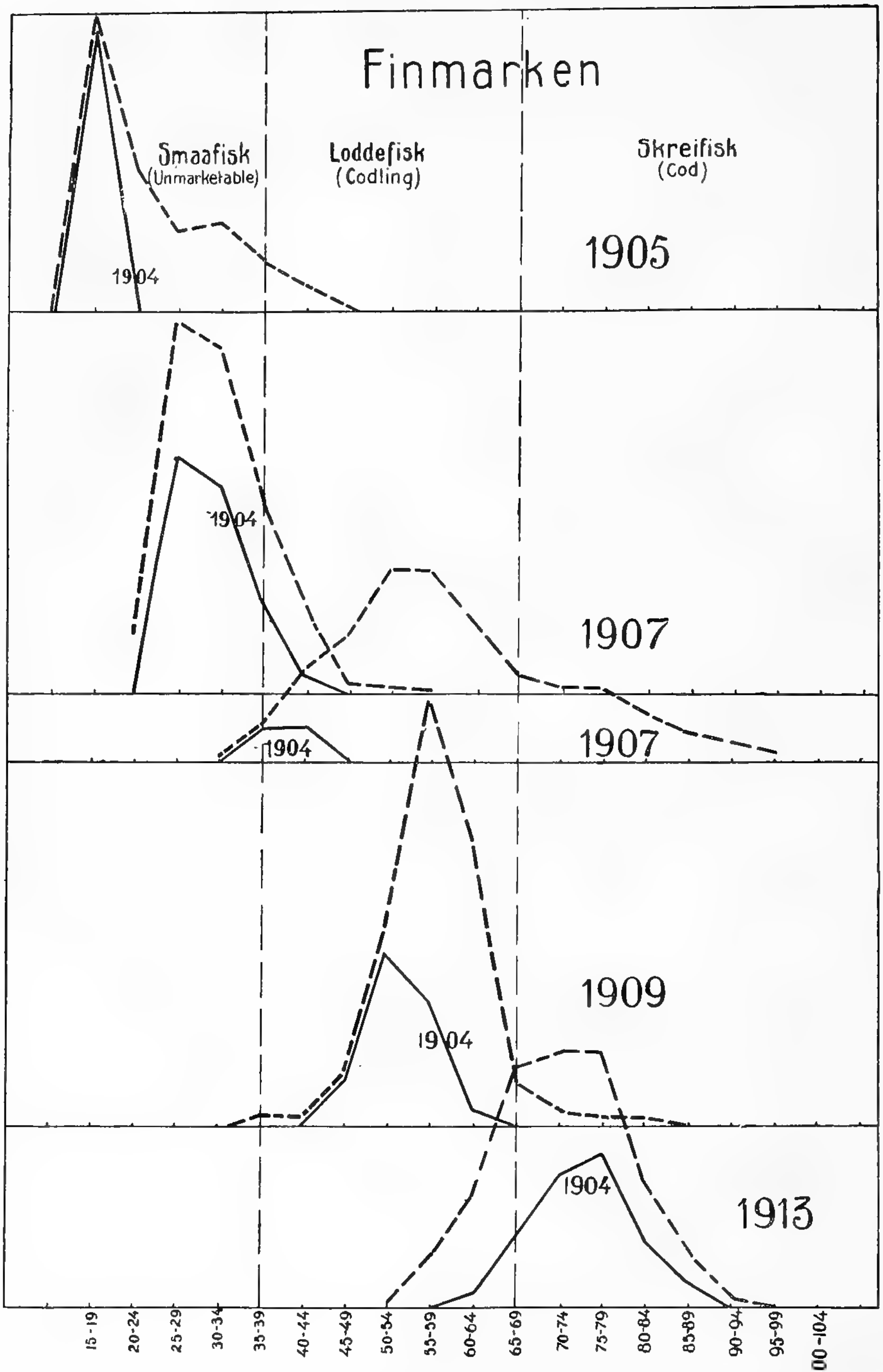

Fig. 92. Samples showing the 1904 year class among the Finmark cod. The two uppermost samples taken with fine-meshed trawl, those below being line-caught fish.
—— Composition in point of size of 1904 year class; percentage of whole sample.
- - - - Composition in point of size of whole sample.

In 1907, similar trawling catches (Table p. 130) showed 55 % of three year old cod, between 25 and 35 cm long. This year class has thus played a predominant part among the *young cod*, both in 1905 and 1907. Among the loddefisk, however, the 1904 group amounted to only 6.9 % (vide Table p. 131 and the third curve from above in Fig. 92). Cod of 25—35 cm. are never of any great importance in the line fishery. In 1909, also, the importance of this class, though greater than in 1907, was less than was subsequently the case, the dominant year classes in the Finmark stock in 1909 being the 5 and 6 year old fish, with 32.5 and 33.3 % respectively. It will be seen from Fig. 92 that in 1909, only the smallest of the Finmark fish belonged to the 1904 year class. It must therefore be presumed that only a part, viz, the largest specimens, of this year class had up to that time joined the shoals of the loddefisk.

Between 1909 and 1913, we have unfortunately a long blank period for which no observations are available. This is the more to be regretted, as in these years especially there would have been occasion to study the transition stages, the immigration of the 1904 year class into the loddefisk group, and later into that of the skrei, where they are found in 1913, when they amount to almost half of the total Finmark stock, being then some 70—80 cm. long.

Thus much, it is true, we may learn from the samples described; that the 1904 year class was extremely numerous among young cod, loddefisk and skrei; this could, however, have been better and more definitely proved had observations been available for the years 1910, 1911 and 1912.

It is therefore most fortunate that we are able, after all, to obtain reliable information as to the Finmark fish during these years. For this we have to thank Consul Charles Robertson, one of the principal business men in Finmarken, who has been kind enough to interest himself in the matter, and undertake the task of going through all his records of dried fish, subsequently furnishing me with the results obtained. In order to appreciate the value of this material, we must first consider the relation between the size and weight of the cod, and the same factor for the dried fish.

Relation between size and weight of the cod.

When the cod are to be cured or dried, the head is first cut away, and the intestines removed. The fish are then said to be "gutted". Distinction is therefore made between the weight of the cod when whole, and its weight when gutted. "Whole weight" is the weight of the fresh cod as taken from the water, "gutted weight", the weight of the fish minus head and intestines. If the gutted cod are to be cured as "Klipfisk", a part of the back bone is then further removed, and the fish salted, and afterwards dried. The "Tørfisk" are hung up in the open air and dried. Owing to the different method of preparation, the split cod (klipfisk) will thus have a greater weight than the tørfisk. We will first of all consider the original whole weight of the fish at different sizes.

Whole weight of the cod.

The different individuals vary considerably in weight, even when of the same size (i. e. length). They vary also with the season, according to their condition as regards

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nourishment; there can, moreover, be some variation between the different specimens taken in one and the same haul. Of 13 cod, all belonging to the sample from Honningsvaag 6th May 1913, and all of 73 cm. length,

1	weighed	2.4 kg.
2	»	2.6 »
2	»	2.8 »
1	»	2.9 »
3	»	3.0 »
1	»	3.1 »
2	»	3.2 »
1	»	3.4 »

the average weight being thus 2.923 kg.

Still greater variation is naturally found in the 5 cm. groups, upon which the calculations given in this chapter are based, but as the variations are more or less alike for all groups, we can obtain a sufficiently accurate, and far more clear survey of the prosition by keeping to the *average weights* for the different groups.

We will first of all consider the weights of two samples, one of young cod, the other of skrei.

Average weight (whole) in kilos, of cod of different size groups, Barents Sea, 1907.

15—19	20—24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64
0.04	0.07	0.13	0.24	0.38	0.57	0.82	1.23	1.25	2.09

The small cod, under 40 cm., which are rarely taken by the lines, are thus all seen to weigh less than half a kilo, (one pound), their weight increases, however, almost twofold from one 5 cm. group to the other. *The sizes of principal importance in the Finmark loddefisk stock, viz, from 50—64 cm., lie between the whole weights of 1 and 2 kilos.*

Proceeding to consideration of the skrei, we find the following figures:

Average weight (whole) in kilos. of skrei of different size groups, Røst 1913.

55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100-104	105-109	110-114	115-19
1.5	1.8	2.3	2.8	3.4	4.1	5.1	5.8	7.5	7.7	10.7	12.4	13.0

The fish here increase in weight by about ½ kilo for each 5 cm. of size from 65—69 to 85 cm, later by between 1 and 2 kilos for each 5 cm. group. From 65 to 112 cm., the weight increases from 2 to 13 kilos, or more than sixfold. First in importance are naturally those groups which are most numerously represented in the stock, from 65—89, and which cover a field of from about 2 to about 5 kg. average weight.

It is very interesting to note how the weight increases with *age*. As we have already seen (vide pag. 130), the average length of the cod in the Barents Sea was as follows according to catches by:

Finemeshed trawl				Long-lines.						
1½	2¼	3¼	4¼	5¼	6¼	7¼	8¼	9¼	10¼	years
15.1	21.9	31.2	35.0	52.4	56.3	62.2	66.2	73.9	80.1	cm.

The average weight of the fish will thus be approximately as follows:

At	1½	years	0.04	kg.
»	2	»	0.07	»
»	3	»	0.2	»
»	4	»	0.4	»
»	5	»	1.2	»
»	6	»	1.5	»
»	7	»	1.8	»
»	8	»	2.3	»
»	9	»	3.0	»
»	10	»	4.0	»

At two years of age, the weight of the cod is nearly a hectogramme, at three, it is twice that figure, and at four years, the weight is about 4 hectogrammes. A five year old fish weighs about a kilo, next year one and a half, and at seven years, about 2 kilos. At nine years of age the fish weigh three, at 10 years four kilos. All these figures are naturally only approximate, and subject to great variation from one individual to another; they serve, however, to give a sufficiently accurate idea of the relation on the whole.

One variation in the weight of the cod is of great importance, viz, that consequent upon spawning. As the genital organs mature, all reserve matter, fat, etc. disappears from the whole of the body, being consumed in the formation of the milt and roe. When the fish are fully spent, the weight is found to have greatly decreased; after spawning, however, the fish again commence to grow fat and heavy. The weight, and the amount of fat are at their highest in summer, when the fish have been able to feed liberally on the shoals of capelan etc. It is therefore of particular interest to compare the weight of the spent skrei (1) with that of Finmark fish (2) of the same size. An exceptionally favourable opportunity of so doing occurred in 1913, when the skrei and the Finmark fish consisted almost entirely of the same sizes. I therefore give below the average weight for the different sizes of skrei and Finmark fish in 1913.

Average weights (whole) in kilos, of different size groups of skrei and Finmark fish 1913.

Nr.		65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	105—109
1	Sørvaagen 23. April	2.0	2.2	2.9	3.4	4.3	5.6	6.2	6.8	8.6
2	Vardø 21. May....	2.3	3.1	3.8	4.7	5.5	6.5	7.9	9.8	11.3
	1 % of 2...	87	71	71	75	78	86	78	70	76

The figures in the last line express the percentages furnished by the spent fish in each group of the weight of the fat summer fish. It will be seen that these amount to between 70 and 87 %. This is to say, that the spent fish have lost ¼ or $^1/_5$ of their midsummer weight; so great are the fluctuations which may take place in the course of the year.

Weight of gutted cod.

In dealing with measurements of thousands of fish, it is surprising to note *the regular proportion between the whole and gutted weights for all size groups in the same sample.* As an example of this, we may take the following comparison of the two factors in a sample of Finmark fish from 1913. The weights are stated in kilos, the percentage of the whole represented by the gutted fish being given below. In all the skrei sizes, over 65 cm.

Comparison of whole and gutted weight, Finmark fish, May 1913.

	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94
Whole weight.	1.5	1.8	2.3	3.0	3.5	4.2	5.1	5.9
Gutted weight	1.1	1.25	1.6	1.9	2.3	2.8	3.3	3.9
Gutted % of whole weight	61	68	69	67	66	66	66	65

the average values vary only between 61 and 69 %. Thus a whole fish weighed here one and a half times as much as a gutted, the latter being ²/₃ the weight of the former.

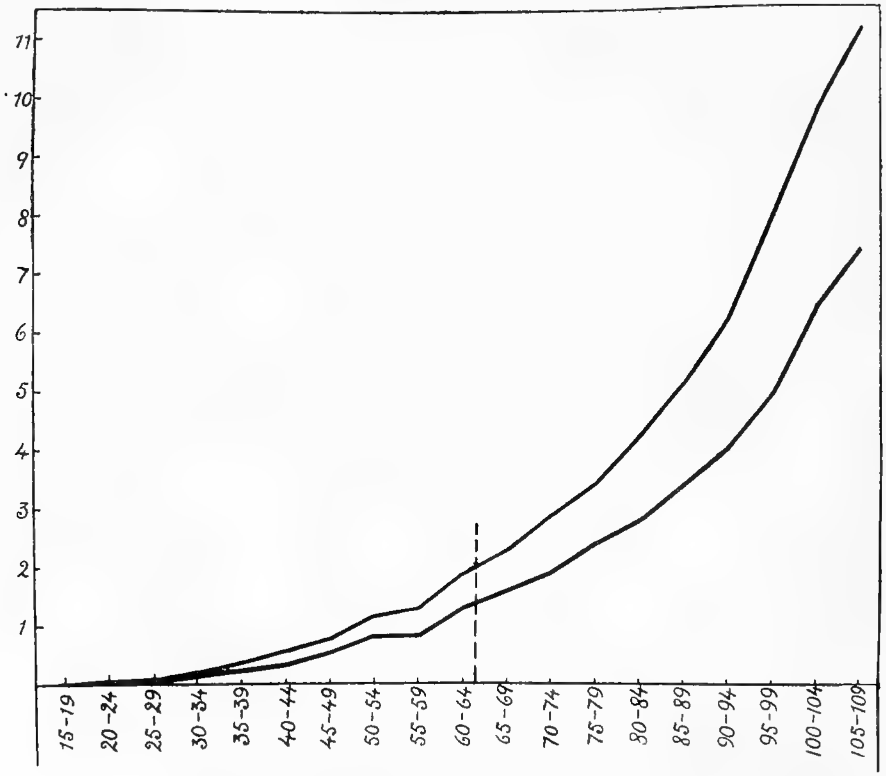

Fig. 93. Curves showing average weights (kilos) of the different size groups, whole weight, (uppermost); and gutted weight.

The third part (or 33 %) lost consists of head, liver, and intestines. Of this, the head may represent 20 %, the intestines 7—10 % and the liver about 4 %, varying according to the size of the fish. The relative similarity between the whole and gutted weights is also distinctly indicated by the curves of the two average weights for different size-groups, as shown in Fig. 93.

From this figure it will be seen that the weight increases greatly with increasing size, especially in the case of the whole weight. The gutted weights of the skrei lie between *1½ and 7—8 kilos. The average weights of the skrei (corresponding to the size group 75—79 cm.) lie between 2 and 2½ kilos.* The weights of the small fish are not easily discerned in the figure; the following table shows these more distinctly:

Average weight in kilos for gutted small fish of different size groups, Barents Sea 1907.

15—19	20—24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64
0.02	0.05	0.08	0.16	0.25	0.38	0.54	0.82	0.83	1.33

Thus most of the young cod under 40 cm. are seen to fall below 2 hectogr.

The	40—45	group	approximately	4	hectogr.
»	45—49	»	»	5	»

and *the true loddefisk sizes lying between ½ and 1 kilos.*

The gutted weight also exhibits a variation according to season: thus the spent skrei lose more in the process of gutting than do the Finmark fish, which retained some 67 %, whereas the gutted skrei only showed 60 %, or even 50 % of the whole weight. The fact that these low percentages are particularly noticeable among the small fish would seem to point to a certain regularity in the cause of the diminution; the spawning apparently occasioning a relatively greater loss of weight in the younger fish.

Weight of the dried fish.

In the fish trade, the relation between the gutted and dried weights of cod is expressed by the general rule that one kilo of dried fish represents about 4—4¼ times that weight in fresh, gutted fish, equivalent to 6 kilos of fresh whole fish.

The tørfisk are sorted into certain classes according to weight, the principal being

50—100 gr., 100—200 gr., 200—400 gr., 400—600 gr. and over 600 gr.

In dealing with tørfisk, it is useful to know what sizes of live or fresh fish correspond to these classes; in other words, what size groups they contain. This can be ascertained in two ways, either by multiplying the weight of the tørfisk by 6, by which the approximate whole weight is obtained, and then calculating the length according to the tables

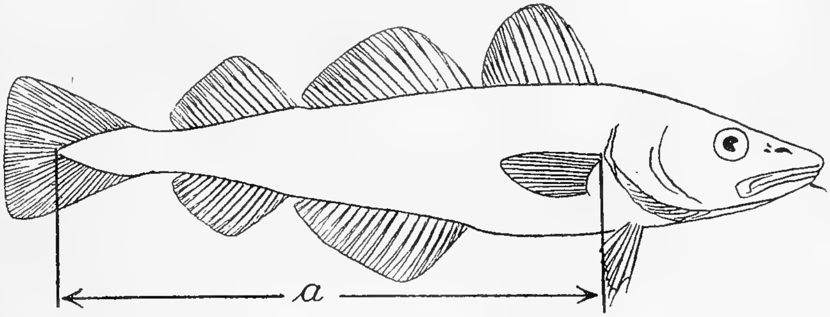

Fig. 94. Cod. *a* indicates measurement used in calculating original whole length from tørfisk. *a* multiplied by abt. 1.5 gives the length of the fish.

given above, or by measuring the length of the tørfisk, and calculating its length when alive. By means of a great number of measurements, I have found that the distance from the forepart of the pectoral fin to the extremity of the root of the tail, multiplied 1½ times, gives the approximate length of the live fish. (Fig. 94).

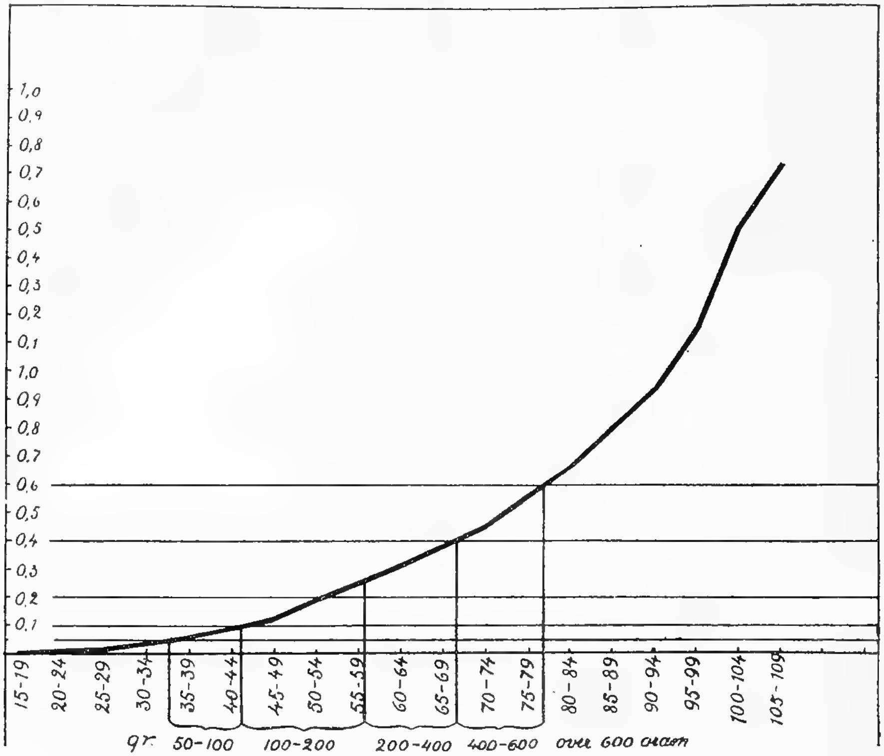

Fig. 95. Curve showing the average weight.

By employing both of these methods, the curve shown in Fig. 95 was obtained, illustrating the relation between the different size groups and their dried weight. It appears, that the

50—100 gr.	class	corresponds	to the	lengths of	33—42 cm.
100—200	»	»	»	»	42—52 »
200—400	»	»	»	»	52—67 »
400—600	»	»	»	»	67—83 »
over 600	»	»	»	»	over 83 »

fresh, whole fish.

We can now again compare these trade classes with the groups for whole and gutted weight, as well as the age classes. The results of such comparison will be found in the following table, which may perhaps also be of value for other purposes than that immed-

Dried Cod. Finmarken.

	50—100 gr.	100—200 gr.	200—400 gr.	400—600 gr.	over 600 gr.
Size fresh in cm........	33—42	42—52	52—67	67—83	over 83
Weight whole, kilos....	0.3—0.6	0.6—1.2	1.2-2.5	2.5—3.8	over 3.8
Gutted weight, kilos ...	0.2—0.4	0.4—0.8	0.5—1.7	1.7—2.5	over 2.5
Age groups	**3** and **4**	**4** and **5**	**5—8**	**7—9**	**9, 10** and upwards
Maximal occurrence of 1904 year class.......	1907 and 1908	1908 and 1909	1909—1912	1911—1913	

iately before us. The most important point at present is to compare the different classes of tørfisk with the age groups (see pp. 132 and 136). We find, that the smallest

tørfisk of 50—100 gr. consist chiefly of 3 and 4 year old cod,
» 100—200 » » 4 » 5 » »
» 200—400 » » 5 — 8 » »
» 400—600 » » 7 — 9 » »
» over 600 » » fish of 9 years old and upwards.

Cured weight of Finmark fish for the years 1908—1912.

We are now in a position to more closely consider the material furnished by Mr. Robertson, consisting of the weights of tørfisk which passed through his hands in 1908—1912. Mr. Robertson delivered during this period some 240,000 "weights" (of 20 kilos) or 4,800,000 kilos of tørfisk, equivalent to some thirty million kilos of fresh whole fish. The whole of this great quantity was sorted in the manner above described; the figures for each of these years will be found in the following table (1). In 1908, the classification is only partially complete. Mr. Robertson's tables II and III show the same results expressed in percentages of the whole year's production. In Table III, the largest fish have not been included. This table is especially worthy of notice, as it best shows the variations during this year between the actual sizes of the Finmark fish. We find the

Tables and calculations by Mr. Chas. Robertson, Hammerfest.

Table. I. Mr. Robertson's output of cured fish in "weights" of 20 kilos. Quantities and sizes reckoned as for cured fish (1 kilo cured = abt. $4^1/_4$ kilo fresh gutted fish).

Year	Under 100 gr.	100—200 gr.	200—400 gr.	400—600 gr.	Over 600 gr.	200 up to and over 600 gr.	In all
1908.....	201	9 327	...	...	...	34 905	= 44 433
1909.....	45	3 132	29 691	18 817	4 565	...	= 56 250
1910.....	132	1 230	12 375	10 070	2 398	...	= 26 205
1911.....	...	1 479	27 175	31 918	7 458	...	= 68 030
1912.....	...	997	14 000	23 858	6 740	...	= 45 595

Table II. The same in percentages of the different weights.

Year	Under 100 gr.	100 - 200 gr.	200—400 gr.	400—600 gr.	Over 600 gr.	200 up to and over 600 gr.
1908	0.5	21	—	—	—	78.5
1909	0.1	5.6	52.8	33.5	8	—
1910	0.5	4.7	47.2	38.5	9.1	—
1911	0.1	2.1	39.9	46.9	11	—
1912	0	2.2	30.7	52.3	14.8	—

Table III: The same; largest fish (over 600 gr. cured) excepted.

Year	Under 100 gr.	100—200 gr.	200—400 gr.	400—600 gr.
1909	0.1	6.1	57.4	36.4
1910	0.6	5.1	52	42.3
1911	0.1	2.4	44.8	52.7
1912	—	2.5	36	61.5

Table IV. Weight (cured) of sample from Honningsvaag May 1913.

Under 100 gr.	100—200 gr.	200—400 gr.	400—600 gr.	Over 600 gr.
0	0	17.3	46.9	35.8

Table V. Weight (cured) of sample from Medfjord, May 1913.

Under 100 gr.	100—200 gr.	200—400 gr.	400—600 gr.	Over 600 gr.
0	0	16.9	32.6	50.5

Table VI. Weight (cured) of above sample, largest sizes excepted.

Under 100 gr.	100—200 gr.	200—400 gr.	400—600 gr.	Over 600 gr.
0	0	21	40.7	38.3

Table VII. No. of cod of different sizes, per 100 kilos cured.

Year	Under 100 gr.	100–200 gr.	200—400 gr.	400—600 gr.	Over 600 gr.	In all
1909	1	37	176	67	10	= 291
1910	7	31	157	77	11	= 283
1911	1	14	133	94	14	= 256
1912	...	15	102	105	18	= 240

Table VIII. No. of kilos fresh loddefisk taken in Finmarken 1909—1913, and calculated no. of cod (at 425 kilos fresh per 100 kilos cured fish).

Year	Million kilos taken	No. of cod
1909	52	35.6 m.
1910	63.1	42 „
1911	80.4	48.4 „
1912	99.2	56 „

following "movement" of the sizes. In 1908 and 1909, many of the fish were small, belonging to the groups 100—200 and 200—400 gr. From 1909—1912, the numbers of the 200—400 group decrease, while the 400—600 group is seen to increase from 36.4 % in 1909 to 61.5 % in 1912. During the last two years, 1911 and 1912, the "over 600" group (Table II) also increased. This was still more noticeable in 1913, as will be seen from the Tables IV—VI, where my own weighings and measurements of whole fish are expressed as for tørfisk, enabling us to directly compare these with the corresponding figures for the previous years.

A graphical representation of Mr. Robertson's Table II will be found in Fig. 96 B. On comparing this with the table, it will immediately be noticed that the numbers of the smaller sizes greatly decreased in 1909—1913, with an increase of the larger, (over 400 gr). I have also drawn, on the basis of tørfisk observations, a curve expressing the composition in point of size of the fresh fish in 1911, no actual measurements of such being available for this year. In Fig. 96 A, this curve will be found compared with that for the size of the Finmark fish in the years 1909 and 1913, and it will be noticed, that a constant increase is apparent in the latter during this period. It is most interesting to note, that a comparison of the above table with those furnished by Mr. Robertson immediately shows this to be due to the increasing number and size of individuals of the 1904 year class among the Finmark fish. In 1909, the most important group according to the trade assortment was that of 200—400 gr; in other words, many of the fish caught must have been 5 and 6 years old. This is also indicated by the determinations of age for the 1909 sample (Fig. 92). By 1910, the fish of the 1904 year class have grown to a size when some, at any rate, pass into the trade group 400—600, this being to a still greater degree the case in 1911, while in 1912, they would have been predominant among the 400—600 gr. fish. The 1903 year class, however, would also appear to have played a considerable part, which is confirmed by the determinations of age from Finmarken in 1913 (*vide supra*). In 1913, these two year classes played a most important part in the yield, which entirely agrees with the fact that the majority of the tørfisk were then over 400 gr.

We may therefore take it as to all intents and purposes proved, that the 1904 year class has played an extremely important part, as compared with the other year classes, among the Finmark fish from the year 1909, or especially 1910, to 1913 inclusive; a phenomenon which exactly corresponds to the predominance of the same year class in the spring herring fishery for the years 1910—1913.

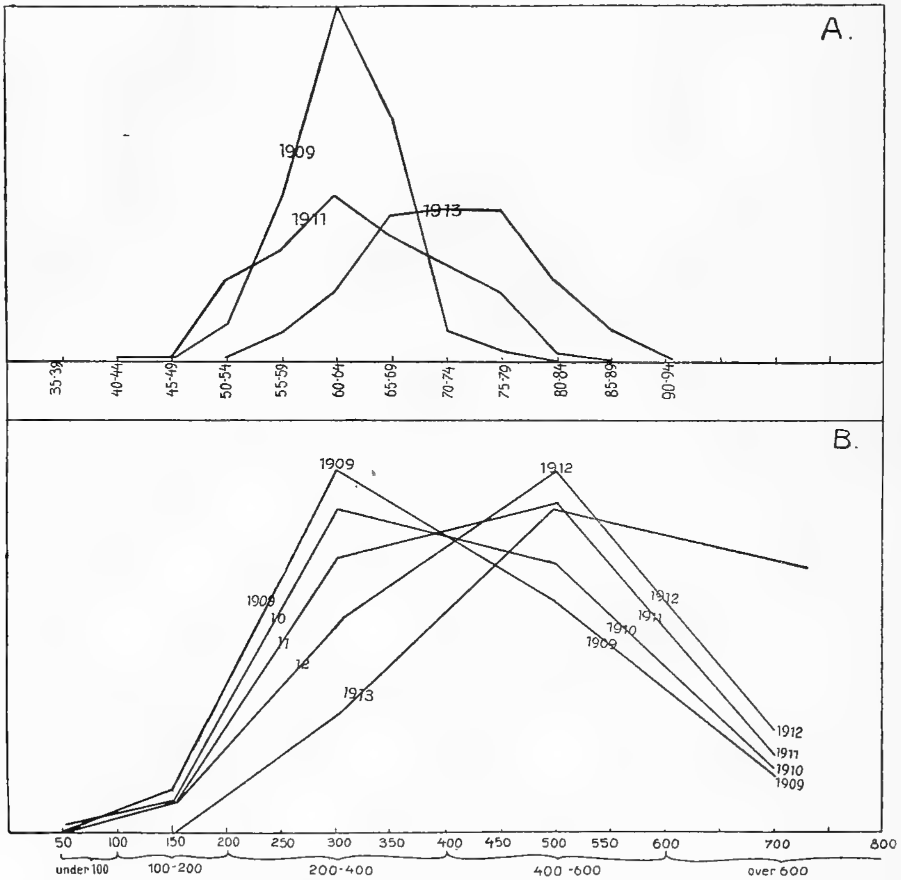

Fig. 96. A. Composition in point of size of Finmark fish in the years 1909, 1911 and 1913. 1909 and 1913 from samples examined, 1911 calculated from samples of tørfisk.
B. Graphical view of the numbers in the different weight groups in Consul Robertson's output for the years 1909—1913.

Rich yield of the Finmark fishery in the years 1910—1913.

The yield of the Finmark fishery for the years 1909—1913 included the following quantities of cod, stated in millions of kilos, and here calculated to corresponding figures for millions of fish:

	Million kilos	Million fish
1909	52	35.6
1910	63.1	42.0
1911	80.4	48.4
1912	99.2	56.0

In 1910, the first year in which the 1904 class, then six years old, could be of great importance in the Finmark fishery, we notice a marked increase in the yield, this being still more evident in 1911 and 1912, when the yield of the Finmark fishery reached a figure never previously attained. The 1904 year class must thus have been not only richer than other contemporary year classes, but also unusually rich in comparison with any earlier known.

Fluctuations of the fishery in former years.

We have hitherto confined ourselves to the period during which the 1904 year class played so great a part in the fishery of the northern Norwegian waters, especially the years 1909—1913. It would be natural now to glance back at the earlier years, and endeavour to ascertain whether similar fluctuations in the stock, and thus also in the fishery, are here again apparent. The farther back we go, however, the less satisfactory do we find the available material. A thorough investigation of the question demands the examination of many samples both as regards age and size; and of such material but little is obtainable. We may however, investigate what there is, by comparing the information at hand as to the Finmark fish with that regarding the skrei.

1901—1903.

We may commence with the years 1901—1903, the earliest years for which extensive measurements exist. My own investigations were begun in Finmarken in 1901, and in 1902, measurements of both skrei and Finmark fish were taken; in 1903 on the skrei banks off Tromsø, Røst and Lofoten. Fig. 97 shows the results of all the measurements taken, the skrei samples being represented by a full-drawn curve, the Finmark fish by a dotted line. In Finmarken, only a few (abt. 20 %) skrei (over 65 cm.) were found in 1901, the stock consisting for the most part of fish about 55—59 cm., including also many (some 40 %) under 55 cm. It must therefore be supposed that the line-caught fish consisted of several year classes, the largest fish being 4, 5, and 6 years old. The curve is very wide, without any strongly marked maximum. This is even more distinctly noticeable when we consider, not the line caught fish above, but also the trawling catches for this year. In the latter part of May 1901, I made a number of hauls with the trawl in the Varangerfjord, which gave the following results as regards the cod:

Composition in point of size. Trawl-caught fish, Varangerfjord, May 1901.

Under 20	20-30	30-34	35-39	40-44	45-49	50-59	55-59	60-64	Over 65
6.6	6.9	4.3	10.1	13.2	21.3	14.2	6.1	5.8	11.8

Here we find the 45—49 cm. group predominant; thus the 3 and 4 year old fish must have been numerous, especially the latter.

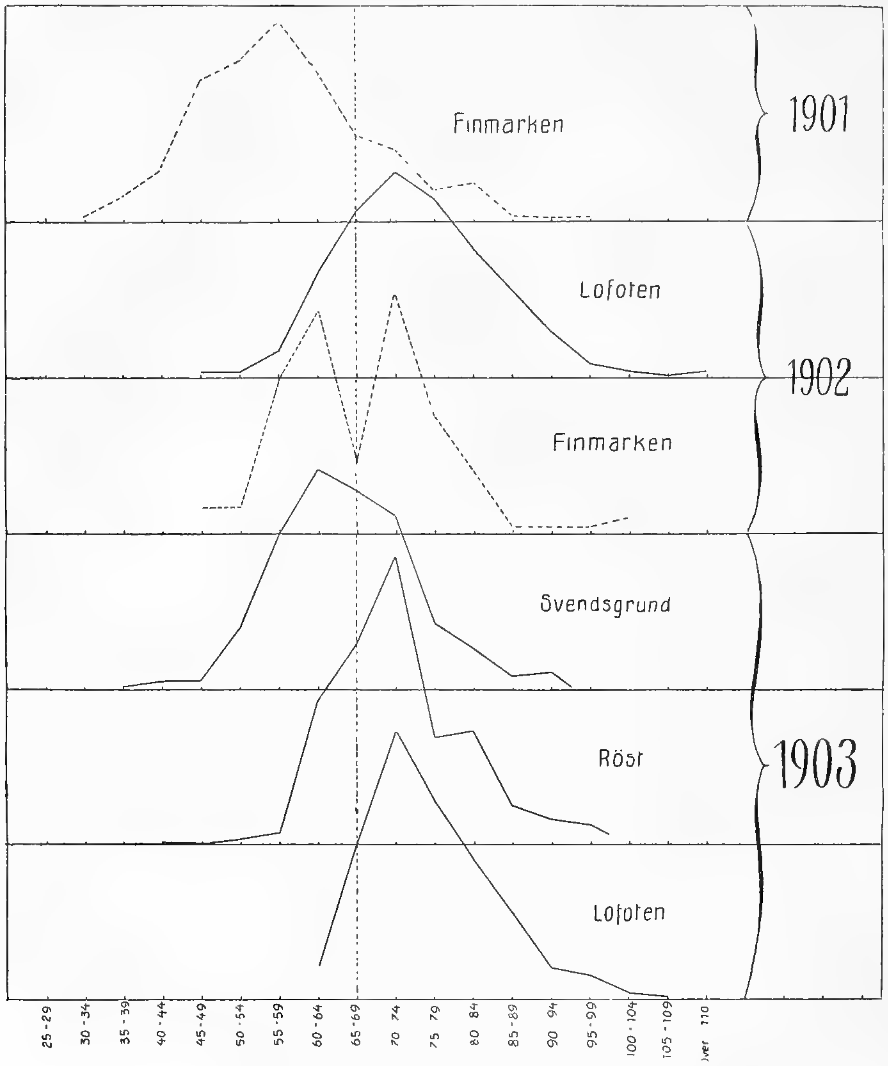

Fig. 97. Composition in point of size of cod samples from the years 1901—1903.
Finmark fish. ——— Skrei.

If we then look at the Finmark fish in 1902, we find early in the year a curve with two distinct summits, a "loddefisk" group and a skrei group. The former consisted, in 1901 and 1902, of the following percentages of the different sizes.

	45—49	50—54	55—59	60—64
1901	14.5	16.6	20.8	15.1
1902	2.8	2.8	16.0	23.0

Comparison of the two rows of figures shows an increase in the sizes, which may be explained by the fact that the fish which in 1901 were 4, 5 and 6 years old would in 1902 be a year older and consequently larger. On the other hand, the 1902 sample can scarcely have been fully representative of the "loddefisk" stock, there being so few small fish present, while the trawl catches in 1901 showed many under 50 cm.

We will next proceed to consider the skrei in 1902 and 1903. In 1902, a great number of skrei were measured on the Malangsgrund, off the coast of Tromsø. The sizes are shown in the figure, the 70—75 and 75—79 cm. groups being numerously represented. In 1903, again, measurements of skrei were taken on the bank in the immediate vicinity, Svendsgrunden. The skrei here found were the smallest ever observed. No less than 46.8 % were under 65 cm., the average percentage of these undersized fish for all the years from which measurements exist being 9.8. The average size of the whole sample, also, was only 66.1, the normal average for skrei being 76.4. The average here thus corresponded approximately to the normal average for Finmark fish. According to the average sizes of the different age classes of skrei, these fish must have consisted mainly of *6 and 7 year old* individuals, possible also a number of 8 year olds. This again agrees with the composition of the Finmark fish in 1901 and 1902:

1901 .... — 4, 5, 6 year fish
1902 .... — 5, 6, 7 » »
1903 .... — 6, 7, 8 » » ,

or for all years, the year classes 1897, 1896 and 1895.

From Svendsgrunden, the investigations were extended to Rost and Lofoten. Here the fish were, in March, considerably larger, about the same as on the Malangsgrund the year before. This is not easily explained at first sight. I can myself only suggest that it should be due to a phenomenon similar to that which took place among the spring herring in 1908 (Chap. I. Fig. 22) viz., an extensive immigration of young fish into the shoals of the older and larger individuals. We noticed, in the case of the spring herring fishery in 1908, that in February, at the beginning of the season, there were many old and large fish, whereas later on, in April, the size had considerably decreased, owing to the great immigration of four year old fish (the 1904 year class) into the spawning shoals. In a similar manner, I believe that the Lofoten skrei stock in March 1903 must have been comparatively small and chiefly composed of older fish, while farther to the north, shoals of quite young skrei were on their way southwards to the Lofoten banks. It is greatly to be regretted that no such accurate measurements were taken in April 1903. In the report of the fishery authorities, however, we find two points of importance, firstly that the principal fishery at Lofoten did not commence until April, and secondly, that the average weight of the Lofoten skrei for the year was 1.5 kilos (gutted weight).

As to the yield of the fishery in different months of the season in 1903, the fishery report gives the following figures.

Lofoten fishery, percentage of total catch.

	January and February	March	April
Average for 1871—1890	19.8	62.7	17.5
Average for 1891—1900	12.3	65.4	22.3
1901	13.8	60.0	26.2
1902	16.1	59.4	24.5
1903	*0.0*	*31.4*	*68.6*

The year 1903 was thus (exactly as 1908 for the herring) a late season year. The samples examined at Lofoten in March were taken before the arrival of the young fish. As regards the average weight of the line-caught fish, the fishery report places this at 152 per 100 kilos. According to my own weighings of skrei in 1913, the averages (gutted weight) for the different size groups were as follows:

55—59	60—64	65—69	70—74	75—79	80—84
1.0	1.1	1.4	1.8	2.4	2.6

When we remember that the average size of the skrei sample taken at Svendsgrunden in March was 66.1, it would seem reasonable to suppose that the late Lofoten fish taken in April must have been skrei similar to those measured at Svendsgrunden, and that a great immigration of small skrei must have taken place this year; i. e. of the same fish which in 1901 and 1902 belonged to the Finmark loddefisk.

1904—1909.

No measurements are available for 1904; it is however, interesting to note that the fishery authorities report a similar low average for this year, which is difficult to explain save by the theory that immigration should also in this year have taken place. This was almost to be expected, judging from our observations in Finmarken in 1901, when many 3 and 4 year old fish were noted; these fish would in 1904 be 6 and 7 years old, i. e., at the transition stage between loddefisk and skrei. We may thus suppose, that besides the immigration of the year classes 1897 and 1896 already suggested, a similar movement took place as regards the 1898 year class.

In considering the composition in regard to size of the skrei for those years for which measurements are available, I called attention to the remarkable *increase in the size of the skrei during the years 1905—1907.* (See page 69 and Fig. 61.) The reports of the fishery anthorities entirely confirm this result of our measurements. The statements in the reports as to average weight (gutted) of Lofoten line-caught fish are as follows:

1903	— 1.5
1904	— 1.45
1905	— 1.8
1906	— 2.3
1907	— 2.5
1908	— 2.9
1909	— 3.0

In the years 1904—1909 we have thus a steady increase in the average weight, from 1.5 to 3, or no less than 100 %. The question now arises, whether this can be explained, as in the case of the spring herring, and the 1904 year class among the Finmark fish, by the theory that the fish which had already joined the skrei shoals gradually grew older and increased in size, while the number of new arrivals from the younger year classes was only small. The lack of observations is here severely felt. It is of interest, however, to consider the point, and investigate it as far as the available material permits, if only for the sake of facilitating the future study of similar problems.

We will therefore consider Fig. 98, which shows a number of curves representing the Finmark fish in the years 1905, 1907 and 1909, as well as the skrei in 1906 and 1907. Two points are here worthy of note.

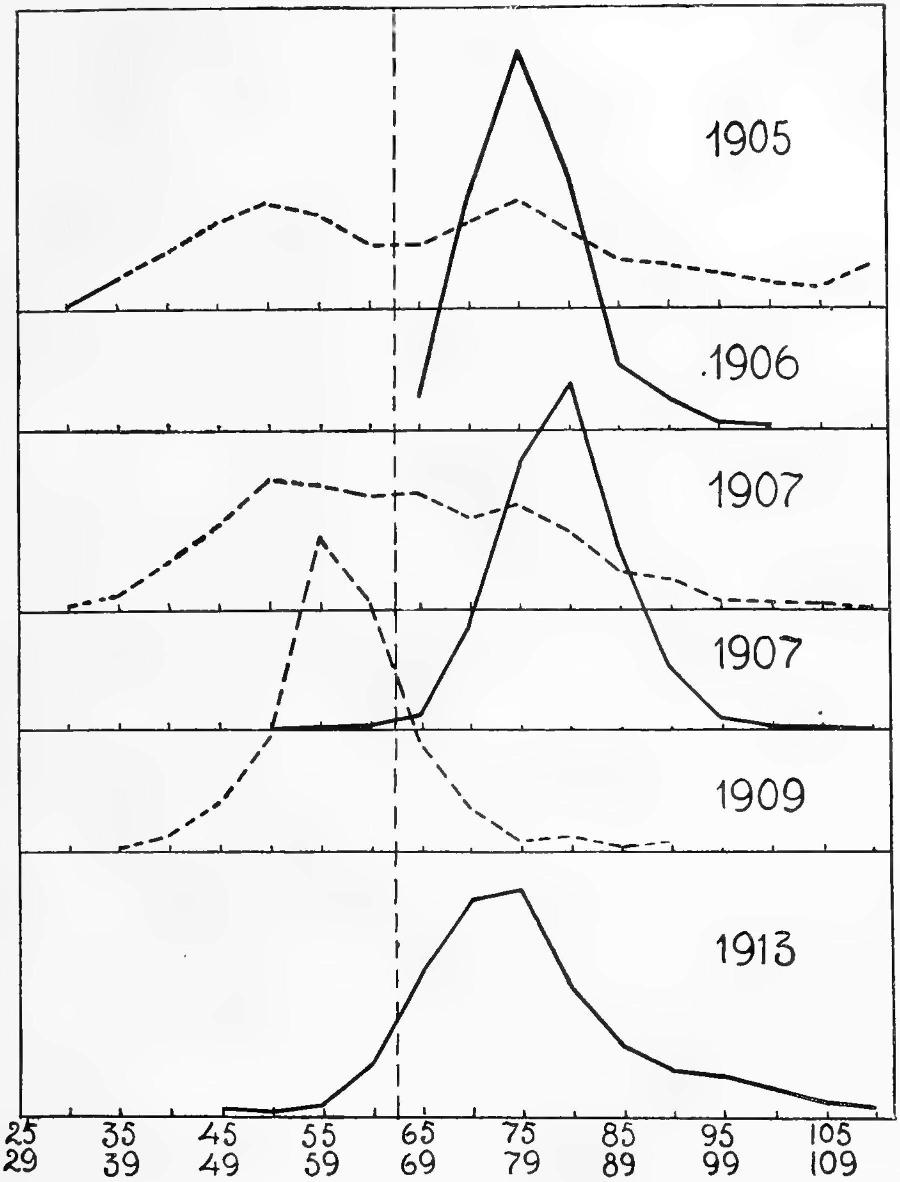

Fig. 98. Composition in point of size of cod samples from the years 1905, 1906, 1907, 1909 and 1913.
---- Finmark fish. —— Skrei.

The size of the skrei increases from 1906 to 1907, decreasing from then to 1913.

In the years 1905 and 1907, there are no dominant size groups among the Finmark fish; these are first noticeable in 1909, (year classes 1903 and 1904). This comparison between the Finmark fish and the skrei appears to support the hypothesis stated above. Moreover, both measurements and age determinations are fortunately available for the skrei in the years 1906 and 1907. These figures, which form the most important part of the material at our disposal here, are given below.

Composition in point of size, for skrei 1906 and 1907.

	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1906	..	..	..	3.2	24.9	33.5	28.1	4.9	3.2	2.1
1907	0.5	0.0	0.5	1.4	10.5	25.5	34.1	18.6	6.4	2.7

Composition in point of age for skrei 1906 and 1907.

	1902	1901	1900	1899	1898	1897	1896	1895	1894	1893
1906	..	..	..	11.9	37.3	34.1	11.9	4.3	0.5	..
1907	0.5	0.5	1.8	19.5	43.6	25.0	7.7	1.4	..	..

It is immediately noticeable that in both of these years, there are scarcely any fish under 65 cm. ($^1/_2$ % for the two years in average) or even under 70 cm. (2.8 % for both years in average). In contrast to this, the skrei sample from Svendsgrunden in 1903 showed 46.8 % under 65 cm. In like manner, the figures for 1906 show none under 7 years old, for 1907, only 2.8 % under 8 years. This proves that only *a very slight immigration of young skrei* took place in these years, and it is easy then to understand that the size must have increased, the same fish of the same year classes constantly growing older. The two most numerously represented year classes, both in 1906 and 1907 are those of 1898 and 1897; these fish were

in 1901 ..... 3 and 4 years old
» 1902 ..... 4 » 5 » »
» 1903 ..... 5 » 6 » »

and must, with the 1896 year class, have furnished the greater part of the additions to the skrei stock during the period under discussion.

Periodical variations in the average size of the skrei.

It must thus be certain that the stock of cod has certain periods of renewal, and other periods with but slight addition of young fish. As the loddefisk are recruited from the small fish, so the former in turn send batches to join the skrei, as soon as a new and rich year class has reached the age at which the fish can pass from one group to the other. *The periods of renewal of the shoals are distinguished by a decrease in the average size. When the immigration of young fish is slight, the average size increases with the growth of the individuals.* There will thus arise a fluctuation in size of the the stock, with periods of increase and of decrease.

The fishery authorities endeavour each year to calculate the average weight of the Lofoten skrei, and it is interesting, in this connection, to examine these averages for a considerable period of years.

Fig. 99 shows these averages furnished by the fishery authorities (average *gutted weight*) for the years 1882—1912. It will be noticed that the line joining the different averages presents a wavy appearance. From 1882, there is a decrease until 1884, then an increase until 1889. The years 1894, 1895 and 1896, however, lie in a deep hollow. Then follows a rise, until 1899, a sharp fall to 1903 and 1904, with an equally steep rise to 1909, and finally a decrease towards 1912.

According to the hypothesis above put forward, the fall of the curve from 1901—1904 should be due to the great addition of young fish to the skrei stock in these years, the immigrants being chiefly fish of the year classes 1896, 1897 and 1898. The rise from 1905—1909, should in like manner be explained by paucity of new arrivals, and increasing size of the older fish already present. The average size culminates in 1909, sinking again in 1910, 1911 and 1912. During these years, the 1904 year class, being then 6, 7 or 8 years old, begins to make its presence felt among the skrei stock, thus naturally occasioning a decline in the average weight.

As regards the earlier "periods" it is naturally difficult to form any certain opinion.

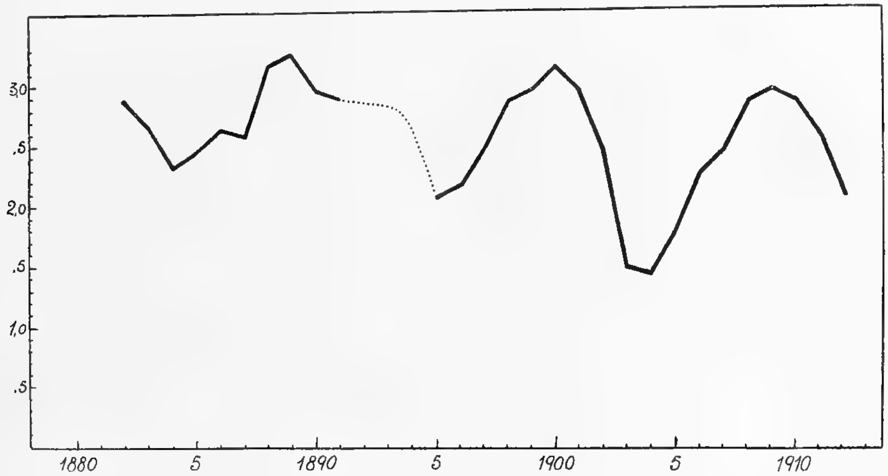

Fig. 99. Curve showing average weight of Lofoten skrei for the years 1882—1912, from statements of the Fishery Inspectors. 3,0 = 3 kilos gutted weight.

The average weight is not in itself a sufficiently reliable indication as to the composition of the stock in point of size. The same average weight may arise in the case of a mixed stock, large and small together, as in the case of one consisting throughout of medium sized fish. The many different size groups can furnish a great number of combinations, all equally possible. Only by measuring so great a number of fish of all sizes as to ensure a true picture of the composition can reliable information be obtained. The fishery authorities have, in some years, endeavoured to make measurements of the fish; the numbers dealt with have, however, been so few, (e. g. ten fish) that it is impossible to attach any value to the results.

Of more importance are the statements contained in the Inspectors' reports as to the size of the skrei. Thus in the Lofoten reports from 1894 to 1899, it is interesting to note the following:

1894. At first large, later unusually small.
1895. Unusually small and poor.

1896. “This winter also, the skrei were small, very different, however, from last year”.

1897. “Skrei larger and fatter than last year”.

1898. “This winter, the skrei were everywhere large and fat. The richer the fishery the more even are the fish in size”.

1899. “Roe about the same as last winter, liver larger, and general condition much better”.

The curve for the years 1894—1899 should be compared with these statements.

From 1881 to 1883, the reports are so vague that it is difficult to obtain definite information from them. In 1883, we find the complaint that the fish “often vary greatly from one day to another, even fish taken on the same day frequently showing very different results. It is difficult to say what is the cause of this irregularity; the popular opinion however, that it is due to the arrival of different shoals on the ground, may be not far wrong. Thus at the commencement of the season, one day’s catch was reckoned at 900—1000 fish to the barrel” — i. e. of liver — “while on the following day, only 6—700 fish were required to make up the same quantity. Some connection doubtless exists between the smaller amount of liver and the smaller size of the fish. As to the reason of the irregular net fishery, it is possible that the mesh used is too large, so that not all the fish are held”, — etc. etc.

In 1886, however, we find the following definite statement: “This year, the skrei, especially those taken in January and early February, were large, fat and in good condition; the generally expressed opinion was that such thoroughly fine fish had not been seen in Lofoten for many a year. After the middle of February, the fish were somewhat smaller, but still fine and fat”.

Thus we find, in these reports, a great deal of information as to the fluctuations of the fishery from year to year, or even within one and the same season. It will, however, here suffice to point out that the reports indicate, for the earlier years, a similar wave-movement to that which has been shown in the foregoing for the period 1903—1913.

The periodical fluctuations, renewal and mortality of the skrei.

Consideration of these movements at once suggests two questions:

Firstly as to the cause or causes of the great difference in the numerical values of different year classes, in which each new wave originates.

Secondly, as to the conditions which determine the length or duration of such increase.

The first question cannot be dealt with until I have been able, in subsequent chapters, to set forth the whole of the material now at my disposal. The second, however, belongs naturally to the sphere of the present chapter.

Longevity of the skrei. Mortality among the stock.

If the increase in the weight of the skrei is due exclusively to the growth of a single year class, and this class could be imagined to be isolated from the others, then it is evident that the increase in weight would depend upon the longevity of this one year class. Should there, on the other hand, be many year classes to be considered, no single one among them being specially predominant, we have then to reckon with many and various factors. In any case, the influence of each individual year class will be dependant upon those general laws which govern the life cycle of the species; it is therefore of primary importance to ascertain the nature of these laws, before it is possible to understand the complicated conditions which prevail among the stock on account of the many different year classes in its composition.

In considering the question of the longevity or mortality of the cod, it will be natural to commence with the analyses of age of the skrei samples examined. The relation between age and size once determined, we are then in a position to obtain valuable information from the far more extensive material at hand in the form of measurements. Age determinations exist only for the three years 1906, 1907 and 1913. The following table shows the percentages of the respective year classes in these samples:

Percentage of year classes 1906—1894 in skrei samples 1906, 1907 and 1913.

	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1894
1906. .	..	..	..	..	..	..	..	11.9	37.3	34.1	11.9	4.3	0.5
1907. .	..	..	..	..	0.5	0.5	1.8	19.5	43.6	25.0	7.7	1.3	..
1913. .	6.3	18.0	49.5	14.1	6.8	2.9	2.4	..	..	..	..	..	..

Majority of skrei between 7 and 10 years old.

From this it will be seen that none of these samples contained as much as 10 % of any single year class over 10 years old. The highest percentage for 11 year fish is 7.7 (in 1907), for 12 year olds 4.3 (in 1906) and for fish of 13 years 2.4 (in 1913). *In the three years in question, only the 8, 9 and 10 year old fish play any important part in the stock. The stock will thus have become almost entirely renewed in the period from 1907 to 1913.* The year classes 1902, 1901 and 1900, which in 1907 formed the youngest part of the stock, (the 5—7 year old fish) would in 1913 be among the oldest, and thus represented by only small percentages.

It is now a question whether the three years can be taken as representing the general and permanent conditions prevailing among the skrei, a point which can obviously only be finally determined by long experience. The further material available consists of the measurements already noted in the table on p. 92 and the statements of the fishery authorities. According to the measurements, the three years 1906, 1907 and 1913 would not seem to be entirely representative; in particular it is noticeable that in certain years (1903) a greater number of young fish (6 and 7 years old) may be present than was the case in these years. On the other hand, 1907 shows a higher percentage of old (large) fish than any other year included in our measurements, but not so high an average weight as that of the years 1908 and 1909. (See Fig. 99.)

Number of spawning years per fish.

I have looked through the Lofoten reports from 1860 to 1902; in these 53 years, the average weight of the skrei (gutted weight) varied between 1.45 (in 1904) and 3.3 (in 1889). These averages correspond, according to my weighings and measurements of skrei in 1913, to the size groups 65—69 and 85—89. These should form the limits of the field of variation of the average size. Judging from the age determinations, we may suppose that this factor would vary between 6 and 11 years, chiefly however, from

7 to 10 years. If the renewal of the stock is effected by a single year class, so numerous as to be of decisive importance in the average size of the stock for years in succession, then we should have an increase in the average weight for at least four successive years, or, in the case of two rich year classes appearing one after the other, for at least five. The curve in Fig. 96 agrees with this, as regards the rises from 1883—1889, 1895—1899 and 1904—1909. The last named period is naturally of greatest interest, since it is from these years that we possess the most extensive material. We can thus understand, that the increase must cease about 1908 or 1909, and a decrease in size take place, as the young fish of the 1903 and 1904 year classes begin to appear among the skrei shoals.

Oldest skrei.

Among the skrei are always found some large fish beyond the age and size at which they appear in any considerable numbers in the stock. In the samples from 1913, the size groups *over 89 cm.* showed the following percentages.

Percentage of largest skrei 1913.

cm.	90—94	95—99	100—104	105—109	110—114	115—119	Over 120
%	4.2	1.9	1.0	0.6	0.1	0.03	0.03

Average longevity of the skrei determined by the fishery?

Why then, do not more skrei reach such sizes, when some of them can attain those here shown? Before answering this question, it is necessary to ascertain whether the size of these fish is due to rapid growth or to extreme age. Investigation shows the last mainly to be the case. Skrei of 15, 18 and even 20 years old are known, though rarely found; moreover, it is difficult to accurately determine the age of such fish, the annual rings on the scales of very old specimens being very narrow and indistinct.

Since however, it is beyond doubt that the skrei can attain an age several years beyond that of 10—11 years, at which they are numerous, the question arises, whether the natural longevity of the species is affected to any great extent by the fishery. This important point can only be decided after material has been collected for a long period of years; it is however, well worth while to bear in mind, in further consideration of the question, the results of our marking experiments in Lofoten in 1913, viz, that every fourth or fifth fish was captured in the course of the Lofoten fishery. Moreover, it should be remembered that it is the same stock which is fished in the Finmark waters, on the Murman coast, and by the trawlers in the Barents Sea. It is impossible to say, as yet, how far the results obtained at Lofoten in 1913 may be considered as representative of the skrei fishing all along the coast; possibly the fishery is more intense here than on many other skrei grounds within the range. Only by continued marking experiments can this be satisfactorily determined. It should be borne in mind, however, that the whole spawning area of the cod is now, after the investigations of recent years, known, mapped, and, for by far the greater part, exploited by the fishery. Thus even though we may not at present be able to accurately determine the exact percentage of the stock taken by the fishery, we can at least assert that it is very considerable. So much so, indeed, that the remarkable diminution in numbers of the skrei as they increase in age may possibly be due to the intensity of the fishery, so that for instance a rich new stock of 7 year old fish would, after four or five years' intensive fishing, be considerably reduced in numbers.

Renewal of the stock affected by the fishery?

In order to appreciate the influence of the fishery on the whole stock, we must first of all ascertain its effect upon the renewal of the same; i. e. the extent of the natural increase of the stock and the influence of the fishery upon the mortality.

As regards the renewal of the stock, we have seen in the foregoing that this takes place, as in the case of the herring, in a very irregular manner, the number of young individuals which form the annual increment varying greatly from year to year.

The renewal of the stock can thus scarcely be dependent upon so regular and constant a factor as the fishery; it must depend upon highly variable natural conditions.

The mortality, on the other hand, would appear, from the facts already noted, to be greatly influenced by the fishery. The question is, whether this influence is so great as to prejudice the actual yield of the fishery itself, and how great is the mortality attributable to the fishery in comparison with that due to natural causes.

The growth continues throughout a long period in the life of the cod, beyond the average age of the skrei. Thus we may find good growth in the case of 13, 14 and 15 year old fish. It is obvious, that the earlier a fish is taken from the sea, the greater is the amount of possible future growth lost. How far it might be advisable to take the young fish, disregarding the far greater profit which it would represent if allowed to spend some years more in the sea, is a point which depends on many different factors, as for instance the chance of its death from natural causes unaided by man, and, of course, the chances of capturing it again. The greater our knowledge as to the longevity of the stock and the percentage taken by the fishery, the better shall we be able to deal with this important question. Continued observation will also furnish reliable information as to the serious problem of how far the longevity of the skrei is gradually being reduced; whether the fish, owing to the increased intensity of the fishery, exhibit a constantly diminishing average size. As to past years, there is but little material available in this respect: we have only the frequently mentioned average weights from Lofoten. These show, for the period from 1861—1869, an average weight (gutted) of 2.54, for 1882—1891 of 2.8, and for 1900—1909 of 2.42. It would seem impossible to draw any other conclusion from these figures than that the average weight of the skrei is subject to continual variation.

Relation between the periodical variations in the average size of the skrei and the fluctuations of the fishery.

We have now seen, that during the period when the 1904 year class played a great part among the Finmark stock and the skrei, there was a close connection between the occurrence of this year class and the yield of the fishery in subsequent years. We have also learned that the 1904 year class is not the only one which has been distinguished by a higher numerical value than usual, but that it appears to be a regular feature in the history of the skrei stock, that rich year classes arise at somewhat varying intervals.

In Fig. 100 I have marked off, uppermost (A) the yield of the herring fisheries, the spring herring, (fully drawn) and fat herring, (dotted line); below, the cod fisheries, Curve 1 the skrei and Curve 3 the Finmark fish, while Curve 2 shows the fluctuations in the weight of liver, which exibit a movement corresponding to that of the average weight (this will be dealt with in the following chapter). The curves embrace the years from 1866 or 1880 to 1913.

On examining these curves, it is immediately evident that we have here a task of considerable difficulty; it will at once be seen that they can only be satisfactorily understood when supplemented by an extensive material in the form of observations as to age and size. Thus the later years are easily understood. The herring fishery exhibits rich yield of fat herring at the time when the 1904 year class was 3, 4 and 5 years old, as also of spring herring when the same fish were 6—9 years old, (1910—1913). Similarly, we note an increase in the yield of Finmark fish in 1909—1912, when the 1903 and 1904 year classes commenced to make themselves increasingly apparent in the line hauls there, while the skrei yield shows high figures for 1911 and 1912. On the other

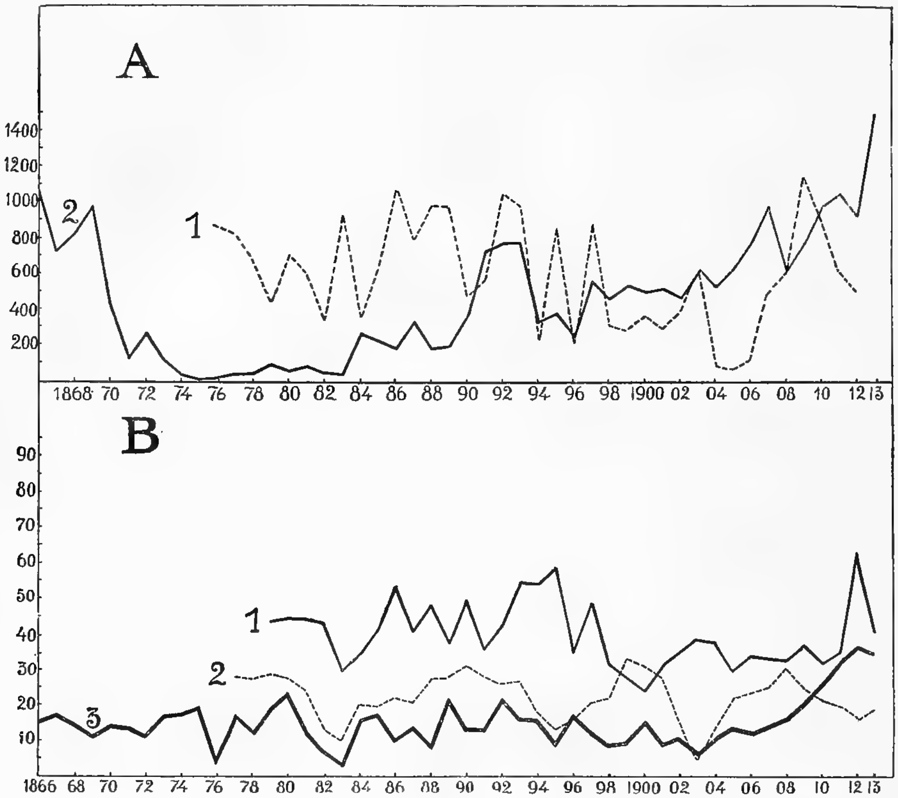

Fig. 100. A. Yield, in thousands of hectolitres, of the Norwegian herring fisheries during the years 1866—1913.
2. Spring herring fishery,
1. ---- fat herring fishery.

B. Yield of the cod fisheries, in millions of fish, for the years 1866—1913.
1. Skrei fishery,
3. Finmark fishery,
2 Showing the fluctuations in the quantity of liver (cf. Chap. V, Fig. 106).

hand, it is impossible to understand the decrease in the skrei yield in 1913, which can only be explained by future observations.

The earlier periods, however, present a more difficult problem, and we are tempted to pass over this part of the question and devote our attention to consideration of the future. I will here, however, with all reserve, call attention to two points which seem to exhibit some indication of regularity.

1) Looking first at the curve for quantity of liver, or average weight, and especially the deep hollows of the same (i. e. the years 1911—13, 1902—1904, 1894—95) it will be noticed that these periods were especially marked by the great *number* of individuals (the skrei curve shows numerical values; millions of *fish*). Regarding the hollow for the 80's, the curves are as difficult of comprehension as the fishery reports for the same period.

2) There seems to exist a constant relation between the Finmark and Lofoten fisheries similar to that noted as between the fat herring and spring herring yields, viz; that the two "younger" branches, (the Finmark and the fat herring fisheries) first exhibit an increase in the yield, which later makes itself apparent in the catches of spawning fish (skrei and spring herring). Thus we find a rich yield in Finmarken in 1910 and 1911, before the increase in the skrei fishery. Similarly. a rich yield of fat herring in 1909 and a corresponding increase of spring herring in 1912 and 1913. See further pages 43—44.

This connection between the Finmark and skrei fisheries has earlier formed a subject of discussion in fishery circles, though the relation has not as yet been clearly understood. In a lecture given at the International Fishery Congress in Bergen in 1898, Dr. J. BRUNCHORST called attention to the point. He had made statistical comparisons by means of curves for the Finmark and Lofoten fisheries, and calculated that in certain cases, the yield of the latter could be arrived at by adding some 18—19 millions to the amount of the former *for the previous year.* According to our present theory, however, the matter is not so simple, since the Finmark stock, in the first place, consists of both small fish (loddefisk) and skrei, the former again including several different year classes. Fishery in Finmarken can thus be carried on both for skrei and for loddefisk, which will not enter the skrei class until one or two years later. Another difficulty in the way of quantitative comparison is the fact that the yield of the Finmark fishery is stated in kilos, while the Lofoten yield is expressed in millions of fish. Dr. BRUNCHORST's theory is interesting, however, as one of the first expressions of any conception as to relation between the two fisheries.

Considerable interest has also been exhibited in fishery circles as to observations of the size of fish, since the investigations as to age have begun to be more generally known. A rich yield of small fish in one year is now widely regarded as an indication of good yields of larger fish in the years to come. Fishermen have told me, that they had great hopes of a rich future for the Finmark fishery when they noticed the enormous amount of small fish of about 40 cm. which were taken in 1908 and 1909, these fish being then returned to the water as valueless, and floating in great quantities out to sea.

Consul AND. AAGAARD, of Tromsø, in an article in "Fiskeritidende" 1909, called attention to the enormous quantities of young cod which first made their appearance in 1907, thereafter, *in increasing sizes, during 1908 and 1909.* From this he concludes that we may expect to find "a great quantity of Finmark fish of from 400 gr. (dried weight) and upwards, with but few of the "Bremer" and "Hollænder" class". As we have seen, this has also proved to be the case in the following years.

Investigations of cod and haddock in the North Sea and southern Norwegian waters.

Hitherto we have only considered the stock of cod in northern Norwegian waters, the material here being larger and more methodically collected than elsewhere. It may, however, be of interest to briefly mention some results already published, which exhibit the closest agreement with what has been set forth in the present work.

I mentioned in the introduction, that the International Commission for the study of the cod fishery had instituted the collection, on a methodical basis, of measurements of the trawl-caught fish, as also of material for age determinations. The object of these investigations was to study the size and age of the cod, and especially the variations in both factors from year to year in different localities. The material was dealt with in the Norwegian fishery laboratory, Dr. K. Dahl, Dr. D. Damas, and Dr. B. Helland-Hansen taking part in the work. The results are published in the Report of the Commission referred to above.

Many of the samples collected exhibited great variation in the numbers of the different age classes, and it was also apparent, in these samples, that the 1904 year class was distinguished by a relatively high numerical value. Most surprising to those engaged upon the work was the fact that this year class proved to be the richest in samples taken at places a great distance apart, as in the Skagerak and off the coast of Romsdal. This will be seen from the following table, showing the composition in point of age of the haddock in samples taken at different places. The analyses have previously been published in Dr. Damas' treatise. The localities at which the samples were taken are as follows:

Skagerak	1. Off the coast of Norway, August—October 1906: fishing experiments by Dr. K. Dahl.
	2. Jutland Bank, July-August 1906; trawl catches, "Michael Sars".
Romsdal	3. Haugsholmen, August 1906, "Michael Sars".
	4. Romsdal, samples collected in winter 1906—1907.
North Sea	5. Dogger Bank 1906.
	6. Between Flamborough Head and Dogger Bank, September 1906.
	7. Great Fisher Bank, 1th August 1906.
	8. Deep waters of the North Sea, 1906, "Michael Sars".

Age analyses of haddock, Skagerak, Romsdal, North Sea 1906.

No. of sample	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1894	1893
1....	..	0.4	48.2	3.5	11.3	27.5	6.7	2.1	0.3	..	0.1	..	..	..
2....	10.8	9.0	76.2	3.0	0.2	0.4	0.4	..	..	..	..	..	..	..
3....	..	19.2	73.5	6.8	0.3	0.3	..	..	..	..	..	..	..	..
4....	..	13.4	42.1	13.2	8.6	10.5	6.5	3.1	1.5	0.5	0.1	0.3	0.1	0.2
5....	..	..	77.1	10.5	11.1	1.4	..	..	..	..	..	..	..	..
6....	..	3.2	91.6	5.3	..	..	..	..	..	..	..	..	..	..
7....	..	9.0	58.5	6.5	13.9	9.0	2.3	..	..	0.8	..	..	..	..
8....	..	7.9	54.2	19.0	15.3	2.7	0.8	..	..	..	..	..	..	..

Under such distinctly marked conditions as those indicated by these age determinations, it was natural that the measurements should show great fluctuations in the stock. The material furnished by the English and German research vessels is thus of particular interest; I therefore give, in Fig. 101 (drawn by Helland-Hansen), the average weight and number of individuals of the different centimetre sizes in the samples. The vertical lines also indicate the limits for the different market classes of haddock, i. e. between extra small, small, medium and large, the principal classes in the English trade. We see from the figure that the fish were large in 1903 and 1904, more so in the latter year. In 1905, a number of quite small fish, between 15 and 20 cm., made their appearance; these were, in 1906, between 20 and 25 cm. long. Even before the conclusion of the work of the Commission, in 1906 and 1907, it was evident that these fluctuations were also to be felt in the yield of the fishery. Thus the English fishery statistics showed an increase in the catches of small haddock in the autumn of 1905. That was some years ago, and it is now interesting to note the statements of the fishery statistics for the intervening years, although unfortunately, I have no material from age investigations during this period. The time and assistance at my disposal have been too fully occupied to permit of my undertaking the work. In spite, however, of the fact that no biological material is here available, the figures for haddock landed in England (in millions of kilos) should be of considerable interest, and will be found (quoted from the English authorities) in the following table:

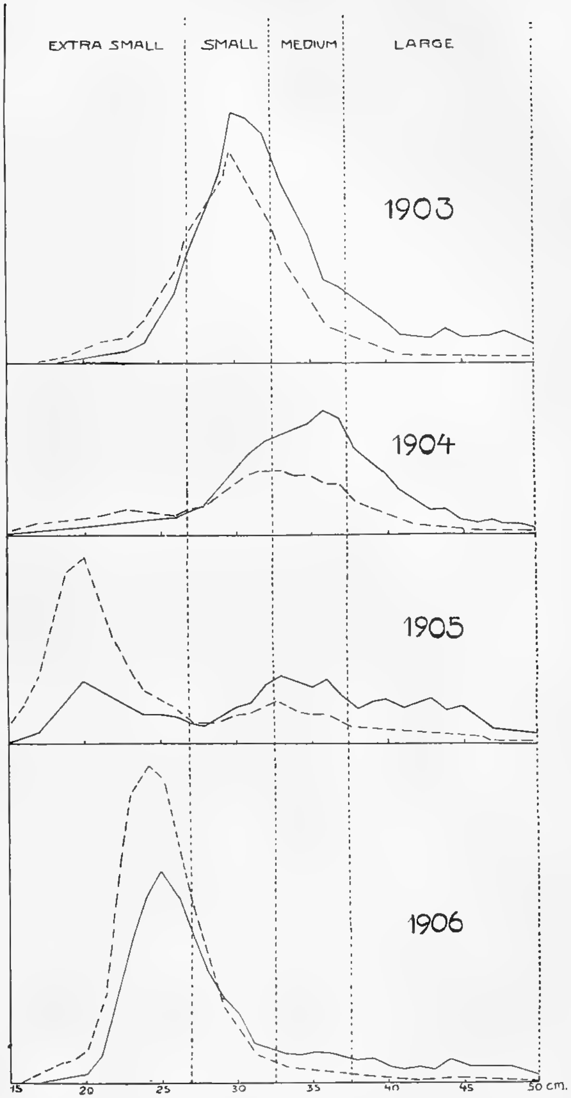

Fig. 101. Average catch of haddock by the research steamers pr. trawl-hour for all portions of the area examined, during the different years in which investigations were made.
- - - - average numbers.
—— average weights.
(drawn by Helland-Hansen).

Year	"Small"	"Medium"	"Large"
1906	*66.3*	13.2	22.6
1907	61.0	*16.7*	30.0

Year	"Small"	"Medium"	"Large"
1908	43.0	14.2	*31.9*
1909	34.7	10.3	29.1
1910	32.2	7.4	29.6
1911	35.7	9.7	25.1

It will be noticed that the small haddock were most numerous in 1906, the medium in 1907, while the large show high figures for all the years from 1907—1910. This is just what was to be expected from the age analyses of 1906.

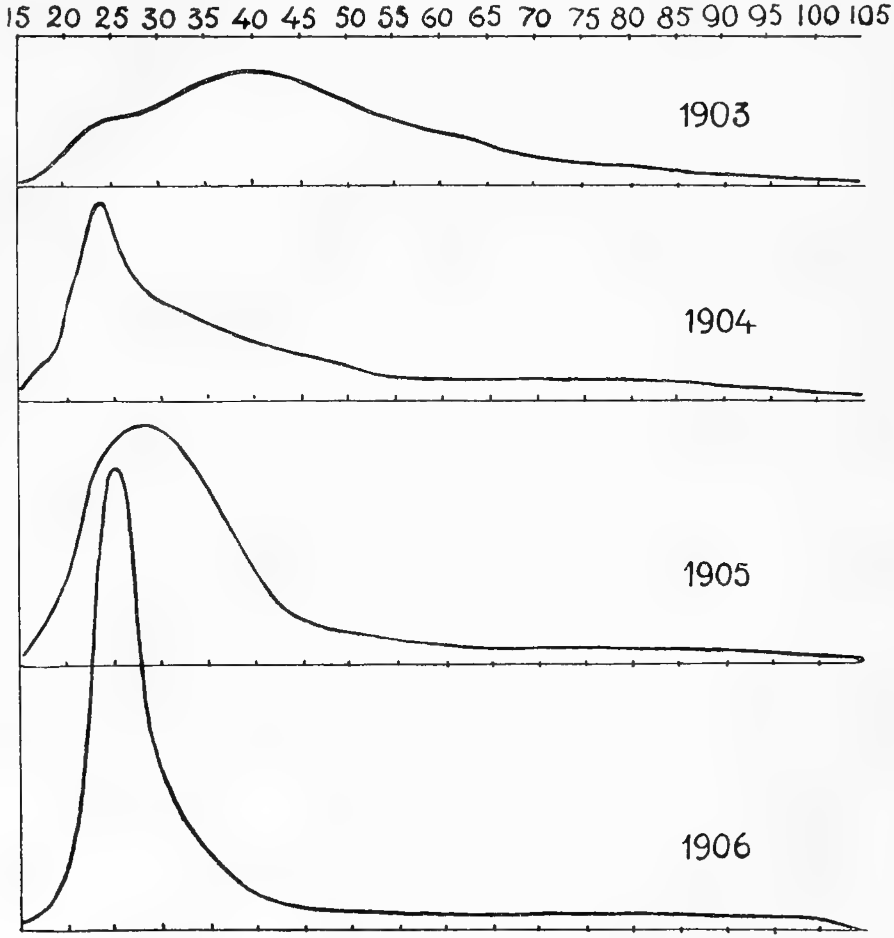

Fig. 102. Composition in point of size of cod from trawl catches in the North Sea, from the years 1903—1906 (Helland-Hansen).

The Norwegian fishery statistics give the following quantities for the years 1908—1911 (Before 1908, these statistics did not unfortunately include any statements as to the haddock). I have also included the figures for coalfish, the movement being the same, while the earlier material seems to indicate that the 1904 year class was also richly represented among this species.

Year	Haddock	Coalfish	
1908	6.1	17.8	Millions of kilos landed in Norway.
1909	8.0	21.1	
1910	10.2	30.0	
1911	6.8	24.7	

As regards the *cod*, the age investigations in 1903—1906 were not carried out to such an extent as to permit of our employing them in the study of fluctuations among the year classes in the North Sea. The measurements, however, showed, as in the case of the haddock, that large numbers of small fish between 20 and 30 cm. occurred in 1906. A very distinct difference is apparent in the composition in point of size for 1903—1905 on the one hand and 1906 on the other. In view of the constant relation between size and age in the case of the young cod, we may, from the measurements above (Fig. 102) conclude that the 1904 year class must also in the North Sea have played an important part in the stock of cod. After 1906, I have no material available; it is however, interesting to consider the statistics for the years 1908—1911 (and partly 1912) as they render it at least highly probable that the conditions noted in 1906 also prevailed throughout these years. I have before me an interesting article by Quibbon*) who, without any knowledge or mention of the investigations made, calls attention to the peculiar movement of the yield, also pointing out its remarkable similarity to that of the Norwegian fisheries. We may first of all take the total quantity of cod landed in England and Scotland in 1908—1912.

Cod; millions of kilos landed in

Year	England	Scotland
1908	98	42
1909	109	45
1910	120	50
1911	130	61
1912	...	63

It will be seen that the great increase commenced to make itself apparent in 1910.

We will then consider the quantities (millions of kilos) of the different sizes of cod landed during these years in England and Wales, from all waters.

Year	"Small"	"Medium"	"Large"
1908	17	23	55
1909	34	26	44
1910	34	30	48
1911	37	31	53

In 1909, we find an increase in the quantity of small and medium fish, in 1910 and 1911 also in that of the large. This curiously resembles the increase in the Finmark fish in 1909 and 1910, and later among the skrei.

*) Fish Trades Gazette, 26. July 1913, p. 35.

Finally, it may be of interest to note the average catch *per day* for each fishing steamer during the voyage at sea. The article referred to gives the following figures:

Yield per day at sea in kilos for

Year	North Sea	West of Scotland
1906	179.83	159.51
1907	159.00	151.89
1908	170.69	195.58
1909	240.28	214.78
1910	250.44	310.90
1911	242.82	316.48

From this last table it would seem that there has been a great and distinct increase in the case of the North Sea, as also for the waters west of Scotland.

As regards the North Sea, even more than the Norwegian waters, future investigations must further pursue and elucidate these questions. The object of the present work has rather been to call attention to the problems, and to show that there is good reason to make the same, also as regards these waters, the subject of future exhaustive investigations.

CHAPTER V

Fluctuations in quality.

Use of the word quality.

The previous chapters have dealt with the fluctuations in the herring and cod fisheries with regard to the amount of the yield, the *quantity* of fish landed. The value of the yield, however, depends not only upon the quantity of fish; the *quality* is a factor of the greatest importance, and one, moreover, which also exhibits great fluctuations.

By "quality" I here understand the chemical composition of the fish; a meaning which is not always intended by the word when used in the practical industry, where quality is frequently found to depend, in some degree, on the ruling prices of the day, or the point of view of certain special trade considerations. Thus a dealer buying fish by number, and selling them again by weight, would naturally come to consider the large specimens as of "better quality" than the small. We therefore frequently find, in practical affairs, the word used in a vague and arbitrary manner, which, as will be evident later on, gives rise to a great deal of misunderstanding and erroneous impressions as to the conditions upon which the quality of the fish depends.

Importance of fat as a determining factor in the quality.

Science is as yet far from being able to fully describe the chemical processes which attend the changes in the quality of the fish; it must for the present suffice to examine certain kinds of matter which are comparatively easy of investigation. From very early times, the practical industry has attached especial importance to the varying quantity of fat, primarily on account of the nutritive value which it represents, the importance of the fish as an article of human consumption depending to a great extent upon the amount of fat contained. Moreover, the fatty matter is contained in special organs, or at any rate, in such a manner as to render it possible to form, by immediate observation, and without any complicated scientific aids, an approximate quantitative estimate of the amount. Finally, the quantity of fat discernible appears to stand in some relation to the general condition in point of nourishment, and thus serves to express the quality of the fish as a whole.

The quantity of fat may be determined by two methods, of which the one supplements the other, both being therefore desirable. One is the process of chemical analysis, the other examination (sometimes measurement or weighing) of the organs, where the fat is chiefly deposited, (the "ister" of the herring, and the liver of the cod).

Variation in quality of the herring; varying amount of "ister".

As mentioned in Chapters I and II, a great amount of material has been obtained during the last few years, by the collection of numerous samples, from which to study the natural history of the herring. For each separate collection of scale samples we have statements as to the length, weight, and degree of maturity of the individual, and also as to the quantity or size of the "ister". The "ister" is the fat-containing organ which surrounds the intestines of the herring, and plays a most important part in the process of nutritive assimilation. We may here, as in the case of the genital organs, distinguish between different stages of developement, I, II and III, I here indicating small, II medium and III large ister. These distinctions are naturally not absolutely exact, but with practice, a high degree of accuracy may be attained in classification. It is then also possible to sort a large sample by determining what percentage of fish fall to each degree, and also to calculate the average quantity of ister for the whole sample.

An examination, on these lines, of 100 first year fish from Nordland in 1912 gave the following results:

8 fish with large ister, class III
51 » » medium » » II
41 » » small » » I

The average is thus 1.67, i. e. the majority of the fish fall between the I and II classes, (small and medium ister).

We may next consider a large sample of fat herring, consisting of 610 fish taken in Nordland in August 1909 and examined as to age, length, and quantity of ister. The results of these investigations are shown in the following table, the percentage of each of the three fat classes being stated for each year group represented in the sample.

It will be seen that these fat herring, of from 23—27 cm. length and 2—6 years of age, exhibit a far greater quantity of ister than the young fish referred to above, the average being very near Class III. The youngest of the fat herring, fish of 2 and 3 years old, stand highest, with a percentage of 2.92 and 2.96 respectively.

All these fat herring are immature; in the case of the mature fish, the large herring

Year class	Age	Average length in cm.	No. of fish with				Average percentage of ister
			large ister, 3	medium ister, 2	small ister, 1	no ister, 0	
1907	2	23.1	92	8	0	0	2.92
1906	3	24.3	96	4	0	0	2.96
1905	4	25.5	79	21	0	0	2.79
1904	5	25.9	80	20	0	0	2.80
1903	6	26.8	77	23	0	0	2.77

and spring herring, the proportion of ister is never so high as in the case of the fat herring. This will be easily seen from the following table, showing the same factor in the case of 380 herring taken on the Viking Bank, west of Bergen, on the 16th September 1909. The results here given are stated as above, in percentage of each fat class falling to each of the year groups represented.

Year class	Age	Average length in cm.	No. of fish with				Average percentage of ister
			large ister, 3	medium ister, 2	small ister, 1	no ister, 0	
1905	4	28.8	0	33	67	0	1.33
1904	5	29.1	4	35	56	5	1 38
1903	6	29.9	3	39	55	3	1.42
1902	7	30.2	0	42	54	4	1.36
1901	8	30.0	0	35	47	18	1.17
1900	9	30.5	0	18	68	13	1.04
1899	10	30.3	0	20	64	16	1.04

Although these fish were taken in September, the most favourable season, the quantity of ister is far less than in the case of the fat herring. As the herring near their spawning, the quantity of ister rapidly decreases, the spent fish all having to be placed in Class O.

We have thus seen, that the *contents of ister varies with the age of the fish*, the develepement of the genital organs in particular being a factor of great significance. In addition to this, the quantity of ister also varies greatly according to the time of year; this applies not only to the ister itself, but also to the contents of fat on the whole, as shown by chemical analysis.

Amount of fat in herring.

H. Bull has at various times made numerous analyses of the amount of fat in herring. Some of these will be found in the following table*), which shows the percentage of fat for each cm. of size from 15 to 24 cm, and for these sizes at different times of the year from May to November, 1910.

The table gives an instructive view of the manner in which the amount of fat varies both with the age of the fish and the time of year. Within the limits of size here stated,

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*) Aarsberetn. vedk. Norges Fiskerier. 1912.

Percentage of fat in herring.

	Average	Centimetres									
		15	16	17	18	19	20	21	22	23	24
May 1910	7.52	4.08	5.55	6.96	8.04	8.51	8.82	7.62	7.5	...	...
June ,, ...	8.11	4.97	6.34	6.34	8.13	9.23	14.23	14.33	...	...	...
July ,, ...	13.66	...	...	...	11.71	12.80	14.66	14.68	11.73	...	...
August ,, ...	12.05	...	...	8.85	9.16	11.48	11.19	11.34	13.38	15.94	19.22
September ,, ...	13.6	...	...	...	8.93	7.0	10.75	12.70	15.38	15.11	16.84
October ,, ...	12.45	...	...	...	...	8.26	11.04	11.28	12.88	13.32	15.64
November ,, ...	12.91	...	...	...	...	...	...	...	15.24	12.74	11.59
Mean...	11.51	4.52	5.94	7.38	9.20	9.55	11.78	11.99	12.69	14.28	15.82

the amount of fat increases with the length of the fish; thus the fish of 15 cm. exhibited, in June 1910, 4.97 % of fat, the 21 cm. fish examined at the same time showing 14.33 %. During spring and winter, the percentage of fat is low, in summer and autumn high. According to Bull's investigations, mature herring may also, at certain seasons of the year, exhibit a high percentage of fat. Thus he has found Scottish "fulls" with a percentage of up to 15 %, whereas the spent winter fish may show as little as 2½ %.

From the analyses made by Bull, Lea*) draws the significant conclusion that the supply of fat increases during the summer and is consumed during the winter, while water is excreted in the summer and assimilated in the winter. During the winter, part of the dry matter in the system is consumed, and replaced by water, so that no great loss in weight is apparent. The quality of the fish, however, is considerably affected.

Amount of fat in the sprat.

Bull has also investigated the amount of fat in the sprat, and drawn up the following figure expressing the results obtained. The thick black line shows the average contents of fat, the dotted line the lowest, and the third line the highest quantity of same for the cm. groups.

This figure distinctly shows the same great seasonal variation which we noticed in the case of the herring, the percentage being high in summer and autumn, low in winter and spring. Oscar Sund has made a comparison of this variation in the quantity of fat with the variations in temperature of the water off the west coast of Norway. The results of this comparison are shown in figure 104.

We notice that the quantity of fat and the temperature of the water both vary from summer to winter. In the spring, the increase in fat appears to be almost simultaneous with the rise in temperature; in autumn, however, the two curves by no means agree. It is thus impossible to assert that the amount of fat at all times corresponds to the temperature of the water; there are evidently other factors to be taken into consideration.

The same writer**) has also carefully investigated the age and growth of the sprat.

*) Publ. de Circ. No. 61.

**) Oscar Sund: Undersøkelser over brislingen i norske farvand. Aarsberetning vedk. Norges fiskerier, 3die hefte, 1910.

He found that the fish after their first period of growth (i. e. when one year old) measured 5—7 cm., after the second (at two years of age), 8½—11½. All were then immature. At the end of the third period, being then three years old, some of the fish are 11—13 cm. long, and still immature, while others have a length of 13—14 cm., and have arrived at maturity. The attainment of maturity can thus be placed at somewhat over the third year, and at a length of about 13 cm. This agrees with BULL's analyses, which show the amount of fat as increasing with size up to a length of 11 or 12 cm., after which it commences to decrease.

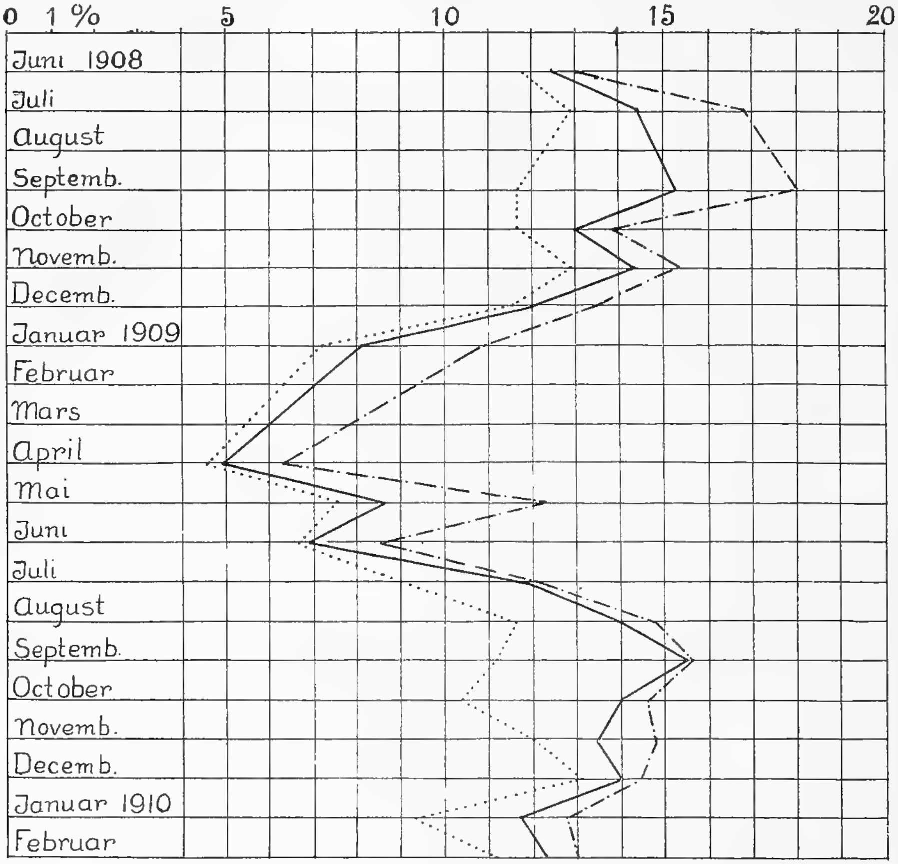

Fig. 103. Amount of fat in sprat.
—·— greatest ——— average ········ smallest (BULL).

Variations in the composition in point of age and size of the sprat.

In the course of the sprat investigations it was noticed that the composition in point of size exhibited considerable fluctuations during the years 1908—1910. BULL gives (l. c.) a table showing the composition in this respect, indicating the average percentage in weight for each cm. group in each of the years 1908—1910. The averages are based on 74 different samples.

	7	8	9	10	11	12	13	14 cm
1908	3.3	11.7	25.7	33.6	18.7	7.2	0.7	. .
1909	. .	2.0	7.9	37.2	38.7	10.9	2.6	0.7
1910	. .	. .	17.1	33.1	26.1	19.0	3.0	1.7

It will be noticed that there were far more small fish (7—9 cm.) in 1908 than in the other two years. In 1909 the fish consisted almost exclusively of individuals of 10—11 cm. long, whereas in 1910 the sizes were more evenly distributed among the groups from 9—12 cm. These fluctuations are of great importance in the practical industry, the variations in the size of the sprat being often regarded as variations in quality.

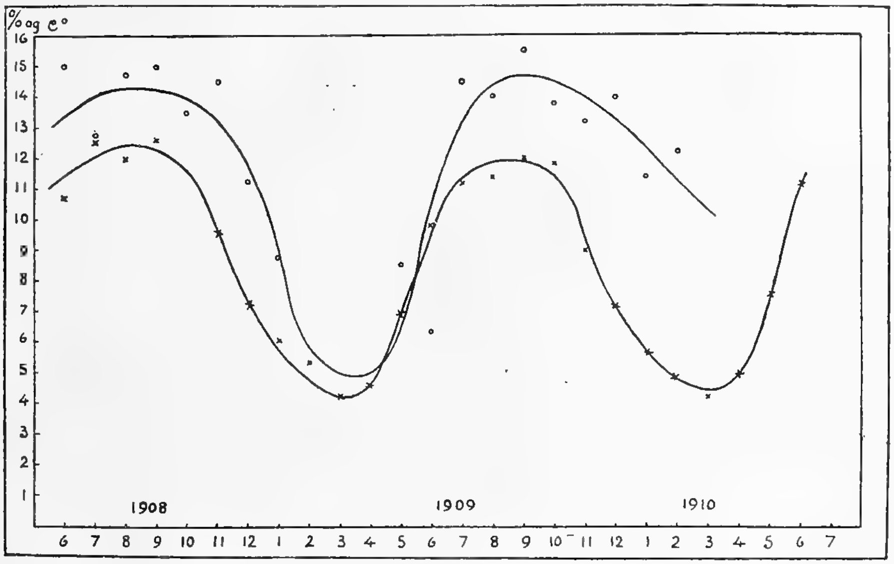

Fig. 104. Amount of fat in West Coast sprat; mean percentages for each month.
× mean surface temperature of the sea for the month, taken at Hellisöy, near Bergen (Sund).

On examination, it was found that the fluctuations in size were here, as in so many other cases, due to a difference in the composition with regard to age, or to the different numerical value of the year classes represented. Oscar Sund, in the work above referred to, gives the following table showing the composition in point of age of the stock of sprat in the Norwegian fiords during the years 1908—1910:

From samples	Group I		Group II		Groups III and IV
examined in	Average length	No. %	Average length	No. %	No. %
1908	10.15	90.6	11.73	6.4	3.0
1909—1910	10.20	22.7	11.09	74.8	2.5

A very great difference is here noticeable in the composition with regard to age, which would seem to indicate that the species is subject to great and rapid changes in this respect, "possibly greater than is the case with any other of our food fishes, a phenomenon which may doubtless be explained as chiefly due to the shorter life of the fish".

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We thus see, that fluctuations in the composition with regard to age (the variation in numerical value of the year classes, as noted in the previous chapters) may occasion fluctuations in the size, and consequently in the quality, of the fish. It might be advisable to investigate the question whether the fluctuations in the French sardine fishery may not be due to similar causes.

Comparison of different species of Clupeidæ.

We have seen in the foregoing, that a characteristic feature of both herring and sprat was the existence of certain distinct periods in the development of fatty deposit. First

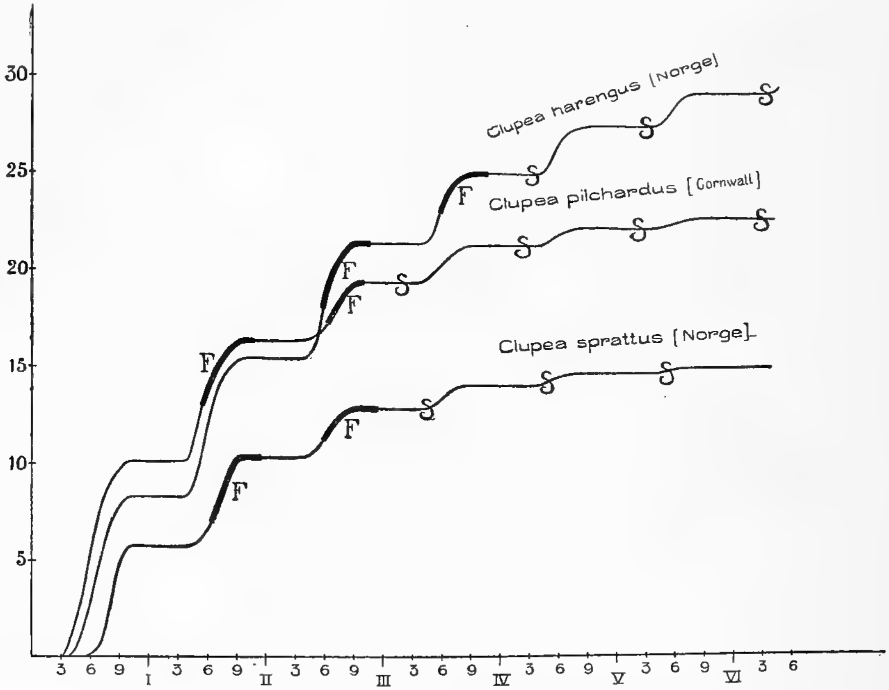

Fig. 105. Growth rate of herring, sprat and pilchard.
F = ister stage. S = spawning stage.

of all, in the case of quite young fish, a period when little fat is found, then the ister stage, in the older but still immature herring and sprat, and finally, that of the grown, mature fish, in which the developement of the genital organs plays so great a part in determining the quality. As the different species differ widely both in growth, and as regards the age at which maturity is reached, it is evident that the alterations in the process of nutritive assimilation and general change of matter must differ in like degree. This will best be seen by comparing the rate of growth and period at which the ister stage and that of maturity are reached in the case of some closely related species. In figure 105, I have endeavoured to give a comparison, entirely schematic, of the three species; herring, sprat, and pilchard.

From the figure here given, it is possible to compare the growth rate of the three species, not only from year to year, but from month to month. The letter F, and a thickening of the line, indicate the ister stage; i. e. a high percentage of ister and fatty matter. The letter S denotes the time of spawning.

A comparison of the three curves immediately reveals the fact that the rate of growth differs greatly in the three species. During the first period of life, the pilchard exhibits the most rapid growth, being, however, soon overtaken by the herring, while the sprat is from first to last some distance behind. The first spawning takes place, in the case of the pilchard and sprat, at 3 years of age; as regards the herring, I have in the figure noted this as at 4 years of age. This is true of the herring found on the west coast of Norway; as we have seen, however, the North Sea herring frequently spawn when only 3 years old, while on the north coast of Norway, 5 or 6 years is the usual age.

No ister stage is apparent in any of the three species during their first year of life. The pilchard and sprat reach their first ister stage when 1½ years old; the herring (on the west coast of Norway) at an age of 2½ years.

Both pilchard and sprat attain maturity when three years of age, and have therefore an ister stage both in the second and third year of life. As regards the herring, the North Sea fish have probably only one, the West Coast herring two, and those of the North Coast as many as four ister stages before reaching maturity. A notable phenomenon in the fishing industry, viz, the fact that the *fat herring* (immature fish in the ister stage) are nowhere of so great importance in the total herring stock as on the North Coast of Norway, is thus explained. In the North Sea, with its enormous numbers of young herring, the fat herring are for the most part confined to a single year class, whereas those of the North Coast may include fish of from 2½ to 5½ years old. In the case of grown, mature herring, the fat-containing organs have an annual period of developement. The spring spawning fish have these organs most highly developed in autumn (August and September), the summer spawning fish in the spring. Thus spring spawning herring are in autumn fat and in good condition, while the summer spawning fish are spent and poor, the reverse being the case in the spring.

It will be easily understood, from the foregoing, that herring, pilchard and sprat of the same size (i. e. length) must differ widely as regards quality. Of three fish, a herring, a pilchard, and a sprat, all measuring between 9 and 13 cm., and all taken in summer, the sprat will be in best condition. Both herring and pilchard will then be thin and poor, the sprat on the other hand, being fat and full of ister.

It will be otherwise, however, when a length of 15—16 cm. has been reached. A sprat of this size will be mature and of little value, while the pilchard is at its best, the herring not yet having arrived at the "fat" stage. This is not reached, in the case of the herring, until a length of some 20 cm. is attained. The sizes between 20 and 27 cm. include, in Norwegian waters, the finest immature fat herring, which are in every respect the equal of any other species of herring as regards quality. Pilchard of this size are mature, and always meagre, even in summer.

In winter, all three species are, at all stages, considerably poorer than in summer. *The quality of all three species must therefore be regarded as a factor varying with age and season.*

A point of paramount importance is naturally the question as to how the fish attain renewed developement of their fat-containing organs; the nourishment required for this purpose, and the migrations undertaken by the fish in search of the same. For many years, distinction has been made (in Norway especially by G. O. SARS) between *spawning migration* and *migration in search of food.* SARS places in the latter category the movement of the loddefisk towards the Finmark coast, in pursuit of the capelan, as also the sojourn of the fat herring in North Coast waters, where abundance of plankton is to be found. Sailing from Bergen in summer towards the Shetlands, one encounters first, on the Revkant, the Norwegian herring which have spawned during the spring, and develope their genital and fat containing organs again in the course of summer and autumn. Farther on, one meets the Shetland herring, moving in to their spawning grounds. It is interesting to compare, at this time of year, the contents of the stomach in these two races of herring and the pelagic organisms in those parts of the sea in which they move. I had occasion to make some investigations of this nature in 1912, and will here mention some of the results obtained, on the basis of the samples taken, which were determined by PAUL BJERKAN.

In the Norwegian Channel, vertical hauls from bottom to surface, (e. g. from 360—0 m) with a 1 m. silk net, showed, besides small crustaceans, Copepoda (Calanus, *Euchaeta norvegica*, Metridia) also larger crustaceans, Ephausida (Meganyctiphanes norvegicus, Thysanoessa longicaudata). Vertical hauls from lesser depths (75—0 m) showed only Copepoda, no Ephausida, which latter must therefore be presumed to be restricted to the deeper water layers. Closer in, on the banks, only larvae of Ephausida were found, no full-grown specimens. The crustaceans here consisted almost exclusively of Copepoda.

On examining the contents of stomach of the herring, it was at once noticed that the Shetland fish contained far less than those from the Revkant. In samples of 50 Shetland herring, the contents of stomach varied between 20—60 cubic cm., whereas 50 of the Revkant fish exhibited a total of 205 cubic cm., consisting of 338 Meganyctiphanes norvegicus (of more or less equal size), and 8 Rhoda (Boreophausia) raschii, (of different sizes). Some of the stomachs being empty, this gives an average of more than 7 crustaceans per fish.

Investigations of this nature should furnish very valuable results, if extended to various waters, and carried out at different times of the year.

Similar investigations have occasionally been made as to the contents of stomach of cod and coalfish. In the Finmark waters, cod taken in the spring (April and May) often contain large quantities of capelan; I have found as many as twenty or more in the stomach of a single fish, while great numbers of Ephausida may be found in the stomach of the coalfish. Such investigations would go far to explain the migrations of the fish outside the spawning time. Particular interest in this respect attaches to such regions as the Bottlenose Ground, the Barents Sea, and the outer limits of the Norwegian Sea, where Ephausida, cuttlefish, and other organisms are found in abundance in the summer.

Variations in the quality of the cod.

In the cod, the fatty deposit is found partly embedded in the flesh, (between the muscles) and partly in the liver, where it is found in great quantities. This organ, in the case of the cod, discharges the important function of storing up a reserve of fat which is consumed as the needs of the system demand. The state of the liver is therefore subject to very great variation. Among the mature cod, or "skrei" we may find individuals with liver weighing only 10 gr., while in others, it may amount to between 1 and 2 kg. The percentage of fat also, as revealed in the process of boiling down, varies greatly. Instances have been observed of variation from about 60 to less than 20 % of oil.

Thorough investigation as to the size of the liver, and amount of fat contained, at all stages and seasons, has never yet been made; the practical industry, however, especially the Lofoten fishery, has furnished us with a great deal of valuable information as to the variations in the size of the liver and in the percentage of oil therein contained.

In the skrei fishery, where the fish are sold by number, the quantity of liver is taken as meaning the number of hectolitres of liver obtainable from 1,000 fish. A quantity of liver stated for instance as 3, indicates that the liver of 1,000 skrei would amount to three hectolitres*).

The percentage of oil is generally understood as the percentage in volume of medicinal oil contained in the liver.

These two factors are of great importance in the yield of the fishery. In the first place, the liver is in itself a valuable article of commerce, and the value of the liver forms an essential part of the value of the cod. In addition to this, however, it has long been recognised that the state of the liver is very closely connected with the condition of the fish, the quality of the latter improving with the increasing proportional size of the former.

Fluctuations in the quantity of liver from year to year.

It has therefore long been regarded as of great importance to note and record the quantity of liver produced. During the fishing season, the Fishery Inspectors telegraph, as often as possible, information as to the amount, and *the average quantity for each year's fishery* is calculated as closely as possible. This last is of peculiar significance, as for

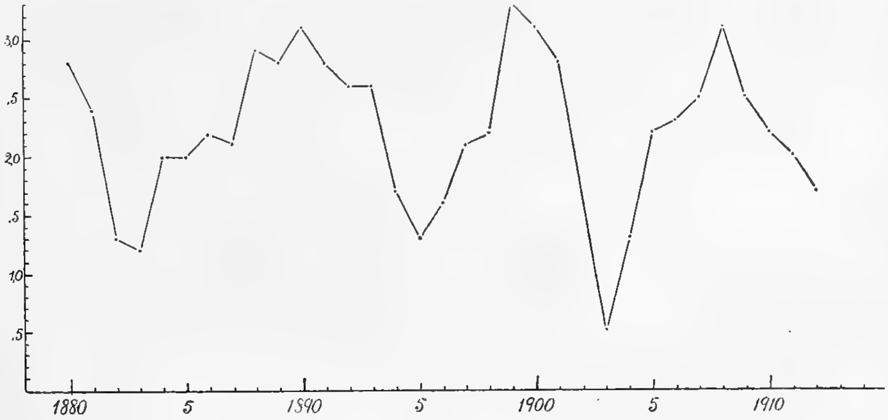

Fig. 106. Hectolitres of liver pr. 1000 skrei in the years 1880—1912.
5 = 5 hectolitres.

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*) This factor is often expressed in opposite terms; i. e., by stating the number of livers necessary to make up a hectolitre. Thus the quality of liver may be noted as 330, indicating that 330 skrei will be required to furnish one hectolitre of liver. In the present work, however, the definition given above will be followed.

many years past it has been noticed that the fluctuations in the annual yield appear to be not altogether fortuitous, exhibiting rather a very regular wave-like movement, with long periods of high and low percentage, each covering several years. Fig. 106 shows the course of this movement from 1880—1912. We find here deep hollows for the early 80's, the middle 90's and at the commencement of the present century, with a rise between each hollow and the next. The whole appearance of the curve is so regular that it is by no means surprising to learn that the question has long been regarded with considerable interest in the fishing industry, the facts as here shown being employed as a basis for speculation as to the price in coming years.

This curve representing the quantity of liver follows very closely that for percentage of oil, as will be seen from figure 107. For the statements as to fluctuations in the percentage of oil for the years 1880—1912, I am indebted to Mr. P. M. Heyerdahl, who has had occasion to personally observe the course of the fishery throughout this period, and whose experience in collecting reliable information on the subject, and in estimating the representative value of the same, is probably unique.

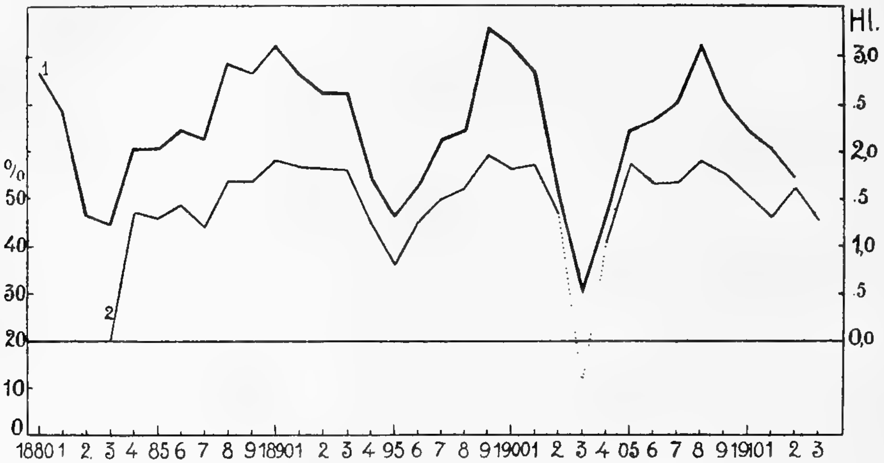

Fig. 107. Curve 1 (scale to right of figure) indicates no. of hectolitres of liver pr. 1,000 skrei in the years 1880—1912.
Curve 2 (scale to left of figure) indicates average percentage of fat in skrei liver for the same years.

It will be seen that the two curves exactly correspond, showing that the fluctuations in the size (volume and weight) of the liver coincide with those of the percentage in volume of the oil.

It is therefore not surprising that the quality of the fish, its condition in point of nourishment, has long been regarded as subject to great fluctuations, exhibiting a peculiar periodical movement, with alternating "fat and lean" years, or rather series of years. The natural conclusion would then be that these fluctuations were due to corresponding variations in the nutritive matter present in the sea, upon which the fish depend for food.

Fluctuations in the currents.

In view of this, attention was drawn, at a very early date, to the question of changes in the sea itself, and the study of the subject was soon included in the programme of the Norwegian fishery investigations.

In the 90's, H. H. Gran and the present writer*) arrived at the conclusion that the first necessity in any investigation of the changes in the sea must be a study of the so-called Atlantic current, or Gulf Stream, which passes from the Atlantic through the Faroe-Shetland channel into the Northern Ocean. Despite the paucity of means at our disposal, we succeeded in carrying out a summer and a winter section of this current. Our observations of salinity did not, unfortunately, attain such a degree of accuracy as has been rendered possible of late years by the developement of this branch of marine research in the course of the International Investigations. From the observations as to temperature, however, and distribution of the pelagic organisms, we could not but conclude that the fluctuations in this current were of so great extent as to render them of the highest significance to the animal life in the Northern Ocean.

When the Norwegian research steamer "Michael Sars" was built in 1900, I therefore instituted, as part of the annual programme of work for the vessel, cross sections of the Atlantic Current, to be carried out at the same time of year (in May), with a view to comparing the volume of the current from year to year. The route was laid from Sognefjord to a point east of Iceland (the Sognefjord section) and thence to Lofoten (the Lofoten Section), making two sections of the current at different latitudes. These cruises were carried out in the years 1901—1904, care being taken to hold the same course, as nearly as possible, each year.

Helland-Hansen's and Nansen's comparison of fluctuations in the ocean currents with those of the fishery.

The material thus collected was dealt with by B. Helland-Hansen and F. Nansen**), who endeavoured, in the course of the work, not only to make clear the fluctuations in the volume of the currents, but also to discover how far any definite relation could be said to exist between these and the fluctuations of the fishery.

Figs. 108—11 show the sections drawn by Helland-Hansen and Nansen of the Atlantic current along the southern route, (the Sognefjord section). The shaded surfaces show the cross section of the so-called Atlantic water, (salinity over 35 %) the darker shading indicating water of over 35.2 % salinity. For these, i. e. for all water over 35 % salinity, the average temperatures have been calculated, both in the Sognefjord and the Lofoten section. The figures obtained were taken as characteristic of the temperature of the Atlantic current during the years in question, and curves were accordingly drawn for purposes of comparison with certain features of importance in the fishery. We may here consider some of the comparisons made.

*) Currents and pelagic life in the Northern Ocean (in Report on Norwegian marine investigations 1895—97). Bergens Museums Skrifter, Vol. 1, 1899.

**) Die jährlichen Schwankungen der Wassermassen im Norwegischen Nordmeer etc. Internationale Revue der ges. Hydrobiologie und Hydrographie: Bd. II, Hefte 3.

The Norwegian Sea. Report on Norwegian Fishery and Marine Investigations. Vol. II, No. 2, 1909.

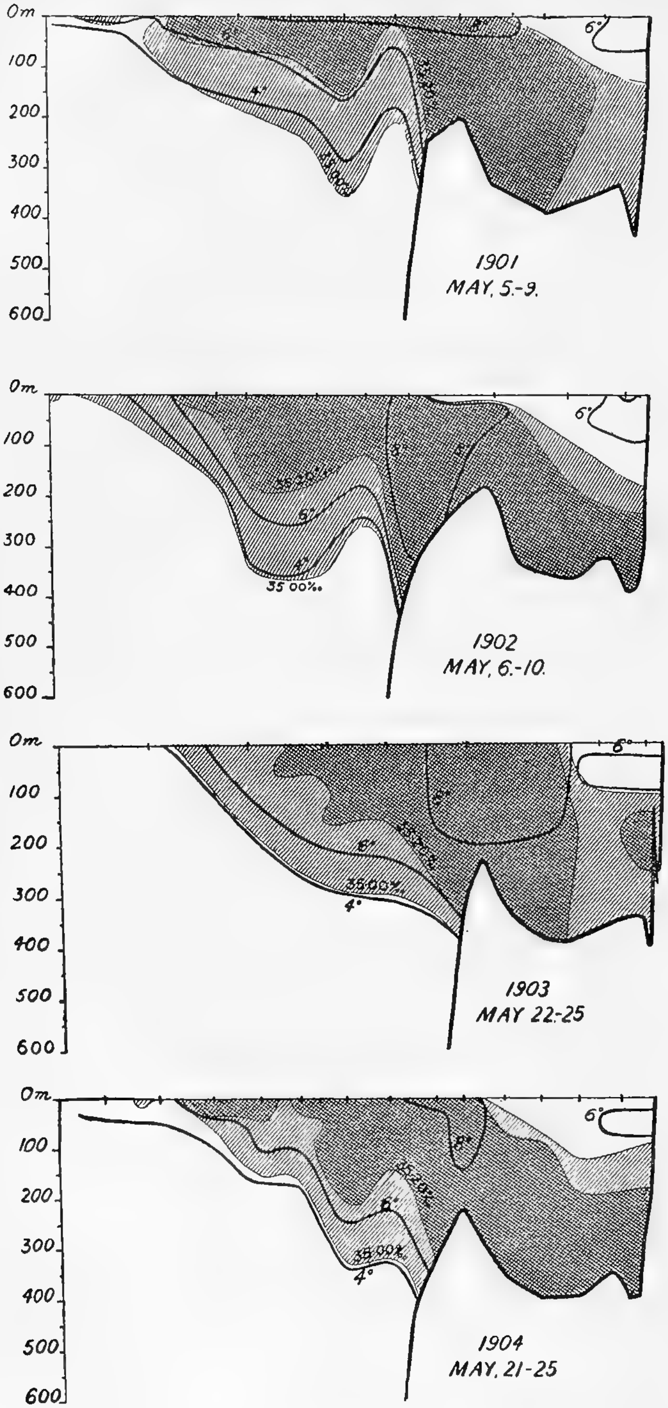

Fig. 108—111. Sognefjord section, 1901—1904. Vide text. From Helland-Hansen and Nansen.

Fig. 112 shows the fluctuations in temperature of the Atlantic current, as compared with the amount of liver and roe found in Lofoten skrei. The writers found that a certain relation was here apparent, a high average temperature in the Sognefjord section corresponding to a low percentage of liver and roe at Lofoten *in the following year*, whereas a high average temperature in the Lofoten section was accompanied by a low percentage of liver in the Lofoten skrei *the same year*. This is explained by the intervening distance, the Atlantic water being supposed to take about a year to shift from the Sognefjord section to the Lofoten section, so that the conditions prevailing in the southern region should not make themselves apparent in the northern water until some twelve months later. The fluctuations in the *quality of the fish* are for both regions presumed to be due to variations of temperature in the ocean currents.

In addition to this, the same writers are of opinion that the *quantity of the yield* is also dependent upon the temperature, which they explain in the following manner: The writers presume, in the first place, that a certain relation exists between the quantity of roe in Lofoten fish in any one year and the yield of subsequent years. The usual age of the Lofoten skrei, according to previous investigations made by Damas, being taken as from 7—12 years, and that of the Finmark fish at about five, Helland-Hansen and Nansen have compared the quantity of Lofoten roe in various years with the number of fish taken at the same place seven years *later*, and in Finmarken five years later. This comparison may be seen in figure 113, where the curves for the yield of the Lofoten and Finmark fisheries are moved forward seven and five years respectively, in relation to the curve showing amount of roe and liver.

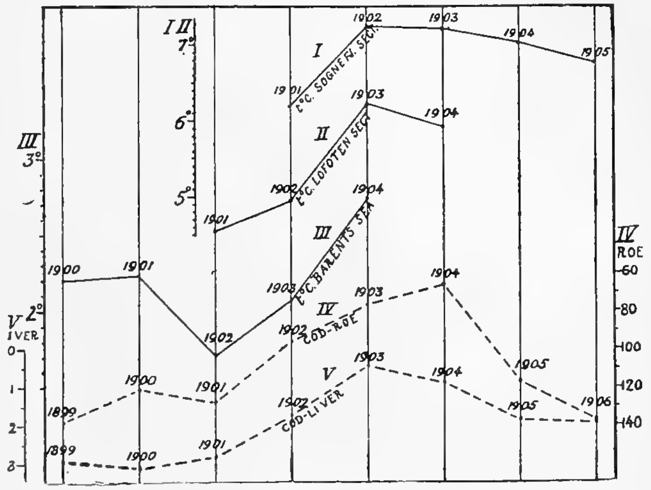

Fig. 112. I & II. Mean Temperature of intermediate Atlantic water in Sognefjord and Lofoten Sections.
III. Mean Temp. of Barents Sea Stations.
IV. Quantity of Cod Roe obtained during the Lofoten Fisheries (in Litres pr. 1,000 Fish; scale to the right).
V. Quantity of Cod Liver obtained during the Lofoten Fisheries (in Hectolitres pr. 1,000 Fish; scale to the left) (from Helland-Hansen and Nansen).

The amount of roe and liver being taken as proved to depend upon conditions of temperature, the next conclusion is then that both the quality and quantity of the Lofoten fish are dependent upon the fluctuations in the ocean currents. The Lofoten fishery is presumed to be influenced by the Atlantic current, the sprat fishery by the movements of the coastal water.

In many other respects, also, (climatic, agricultural, etc.) these authors find the influence of the ocean currents and their fluctuations apparent. We cannot, however, here enter upon any closer consideration of these sides of the question; I will merely mention a single instance of comparison between the average temperature of the Atlantic current and the percentage of fish taken at Lofoten before the 15th of March, as illustrated by figure 114, in which the temperature in the Sognefjord section is compared with conditions prevailing in Lofoten a year later.

Throughout their work, Helland-Hansen and Nansen seem to have devoted the greatest interest to comparison of the temperature of the Atlantic current with the amount of liver in the Lofoten fish. It is by no means surprising that a comparison with the long known and remarkably regular, wave-like curve for this factor should attract particular attention. In the periodical course of this curve these writers found a certain similarity to that of another well known figure, viz, that representing the varying numerical value of the spots on the sun, a resemblance which is the more remarkable in view of the opinion held by many meteorologists, that the sun's spots exert a certain influence upon the currents of the ocean and the climate of the earth. Just as the sun's spots are supposed to influence the temperature of the ocean currents, it may be supposed that these again occasion the fluctuations in the fishery, so that the relation of these last to their primary causes may be followed with almost mathematical exactitude.

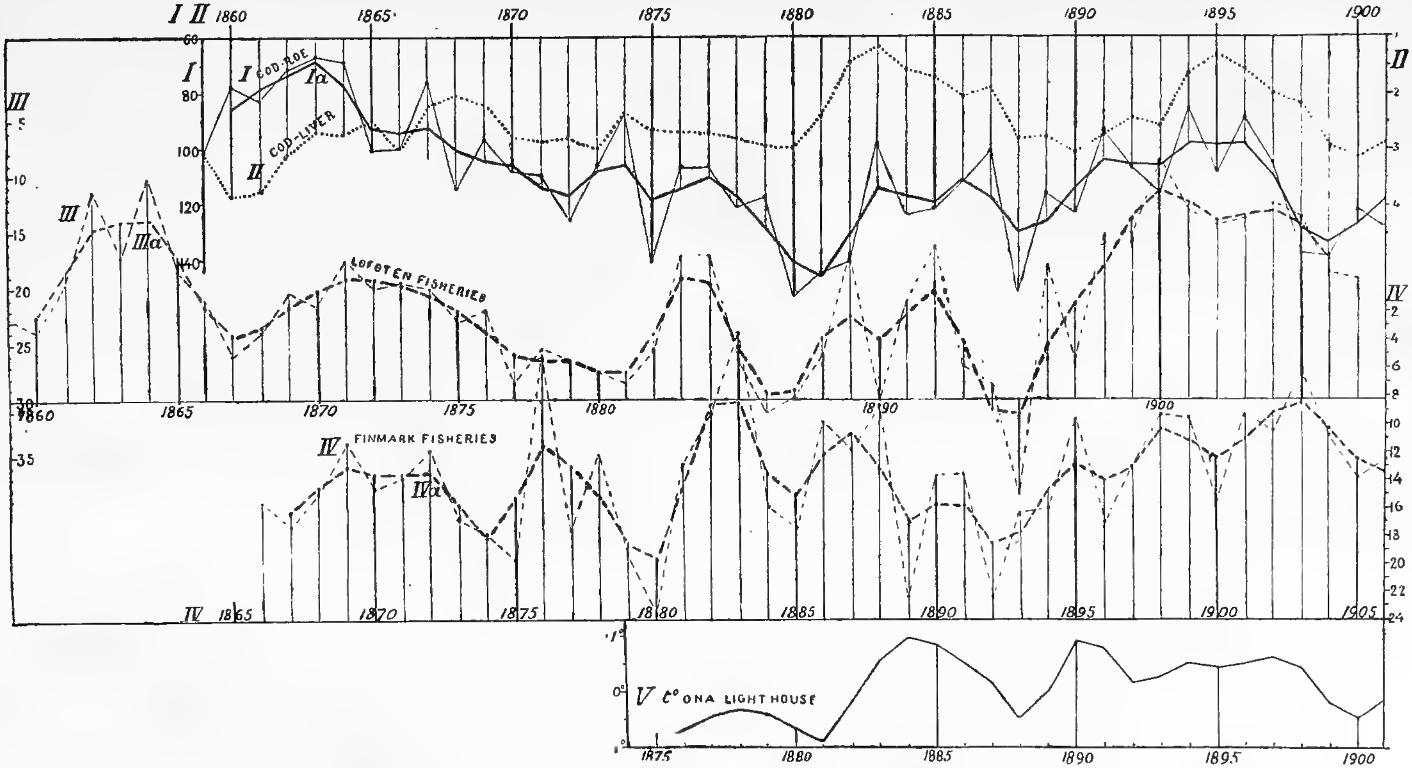

Fig. 113. I. Quantity of Cod Roe, in Litres pr. 1,000 Fish, Lofoten Fisheries 1859—1901. I a Average Curve.
II. Quantity of Cod Liver, in hectolitres pr. 1,000 Fish, Lofoten Fisheries (scale to the right).
III. Total Number of Cod, in millions, caught during the Lofoten Fisheries, 1859—1907 (scale to the left). III a Average-Curve.
IV. Total Number of Cod, in millions, caught during the Finmark Fisheries, 1866—1906 (scale to the right). IV a Average-Curve.
V. Average-Curve of Mean Air-Temperature (Nov. 1—April 30) at Ona Lighthouse.

Later observations as to the theories of Helland-Hansen and Nansen.

Theories and conclusions such as these very naturally aroused the greatest attention and interest. On the one hand, it would seem nothing short of marvellous that such to all appearence complicated biological and human phenomena as the fluctuations in the yield of the fishery should have their origin in the simplest physical causes. On the other hand, it was by no means easy to refute the theories in question, since the task of showing them false was apparently no less difficult than that of proving them true. Despite the fact that many points long since acknowledged in the fishing industry were in direct opposition to the theories now put forward, I endeavoured, for my own part, during the following years, to continue and extend the investigations before coming to any conclusion as to the hypotheses which Helland-Hansen and Nansen had built upon the material collected by the Norwegian fishery investigations.

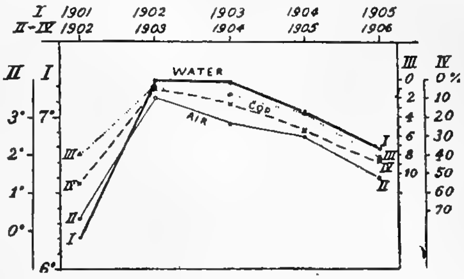

Fig. 114. I. The mean temperature of the intermediate Atlantic water in the Sognefjord Section, in May.

II. The mean air-temperature at noon, observed at Svolvær, in Lofoten, during the fishing season.

III. The number of Cod (in millions) caught before March, 15.

IV. The percentage of Cod caught before March 15, in proportion to the total quantity of the whole season.

In the following pages, I will endeavour to make clear my own opinion on the matter; it may, however, be as well to glance for a moment at the fluctuations in the fishery itself, first as regards the quantity, and secondly the quality of the fish.

Varying yield of the cod fishery; quantity.

The first supposition or basis of Helland-Hansen and Nansen's theory was, that a rich yield of roe in the Lofoten fishery was followed by a good yield of fish in Lofoten seven years later, and in Finmarken five. We have now, in the previous chapters, seen how the fluctuations in the yield of the cod and herring fishery exactly coincide with those in the numerical value of the year classes, some of these being richer than others, and thus occasioning an augmented yield in the years in which they are chiefly taken. It would therefore be natural to glance at the conditions prevailing in Lofoten as regards the quantity of roe during the years in which the richest year classes were spawned; in the case of the cod, especially the years 1903 and 1904.

The fishery statistics give the following statements.

Year	Quantity of roe (in 1,000 hectolitres)	No. of hectolitres of roe per 1,000 fish
1901	16.6	1.41
1902	13.7	1.12
1903	10.5	0.85
1904	8.1	0.79
1905	15.7	1.16

Year	Quantity of roe (in 1,000 hectolitres)	No. of hectolitres of roe per 1,000 fish
1906	25.4	1.43
1907	22.0	1.71
1908	19.9	1.36
1909	20.5	1.80
1910	20.1	1.87
1911	17.8	1.16

From the figures here given, we arrive at the remarkable result that the two years 1903 and 1904, which produced (judging from the subsequent yield of the Finmark and Lofoten fisheries) the greatest quantities of cod known in recent times, were the very years in which the quantity of Lofoten roe was at its least. As will be seen later on, this can scarcely be accidental; many observations would even seem to indicate that the richest year classes may be spawned in years when the quantity of roe taken is small (*vide* Chapter VI). We cannot, however, therefore conclude that the years when the spawning is at its lowest are those which produce the greatest number of fish, and although much would appear to support such a view, no investigations have yet been made which can satisfactorily demonstrate its truth. Be this as it may, it is in any case entirely unjustifiable to assume that the years exhibiting the richest yield of roe are those which produce the greatest quantity of fish.

It is, moreover, equally unwarrantable, in view of actual experience, to fix the age of the Lofoten skrei at 7 years and that of the Finmark cod at 5. The Lofoten fish consist, as we have seen in the previous chapters, mainly of individuals from 7—11 years old. Within these limits, the age of the fish varies considerably from year to year, now 8 year fish, now 9, and at other times 10 year old individuals being in the majority. If, therefore, it is desired to compare the quantity of roe taken in the Lofoten fishery during the birth year of a certain class, with the subsequent yield of grown fish, with the object of discovering the relation between the amount of roe and size of the resulting stock, then the relative position of the curves must be adjusted, not in accordance with a single permanently valid formula, but according to the actual composition in point of age of the Lofoten stock in each separate instance. With regard to the Finmark fish, the case is here even more complicated. As we have seen in the foregoing chapters, the stock in these waters consists of two different kinds of fish, the skrei and the loddefisk. The skrei here vary with regard to age in the same manner as in the case of the Lofoten stock; the loddefisk include several year classes, mainly those from 5 to 7 years inclusive, the relative value of these year classes again varying from year to year. Thus there is very little similarity apparent between the curves shown in Fig. 113; the conditions are too complicated to permit of any so schematic illustration. The great secret which has been the problem of the fluctuations in the quantitative yield of the fishery is of an entirely different character to that supposed by HELLAND-HANSEN and NANSEN.

Variation in quality of the fish.

It might nevertheless be supposed that the variations apparent in the *quality* of the fish may be due to the causes and regulated by the laws to which HELLAND-HANSEN and

Nansen have endeavoured to relegate their origin and governance. Closer examination of the question, however, reveals great difficulties also here. According to these writers' theory, the quantity of liver (and roe) in Lofoten, varies according to the temperature of the Sognefjord section for the previous year, whereas in the North Sea and Romsdal waters, it corresponds to that for the same year. This theory naturally leads us to examine the statements in the fishery statistics as to the quantity of liver obtained from the skrei in different years in various parts of the Norwegian coastal waters. This I have done, as will be seen in Fig. 115, where the curves show the quantity of liver obtained in each district from Romsdal to Tromsø, in the years 1900—1911. It will be noticed that all the curves coincide as nearly as could possibly be expected, from which we may conclude, that the *fluctuations in the quantity of liver obtained along the whole of the northern coast of Norway are simultaneous, and of like direction and degree.* This observation is not new; merchants trading in oil have, to my knowledge, long

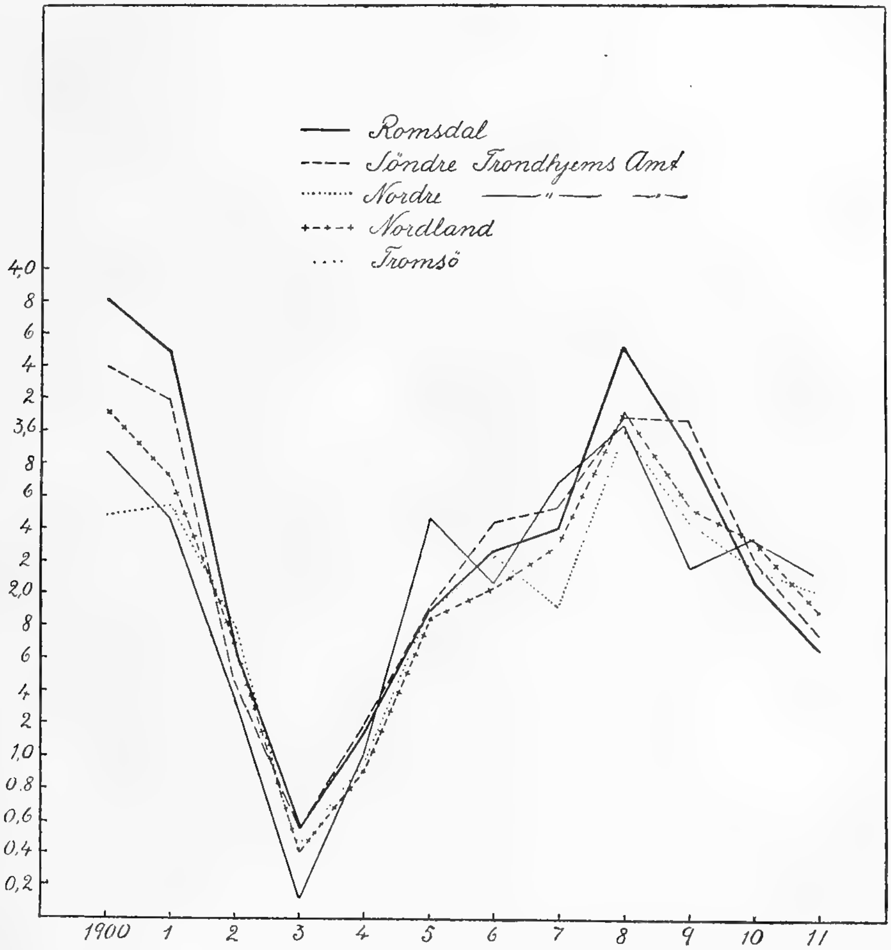

Fig. 115. Hl. liver pr. 1,000 skrei in the years 1900—1911.

been acquainted with the fact. One of the most experienced merchants in Bergen has informed me that he has for many years been accustomed to form an estimate of the prospects of the Lofoten liver supply by examining, early in the season, the fish offered for sale in the Bergen market. It is thus evident, that in considering these fluctuations, we have to deal with phenomena of great and far-reaching influence and belonging to a wide geographical area, at least to that included between the Sognefjord and the Lofoten section. The marking experiments have also proved, that the cod may cover such a distance in the short time of some months or perhaps even some weeks.

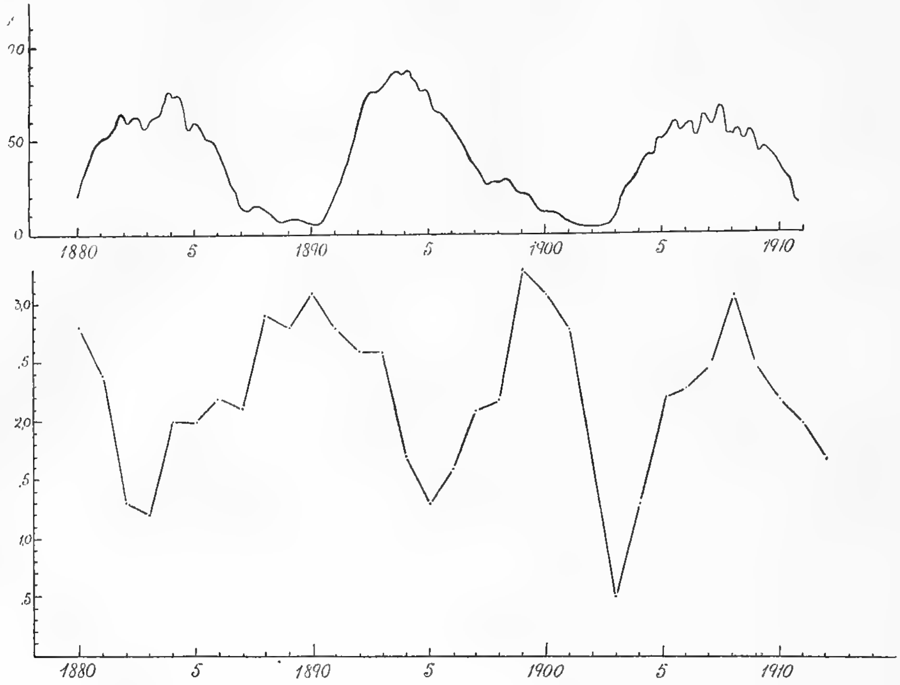

Fig. 116. Curve showing no. of sun spots for the years 1880—1911 (uppermost); below, curve showing quantity of liver in Lofoten skrei for the same years.

No relation between the number of sun spots and quantity of liver.

Nor does a comparison of the number of sun spots with the quantity of liver appear to give any satisfactory result. Fig. 116 shows the curves for these two factors, for the years 1880—1911. The curve for quantity of liver is that already given, that for the sun spots is taken from a work by Prof. Otto Pettersson. The two curves have, it is true, so much in common, that both exhibit distinct rise and fall; they do not, however, by any means coincide. A rise in the one may occur simultaneously with a fall in the other, and *vice versa.* The only warrantable conclusion would seem to be, that no relation can be shown to exist between the two phenomena, in any case not for the present, nor in the way suggested by Helland-Hansen and Nansen.

Einar Lea's hydrographical investigations, 1910—1912.

In spite of these objections and disabilities however, which previous experience had already indicated, I nevertheless considered it advisable to continue the current investigations, and applied to the Government for permission to repeat, in the years 1910—1912, the May cruises along the Sognefjord section. These investigations were carried out during the years in question by EINAR LEA, who endeavoured, not only to collect further material, but also to arrive at some means by which it might be possible to test the accuracy of the methods employed. In particular it was desirable to ascertain how far such sections of the Atlantic Current might be relied upon to give a truly characteristic and representative view of the hydrographical conditions prevailing at that season of the year. Mr. LEA's treatise on the subject has not yet been published; he has, however, furnished me with the following brief survey of the principal results obtained. In consideration of the importance of these results as bearing upon the questions dealt with in the present work, I give this preliminary report *in extenso.*

Methodical hydrographical investigations.

»The hydrographical investigations of May 1912 were carried out with a view to obtaining material from which it should be possible to determine the representative value of a hydrographical section. Observations were therefore made both on the outward and homeward voyage, on approximately the same course, viz., between the mouth of the Sognefjord and a point situate at Lat. 63°43′ N, Long. 5°11′ W. I thus obtained figures for two hydrographical sections (A and B in figs. 117 and 118) along the same line, both with the same number of observations, and with but slight difference in point of time, the one series being taken between 10.45 a. m. on the 24th of May and 4.45 p. m. on May 27th, the other between the afternoon of the 27th of May and 10.30 a. m. on May 30th.

»A comparison of these two series of observations will serve to indicate the variations which may occur in the section during a very short time. Some of the possible comparisons are shown in Table 1. This table gives, for both series, the figures for average surface temperature of Atlantic water (> 35.00 ‰), average temperature of Atlantic water at intermediate depths, quantity of heat in Atlantic water, extent of coastal water area (< 34.00 ‰) and finally for difference of average temperature of Atlantic water at the surface and at 200 metres' depth.

»These are the factors which have been employed by HELLAND-HANSEN and NANSEN in their comparisons of the fluctuations in the growth of fir, variations in climatic conditions, in the quantity of cod liver, in the yield of the fisheries, etc. All calculations have been schematically rendered, as in the comparisons made by the two writers above mentioned.

Tab. 1.

	Section A.	Section B.	Difference
Mean surface temperature of Atlantic water.....	8°.37	8°.04	0°.33
Mean temperature at intermediate depths.......	7°.55	7°.41	0°.14
Quantity of heat............................	906	955	49
Extent of coastal water area (< 34.00 ‰)......	4.12 km².	3.88 km².	0.24
Difference in mean temperatures at 0 and 200 m depth................................	1°.21	1°.13	0°.08

»As will be seen from the above, the differences exhibited are but slight, and we may fairly conclude that a hydrographical section with so close observations as in the present instance more or less accurately represents the actual conditions as to temperature and salinity.

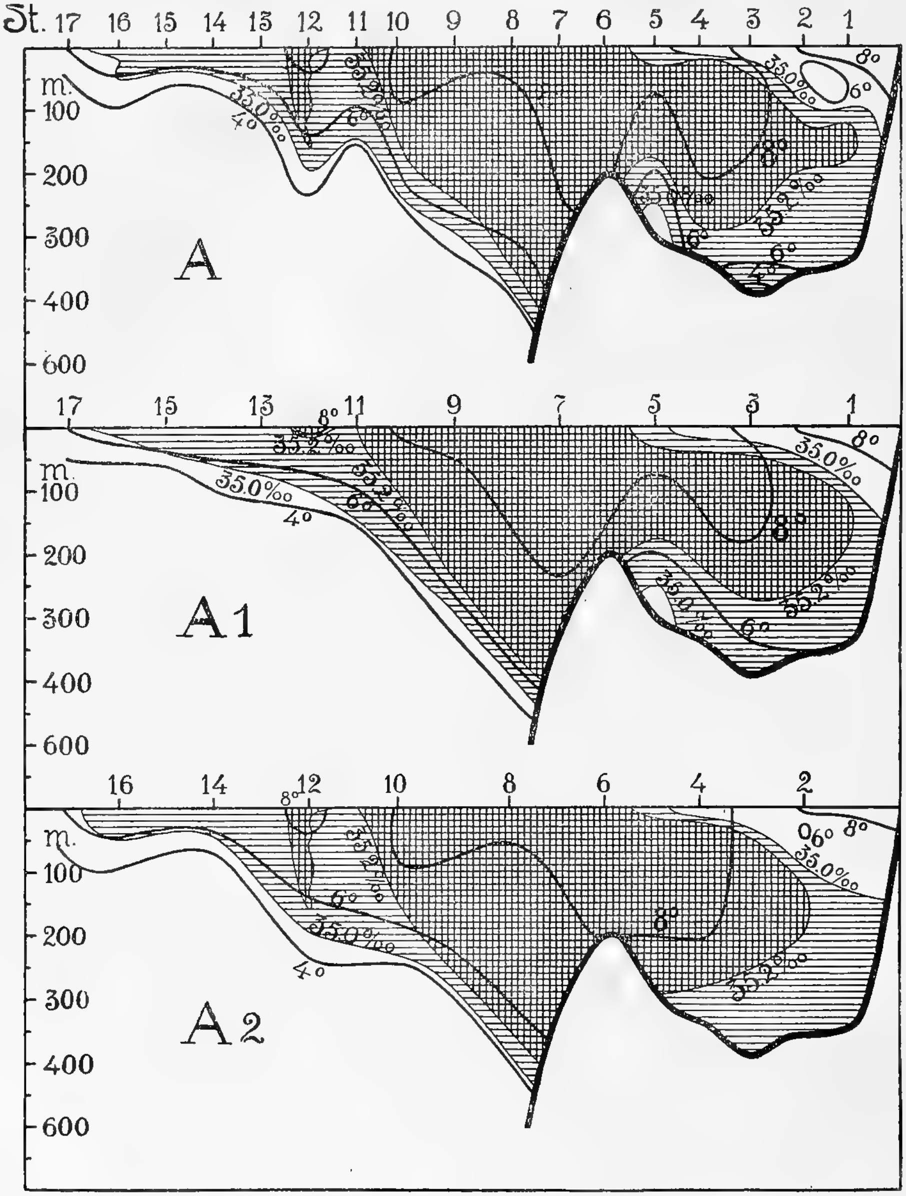

Fig. 117. Sognefjord section, on outward voyage from Sognefjord 1912.
A. From figures for all stations. A_1, A_2. From figures for alternate stations (Drawn by **Lea**).

»In order to discover the amount of the error occasioned by constructing sections on the basis of fewer observations, four additional sections were drawn up, omitting every alternate station, the mean temperatures, etc., being calculated as in the previous pair.

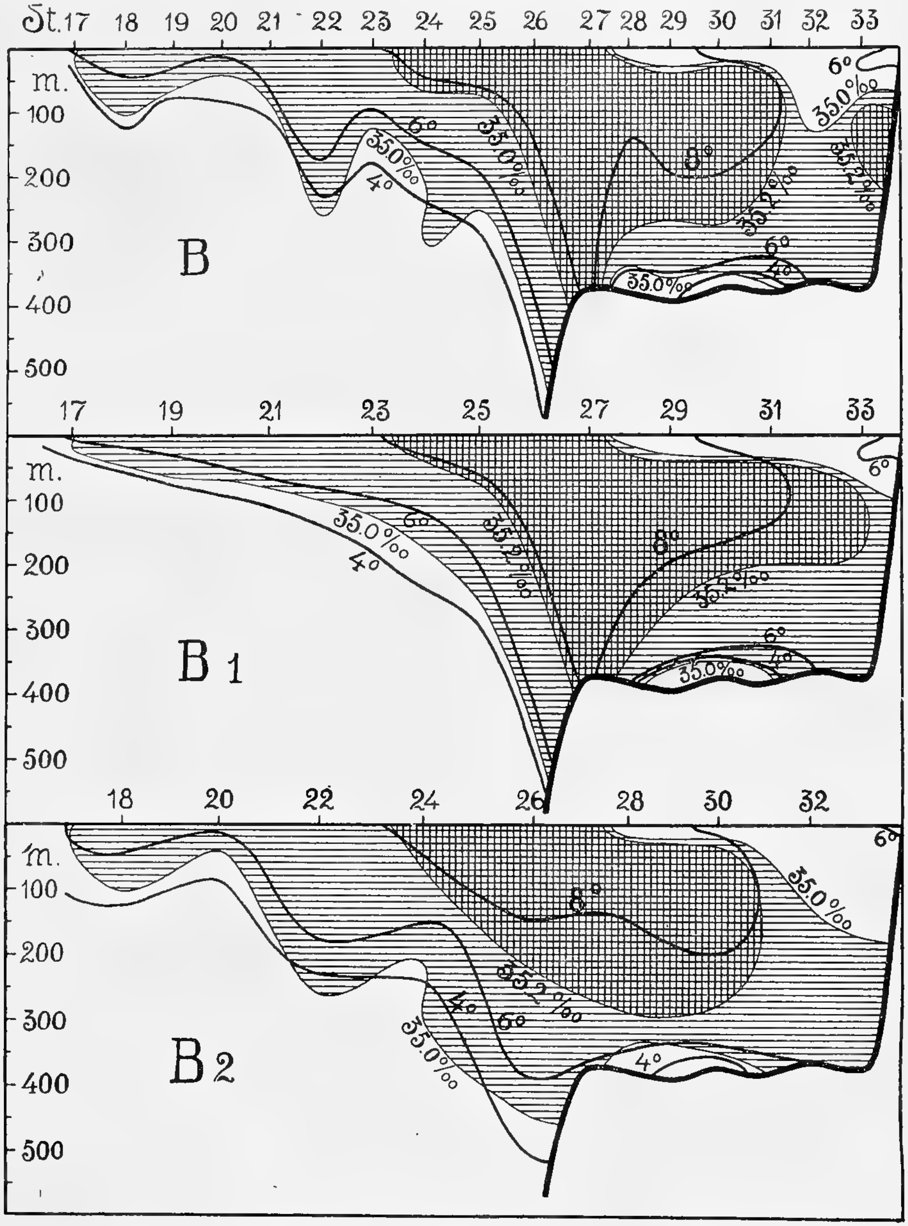

Fig. 118. Sognefjord section; homeward voyage 1912.
B. From figures for all stations. B_1, B_2. From figures for alternate stations (Drawn by LEA).

»These latter sections (A_1, A_2, B_1 and B_2 in figs. 117 and 118) are based upon the same number of stations and observations as those of HELLAND-HANSEN and NANSEN. The results of these calculations will be found in Table 2.

Tab. 2.

	A_1	A_2	B_1	B_2	Greatest difference
Mean temperature of Atlantic water at intermediate depths..........	7°72	7°62	7°82	7°62	0°20
Quantity of heat..................	861	960	872	906	99
Difference in mean temperature at 0 and 200 m. depth..............	0°88	1°43	0°62	1°38	0°81

»It will be noticed that the differences are here considerably greater, being indeed, in one case, of the same numerical order as the values themselves. These differences may be taken as indicating the amount of error to which calculations are liable when based on so few observations as those of Helland-Hansen and Nansen. A comparison of the variations thus occurring in four sections, taken, practically speaking, at the same time, with the variations which these two writers believe to have noted as from year to year shows that the variations in question are in many cases very little greater than the error apparent in the values themselves. Thus the difference in the quantity of heat between 1902 and 1903 is only 45, between 1903 and 1904 127, between 1911 and 1912 again 40. In particular, the figures for difference between mean temperature of Atlantic water at 0 and 200 m. depth appear to be liable to so great errors as to render the annual variations in this factor indiscernible.

»This leads us to the conclusion that hydrographical sections based on such number of observations as employed by Helland-Hansen and Nansen are subject to an error which in some cases falls within the same numerical order as the variations noted by these writers between one year's observations and those of another. These errors are apparently due to the comparatively high rapidity of variation in the distribution of temperature and salinity, as will be seen by a comparison of the conditions prevailing at slightly different times in one and the same spot. Tab. 3 shows the variation in depth of the different isotherms at one place, (Lat. 63°21′ N, Long. 4°00′ W) during an interval of 16 hours.

Tab. 3.

Isotherm	7°	6°	5°	4°	3°	2°	1°	0°
Distance from surface I	6	33	46	59	103	183	287	450 m.
» » » II .... (16 hours later)	..	33	57	75	83	86	90	94 »
Movement (+ = upwards)	>6 m	0	÷11	÷16	20	97	197	336 m.

It will be seen that the movement of the isotherms is in some cases enormous.

Investigations as to the relation between variations in hydrographical and biological conditions.

»Hydrographical observations, similar to those employed by Helland-Hansen and Nansen in their discussion of the relation between fluctuations in the state of the sea and in the yield of the fishery, etc, are also available for a further period of three years. Fig. 119 shows the mean temperature of Atlantic water in the Sognefjord section for the years 1901—1905 and 1910—1912, the quantity of liver obtained from the skrei in the following years being noted on the same ordinates. A certain parallel may, it is true, be drawn, the rise in temperature in 1910—1912 being succeeded by a decrease in the quantity of liver in 1911—1913; on the other hand, the quantity of liver in 1911 and 1912 is seen to be relatively high, despite the fact that the temperature here, instead of being low, is *high*, (cf. 1903 and 1904). No direct relation can therefore be proved.

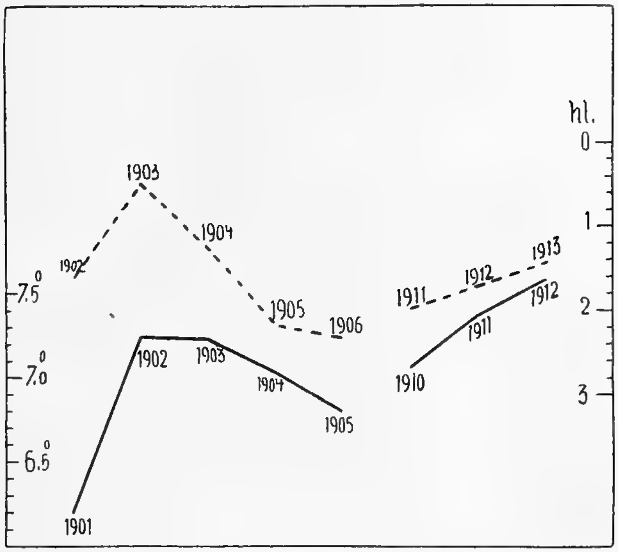

Fig. 119. —— Mean temperature of Atlantic water.
- - - - Amount of liver in skrei (hl. pr. 1,000 fish).
(Drawn by Lea).

»Fig. 120 shows the variations in extent of the coastal water area and in the yield of the sprat fishery in different years. Helland-Hansen and Nansen have suggested the existence of a relation between these two factors, on the basis of the curves for 1901—1905 (on the left of the figure). The conditions prevailing in 1910—1912 cannot, however, in any way be made to fit in with this theory. Even disregarding the great increase in the yield of the fishery (here indicated by the height of the curve in 1910—1912 as compared with 1901—1905), the general direction of the two curves exhibits so little similarity that we find the "relation" between the yield of the fishery and the extent of the coastal water area 1910—1912 exactly the reverse of that indicated for 1901—1905.

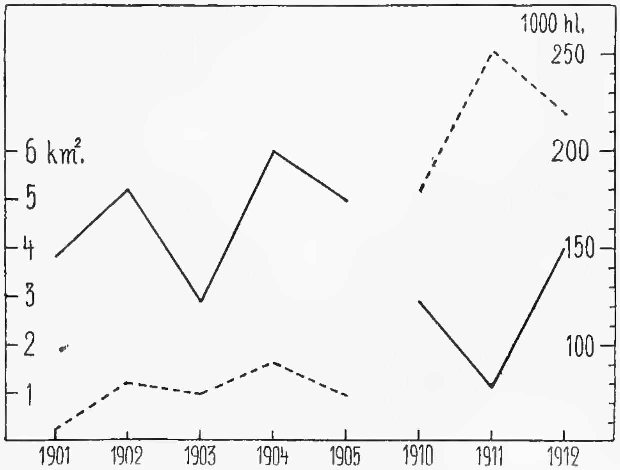

Fig. 120. —— Extent af coastal water area.
- - - - Yield of sprat.
(Drawn by Lea).

Conclusions.

»1) The hydrographical conditions at any one place can in the course of a very short time undergo great alteration.

«2) Owing to these rapid changes, the *details* of any survey of hydrographical conditions as expressed in a section can only be regarded as expressive of these rapid variations.

»3) Since however, the direction of the rapid changes referred to varies for the different points of observation, such a section will yet suffice to give a fairly representative view of the hydrographical conditions at the time of observation.

»4) Such a survey will nevertheless be subject to certain errors, which may in some cases be of the same numerical order as the figures for the variations noted from year to year.

»5) The relation which Helland-Hansen and Nansen believe to have discovered between the fluctuations in hydrographical and biological conditions may in certain cases be merely fictitious, and due to errors in the observations.

»6) The alleged relation between the extent of the coastal water area and the yield of the sprat fishery is not confirmed by the investigations of recent years.«

Biological investigations as to the fluctuations in quantity of cod liver and roe.

The hydrographical investigations are thus still far from being able to furnish any full and simple explanation of the fluctuation in the quality of the fish. It will also be evident, on closer consideration, that no satisfactory result can be arrived at in this respect until the biological phenomena which it is desired to explain are far more accurately and distinctly defined than has been the case in the course of the investigations made by Helland-Hansen and Nansen. The present writer has long entertained the project of carrying out such preliminary biological investigations; not until 1913, however, was it possible to realise this plan, by personal observation of the Lofoten and Finmark fisheries. The data here obtained will be briefly described in the following.

First of all, it appeared to be of importance to study the variation (in weight and volume) of the liver in fish of different size and different condition as regards quality. With this end in view, several hundreds of cod were measured (as to length) and weighed, the liver and roe of each being then weighed, for purposes of comparison with the length and weight of the fish. It was immediately apparent that the liver, as every fisherman and dealer knows, exhibits very great variation in size and weight, even in fish of the same size. On examining a large number of fish, however, and calculating the *average weight* for the different lengths, it is noticeable that *these average weights increase at a high rate of progression with the size of the fish.* Fig. 121 illustrates the method of investigation here employed. For each centimetre group of cod (e. g. for fish from 50—59 cm. in length) the single liver weights are grouped according to size. We thus obtain a view both of the variation in weight, and the average weight of the group. This is indicated in the figure by the fully drawn curve, which shows an increase in the average weight from each size group to that next following. In like manner, I examined a great number of samples, arranging the individuals, as a rule, in 5 cm. groups, as in the size investigations described in Chap. III. The results of all these investigations tend to show an increase in the average weight of the liver with increasing length or weight of the fish.

Comparison between size of fish and weight of liver.

In view of the importance of more closely considering these features of the question, I have drawn up the table on page 194, showing the results obtained by investigation of two samples, one consisting of spent Lofoten skrei (from Sørvaagen) taken in the latter part of April 1913, and the other of Finmark fish, taken on the 6th of May in the same year. In each case, the average weight (whole) is given for each 5 cm. group, as also the average weight of liver and the proportion between the weight of the liver (i. e. the percentage of liver).

In both samples, the average weight of liver is seen to increase with increasing length and weight of the fish; in the Lofoten sample, the increase from the 60—64 cm. group to that of the 115—119 cm. fish amounts to as much as 3,000 %. In both samples, moreover, it is distinctly evident that *the weight of the liver increases not only in proportion to the weight of the fish, but at a far higher rate.*

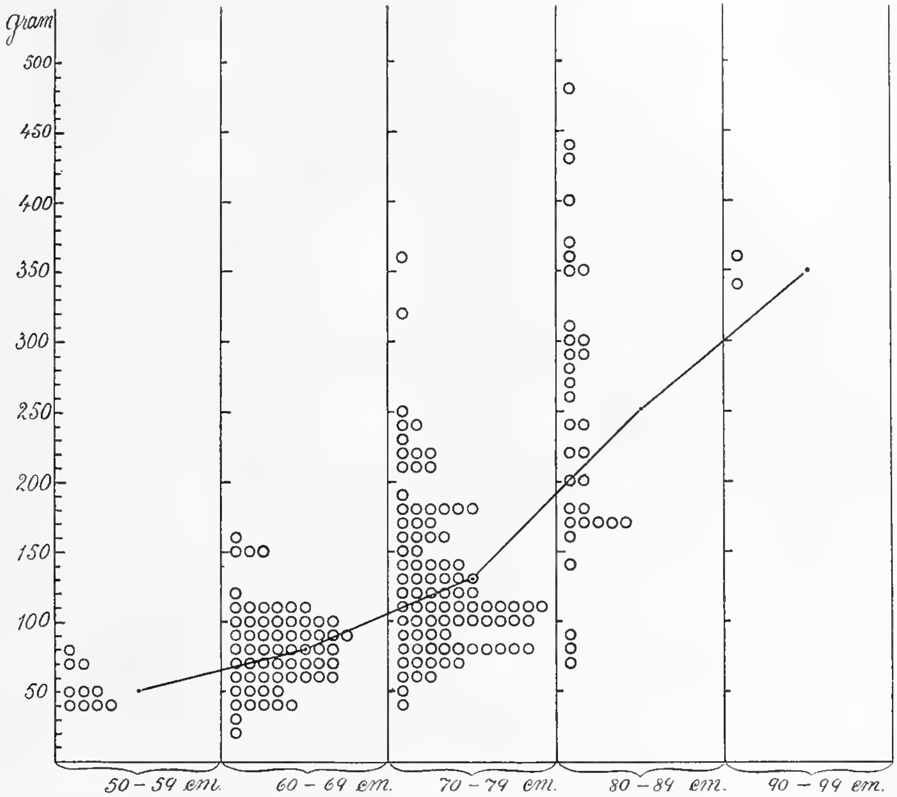

Fig. 121. Weight of liver in gr. for each individual (0) within each 10 cm. group. Average weight for each group.

In the Lofoten samples, the weight of liver in the 65—67 cm. fish amounted to 1.2 % of the weight of the fish, whereas the corresponding percentage for the largest individuals was 5.6 %. Equally rapid is the increase noted in the case of the Finmark fish. *The larger the fish, the higher is the percentage of liver contained.* One point of difference is noticeable between the two samples, all the weights, both of fish and liver, being lower in the case of the Lofoten fish than in those from Finmarken. This can only be explained as due to the fact that the Lofoten skrei were then spent, the fat from the whole of the system, muscles and liver, having been consumed in the process of devel-

	Lofoten 23. April 1913			Finmarken 6. May 1913		
5 cm. groups	Average weight of fish, in kg.	Average weight of liver, in gr.	Average percentage of liver (% of weight of fish)	Average weight of fish, in kg.	Average weight of liver, in gr.	Average percentage of liver (% of weight of fish
50—54	...	...	...	...	...	...
55—59	...	...	...	1.5	47	3.0
60—64	1.6	27	1.9	1.8	63	3.4
65—69	2.0	23	1.2	2.3	83	3.6
70—74	2.2	44	2.0	3.0	110	3.9
75—79	2.9	60	2.0	3.5	130	4.3
80—84	3.4	85	2.5	4.2	217	5.0
85—89	4.3	124	3.0	5.1	331	6.4
90—94	5.6	200	3.5	5.9	350	6.0
95—99	6.2	180	3.0	...	...	...
100—104	6.8	270	4.0	...	...	...
105—109	8.6	400	4.6	...	...	...
110—114	11.6	570	5.0	...	...	...
115—119	15.0	890	5.6	...	...	...
Whole sample..	3.0	90	3.0	3.0	131	4.4

opement of the genital products, whereas the Finmark fish had again commenced to store up a reserve of fat, taking advantage of the favourable conditions as regards nourishment afforded by the Finmark water, where the great shoals of capelan furnished an abundant supply of food. We find here the same changes in the course of nutritive assimilation which have previously been referred to when comparing the state of the spring herring with that of the large herring in point of fatness.

Study of the influence of nourishment on the quantity of liver; necessary preliminaries.

We arrive thus at the conclusion, that the size or weight of the liver is dependent both upon the size of the fish, and also on its conditions as regards nourishment. This being so, it is immediately evident that in this, as in any other case where two determining factors have to be reckoned with, an estimate of the respective influence of each factor can only be arrived at by the investigation of material furnishing definite information as to the independent effect of each. In considering the influence exerted by the size of the fish upon the weight of liver, it will be necessary to compare specimens of different sizes in the same condition as regards nourishment; in studying the effect of the last-named factor, specimens of equal size, but differing in point of nourishment, will be required. In a sample of fish consisting of individuals all taken at one and the same place on one and the same day the average of the size groups may reasonably be taken (at any rate, in the case of grown fish) as being influenced in the same degree by the nourishment, and may therefore be used for purposes of comparison as regards the relation between the size of the fish and the weight of liver. On the other hand, examination of several different samples, arranged in such a manner as to permit of each separate size group in every sample being directly compared with the corresponding group in every other, will furnish a distinct view of the effect of varying conditions of nourishment upon all the individuals in the samples.

Cod liver; average weights in gr.

		No. of fish in sample	45—49	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—89	90—94	95—99	100—104	105—109	110—114	115—119	Whole sample
Lofoten	Sørvågen 23. IV..	249	..	..	..	27	23	44	60	85	124	200	180	270	400	570	890	90 gr.
	Røst 14. IV.	206	..	..	..	41	59	98	115	146	240	330	319	264	426	610	710	120 -
Finmarken	Medfjord 7. V. ...	184	..	40	45	55	82	111	140	206	235	343	281	442	680	...	...	...
	Honningsvåg 6. V.	199	..	..	47	63	83	110	130	217	331	350	...	...	...	...	...	131 -
	Honningsvåg 9. V.	82	..	..	..	..	90	117	123	216	238	308	830	...	...	...	...	153 -
	Baadsfjord 24. V..	97	22	33	49	65	114	125	133	231	255	315	...	...	...	...	...	113 -
	Vardö 21. V.	100	..	..	..	..	93	132	207	294	376	478	660	810	1150	...	...	369 -

The table above gives an illustration on these lines, furnishing as it does a comparison both of the different size groups in each sample and of the same size groups in all. The greatest interest here naturally attaches to consideration of those sizes which experience has shown to be most numerously represented among the full grown cod, viz., the groups from 65—90 cm. It will be noticed that there is a great difference between the two Lofoten samples on the one hand, and all those from Finmarken on the other, the former exhibiting far lower weights, lowest of all in this respect being the spent fish from Sørvaagen. Even when taking into consideration the considerable fluctuations here discernible within one and the same size group, these are however, still found to be far slighter than the differences noticeable between the size groups themselves. The difference between the average weights for one and the same size group in different samples in no case exceeds 300 %, whereas far greater fluctuations are apparent between one size group and another.

Quantity of liver for the different size groups.

The figures given in the table above for the average weights naturally furnish a very simple means of calculating the *quantity of liver for each separate size group in* the different samples, or in other words, how many hectolitres of liver may be obtained from 1,000 fish of each size group. On the basis of such calculations, also, the *curves for the quantity of liver in the 5 cm. groups of the different samples* may be drawn. This has been done in Fig. 122, four samples being here selected, two consisting of Lofoten skrei and two of Finmark fish. All four curves exhibit, on the whole, a very similar course, with a very noticeable increase according to the size of the fish. The curves lie, however, at different parts of the scale; the skrei samples exhibit the smallest quantity of liver for all groups, the Finmark samples being highest in this respect. The difference between the Finmark samples and the sample of skrei from Røst, which was taken in the first half of April, is not, however, very great. From this we may conclude that *the greatest "depreciation" in the quality of the cod takes place during their stay on the Lofoten banks, where the genital organs arrive at full maturity, and spawning takes place.*

Varying quantity of liver in the size groups compared with fluctuations in the average amount of liver in the skrei from year to year.

A point of great significance is the fact that these curves all exhibit far greater fluctuations than the curve for quantity of liver from Lofoten for the years 1880—1912, which we have frequently had occasion to refer to in the foregoing. *Thus we find, within one and the same sample of skrei, greater fluctuations in the quantity of liver than are discernible in the curve showing the average quantity of same for the last 30 years. The lowest figure which occurs during this period is abt. 0.5 hl. per 1,000 fish* (*in 1903*) *the highest being somewhat over 3 hl. The same fluctuations are apparent in the sample from Røst,* (*14th April 1913*) *within the groups between 64 and 94 cm. length.*

If the skrei in 1913 had consisted exclusively of fish 65 cm. long, we should thus in all probability have had, during this year, the smallest quantity of liver ever known. If, on the other hand, the yield had been composed of fish about 90 cm. in length, the quantity of liver would have exceeded that of any previous year. *The fluctuations in the average quantity of liver in the skrei from year to year are thus found to lie within such limits as to render it possible to attribute them to the variations in size* (*length or weight*) *of the fish which are known to occur in the shoals.*

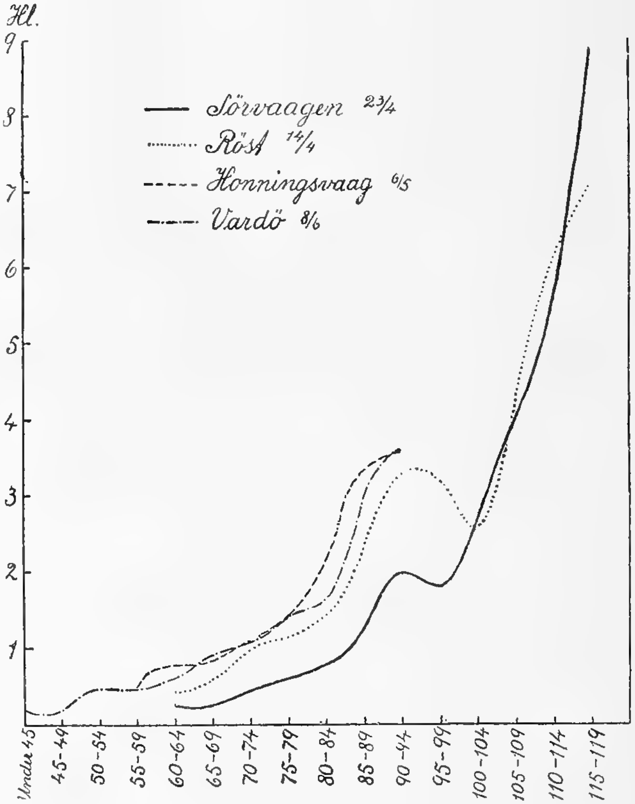

Fig. 122. Quantity of liver for each 5 cm. group.
Hl. liver per 1,000 Cod of each 5 cm. group.

We have seen in the previous chapter, that the fishery authorities at Lofoten, besides recording the average annual amount of liver and roe, also furnish statements as to the average weight of the fish for each year, which will be found graphically illustrated in figure 99, embracing the period from 1880—1912. It is interesting to compare these two curves — the weight of liver and the weight of fish — for these years; Fig. 123 furnishes a comparative view of these factors, the first curve indicating the weight of fish, the second that of the liver, and the third that of the roe. It will be seen that the three curves exhibit the most conspicuous similarity; it would indeed be hard to find an instance of curves of this nature more closely coinciding. This close resemblance is, moreover, especially valuable, illustrating as it does a relation between different factors in the same object (i. e. the same individuals). The greatest value therefore attaches to the testimony afforded by the similarity of the curves here in question. *We see, that the so-called quality of the fish is mainly an expression of their age and growth, of the relative proportion in which the different age classes appear in the stock, and of the previous history of the stock itself; not in the first instance an indication of any momentary condition of the fish as regards nourishment, or of the state of the water in which they move.*

These results thus confirm and support, in a very high degree, the conclusions arrived at in the previous chapter; they show, moreover, the far-reaching effect upon the stock occasioned by the varying occurrence of year classes consisting of large fish or small, with corresponding high or low value as regards the quantity of liver.

The importance of the conclusions which I have here drawn from my own investigations will justify a closer consideration of some of the most important points, and this may especially be necessary, as in the practical industry, many people have long been accustomed to attribute all fluctuations in what is called "quality" to transitory conditions. Moreover, certain remarkable facts have been observed in some recent years, especially in 1903, when the quantity of liver was perhaps less than ever before observed. In this year, the commencement of the skrei fishing season was accompanied by a number of peculiar phenomena, such as the immigration into Norwegian coastal waters of Arctic animals such as the beluga, and the Greenland seal (*Phoca groenlandica*), all of which combined to give the impression that a general dislocation of marine conditions was taking place.

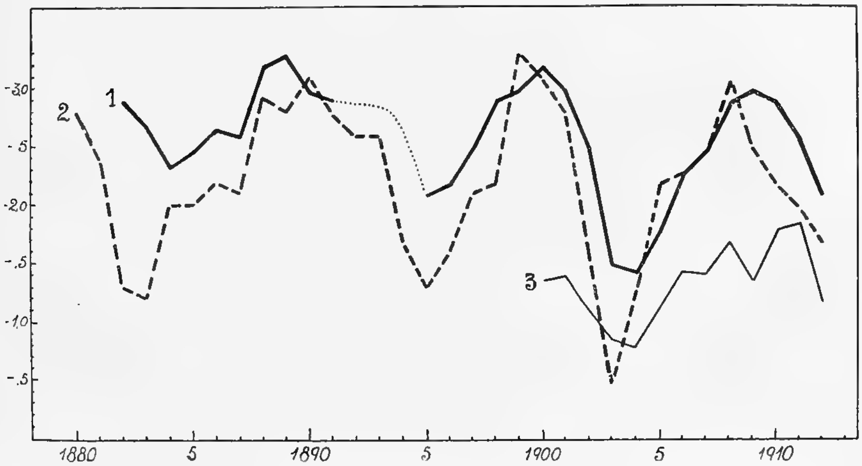

Fig. 123. 1. Average weight of Lofoten skrei. 2. Amount of liver in Lofoten skrei. 3. Amount of roe in Lofoten skrei.

Comparison of the quantity of liver in the first and last week of the skrei fishery.

We have seen in the foregoing, that the changes which take place in the quality of the skrei from the time of their arrival on the banks to the conclusion of the spawning embrace, apparently, a very great proportion of the possible variations for the single year.

The first arrivals, which make their appearance quite early in the year, may exhibit a high degree of fatness, and great quantity of liver, whereas the spent fish are invariably destitute of all fatty matter to the uttermost limit compatible with their continued existence.

If the variations in the quantity of liver from year to year were due to the varying condition of the cod in point of nourishment, it would be natural to expect that the *spent* fish should exhibit approximately the same quantity of liver each year. It is therefore interesting to compare the quantity of liver in the Lofoten skrei in different years at the commencement and end of the fishing season. The curves in Fig. 124 show the amount of liver in the years 1900—1911 in early fish (taken during the first week of the season) and late, (closing week), all from one and the same place, viz., Sørvaagen in west Lofoten. It will be noticed that the two curves are more or less parallel. *There are thus equally great fluctuations in the quantity of liver among spent fish and that of the new arrivals, which are in far better condition as regards nourishment.* This would appear to strongly support the view that the fluctuations themselves cannot be due to the condition of the fish in point of nourishment. If, on the other hand, we attribute them, as I do, to the fluctuations in the composition of the stock in point of size, the facts are easily explained.

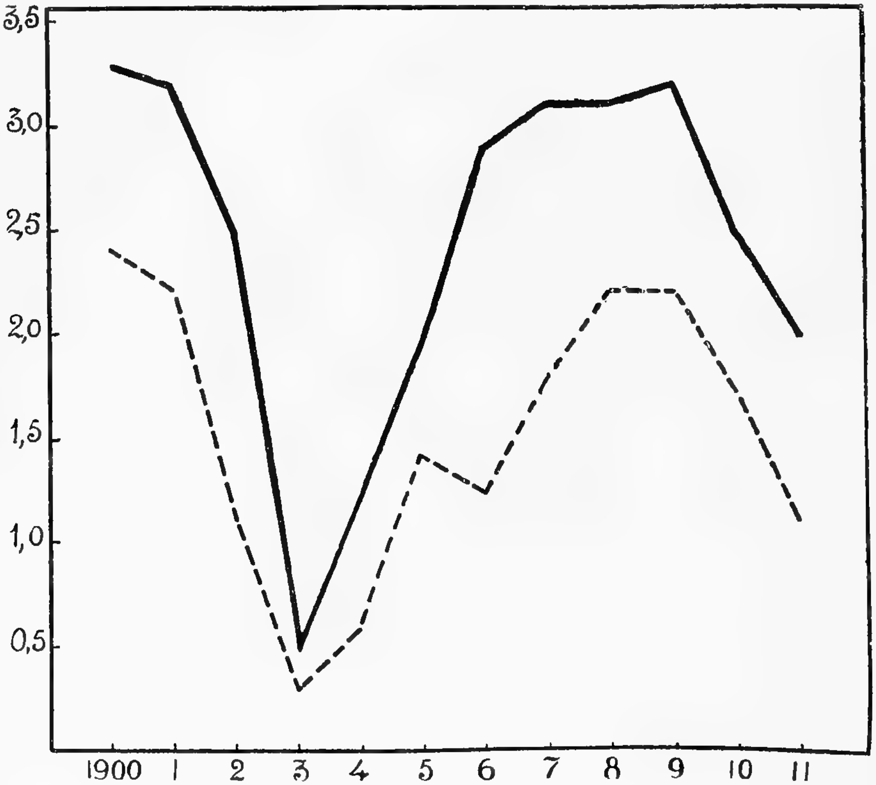

Fig. 124. Amount of liver in Skrei from Sørvaagen (Lofoten) in first (——) and last (- - - -) week of the skrei fishing season 1900—1911.

The Lofoten fishery in 1903 and 1904.

Turning now to especially consider the interesting years 1903 and 1904, we notice from Fig. 124 that the difference between the quantity of liver at the beginning and that at the end of the season is far less than in other years. The natural explanation, however, is evidently this; that the fish in these years arrived on the banks much later than is their wont. The first week of the season generally falls at the beginning of February; in 1903 however, it was the beginning of March, and in 1904 end of February. The following table shows the percentage of Lofoten skrei taken in the month of April during each of the years from 1900—1911. It will be noticed that the two years 1903 and 1904 are sharply distinguished from the others by the lateness of the season, which set in about the time when it is usually nearing its close. This must be considered to have had a great influence upon the quantity of liver in these years, at least in so much as the earliest arrivals had a lesser quantity of liver than would otherwise have been the case judging by their size. The fact that the size in these years varied exactly in the same manner as the quantity of liver is evident from the figure already given on p. 197, showing a comparison of average weight with quantity of liver in Lofoten skrei; the measurements of samples, also, referred to in Chapter III, indicate a like result. The following figure shows a comparison of the quantity of liver with the average sizes (lengths) calculated on the basis of the measurements of skrei samples*).

Yield of Lofoten fishery falling in April (percentage of whole season's yield).

1900	22.6 %	1906	5.4 %
1901	26.2 »	1907	32.6 »
1902	24.5 »	1908	27.1 »
1903	*68.6* »	1909	28.6 »
1904	*78.1* »	1910	19.4 »
1905	22.2 »	1911	23.8 »

I therefore take it as proved that *the great fluctuations which take place in the quantity of liver from year to year are chiefly due to variation in the composition in point of age and size, not in the quality of the fish.* I do not therefore wish to deny that the quality also may be of some importance; on the contrary, it is highly probable that variations in quality may augment or diminish the fluctuations due to size. As to this, however, no definite information based on critical investigation is available. Such investigations could not, moreover, be carried out until it was realised that any comparison between different years must be based on examination of fish *of the same age* . The only exact investigations of this nature hitherto made are Lea's growth measurements of Nordland fat herring in different years. Lea found, as we have seen, (Chap. I, Fig. 23) that the Nordland fat herring exhibited poorer growth in some years than in others. This furnishes an example of variations only to be explained by the fact that the fish must have lived under different conditions as regards nourishment. The carrying out

*) It should be observed that the average length for 1903 was calculated from the samples examined at Svendsgrunden in March of that year. I considered these as being representative of the year's fish in point of size, since they agreed, in this respect, with the statements of the fishery authorities as to average size of the skrei that year.

of similar investigations, both as regards the growth of the fish and their quantity of liver (or fat) is one of the important tasks which have yet to be undertaken.

Hitherto, but little reliable information is available. It is interesting to note, however, in the reports of the fishery authorities for the years when the quantity of liver and average weight of the skrei were at their lowest, certain remarks indicative of the fact that the prevalence of particular conditions among the stock had also been observed in earlier years, as in 1903.

Thus we find, in the Lofoten report for 1883, "The quantity of liver this year was small, as in 1882, or even smaller . . . . There is, however, always a certain amount of uncertainty attaching to these observations, as the fish may frequently differ very much from one day to another, and even in the case of fish taken on one and the same day, greatly varying results may be obtained". Again, in 1895, "The fish this winter were unusually small and poor, especially towards the close of the season, the liver also being generally small, and yielding but little oil. The fish varied more than usual in regard to size and weight, necessitating the frequent weighing of large quantities in order to obtain a comparatively accurate estimate of the average weight, etc."

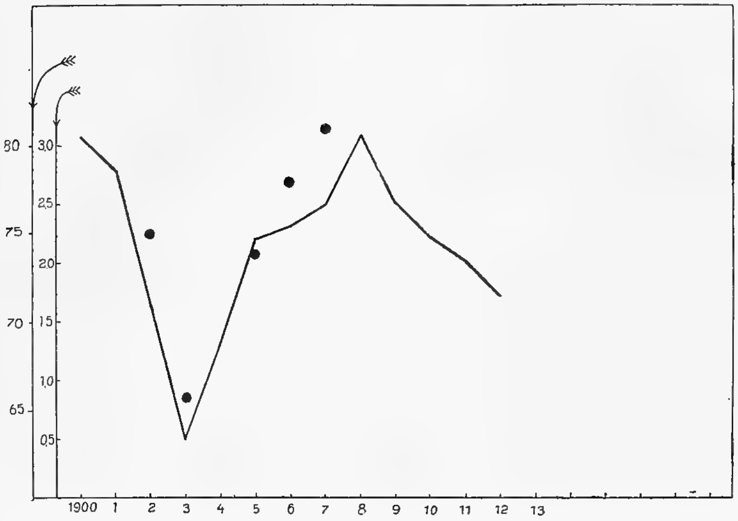

Fig. 125. Average size of Lofoten skrei in cm. (scale to left of figure), from measurements.
The curve shows quantity of liver for the years 1900—1912 (scale to right of first).

It is instructive to compare these statements with the course of the curve for quantity of liver. (Fig. 123). It will be seen, that direct observation of the fish *en masse* also confirms the results here arrived at, viz; that the stock is renewed, from time to time, by the arrival of new shoals of small fish, containing but a small amount of liver, these small fish being so numerous as to have a determining effect upon the average of the whole stock.

Thus a study of the so-called quality of the fish brings us to very much the same results as those arrived at (Chap. III and IV) by observation of the size and age. It remains for future investigations, carried out according to a more distinct and definite plan, to collect the necessary material for determination of the actual fluctuations in quality which take place in the stock from season to season and from year to year.

K. Dahl's investigations as to the fluctuations in the salmon fisheries.

A parallel to the investigations here referred to is furnished by a recently published article of K. Dahl*) concerning the fluctuations in quality of the salmon. In the salmon fishery, distinction is made between "small salmon" (under 3 kilos) and "large salmon", often merely called "salmon", (over 3 kilos). The weight of the large salmon varies so greatly that the yield in one year (in Trøndelagen) may show an average weight of 9 kilos, and in the following only 6 kilos. These fluctuations, which have been regarded as variations in the "quality" of the salmon, are so great as to seem almost sufficient in themselves to explain the fluctuations in the total quantity of the yield. This will be seen from Fig. 126, taken from Dahl's article. It will be noticed that there is a certain similarity discernible between the fluctuations in the yield of the salmon fishery and the variations in average weight of the large salmon above referred to.

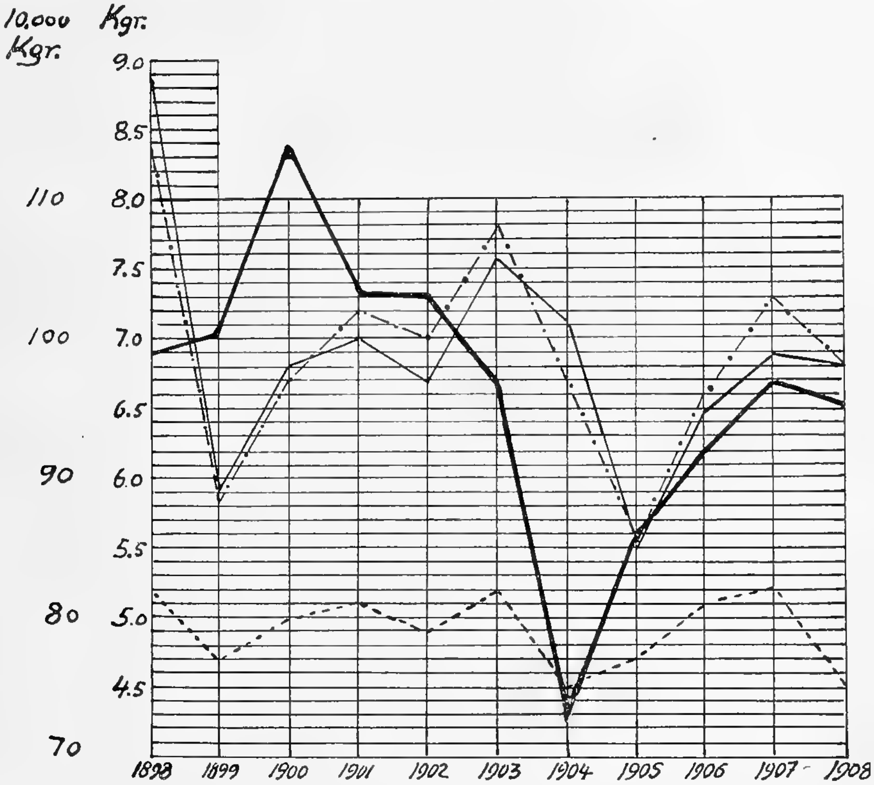

Fig. 126. Average weight of "salmon" 1898–1908.

- - - - at Kristianssand. —— at Moltuen (Trondhjemsfjord). —·— at Utvorden (Namsen Fjord).
—— Total yield of Norwegian salmon fisheries 1898—1908 (Scale to the left).

By means of age determinations of large samples taken at different parts of the coast, Dahl has however, succeeded in demonstrating that the fluctuations in the average

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*) Aarlige Vekslinger i Laksens kvalitet, deres aarsager og virkninger, Norsk Fiskeritidende, November 1913. Some Salmon Studies, Salmon and Trout Magazine, London 1913.

weight of the large salmon are due to varying composition in point of age in different years. The years in which the yield shows large quantities of fish of *over 3 winters* (after the time when they, as emigrant young, left the rivers), exhibit a high average of weight for the large salmon. In the years when the two-winter fish are predominant among the large salmon, the average weight of the latter is low. Here again we find, that the "quality" is not necessarily the outcome of temporary conditions as regards nourishment, but rather due to the composition in point of age, which has its origin some years back.

Here also it is evident, that any investigation of the actual variations in quality from year to year must be based upon a knowledge of the composition in point of age of the stock, which alone can enable us to subject the question to critical analysis. An examination of Fig. 126, showing the fluctuations of the salmon fishery, at once suggests comparison with those apparent in the quantity of cod liver obtained in the same years, and considerable resemblance will also be discernible, (cf. Figs. 106 and 123). Speculations of this sort, however, would lead us far beyond the bounds of practical reality.

CHAPTER VI

Review of the present position of the Investigations.

Results hitherto obtained.

The most important result which we have been able to refer to in the present work may be briefly expressed as follows: The study of methodically collected material, embracing a period of many years, has demonstrated the existence of an intimate relation between the fluctuations in the numerical value of the stock of fish and the yield of the great fisheries. This applies to the Norwegian herring and cod fisheries, the herring and haddock fishery of the North Sea, and in all probability also to the North Sea cod fishery.

The opinion generally prevalent hitherto was that the renewal of the stock of fish took place, as in the case of the increase of any human population, by means of a more or less constant annual increment in the form of new individuals; the results here arrived at, however, indicate that this renewal, in the case of the species investigated, is of a highly irregular nature. At certain intervals year classes arise which far exceed the average in point of numbers, and during their lifetime, this numerical superiority affects the general character of the stock, both as regards quantity and quality, thus again exerting a decisive influence upon the yield of the fisheries in both respects.

Origin of the fluctuations in renewal of the stock.

These results naturally lead us to enquire into the causes, or better, the natural phenomena which occasion these peculiar fluctuations in the renewal of the stock; the hydrographical or biological conditions which give rise to the occurrence of rich or poor year classes of fish. The problem is one of unquestionable difficulty, embracing as it does all the conditions which in any way affect the fish from the egg stage to the time when they are caught. It will therefore appear most probable that the renewal of the fish stock, as in the case of any stock on land, is dependent upon many factors, *all necessary, and all more or less variable.* Thus in each individual instance, the missing factor will appear to be that which determines the ultimate result. Only *experience* extending over a long period of time can enable us to ascertain with certainty the variation of the different determining factors, and to discover how far one and the same factor is in *all* cases of decisive importance, or whether, in the course of the developement of the fish, there may be several, each varying so greatly as to possibly determine the character of the year's production. It is evident from this, that a closer study of the laws which govern the renewal of the stock will naturally necessitate extended observation of the natural conditions which prevail in the sea, and even of conditions which at first sight have little or no connection with fishery questions. I have therefore always endeavoured, as far as lay in my power, to fix the scheme of the Norwegian fishery investigations upon the broadest general scientific basis. This is especially important in the case of the question at present under consideration, owing to the length of time which must necessarily elapse before the results of the year's production make themselves apparent. In the course of the actual investigation, for instance, of the spawning, it is impossible to say what factors may be of decisive importance, and neglect or omission of data at the time can never be repaired.

Under these circumstances, it is evidently of the highest importance to carefully determine which factors may be considered as of greatest significance, and what material is to be regarded as most essential for the purpose of investigation. The great task here presented for future consideration is, in my opinion, still at so early a stage that I am far from considering myself in a position to exhaustively discuss the questions raised. I will, however, endeavour to indicate the points which appear to me as of principal importance.

Stage at which the numerical value of a year class is determined.

The greater the difficulties which any task presents, the more important must it seem to confine it within the closest possible limits. First of all, it would seem natural to endeavour to ascertain at what stage in the life of the fish the numerical value of a year class is determined. We have seen in the previous chapters, that the rich 1904 year class already made itself apparent among the cod taken with the fine-meshed trawl in Finmark waters during the autumn of 1905. Fish of the same year, 1904, were also particularly numerous in the catches of haddock in the North Sea and Skagerak in the autumn of 1905 and 1906, and finally, the 1904 year class played an important part in the stock of fat herring on the North Coast in the autumn of 1907. *The rich year classes thus appear to make their presence felt when still quite young; in other words, the numerical value of a year class is apparently determined at a very early stage, and continues in approximately the same relation to that of other year classes throughout the life of the individuals.* An illustration of this is afforded for instance by the percentage curves for the relative numbers of the different year classes of spring herring in the years 1908—1913 (Fig. 16).

The above statement, despite the general terms in which I have, for the sake of convenience, preferred to formulate it here, is naturally only intended to apply to the data and material dealt with in the present work, without prejudice as to the possibility of great reductions taking place in the numerical value of the year classes at later periods of life. All that it is desired to assert is that the observations here recorded distinctly point to the conclusion that the fluctuations noted in the stock have their origin in certain conditions prevailing at a very early period in the life of the fish.

Extent of spawning and numerical value of year classes.

The first question which then arises is whether the numerical value of the year classes is dependent upon the extent of the spawning; i. e., the number of eggs produced. As mentioned in the previous chapter, this question has never yet been investigated. It would also be a task of extreme difficulty, especially in Norwegian waters, on account of the irregular distribution of the eggs (*vide* Chap. III) which renders it impossible to accurately ascertain the entire quantitative value of the eggs, at any rate, with the means and methods at present available. Little can therefore be stated as yet beyond the results indicated by the comparison made in the previous chapter between the *quantity of roe* observed during the fishery, and the number of fish in subsequent years. It will be remembered, that this comparison showed *the very years in which the quantity of roe at Lofoten was least to be those which produced the richest year classes.* This being so, it is difficult to avoid the conclusion that the actual quantity of eggs spawned is *not* a factor in itself sufficient to determine the numerical value of a year class. A rich spawning may produce a year class poor in numbers, while a large year class may have its origin in a year when the spawning was at its lowest.

Larvae and young fry stages.

We must therefore look to the later stages of the eggs to find the conditions which determine the numbers of individuals in any year class. This again leads us to the question, at which stage of developement the most critical period is to be sought. Nothing is known with certainty as to this; such data as are available, however, appear to indicate *the very earliest larval and young fry stages* as most important.

In the first place, we have the significant fact that several different species of spring spawning fish (cod, haddock, and Norwegian spring herring) all exhibit remarkably high values for one and the same year class, (that of 1904) whereas the North Sea herring, for instance, which are summer spawning, show specially high figures for the fish of quite other years. This would seem to indicate that the spring of 1904 was marked by the prevalence of certain hydrographical or biological conditions which determined the production of this year, and as the herring, cod, and haddock of this year class were at that time in the larva or young fry stage, it is natural to devote especial attention to the consideration of these stages. Two points immediately suggest themselves in this connection, viz; the conditions as regards nourishment to which the fish were subject at this stage, and the passive movement of the same stages under the influence of the currents.

Nourishment of the larvae.

It has long been a recognised fact, both in connection with artificial incubation of fish eggs and in the study of the youngest egg and larval stages in the sea, that the numbers of individuals rapidly decrease as soon as the newly escaped larvae have consumed their yolk and commence to seek food for themselves. All extant accounts of such experimental culture refer to this point, and anyone who has studied the earliest pelagic stages of the fish will know how difficult it may frequently be to find the young larvae in the same water where the eggs, a short time before, were abundant. In the course of my own egg investigations at Lofoten in 1913, briefly referred to in Chap. III, I again had occasion to notice a phenomenon often before observed, viz, that at the time when the eggs of spring spawning fish abound, the water is almost destitute of all other organisms, animal and plant life. This is perhaps especially noticeable in northern latitudes, where, as I have described elsewhere*) thousands of tons of sea water may be sifted, (down to a certain limit of depth) without revealing more than some few organisms. If, however, the investigations are carried out according to the method employed in my own experiments in February-April 1913, viz; repeated examination of the same spots, it will be observed later on in the spring, (at a time varying probably as to date in different years) that enormous quantities of microscopical plant organisms (diatoms, *flagellata*, *peridinea*) suddenly make their appearance, being found in the form of a thick, slimy, odoriferous layer on the silk of the net, which had previously been perfectly clean, containing nothing beyond fish eggs and some few crustaceans. It occurred to me therefore, during these last investigations, that it should be well worth while to endeavour to ascertain how far the sudden appearance of this extensive growth might be of importance for the continued existence of the young fish larvae. If the time when the eggs of the fish are spawned, and the time of occurrence of this plant growth both be variable, it is hardly likely that both would always correspond in point of time and manner. It may well be imagined, for instance, that a certain — though possibly brief — lapse of time might occur between the period when the young larvæ first require extraneous nourishment, and the period when such nourishment is first available. If so, it is highly probable that an enormous mortality would result. It would then also be easy to understand that even the richest spawning might yield but a poor amount of fish, while poorer spawning, taking place at a time more favourable in respect of the future nourishment of the young larvae, might often produce the richest year classes. In this connection it must be remembered that one single cod may spawn millions of eggs.

The French scientists Fabre-Domergue and Bietrix have shown, in the course of two interesting works on the common sole and artificial incubation**) that the small larvae, even before their yolk is exhausted, commence to seek other nourishment, and those individuals which do not succeed in finding such become anæmic, and die *of hunger*. This is, in the opinion of the writers referred to, the reason why all attempts at artificial incubation have hitherto proved so unsuccessful; these writers found, that when the young larvae were duly supplied with the requisite nourishment, i. e. microscopical plant organisms, either cultivated, or taken direct from the sea, the anæmia disappeared, and the individuals could be raised to later stages of development.

The fishing industry furnishes many instances of variation in the time of the skrei fishery from year to year, the season sometimes commencing earlier, sometimes later.

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*) Fiskeri og Hvalfangst.

**) Developpement de la Sole. Introduction à l'Etude de la pisciculture marine. Paris 1905. Fabre-Domergue: Etude sur la rôle et les procédés de la pisciculture marine. Bulletin de la marine marchande. Paris 1900.

I have previously (p. 199) given a table showing the variations in the quantity of fish taken at Lofoten during the month of April, the latest month in which the fishery ever occurs. And it is a very curious coincidence, if such it be, that in the two years 1903 and 1904, when the rich year classes previously referred to were spawned, the fishery set in remarkably late, in comparison with previous and subsequent years. In 1903, 68.6 % of the total Lofoten yield for the year was taken in April; in 1904, the percentage for April was 78.1, whereas the usual figure is a little over 20 %. In consideration of the foregoing, it might well seem possible that the high numerical value of these two year classes, especially that of 1904, should be due to the fact that the spawning set in so late as to ensure an adequate supply of nourishment for the young larvæ at the stage when this was required. This question appeared to me of so vital importance, that I thought it best to lay the facts before one of the greatest authorities on microscopic plant life, H. H. Gran, who entirely agreed with me as to the significance of the point at issue. We therefore, in September 1913, laid before the International Council for the Investigation of the Sea a proposal concerning the organisation of future research work, both as regards the question of nourishment in young stages of fish, and the spring flowering of microscopical plants. The International Council subsequently agreed to devote especial attention to these questions during the coming years*).

Drift of the larvæ and young fry with the currents.

I have already drawn attention to another point which might be considered as possibly exerting some influence upon the mortality of fish in the early stages, viz, the passive movement of the larvæ with the currents. During the first cruise of the "Michael Sars" in the Norwegian Sea, I encountered great numbers of young cod fry drifting in the water above the great main depression in this region. It is possible that many individuals perish during such drifting movements: nothing is, however, definitely known as to this. It would be especially desirable to ascertain the extent of such movement, and how far the young fry are able to return, of their own volition, to such localities as offer favourable conditions for their further growth.

Later stages.

The remarks here set forth as to the conditions in respect of nourishment, and movements of the fish in their youngest stages, naturally also apply, in a certain degree, to the older individuals, the fish at every stage of life being dependent upon some or another form of nourishment, the available quantity of which is a factor of great importance. We have seen in the foregoing that the stock of fish varies greatly in numbers from year to year; in like manner, recent investigations have shown that also other forms of animal life exhibit great variations in the numerical value of their occurrence. As regards the larger pelagic organisms, (larger crustaceans, cuttle fish, etc.), the uncertainty of quantitative determination renders this difficult to prove; with regard to bottom organisms, however, the interesting investigations carried out of late years by C. G. Joh. Petersen have definitely proved the existence of great variations in the numerical value of the different year classes. No complete statement as to this work has yet been published; I had, however the privilege of learning from Dr. Joh. Petersen, in conversation,

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*) Rapports ét Proc. Verb. Vol. XIX Copenhagen, 1913, pp. 124—127.

something as to the nature of the results obtained by him. Considering these to be of great importance to the questions here dealt with, I requested and obtained the favour of a brief communication concerning the investigations, and am now, by the courtesy of the author, enabled to insert the following particulars as to the variations in occurrence of bottom organisms in the Limfjord.

C. G. Joh. Petersen: Fluctuations in the annual numbers of certain Invertebrata.

"Dr. Johan Hjort has asked me to give some details as to the investigations on which I have based my statements*) as to the varying numerical value of certain species of lower marine organisms. In accordance with this request, I here furnish the following particulars.

"By means of valuation experiments in the Limfjord, I have at last been able to demonstrate the great variation which takes place from year to year among certain *Invertebrata* as regards the *number of individuals per m*² of the same species. This is the only means by which such investigations, based upon actual figures, can be carried out.

"As regards the small varieties of common mussels, *Abra alba*, *Corbula gibba*, *Solen pellucidus*, the counting can be carried out with great accuracy; 100 or 50 samples were taken at different spots embracing the whole of Thisted Bredning, each sample representing 0.1 m². The table below is based throughout upon 50 samples = 5 m², the 100 being divided by 2. It was found that 50 samples gave sufficiently accurate results.

No. of specimens found by valuation in Thisted Bredning; 50 samples à 0.1 m².

	$^{7-15}/_{10}$ 1909	$^{11-13}/_{4}$ 1910	$^{19-20}/_{10}$ 1910	$^{2}/_{5}$ 1911	$^{16-17}/_{10}$ 1911	$^{31}/_{5}$ 1912	$^{3}/_{10}$ 1912	$^{24}/_{4}$ 1913	$^{13}/_{9}$ 1913
Abra alba........	32	0	419	251	39	10	354	302	20
Corbula gibba....	2	3	1	0	252	809	56	452	113
Solen pellucidus..	146	191	49	78	1131	1130	396	515	310
Buccinum undatum	7	3	4	4	3	2	5	1	3

Nissum Bredning; 40 samples 0.1 m².

	$^{7-15}/_{10}$ 1909	$^{11-13}/_{4}$ 1910	$^{19-20}/_{10}$ 1910	$^{2}/_{5}$ 1911	$^{16-17}/_{10}$ 1911	$^{31}/_{5}$ 1912	$^{3}/_{10}$ 1912	$^{24}/_{4}$ 1913	$^{13}/_{9}$ 1913
Echinocardium . cordatum .	large	14	22	21	19	8	7	6	c. 10
	small	All probably large.			3	0	166 9-19mm.	240 12-25mm.	121 most about 30 mm.

The large specimens all between 35 and 45 mm. long.

"For purposes of comparison with the mussels referred to above, the figures obtained for *Buccinum undatum* are also given, this being an organism which in the waters here

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*) In "Valuations of the Sea", p. 23, English Edition in "Report XXI, Danish Biological Station" 1913.

investigated attains an age of 6—7 years, and has no pelagic larvæ, as in the case of the mussel. *B. undatum* does not exhibit so great and rapid fluctuations, in the number of individuals from 1 to 7; a decrease in numbers from the first four periods to the last four is, however, evident. Such decrease has, moreover, been demonstrated by means of other larger dredges constructed for the purpose; the fishermen also believe to have been able to observe a decrease of this nature in the occurrence of this organism during the time referred to.

"*Abra alba* reaches its maximal quantity in the autumn of 1910, whereas *Corbula gibba* is at this time almost at a minimum. *Corbula* attains its maximum in the spring of 1912, about the same time as *Solen pellucidus*. The maxima and minima of the three species do not thus correspond in point of time; as to the conditions, however, which favourably or otherwise affect the numerical values of these species, I am not in a position to make any statement at present.

"Figures illustrating the recruiting of *Echinocardium cordatum* from young stages in a single favourable year will be found in the last column of the table, calculated from 40 samples (of 0.1 m^2) taken in Nissum Bredning; in one instance, 24-4-1913, only 20 samples were taken, the contents being multiplied in the table by 2. The figures show the rarity of the young stages here in the autumn of 1912, as also the manner in which they increase in size, until the largest specimens, in the autumn of 1913, can only with approximate accuracy be distinguished from the grown organisms.

"We may in all probability expect that *Echinocardium* will occur in considerable numbers in Nissum Bredning in 1914, by which time the great majority of the young should be full grown. In other words, *Echinocardium* takes about two years to attain full growth".

Great mortality of older stages where cold and warmer currents meet.

The fluctuations here described by Dr. PETERSEN may probably be attributed to causes exactly similar to those which occasion the fluctuations among the fish. It is obvious, however, that fluctuations in the numbers of those organisms which to a great extent compose the food of the fish must again affect the vital conditions of the fish themselves. As far as northern waters are concerned, there would appear to be some reason to believe that the older stages, also, of these food organisms may be affected by natural conditions, in such a manner as to occasion, from time to time, considerable mortality among the grown individuals. I have on a former occasion given a survey of what is knonw as to such cases of exceptional mortality among grown organisms, especially in waters where cold and warm currents meet, on the eastern coast of the American continent, and in the Barents Sea*). The capelan, for instance, (*Mallotus villosus*) may at times suffer so excessively that great expanses of sea are found covered with their dead; a fact which might well be of considerable significance to the cod.

Fluctuations among the earlier stages probably of greater importance.

However this may be, the information available up to the present, based upon the investigations of 1901—1913, distinctly points to the earlier stages as of the greatest importance in determining the numerical value of year classes, those year classes which

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*) Depths of the Ocean, pp. 705—708.

have been observed throughout a whole series of years having been found to maintain their original relation to other year classes in this respect. Only the further experience obtained by many years of future observation can, however, determine how far this can be regarded as constantly or generally the case.

Importance of future investigations as to the causes of numerical variation.

It will be evident from the foregoing, that a study of the conditions which determine the numerical value of the year classes can only attain its object when based upon a very extensive plan. As a matter of fact, the object *can never be fully attained;* new questions will constantly arise, as *the knowledge obtained creates the demand for new*, and it will always be possible to increase and intensify our comprehension of the vital conditions affecting the organisms in question. A study of the fluctuations in the population of the sea, both fish and smaller organisms, and thus of the whole organic life existent in the ocean, is therefore the soundest possible basis for marine research, whether with theoretical or practical ends in view. There is moreover, scarcely any other question which is so well calculated to focus the attention of men engaged upon different branches of science, as this must necessarily be the case where several investigators are at work on board the same vessel.

The constantly increasing knowledge of the hydrographical and biological conditions upon which the numbers of the organisms, and especially of the fish, so greatly depend, will naturally be of the greatest importance. Perusal of the mass of fantastic guesses, assertions and suggestions which have been published in various works or in the press, with the object of combating these fluctuations, will suffice to show that only to have led the general trend of ideas into a right or reasonable direction would in itself be an achievement worth all the amount of work involved.

In the interest of biological research, also, it must be of the greatest importance to ascertain the nature of the laws which govern the renewal of the animal population, especially when taking into consideration all that has been written from time to time about overpopulation and the struggle for existence in the animal world, all from the point of view of human conditions.

It is, however, by no means impossible that practical results also may be attained by this means. In particular much might be learned which would serve to elucidate the old questions of pisciculture or incubation, in regard to which the lack of progress and insufficient comprehension of results have long been felt. Once it is possible to indicate with certainty the conditions which determine whether great mortality is to take place among the young stages or not, the whole position as regards these questions may be altered. No definite opinion can of course be expressed as to this until the problems have been solved. It is gratifying to observe, however, that the International Council has now decided to work towards this end.

The knowledge obtained will also be of great practical value in considering the question of possible decrease in the stock due to overfishing, and will at least serve to show that the statement of the fishery statistics can only be safely employed for the elucidation of these problems, when the fluctuations due to natural causes are known.

Knowledge required for predictions as to future composition of the stock and consequent yield.

The principal and most directly *practical* object in connection with these investigations is that of furnishing the fishermen and others immediately interested with *reliable information as to the present condition of the stock and probable alterations in the same*, in other words, of obtaining material on which to base predictions as to the expected course of fluctuations in the stock. In this regard, there is but little reason to believe that continued investigations as to the **causes** of the fluctuations in the numerical value of year classes will be of any great immediate practical significance. I am perfectly aware of the impossibility of making definite statements as to the value of results not yet attained; the facts as at present known should, however, suffice to indicate the improbability of obtaining any adequate basis for such predictions from investigations as to the causes of the fluctuations. Even if it were possible, for instance, to assert, with scientific accuracy, that the nourishment of the youngest larvae, or the passive movement of the young fry, should be regarded as the determining factor for subsequent wealth or poverty of a year class, it is hardly likely that such knowledge would suffice for annual predictions as to the future size of the stock. It would in any case then be necessary to know far more of various other conditions than is at present the case.

The first and principal object of the Norwegian fishery investigations was to determine the **extent** of fluctuations in the stock, if such existed, and in that case, to discover a means of ascertaining and predicting the same. The investigations have therefore purposely refrained from any consideration of the causes of the fluctuations in question, the paucity of available means and staff necessitating concentration upon definite objects. These may now, however, in my opinion, be said to have been *achieved*, in any case in principle. *A method has been arrived at, by means of which the stock of herring and cod in Norwegian waters may be faithfully depicted, and the stock has been found to develope, from year to year, as was expected from the conditions prevalent in earlier years. We have thus for some time been in a position to make predictions of the nature desired.* The previous chapters contain such proof as I am able to advance in support of this assertion; the reader may then form an opinion as to their value. It will be sufficiently evident from the foregoing, that the method in question can only be of value *if properly used*, i. e. by the annual collection of the requisite amount of material, due treatment of same, and publication of results in such a manner as to enable the general public interested to compare the results of the scientific investigations with those of their own observations, and draw their own conclusions. *In other words, an organisation is needed, which shall undertake the regular duty, not of issuing predictions as to the course of the fishery, but of furnishing such information as may facilitate the conclusions in each separate instance.* A final solution of the problem of fluctuations in the fishery by any permanently valid formula must be regarded as an impossibility, and all assertions as to the discovery of such a solution may safely be relegated to the sphere of pure imagination.

Manner of employing the method.

Before finally proposing the formation of an organisation for the employment of the method referred to, it would be natural to point out, as clearly as possible, the preliminaries requisite thereto, as well as the possibilities, difficulties and imperfections attaching to such method.

A characteristic feature of the method is, as we have seen, the comparison of results obtained by age analysis of samples with the fishermen's hauls, as expressed in the statements of the fishery statistics, with a view to forming an opinion as to the composition of the stock in point of age, the relative numbers of the year classes at the moment, and probable consequent size of the stock in the future. It is here presupposed:

That it is possible to obtain samples which are truly representative of the stock as regards composition in point of age.

That the longevity of year classes among the different species is generally known.

That there exists a certain approximate relation, not too closely defined, between the size of the stock and the yield of the fishery.

A final word may here be added as to these three principles.

Possibility of obtaining samples truly representative of the composition of the stock in point of age.

From Chapters I, II and IV we found that the various shoals of fish exhibited one point of difference, i. e. their composition, the mature, spawning fish being remarkably constant and homogeneous in this respect, while the young immature fish appear in shoals of highly variable composition in regard to age within one and the same year. Thus while the samples of large herring, spring herring and skrei were found to correspond very closely, the fat herring and Finmark cod were far less constant in this respect. The most reliable results should therefore be obtained from the study of the mature fish, and it has been found that a comparatively small amount of such material will suffice to give a full and reliable survey. As regards the younger fish, greater difficulties are here apparent; these need not however, by any means be regarded as insuperable. First of all, investigation of a greater number of samples will be necessary, and in addition, a closer acquaintance with the laws which govern the migrations of the different year classes. Such investigations have therefore already been laid down for 1914. It is obvious, that the earlier the period of life at which it is possible to determine the numerical value of a year class, the greater will be the value of the method as a means by which to judge of the future character of the fishery, presenting a longer period of time during which the presence of rich year classes is known.

Possibility of general knowledge as to the longevity of different species.

The next point of importance is to ascertain for what length of time the occurrence of any year class may be reckoned with. It is obviously not sufficient here to take the extreme period during which some isolated specimens may still be encountered; it is necessary to know how long the fish will continue to occur *in numbers*. In other words, it is necessary to know the *mortality* (*or percentage of mortality at different ages*). This can only be ascertained by experience, based on the observation of many years; it is obvious that any accurate scientific determination of the laws which here prevail must rest upon *continued actual observation* of the appearance, presence, and disappearance of several rich year classes. It is scarcely to be expected that the mortality will prove of constant extent; even within one and the same species therefore, it will be necessary to observe considerable caution when drawing conclusions as to the time at which one or another year class should become extinct. It will be readily understood that the Norwegian fishery investigations have for years been keenly interested in noting how long the frequently observed rich year class from 1904 would continue to make itself apparent among the herring and cod, where it has long exerted so dominant an influence, and occasioned so rich a yield. As mentioned in Chap. I, we have hitherto only had occasion to observe the disappearance or great reduction in numbers of a single rich year class among the spring herring; that of 1899, which in 1908 and 1909, i. e., when 9 and 10 years old, still played an important part among the spring herring, but by 1910 had dwindled to an entirely insignificant portion of the stock. This is illustrated by Fig. 16 and Fig. 22, Chap. I. Regarding the cod, we found that the 10 year old fish played a great part among the skrei in the year 1907, and we have seen, that the average weight of the skrei may exceed 3 kilos (gutted weight) corresponding to an average age of at least 11 years. (*Vide* Fig. 99.)

Possibility of deducing amount of yield from the composition of year classes.

As already frequently pointed out, no conclusions can, as a matter of fact, be drawn from the composition in point of percentage of the different year classes as to the numerical value of the stock or to the prospects of future yield. On the other hand, it has often been observed that a comparison of this factor with the actual results of the fishery may in many cases suffice to give reliable indications as to the coming yield. Thus in studying the spring herring fishery, it was found that after the first discovery of the close relation between the high percentage of the rich 1904 year class and the rich yield of the fishery, the same relation continued during several successive years, (1910—1913). The same applies to the Finmark fishery for these years. We have thus had occasion to observe the frequent recurrence of like situations which have at least enabled us to formulate certain predictions with a high degree of probability. It would however, be unjustifiable and premature as yet to conclude from this that such predictions may *always* be made. I have frequently referred to the possibility, both as regards cod and herring, that other factors might have to be reckoned with, as for instance a higher mortality among older individuals than has hitherto been the case in the 1904 year class, or an alteration in the movements or migrations of the shoals. As to fluctuations in the mortality, we can only repeat that our knowledge in this respect must be increased by further experience. As regards the migrations, however, I may here add a few words to the remarks already made upon the subject in Chapters I and III. First of all, in considering the question of relation between the stock and the yield (percentage caught) it is necessary to bear in mind the fact that fishing is not always carried on throughout the whole possible extent of the grounds where the fish occur, in consequence of which it may happen that a part of the stock is entirely exempt from the toll levied by the fishery. If therefore, the stock make any change of ground which the fishermen are unable to follow, we may have a poor yield concurrent with the existence of a rich stock. It will therefore always be of the highest importance to know where the fish are to be found, and the greater the extent to which this is known, or the more nearly the actual fishery embraces the whole area of occurrence of the fish, the closer will be the relation between the size of the stock and the amount of the yield. The fishery investigations have therefore, as noted in Chap. III, devoted great attention to studying the locality of the spawning grounds, most species being especially fished for during their spawning time, and the study of the pelagic eggs furnishing an easy method of ascertaining the whole extent of the area of occurrence. As a result of these investigations, it has been found that the cod species are as a rule fished for — though possibly with varying intensity — throughout almost the whole of their area of distribution during spawning time. The same doubtless also applies to the herring. We arrive, therefore, at the conclusion that it is easiest and more reliable to employ our method as regards the mature, spawning fish. In the case of the young, immature fish, and at other times than the actual spawning season, considerable difficulties are apparent, which must be left to future research to dispose of.

We thus arrive at the conclusion that the method here described may already be employed with every prospect of success as regards the mature, and particularly the spawning fish. I should however, add some qualifying remarks in order to avoid any possibility of misunderstanding. In the fishing industry, as in any other branch of human activity, the attention of the majority is mainly, if not exclusively concentrated upon their own immediate prospects and plans. There will therefore be many who will not exhibit the slightest interest in such a question as that at present before us unless it is possible to give them definite information as to the prospects of the fishery at this or that particular spot where their work in the immediate future will lie. No such predictions can be formulated by the method in question, for the simple reason that the migration of the shoals towards the fishing grounds is subject to certain natural conditions which always exert a considerable influence upon the movements of the fish. The earliest information as to these conditions which is based upon accurate scientific methods of investigation we owe to the Swedish investigators G. Ekman and O. Pettersson*). These writers have, in the course of an interesting series of investigations as to the water layers of the Kattegat, Skagerak and North Sea, demonstrated that the movement of the herring towards the coast of Bohuslän may be hindered by the presence of the cold fresh water layers which in winter pour out from the Baltic, whereas the coastward movement of warmer, salter water from the North Sea, (the Jutland Bank) favoured the progress of the fish in that direction. In other words, these currents have the effect, either of leading the herring in towards the coast (the bank water from the North Sea) or of barring their progress thither (the Baltic water). I have in a former work**) endeavoured to show that similar conditions prevail in the case of the spring herring fishery on the south-west coast of Norway (Flekkefjord-Sognefjord), where the spawning grounds are washed now by salt and comparatively warm water, now by colder, fresher layers, partly from the fiords and partly from the same Baltic current which makes itself apparent in the Skagerak. I have also shown, that this agrees with the long recognised fact that the herring in some years when the water is cold (down to 0°) spawn at greater depths, as low as 100 fathoms, while in other years the spawning may take place quite close

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*) Otto Petterson: Studien ueber die Bewegungen des Tiefwassers und ihren Einfluss auf die Wanderungen der Heringe. Fischerbote, 7, 8 u. 9, 1911.

**) Hydrographical and Biological studies of the Norwegian Fisheries: Videnskabsselskabets Skrifter, No. 9, 1895.

in to shore. Such varying conditions are of great importance in studying the progress of the fishery, and may considerably affect the yield. In such years, when the herring spawn deep, there will probably be a great discrepancy between the prospects as to size of the stock and the yield of the fishery. An investigation of these conditions is therefore of great importance, and it is highly desirable that such should be regularly carried out.

Similar conditions also prevail in the skrei fishery. It may perhaps be of interest in this connection to consider an example illustrative of the Lofoten industry; I will therefore briefly mention the observations made during the last season (1913), with the assistance, at first of Mr. Einar Lea and Mr. Oscar Sund, later also of Capt. Rönnestad, as to the temperature and salinity in Vestfjorden. Figs. 127—130 illustrate some of the results here obtained as to the distribution of temperature in this water in March-April 1913, Fig. 127 showing the various temperatures at 50 metres depth. It will be seen that the temperature outside Vestfjorden was at this depth over 5° C., decreasing inwards to 2°.5 (at Tranö). This must be presumed to be due to the presence of colder water from the fiords, a view which I have already previously advanced, and is also evident from the temperature sections shown in Figs. 128—130.

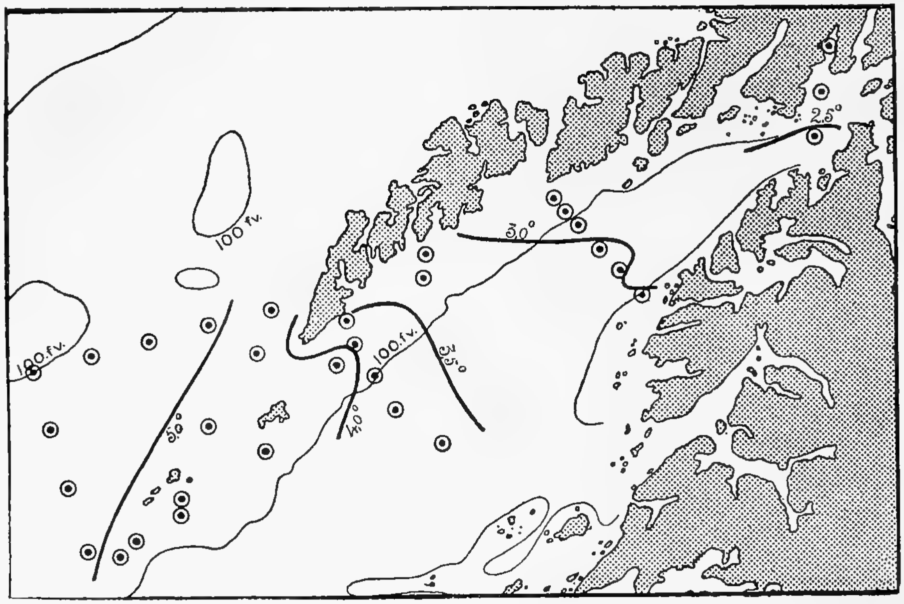

Fig. 127. Temperature in Vestfjorden (Lofothavet) at 50 m. depth, during the skrei fishing season in 1913. The innermost stations correspond to the Tranö section (Fig. 128) those in East Lofoten waters to the Gröttö section (Fig. 129), and the West Lofoten stations to Fig. 130.

The three figures show the conditions of temperature as discernible in cross sections of the fiord, one far up, from Kanstadfjord to Tranö, (Fig. 128) one from Henningsvær to Gröttö, (Fig. 129) and a third from Moskenes in West Lofoten to Helligvær, (Fig. 130). All the sections exhibit a wedge of colder water on the left of the figures, i. e. the Lofoten side, indicating that a part of the banks on which the spawning takes place

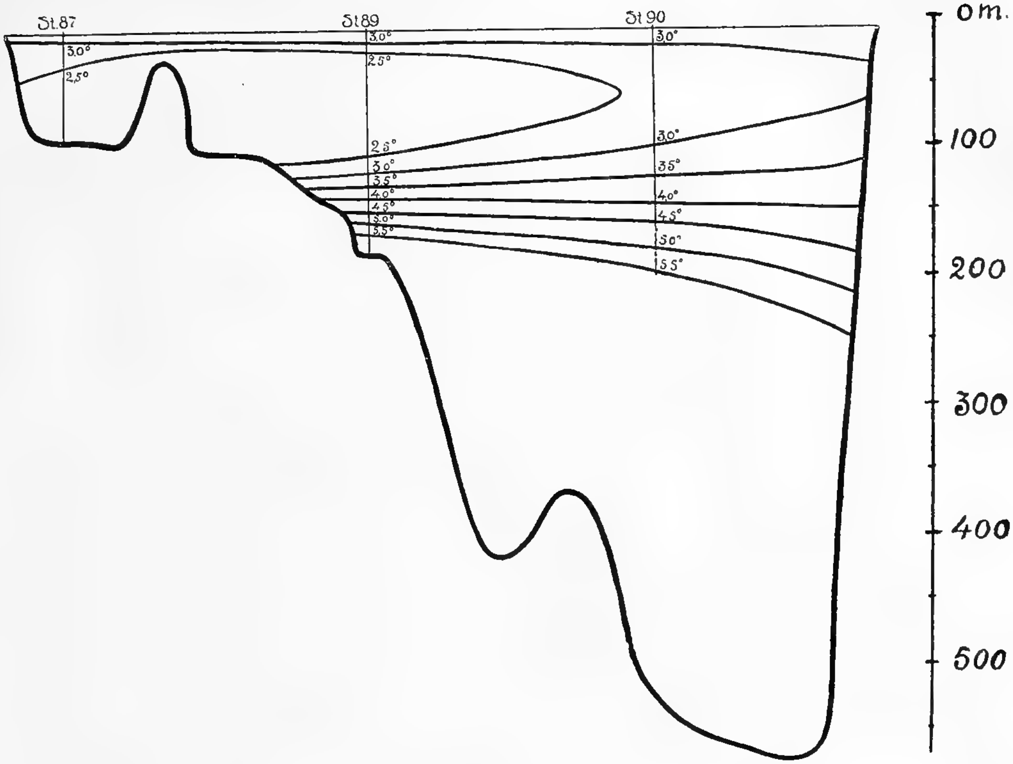

Fig. 128. Tranö section (cf. Fig. 127). 3° = 3° C.

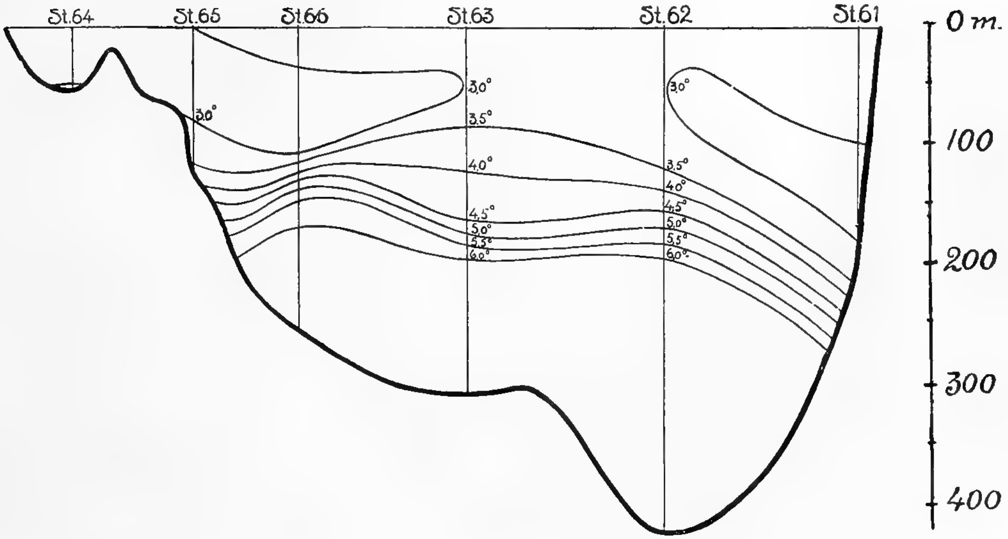

Fig. 129. Gröttö section (cf. Fig. 127). 3° = 3° C.

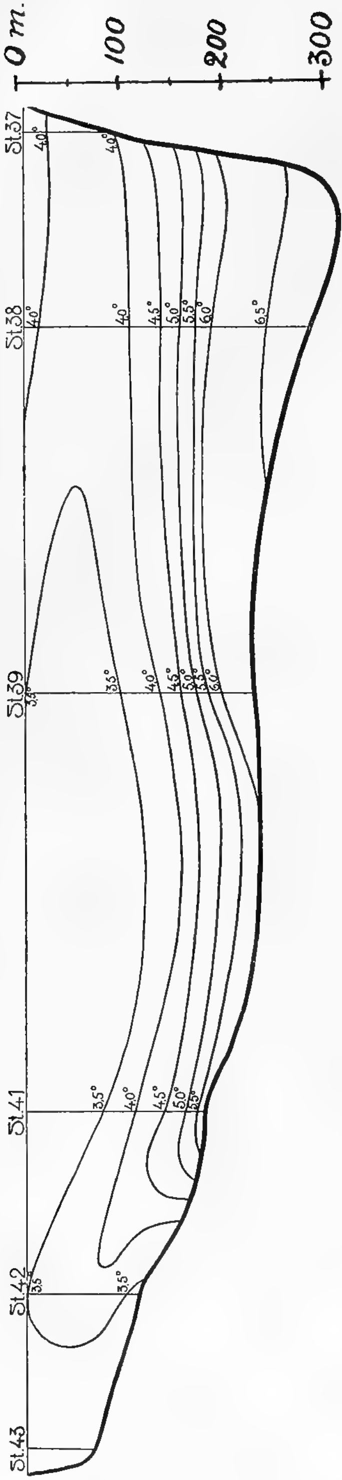

Fig. 130. West Lofoten section, (cf. Fig. 127). 4° = 4° C.

is washed by cold water, the temperature decreasing inwards up the fiords. The deeper water, however, exhibits a higher temperature; 4°—4½° throughout the whole of the fiord at depths of about 200 metres.

These conditions vary greatly from year to year. In some years it has been observed*), that the water far up in the fiord and close to the shore itself had a temperature of 5°, which indicates that the amount of coastal water in such years must have been very low. In other years, cold water has been encountered on the banks down to considerable depth, the temperature being sometimes as low as 0° or there abouts. It is an old theory, though never yet entirely proved, that these fluctuations are accompanied by corresponding variations in the movements of the fish, which in warmer years penetrate far in towards the shore, keeping to deeper water when the general temperature is lower. Various facts appear to support this theory; it is obvious, however, that it can only be entirely confirmed or refuted by extended observation; a matter of considerable difficulty, owing to the great amount of time and expense involved. In my opinion such investigations should be made by means of sections, similar to those drawn up for the year 1913 and shown in the figures previously referred to. Such sections form the best and easiest indication of the prevailing conditions, and would appear to furnish a fairly representative survey of the same for the season. This was at least found to be the case in 1913, the results as noted holding good as long as the fishery lasted. During this year, the fish kept to the edge of the banks, at 80—100 fathoms depth, the principal fishery being carried on in the western waters, from West Lofoten and Røst. As we have seen in Chap. III, most of the fish eggs were found on this side. These investigations thus appear to further emphasize the desirability of continued work in the same direction. In the Varangerfjord also, in 1913, the same peculiarity of temperature was observed;

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*) Gade. Temperaturmaalinger: Lofoten, 1891—1892. Christiania 1894.

O. Nordgaard. Contribution to the Study of Hydrography and Biology on the Coast of Norway. Rep. on Norw. Marine Inv. 1895—1897. Bergen 1899.

cold layers of 1°5 in deep water up in the fiord, while the temperature at corresponding depths outside (off Vardö) was 4°.

However great the importance of these conditions, they must nevertheless, as regards their connection with the points here discussed, be considered as *local questions;* questions of great significance in as much as they concern the *locality* of the fishery, but not as regards the extent of the *total yield.* All the facts herein set forth would seem to indicate that the great principal results are first of all dependent on the *size of the stock*, and that investigations in this direction may and should be carried out according to the method which has here been in part laid down, and which may be perfected in the course of future investigations. As regards the continuation of the work, this must depend upon how far the results set forth succeed in arousing sufficient interest and confidence to warrant the establishment of the organisation requisite for undertaking the same.

Investigations as to the Norwegian fisheries in the spring of 1914.

The manuscript of the present work was written during the autumn of 1913, which precluded the inclusion of information concerning the fisheries and the stock subsequent to the spring of 1913. It is evident, however, that it must be a task of the greatest interest for the Norwegian fishery investigations to further pursue the questions here discussed, especially as to the state of the stock during the spring fishery of 1914, both as regards the amount of the yield, and the composition in point of size and age of the hauls. The information given in the present work was, with the majority of the figures, curves and charts therein contained, laid before the International Council for the Investigation of the Sea during its meeting at Copenhagen in September 1913. It would therefore be of particular interest to compare the facts as then stated with the results of a subsequent year's experience. This would furnish a means of determining how far it is possible, with the methods employed, to lay down, a year in advance, the principles upon which the situation in a following year should develope; in other words, a test of the reliability of the method as a basis for prediction. And the year 1914 should, as already frequently mentioned in the foregoing, furnish valuable information as to the longevity of the herring and cod, since the year class 1904 in this year attains the great age of 10 years.

With these ends in view, great efforts have been made during the past months to procure a large amount of material consisting of observations as to the composition in point of size and age of the large and spring herring, the Finmark cod and the Lofoten skrei. Herring samples have been obtained from the Søndre Trondhjem and Romsdal districts during the large herring fishery, and throughout the whole range from Stat to Kristianssand during the spring herring fishery. Valuable assistance has been rendered in the course of these investigations by Mr. Einar Giertsen, who has sent numerous expeditions to the localities concerned, and has exhibited the greatest interest in supporting the work by placing at our disposition samples taken from characteristic hauls. With regard to the cod investigations, Capt. Rønnestad proceeded in January to Finmarken, where he succeeded, with the aid of Consul Charles Robertson, in obtaining good samples. From there he went on to Lofoten, where samples were collected in February, both from East and West Lofoten. This work is still in progress, both as regards the cod and the herring fisheries, but in view of the great importance of considering the samples collected up to date (the beginning of March) in connection with the results previously dealt with, I will here briefly mention some of the samples already obtained. The fact that it is possible to do so, despite the brief space of time available for working up the material, is due to the great energy and interest exhibited by my assistants, Messrs. Paul Bjerkan, Einar Lea and Oscar Sund, in order to facilitate the inclusion in the present work of the fullest possible survey of the results obtained.

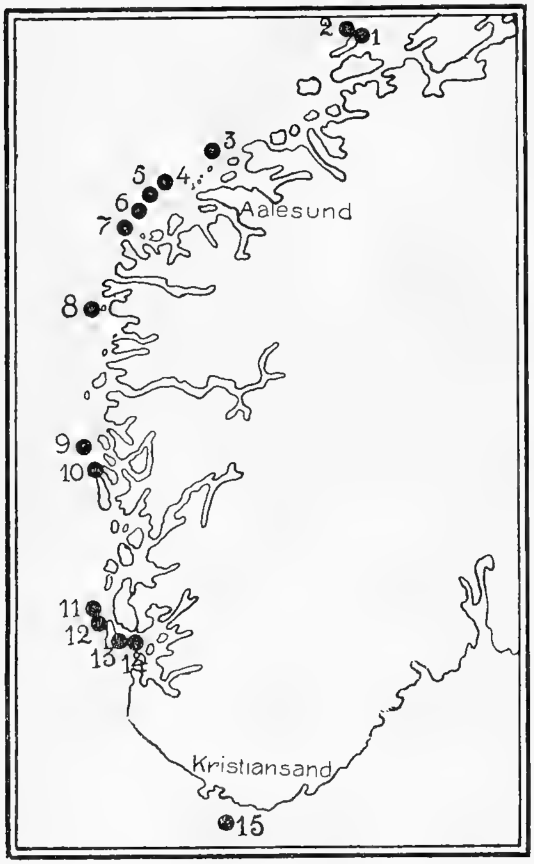

Fig. 131. Localities of capture of the samples shown in table on page 219.
1—7 large herring samples, 8—15 spring herring samples (cf. Fig. 132).

With regard to *herring samples*, 15 in all have been examined, 7 of large and 8 of spring herring; the chart Fig. 131 shows where these samples were taken. It will be noticed that the samples of large herring embrace the range from the mouth of the Trondhjem Fjord to Stat. The northernmost samples were taken in December 1913 and January 1914, the southernmost in February 1914. All the spring herring samples were taken in February, and include the whole of the 2—300 miles of coast from south of Stat (Kalvaag) to Kristianssand.

The table on page 219 shows a comparison of:

I. Average composition in point of age of spring herring for the years 1907—1913, as arrived at by investigation and already described in Chap. I.
II. Composition in point of age of the 7 samples of large herring from 1914.
III. Composition in point of age of the 8 samples of spring herring from 1914.

In the case of the samples from 1914, the numbers in the tables correspond to the figures marked on the chart, Fig. 131. The tables for 1914 show, besides the proportional representation of each year class, also information as to place and time of capture, and number of individuals in each of the samples examined.

As in Chap. I, where, in Figs. 19—21, the composition in point of age of the different spring herring samples from 1910—1913 is compared, so also here, in Fig.

I. Age of Norwegian Spring Herring in the years 1907—1913.

The representation of each year class is given in percentages.

Year classes	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Year 1907..	**1.6**	22.2	18.5	14.8	12.6	19.4	3.4	2.3	1.7	2.2	0.9	0.5	—	—	—	—
— 1908..	—	**34.8**	12.2	11.6	11.1	8.5	14.4	1.9	1.1	1.5	1.5	0.6	0.3	0.1	0.1	—
— 1909..	—	0.4	**43.7**	11.9	4.1	4.8	6.7	17.6	3.3	2.6	1.6	2.3	0.4	0.2	0.4	0.2
— 1910..	—	1.2	9.9	**77.3**	6.7	1.0	0.4	1.1	2.0	—	—	—	—	—	—	—
— 1911..	—	0.6	4.1	17.3	**70.0**	5.5	1.5	0.6	0.5	0.1	—	—	—	—	—	—
— 1912..	—	1.6	3.1	3.9	14.5	**64.3**	6.4	1.6	1.2	1.2	1.5	0.6	0.1	—	0.1	—
1913..	0.1	0.7	2.2	3.4	4.8	13.3	**64.7**	5.1	1.2	1.2	0.5	0.2	0.2	—	—	—

II. Age of Norwegian Large Herring in the winter 1913—1914.

The representation of each age group (year class) is given in percentages.

Sample no.	Locality, Date of capture	No. of individuals	4	5	6	7	8	9	10	11	12	13	14	15	16	17
			1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897
1	NW. of Sulen, 12. 12. 1913	120	—	—	0.8	6.7	4.2	11.7	69.2	2.5	2.5	0.8	0.8	0.8	—	—
2	— - — , 7. 1. 1914..	131	1.5	5.3	5.3	6.9	8.4	17.6	48.1	2.3	3.0	0.8	0.8	—	—	—
3	W of Ona, 21. 1. 1914...	293	0.3	5.1	9.2	6.5	13.6	19.5	36.2	3.8	1.7	2.4	1.4	0.3	—	—
4	WNW. of Storh., 23.1.1914	228	—	0.4	—	3.9	2.2	12.7	44.3	8.3	10.1	10.5	2.6	3.1	0.9	0.9
5	Off Storholmen, 24.1.1914	373	—	0.5	2.7	1.6	3.7	16.1	48.8	5.4	5.4	8.6	4.5	2.7	—	—
6	- Aalesund, 13. 2. 1914.	219	—	1.8	3.2	4.1	8.2	16.9	46.2	4.1	6.4	4.6	3.2	1.4	—	—
7	- Rundö, 19. 2. 1914...	142	—	0.7	0.7	2.1	4.2	28.9	46.5	7.8	5.6	0.7	1.4	—	1.4	—
	Total...	1506	0.3	2.1	3.1	4.5	6.4	17.6	48.5	4 9	5.0	4.1	2.1	1.2	0.3	0.1

III. Age of Norwegian Spring Herring in the year 1914.

The representation of each age group (year class) is given in percentages.

Sample no.	Locality,. Date of capture	No. of individuals	4	5	6	7	8	9	10	11	12	13	14	15
			1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899
8	Kalvaag, 19. 2	175	—	1.7	4.0	2.9	8.0	17.7	52.6	5.1	3.4	2.9	0.6	1.1
9	Feie, 14. 2....................	305	0.7	2.3	3.6	4.6	9.5	14.1	58.4	6.2	0.3	—	0.3	—
10	Solsvik, 26. 2.	44	—	—	2.3	6.8	11.4	13.6	59.1	4.5	2.3	—	—	—
11	1 mile NW. of Røvær, 13. 2...	565	--	1.9	3.7	2.8	5.0	12.4	62.3	7.1	1.6	1.9	0.5	0.7
12	Off Røvær. 19. 2..............	354	0.3	2.6	4.0	5.4	5.1	14.7	60.7	3.4	1.7	0.8	1.1	0.3
13	Karmsund, 19. 2..............	289	—	3.1	5.5	6.2	10.0	17.0	50.2	4.2	1.4	1.7	—	0.7
14	Gjeitungsbogen, Karmsd., 24. 2.	201	1.5	1.5	3.5	4.0	5.5	10.9	61.2	6.0	1.5	2.5	0.5	1.5
15	Off Kristiansand S., 19. 2.	272	2.2	12.9	28.7	8.8	3.3	10.7	29.8	3.7	—	—	—	—
	Total...	2205	0.6	3.3	6.9	5.2	7.2	13.9	54.3	5.0	1.5	1.2	0.4	0.5

132, this has been done for the 1914 samples. Finally, Fig. 133 gives a comparison of all the data now available concerning the composition in point of age of the spring herring, curves being drawn for each of the eight years from 1907—1914, in-

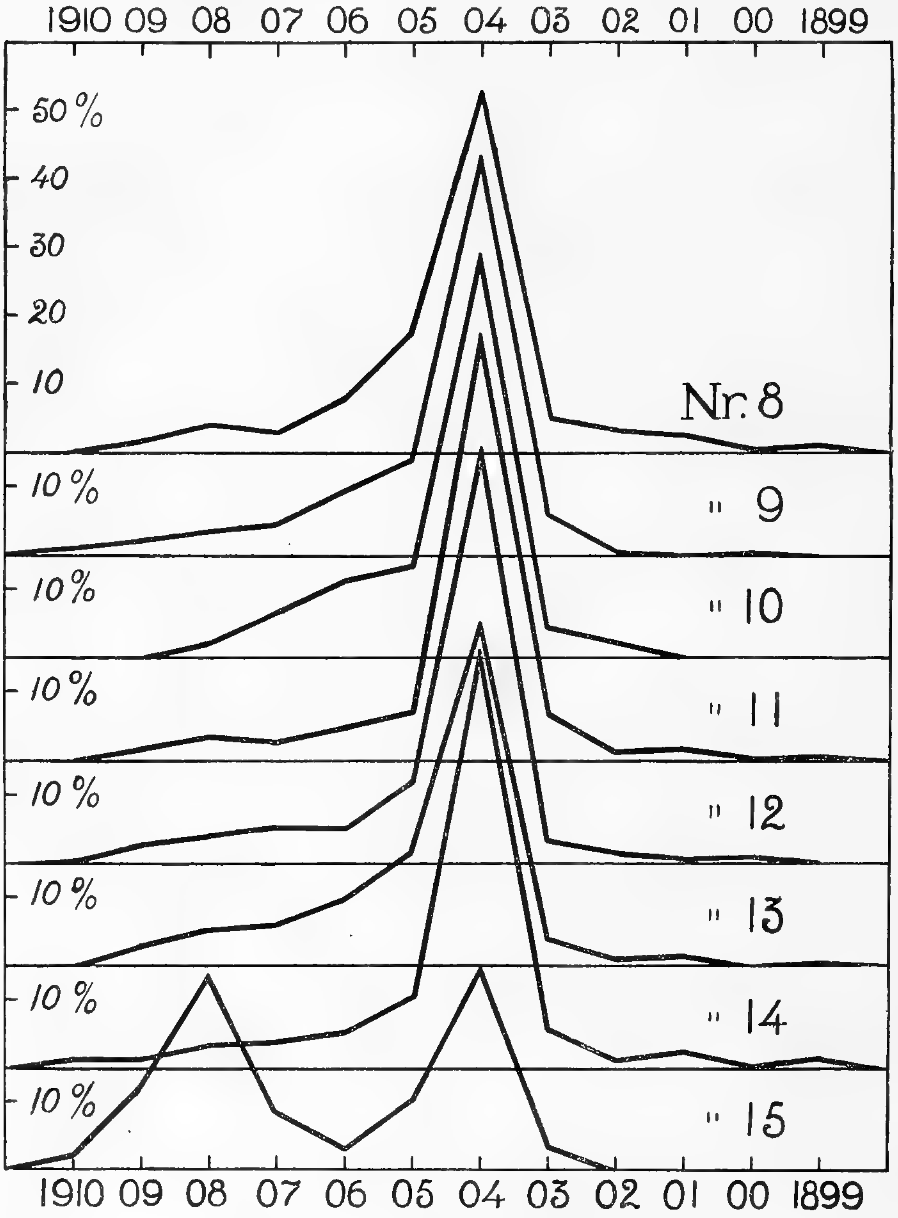

Fig. 132. Composition in point of age of spring samples, February 1914. The numbers are the same as those in the table on page 110 and chart Fig. 131.

dicating the composition in point of age of the spring herring as it appears on consideration of *all* the samples collected during these years.

We will now, on the basis of this material, compare both the individual samples from 1914 one with another, and also the year 1914 with the years previously mentioned.

An examination of the table on p. 219 and of Fig. 132 immediately reveals the fact that the 1904 year class, consisting in 1914 of 10 year old fish, still far exceeds the other year classes in point of numbers. The reader will, moreover, doubtless be surprised, as were those concerned in working out the results, to note the close agreement between the different samples as regards their composition in point of age. In comparing these, the large herring and spring herring samples should be examined separately, since, as already pointed out, it can hardly be supposed that the shoals of large herring and spring herring should be entirely identical. In addition to this, sample No. 15 should be taken separately, this having been taken at Kristianssand, i. e. in the Skagerak, where peculiar conditions evidently prevail, which will require to be further elucidated by continued special investigations. Excluding this sample from the Skagerak, it will be seen that the percentage of the 1904 year class in the 7 samples of spring herring only varies within a field of from 50.2 to 61.2; and for six out of the seven samples the difference is only a few per cent. Sample No. 10 is especially remarkable, consisting of only 44 individuals, purchased in the Bergen market, and exhibiting, in spite of the small number, the greatest agreement with the remaining samples.

Closer observation of the table shows that this agreement not only applies to the 1904 year class, but to all the year classes (always excepting sample No. 15). Thus the 1905 year class is everywhere second in point of numbers. All the other year classes are very poorly represented; only in a few cases do any of them amount to 10 %.

If we then turn to a comparison of the different years, 1907—1914, as shown in the table and in Fig. 133, we find a similar picture of the important part which the 1904 year class has played in the spring herring stock in these years. In 1907 there were no less than 5 fairly rich and fairly evenly represented year classes (the 4—8 year old fish). This even proportion is broken in 1908 by the appearance of the 1904 year class, which in the following years exceeds all the other year classes, culminating in 1910 with 77,3 % and sinking in 1914 to fifty odd. There seems thus to be a distinct decrease, although the year class is still very numerously represented.

The yield of the large herring fishery amounted in 1913 to 275,500 measures (of 150 litres), in 1914 to 216,116. The yield of the spring herring fishery up to 1st March 1913 amounted to 392,500 measures, in 1914 to 158,450, thus showing a great decrease in the spring herring fishery. It is, however, scarcely possible as yet to accurately compare the yield of spring herring in February alone for the two years, partly because the season differs somewhat in point of time in different years, and partly because the month of February in 1914 was unusually stormy. It is, however, certain, that in February this year there were great masses of spring herring present, extending over a great range of coast. The large herring fishery, on the other hand, is for the most part at an end by the beginning of March, so that a comparison may here more easily be made.

The cod fisheries. I have already in Chap. III referred to the marking experiments carried out in 1913. It appeared from these, as also from my measurements and determinations of age, that the Finmark fish in 1913 consisted mainly of skrei, which had spawned on the skrei banks to the south, and had migrated thence to the Barents Sea in the course of the spring (end of April—beginning of May 1913). A considerable number of these fish, 1955 in all, were marked in May and June (*vide* pp. 106—108). The fish recaptured during the following summer had all exhibited a tendency to move eastwards, to the eastern limit of Norwegian waters and farther along the Murman coast (Figs 70 and 71). During the autumn and winter of 1913

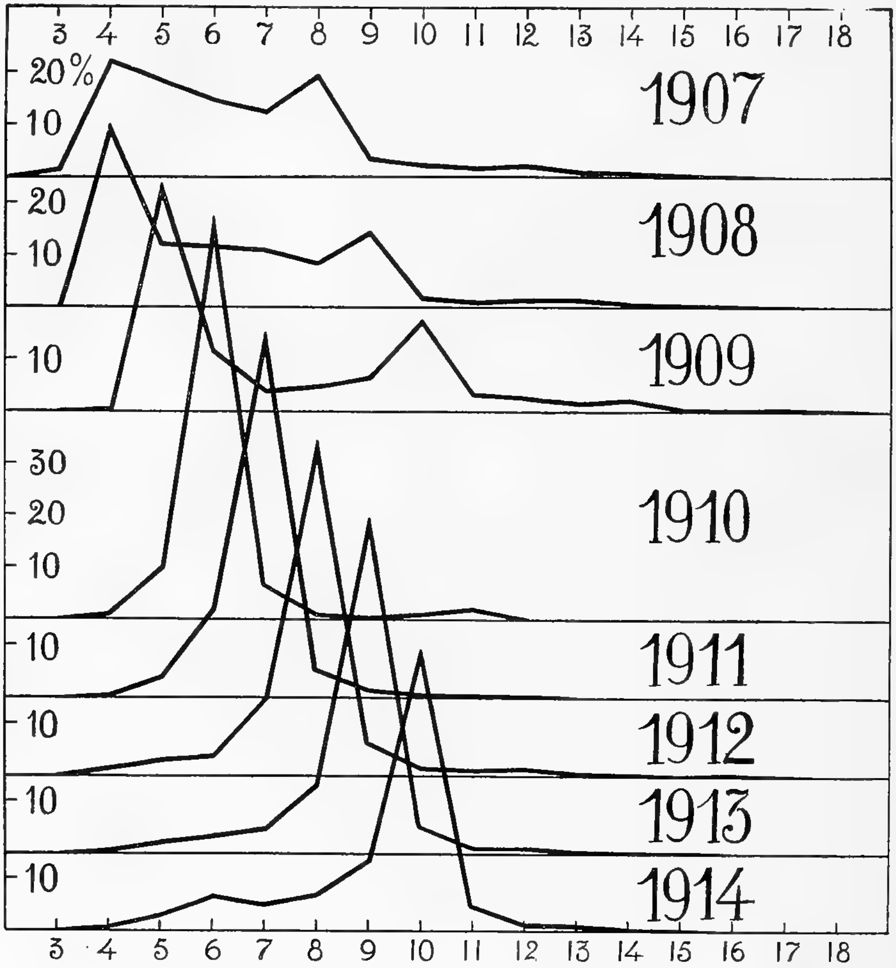

Fig. 133. Composition in point of age of spring herring for the years 1907—1914; average of all samples examined in each year. For 1914 only samples from February included.

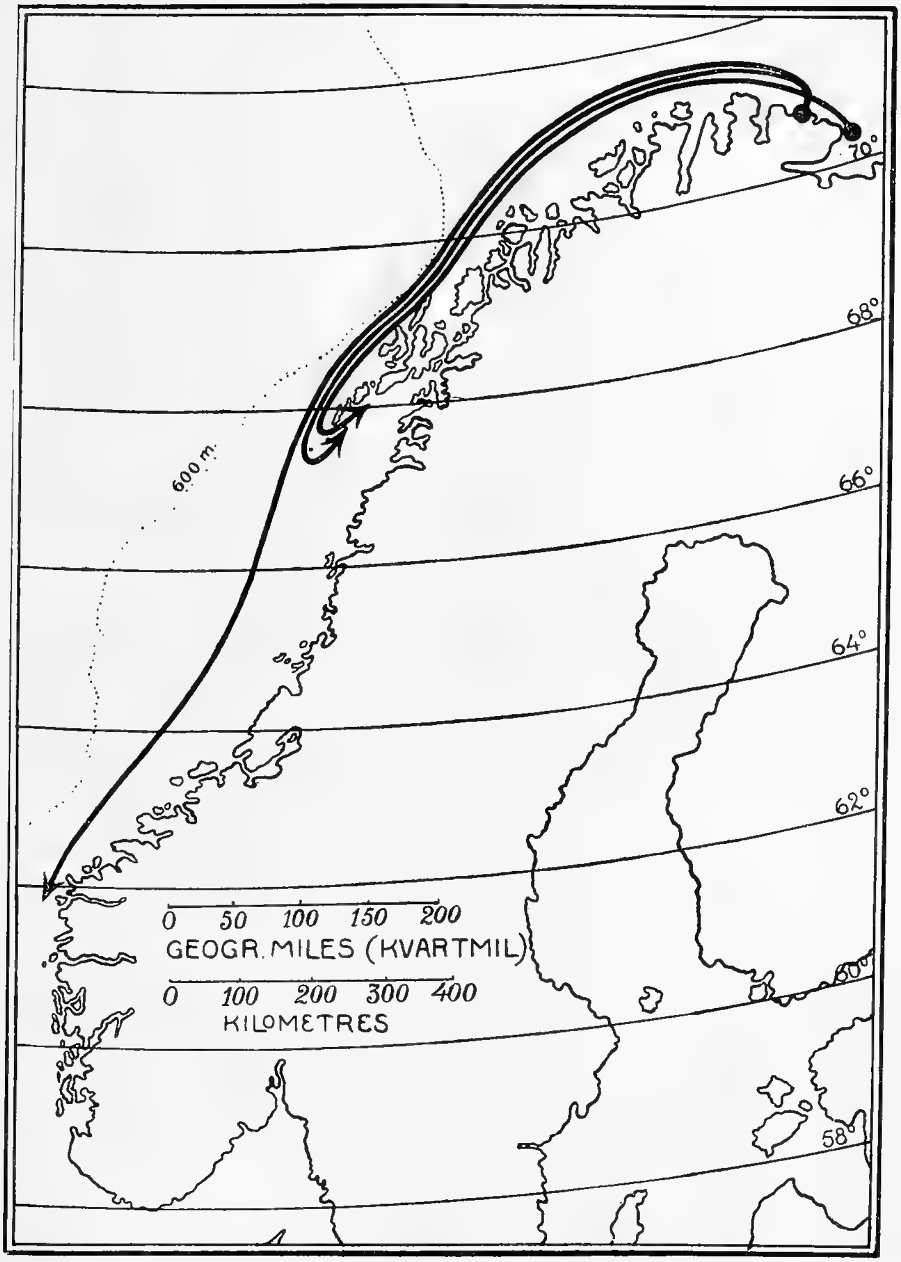

Fig. 134. Examples of migrations to the skrei banks made by Finmark cod, marked in May 1913 and recaptured in February 1914.

no marks, or very few, were sent in; the fish must therefore be presumed to have remained during this period outside the regions worked by the Norwegian fishermen, probably in the eastern part of the Barents Sea. It is therefore the more interesting to note, that with the commencement of the skrei fishery in 1914, marks again begin to be sent in, taken from fish captured on the skrei banks, consisting partly of specimens marked there in the spring, and partly of those marked in Finmarken during the early summer of 1913. At the time of writing (early March) it is still early in the skrei season, and not many marks can be expected to arrive as yet; the following have, however, come in:

A. Marked at Lofoten and recaptured there:

1. Freed at Henningsvær, East Lofoten, 17th March 1913, recaptured at Sørvaagen, West Lofoten, 12th February 1914.
2. Freed at Moskenes 1st April 1913, recaptured at Sørvaagen (almost at the same place) 24th Feb. 1913. Grown from 80—82 cm.

B. Marked in Finmarken and recaptured during the skrei fishery.

3. Freed at Baadsfjord, East Finmark, 26th May 1913, recaptured at Sørvaagen, West Lofoten, 19th Feb. 1914. Grown from 87–91$^1/_2$ cm.
4. Freed at Kiberg, mouth of the Varangerfjord, East Finmark, 22nd May 1913, recaptured at Mortsund, Lofoten, 20th Feb. 1914. Grown from 90—93 cm.
5. Freed at Baadsfjord, East Finmark, 26th May 1913, recaptured at Bremanger, S. of Stat., 26th Feb. 1914. Grown from 107–113 cm.

The chart, Fig. 134, shows the shortest distances which the three last fish can have travelled since leaving Finmarken. Those which made their way to Lofoten must have covered a distance of at least 1000–1100 km.; in the case of the one captured on the West Coast S. of Stat, at least 1700 km. Bremanger, near Stat, is the most southerly point at which skrei fishing is carried on to any great extent. It must thus be considered as proved, that the Finmark fish can migrate to all the larger skrei banks. As to the numbers in which they seek the different banks, the numbers in which the skrei from the various banks migrate to Finmarken, and the quantities of the young spawned on the former which grow up in the different regions along the great range of coast, all these questions must be dealt with by future extensive investigations. By means of marking experiments, the study of growth by measurement and scale studies, and of the drift of the young, it is possible for biological research to elucidate these problems; it will, however, take years of exhaustive work.

If we now turn to the samples collected this year, I must unfortunately at once confess that the amount of time available has not been sufficient to permit of age determinations being carried out, this being, especially in the case of the cod, a very lengthy task. Much information may, however, be obtained from a comparison of the composition in point of size of the samples, and we will therefore proceed to examine some of them in this respect.

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*) Up to the 21 of March the following numbers of marks from the year 1913 have come in:

8 from fish liberated in Lofoten during the skrei fishery 1913 and recaptured in March 1914.

5 from fish marked in Finmarken in May—June 1913 and recaptured in Lofoten in March 1914.

2 from fish marked in Finmarken in May 1913 and recaptured at Søndmør and Bremanger in March 1914.

Fig. 135 shows the composition in point of size of the Finmark samples; the dotted curve for June 1913, the fully drawn line for January 1914.

I have already, in Chap. III. (p. 119 and Fig. 77) described the fluctuations in the stock of cod in Finmarken from May to June 1913. It will be remembered, that in May the Finmark stock consisted only of large fish (skrei) whereas on the Murman coast the fish were mostly small. In June, however, a change was apparent. The large fish moved eastward to the Murman coast, while fish from the eastern waters shifted over to Finmarken, so that the composition in point of age and size of the cod took the form of a curve with double summit, with a very small maximum for the small loddefisk and a great maximum for the large skrei. (Figs. 77 C. and 88, 3.) This is the position indicated by the dotted curve in Fig. 135. Looking next at the fully drawn line, we notice the interesting fact that both maxima have shifted to the right; i. e. *the fish have grown larger*, both as regards the group of small and that of the large fish. The numerical proportion between the two groups is almost unchanged, the small fish being somewhat more numerous, probably owing to the fact that their increased size renders them more liable to be captured by the lines; on the whole, however, the skrei far outnumber the others. This leads us to the definite conclusion that *the stock in January 1914 is exactly identical with*

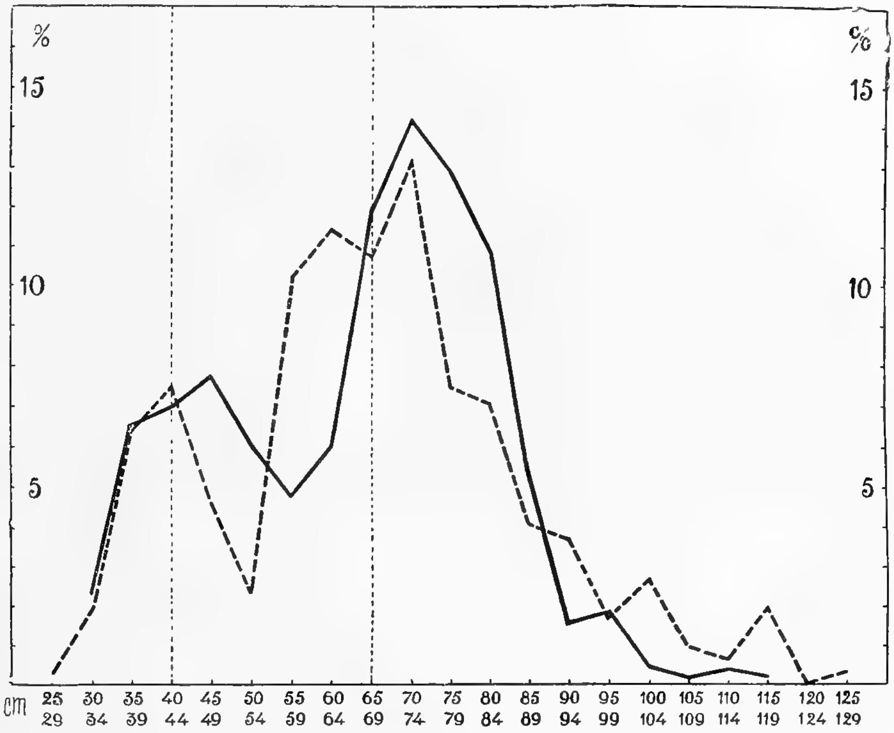

Fig. 135. Composition in point of size of Finmark cod, in samples ---- from June 1913 and ——— from January 1914.

that of June 1913, save only that all the individuals have grown to the extent natural in the period which has elapsed. The increase in size corresponds, moreover, entirely with the normal growth of cod for such length of time.

From Lofoten samples have been taken both from East Lofoten (Henningsvær) and West Lofoten (Sørvaagen) during the two years 1913 and 1914 (*vide* Figs. 136 and 137). In both cases it will be noticed that the samples from 1913 (the dotted lines) lie to the left of those for 1914 (the fully drawn curves). The skrei in 1914 thus consist of larger fish than in 1913. There is no augmentation by smaller fish (younger year classes), and we thus find, in 1914, only the same individuals which already were skrei in 1913, and have now grown a year older. This agrees with the circumstance that in 1913 there were in Finmarken only extremely few younger fish and that in 1913 the skrei had not yet reached the size and age when they begin to rapidly decrease in numbers. A comparison of the years 1913 and 1914 presents very similar features to that of 1906 with 1907 (*vide* Figs. 89 and 90, pp. 137–8).

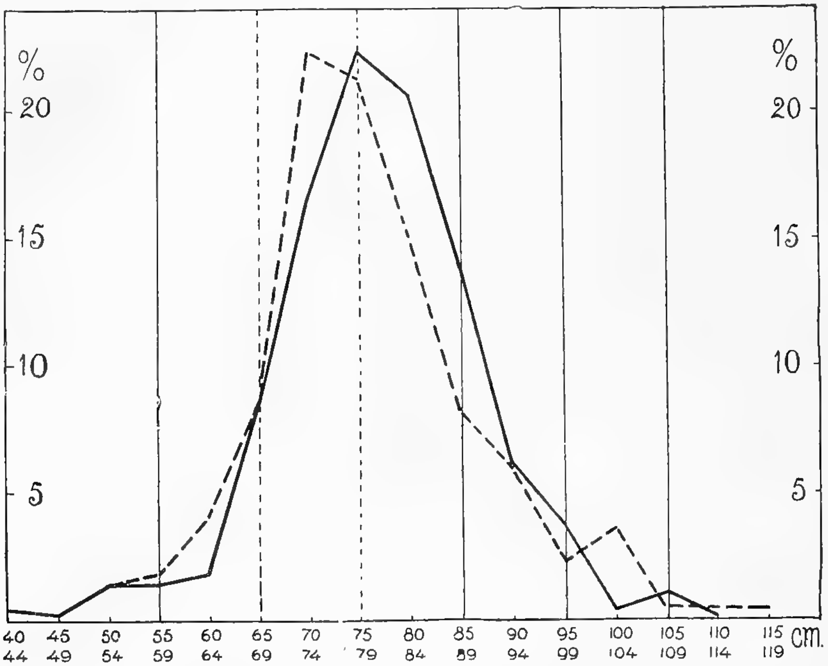

Fig. 136. Composition in point of size of Lofoten skrei in samples from East Lofoten (Henningsvær) during the skrei season
- - - - 1913, ——— 1914.

I will not attempt to push this comparison further; this must be left until the present material has been further supplemented, also by observations as to the age of the fish. I will, however, merely mention that the experience of the fishing industry has already strongly supported these conclusions. The telegrams sent by the Fishery Inspectors in 1914 report a distinct and remarkable increase in the average weight, and contents of liver and roe of the skrei as against 1913.

Future prospects of the Norwegian herring and cod fisheries.

It would, in my opinion, be unjustifiable at present to make any definite predictions as to the immediate future of the fisheries. In the first place, many accidental circumstances may affect the results of the fisheries in certain waters, as referred to in the foregoing; in addition to which we still lack important information, especially necessary in the present case. I here refer in particular to the question of longevity of year classes, or percentage of fish which live beyond the different ages.

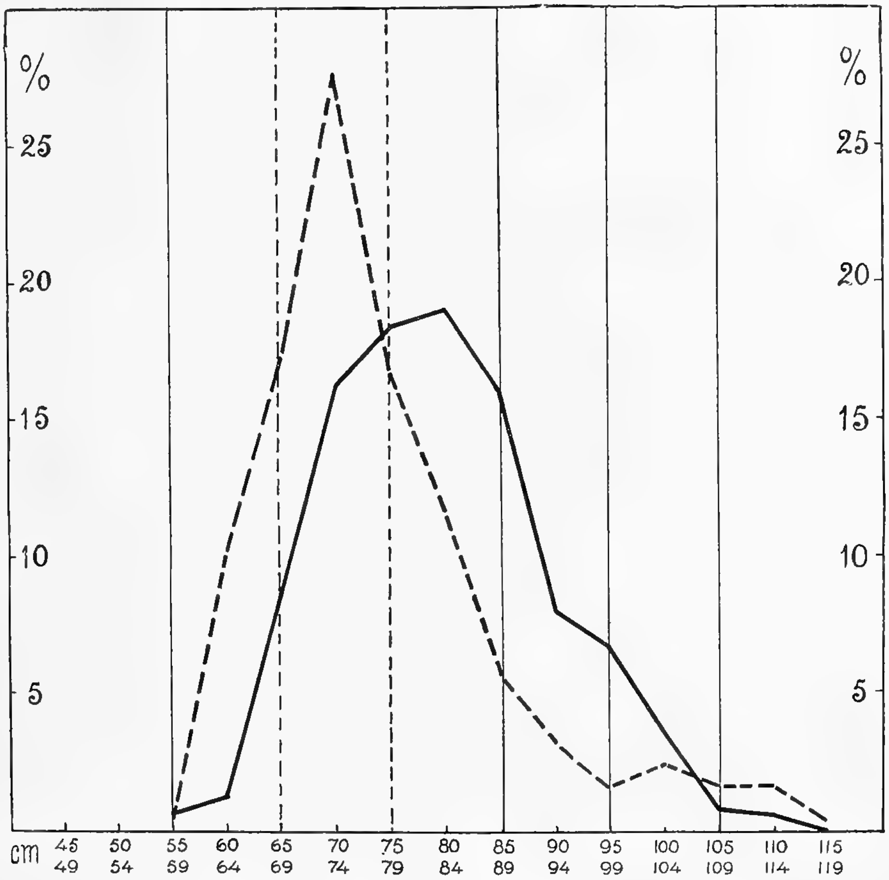

Fig. 137. Composition in point of size of Lofoten skrei
in samples from West Lofoten (Sørvaagen) during the skrei season
- - - - 1913. ——— 1914.

As already frequently mentioned, the investigations record only one instance of the disappearance or relatively great decrease of a rich year class among the spring herring, viz. that of the 1899 year class, which in 1908, when ten years old, appeared for the last time as an important component of the stock. As far as it is permissible to draw conclusions from this single instance as to the 1904 year class, then this latter should by 1915 be further greatly reduced, possibly even sinking to something approaching the numerical value of the other year classes. As the spring herring fishery has been unusually rich in the years when the 1904 year class was so numerous, and there being no *younger* year class among the stock in 1913 and 1914 which even approximately compares with that of 1904, it would seem from our premises that there is a prospect of considerable decrease in the yield.

As regards the fat herring fishery, the yield of the last few years has been extremely poor; small herring, however, of the 1912 and 1913 year classes have been taken in considerable quantities. As to how far this may be due to the increased efforts of the fishermen consequent upon augmented demand, or to the appearance of new rich year classes which in the near future will favourably affect the yield of fat herring, and later also that of the spring herring; these are points which can only be determined when the new year classes begin to appear in the form of great numbers of small individuals in the catches of fat herring. Investigation of the fat herring stock has therefore been included in the programme of work for the "Michael Sars" in the autumn of 1914, and may possibly make the matter clear.

As regards the cod fisheries, our knowledge as to the longevity of year classes is even more uncertain than in the case of the herring. We have, as a matter of fact, only statements as to average weight of the fish available. From these it would seem, that there should still be a prospect of further increase, for some time, in the average size of the cod; in other words, that the same stock which in the past few years has been the object of the skrei and Finmark fishery may still be fished for. As to the younger year classes, but little is known as yet. We know that there were but few of them present on the Finmark coast last year, while on the Murman coast the quantity of small fish was at any rate somewhat greater. As to the numerical value of this stock, however, this can only be determined by future observation, which will be one of the most important tasks upon the programme of investigations for the coming summer.

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