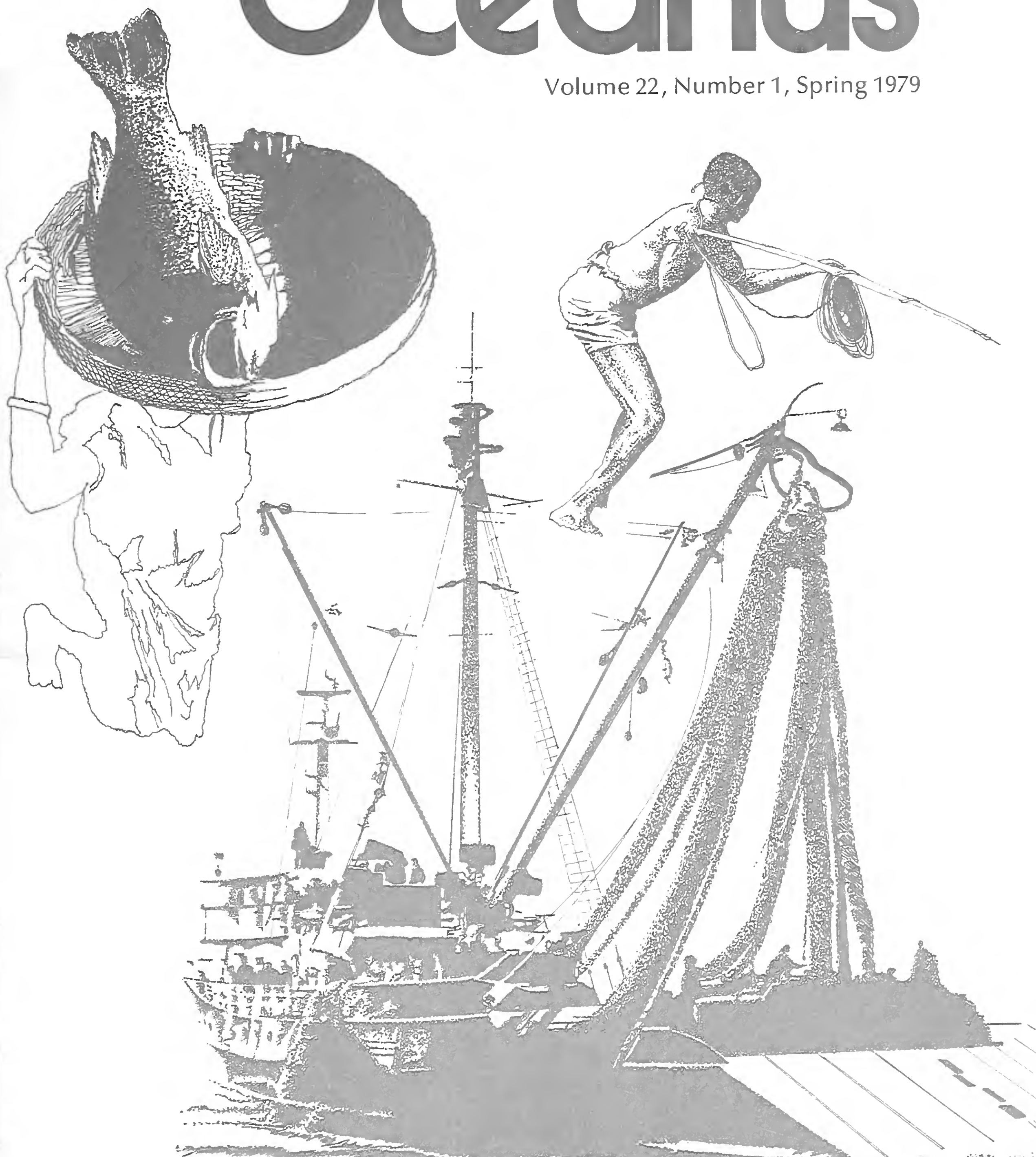
Oceanus

Volume 22, Number 1, Spring 1979



Harvesting the Sea

Oceanus®

The International Magazine of Marine Science

Volume 22, Number 1, Spring 1979

Notice to Readers!

Starting with this volume, the seasonal designation of *Oceanus* has changed to more accurately reflect the publication span of the magazine. This issue is called spring instead of winter; the June issue will be summer instead of spring; the September issue, fall instead of summer; and the December issue, winter instead of fall.

The views expressed in *Oceanus* are those of the authors and do not necessarily reflect those of Woods Hole Oceanographic Institution.

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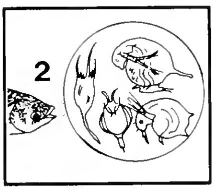

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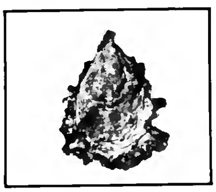

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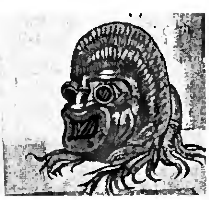

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Marine Fisheries: Food for the Future?

by Richard C. Hennemuth

The oceans have been a mystery to us until recent times, a source not only of admiration and awe but of comforting speculation: anything so vast, the thinking has gone, must hold limitless resources for man to harvest. As populations grew and nutrition became a central world problem, governments asked marine scientists to estimate the food potential beneath the waves. Different techniques were used, the numbers meant different things, and the range of responses varied widely: the figures over the last 25 years have run from under 100 million tons to 2 billion tons of annual production, the larger number more than enough to satisfy the most anxious nutritionist. It has been calculated

School of cod fish on the Grand Banks. (Photo negative by Bell Telephone Lab/NMFS) that about 36 grams of protein per day per person is adequate for essential maintenance. Thus the average annual marine catch of 60 million metric tons in recent years could, if entirely directed to that end, supply 30 percent of the protein needed by the world's 4 billion people. By the year 2000, when most projections place the total population at 6 billion, the catch would have to rise to 100 million metric tons to meet the same need.

Over the last couple of decades, increased fishing effort, primarily by long-distance fleets of large vessels, generally has produced proportional increases in yields. The last six years, however, have seen a leveling off of total harvests despite increased fishing (Figure 1). No one knows whether the trend will continue or be reversed by improved technology. The uncertainty is reflected in today's estimates of yield by the year 2000. Some scientists say that even a doubling is not possible, while others predict harvests five times what they are now. Clearly, it would be useful to examine the bases for these varying projections, the uncertainties involved — including those generated by economic and social as well as purely scientific factors.

The Resource

The number of different categories of marine animals that could be harvested is in the tens of thousands. Most are rare or sparsely distributed or for other reasons do not appear on the tally; species actually caught number little more than a thousand. A case in point: off New England, there are about 200 species of fish of which 30 account for 95 percent of landings.

On a worldwide scale, the clupeoids or herring-like fish are the most ubiquitous. They provide the greatest catches of any group and include hundreds of species. Yet even here 10 species account for about 75 percent of the landings. Nine major groups of species provide about 80 percent of the total world catch of all marine animals and plants (Table 1). Almost all organisms tend to aggregate in concentrations, the densest of which provide the basis for today's successful fisheries. Even the species that do provide high yields, however, on the average are not very densely distributed. Adult demersal fish, those associated closely with the bottom, average about one individual per cubic meter. Pelagic fish also average about one per cubic meter. The adult fish range from 1/10 to 100 kilograms in size. Zooplankton, the small animals (weighing 0.01 grams or less) that drift in the water column, average about 100 individuals per cubic meter in the upper water column.

The largest part of the fishery resource is located on or above the continental shelf out to a water depth of 270 meters. The productivity of some of the richest areas is based on a variable habitat and a multi-species fauna. Yields of from 3.0 metric tons per square kilometer of surface area (Northeast Arctic Ocean, New England Shelf) to 5.0 (North Sea) have been obtained by intensive fisheries. Most of the shelf area is located well within 200 miles of the coastline, and is thus under control of the coastal nations because of recently accepted extended jurisdictions.

The largest share of the global marine catch (60 percent) comes from the temperate waters of the Northern Pacific and Atlantic Oceans. The catch from the central and southern zones follows in decreasing order (Table 2). The north temperate seas have large areas of particularly productive shelf, where correspondingly the fishing has been most intense. These areas border the more

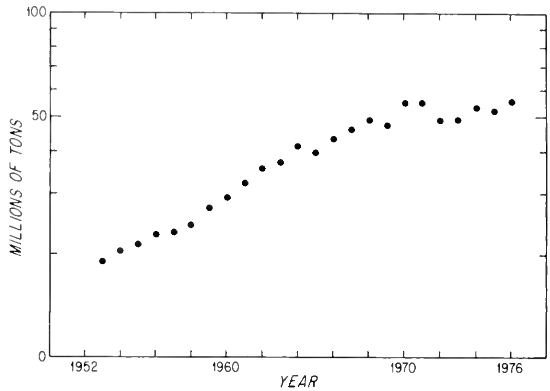


Figure 1. The world catch of marine fishes from 1952 through 1976. (Source: FAO)

Table 1. Leading species groups in world marine catches (in millions of metric tons).

Species	*1976*		*1970*	
Herring, sardines, anchovies	15.1		21.6	
Cod, hake, haddock	12.1		10.5	
Jacks, mullet, sauries (capelin)	7.4	(3.4)	4.1	(1.5)
Redfish, bass, congers	4.9		4.0	
Mackerel, cutlass fishes	3.3		3.1	
Tuna, bonita, billfish	2.2		2.0	
Shrimp, prawns	1.3		1.0	
Squid, octopus	1.2		0.9	
Flounder, halibut, sole	1.1		1.3	
	48.6		48.5	
All marine animals and plants	61.5			

industrialized countries, which have developed strong coastal and distant-water fleets.

The 10 leading fishing nations take about two-thirds of the total marine catch (Table 3). The top two, Japan and the Soviet Union, have the largest catches from non-home waters. The leaders have not changed much since 1970. The greatest changes have occurred in South Korea, which has more than doubled its catch since 1970, and in Denmark, which has increased its catch 150 percent. Twenty countries now harvest more than 1.0 million metric tons annually. Chile and Peru, notably, have depended on one species, the anchoveta; this fishery failed in 1972 (see *Oceanus*, Fall 1978, p. 40), and has not yet recovered. South Africa (pilchard and anchovy), and Norway (capelin) are more than 50 percent dependent on one main fishery. The remainder are rather well diversified. The overall distribution of catch shows that much of the harvest is taken in or near home waters. The long-distance fleets, however, have been important to many countries, both traditionally (Spain, Portugal) and in recent developments (Japan, the Soviet Union, Cuba, Poland, South Korea, to name a few).

In 1976 catches, the leading species group included herring, sardines, and anchovies (Table 4). Traditionally, this group had been at the top, but has dropped significantly in recent years, primarily because of the Peruvian anchovy problem, but also because of decreasing herring catches. The cod, hake, and haddock species group is a close second, and together the two groups account for about 40 percent of the total catch. The herring group in the past has been utilized to a large extent for fish meal and oil, but in the last few years has been used more often for direct human consumption. The cods are almost totally used for this purpose. The third group — jacks, mullet, and sauries — is the only one that has increased markedly since 1970, primarily because of the development of capelin fisheries in the North Atlantic, which were not heavily exploited prior to 1970. These species are used primarily for meal and oil products.

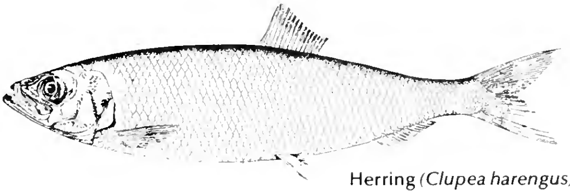
The total 1975 catch in United States continental shelf areas was about 5.8 million metric tons, the foreign catch representing about 3 million of it. Almost all the catch in the United States is taken on the continental shelf; most is consumed domestically. The United States imports about 60 percent of its food fish consumption and in this respect is unique in the world (Tables 5 and 6).

The Ecological Basis of Fisheries

The dynamic renewability of the living marine resources is crucial to their importance as a potential source of food. Sustained exploitation, of course, depends on that renewability. Yet that exploitation is based in large measure on concepts and assumptions having less than satisfactory

Table 2. Marine fisheries catch by area in 1975 (in millions of metric tons).

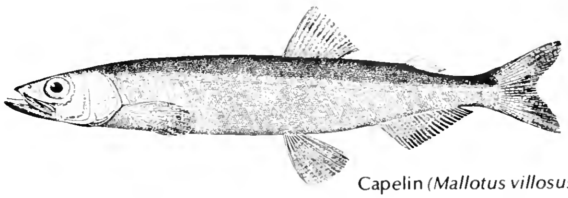
	Atlantic	Pacific	Total
North	15.9	19.3	35.2
Central	6.4	9.3	15.7
South	3.4	4.9	8.3
Total	25.7	33.5	59.2



Herring *(Clupea harengus)*

Table 3. Leading fishing countries in 1976 (in millions of metric tons).

Countries	*1976*	
Japan	10.6	
Soviet Union	10.1	
Peru	4.3	
Norway	3.4	
United States	3.0	
South Korea	2.4	
China (Mainland) and Taiwan	2.3	(4.5 freshwater)
Denmark	1.9	
Thailand	1.6	
India	1.5	(0.9 freshwater)

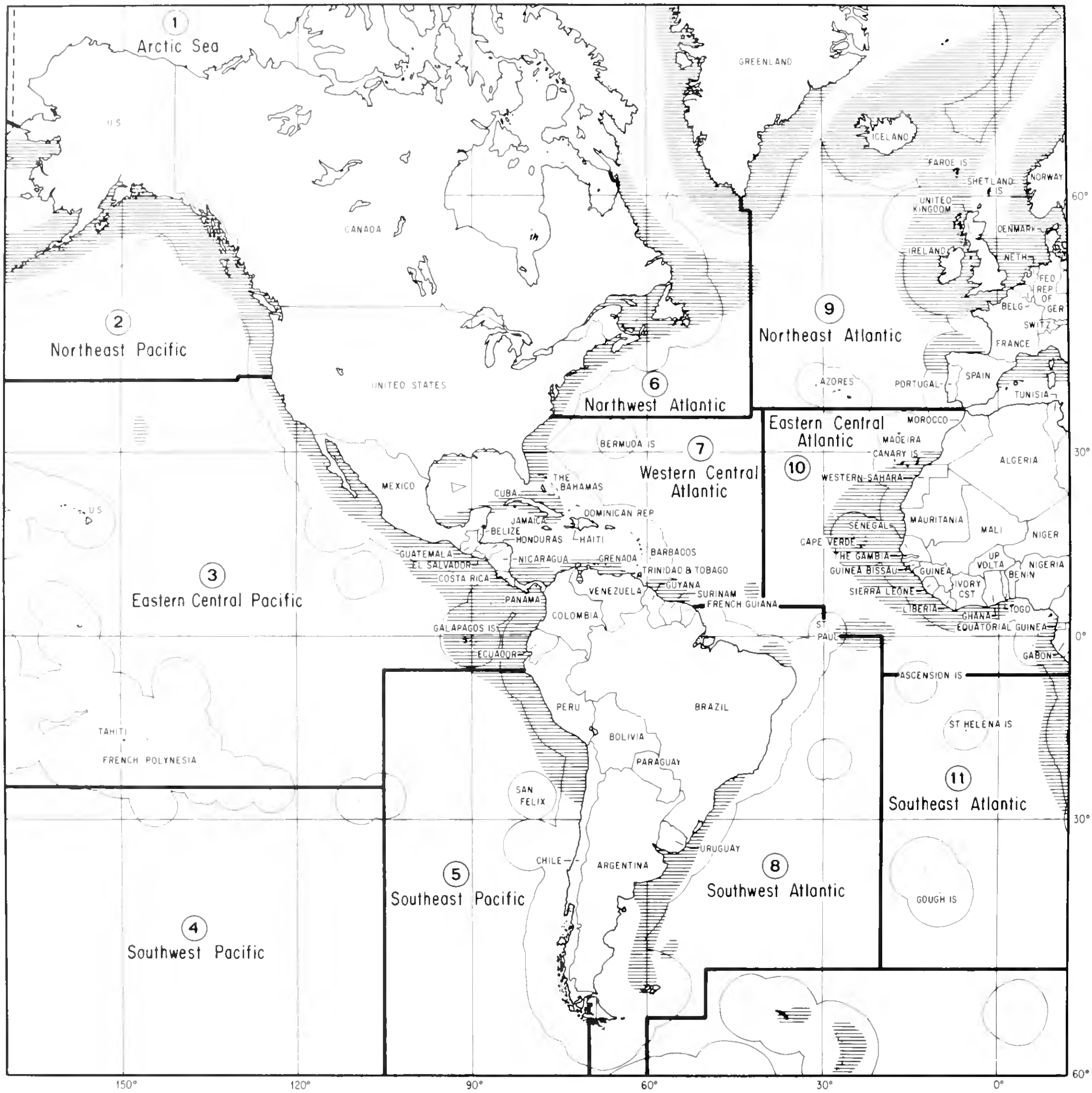


Capelin *(Mallotus villosus)*

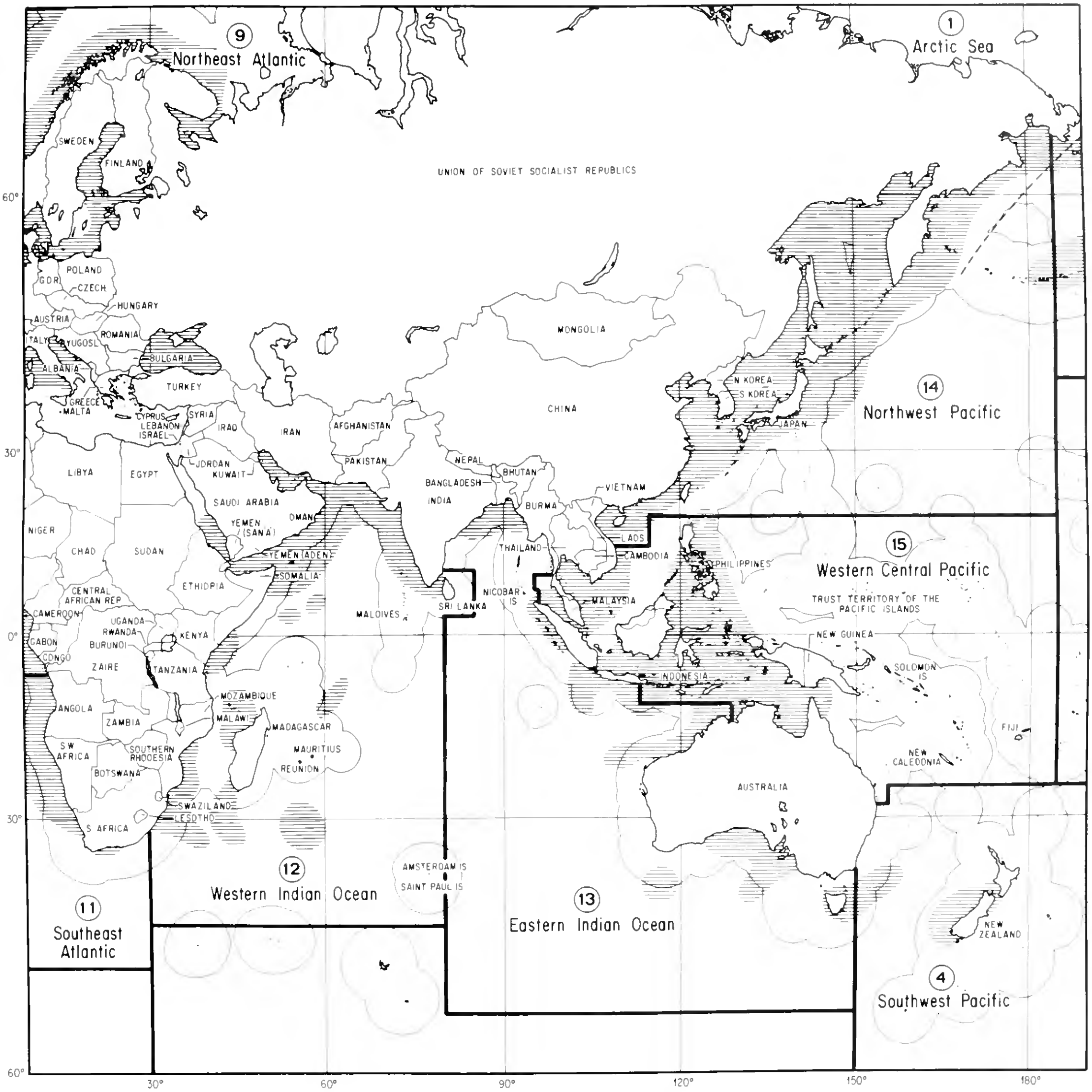
Table 4. Major species categories of world marine catch in 1976 (in millions of metric tons).

Diadromous Fishes (Sturgeon, salmon, shad, etc.)	1.45
Marine Fishes	55.10
Crustaceans (Lobster, shrimp, crab, etc.)	2.01
Molluscs (Oysters, clams, squid, etc.)	3.05
Aquatic Plants (Brown, red, green seaweeds)	1.29

Global Aspects of Marine Fisheries



AREA	MAJOR FISHERIES (in metric tons).	
1 *Arctic Sea*	(No figures available)	
2 *Northeast Pacific*	Alaskan Pollock	1,110,364
	North Pacific Hake	235,926
	Pacific Herring	120,947
	Pacific Cod	87,450
	Flatfish	75,596
	Pacific Ocean Perch	65,104
	Pink Salmon (Humpback)	62,070
	Yellowfin Sole	60,746
3 *Eastern Central Pacific*	Yellowfin Tuna	218,111
	North Pacific Anchovy	195,986
	Pacific Thread Herring	156,132
	California Pilchardi	142,306
	Skipjack Tuna	125,676
	Central Pacific Anchoveta	121,473
4 *Southwest Pacific*	Grenadiers	41,735
	Gadiformes	31,213
	Albacore	18,461
	Jack and Horse Mackerel	15,845
5 *Southeast Pacific*	Anchoveta (Peruvian Anchovy)	4,276,052
	Chilean Pilchard	489,284
	Chilean Jack Mackerel	377,293
	Pacific Silver (Chilean) Hake	133,509
6 *Northwest Atlantic*	Atlantic Cod	530,121
	Capelin	365,393
	Atlantic Herring	322,322
	Atlantic Menhaden	298,125
	Atlantic Mackerel	241,602
	Atlantic Redfish	181,060
	Silver Hake	177,528
7 *Western Central Atlantic*	Gulf Menhaden	561,453
	Spanish Sardine	42,227
	Grunts (Grunters)	21,435
	Mullet	17,105
	Clupeoids	15,932
	Weakfish	14,773
	Spotted Spanish Mackerel	14,623
	Red Grouper	14,573
8 *Southwest Atlantic*	Patagonian (Argentine) Hake	219,715
	Sardinellas	197,320
	White Croaker	86,910
	Weakfish	28,790
	Mullet	27,921
	Bluefish	27,257



9 *Northeast Atlantic*	Atlantic Cod	1,854,830
	Atlantic Herring	856,045
	Sprat	849,956
	Atlantic Mackerel	834,763
	Pollock	700,026
	Norway Pout	646,924
	Sand Eels/Sand Lances	519,766
	Atlantic Redfish	502,219
	Haddock	494,349
	Atlantic Horse Mackerel	353,696
10 *Eastern Central Atlantic*	Sardinellas	866,288
	Jack and Horse Mackerel	433,185
	European Pilchard	420,358
	Chub (Spanish) Mackerel	152,991
	Yellowfin Tuna	120,905
11 *Southeast Atlantic*	Cape Hake	817,273
	South African Pilchard	643,213
	Cape Horse Mackerel	530,820
	Cape Anchovy	306,743
	Cunene Horse Mackerel	118,105
12 *Western Indian Ocean*	Indian Oil-Sardine	290,586
	Clupeoids	165,142
	Anchovies	126,236
	Bombay-Duck	80,541
	Croakers, Drums	79,844
	Sardinellas	65,707
	Indian Mackerel	53,910
	Marine Catfish	52,612
	Yellowfin Tuna	36,770
13 *Eastern Indian Ocean*	Clupeoids	92,942
	Ponyfish (Slipmouths)	45,775
	Hairtails, Cutlass fishes	43,060
	Anchovies	35,329
	Croakers, Drums	30,996
	Indian Mackerel	20,542
14 *Northwest Pacific*	Alaskan Pollock	3,958,380
	Chub (Spanish) Mackerel	1,302,382
	Japanese Pilchard	1,056,958
	Japanese Anchovy	343,023
	Atka Mackerel	295,741
	Pacific Herring	252,141
	Flatfish	235,203
	Pacific Sand Lance	224,312
15 *Western Central Pacific*	Scads	495,972
	Skipjack Tuna	244,073
	Indian Mackerel	238,286
	Ponyfish (Slipmouths)	124,055
	Milkfish	113,102
	Sardinellas	107,197

Source: FAO. 1976 yearbook of fishery statistics.
Shaded areas on map indicate intense fishing zones.

Table 5. Per capita fish consumption averaged from 1972 to 1974 (in kilos).

Rank	Country	
1	Japan	69
2	Iceland	66
3	Portugal	58
4	Hong Kong	51
5	Singapore	48
6	Norway	47
7	Malaysia	41
8	Spain	38
9	Denmark	35
10	South Korea	34
—	United States	16
—	Canada	16

verification. The primary concept is that the environment has a limited capacity to support a given population of fish. The limiting factors tend to either increase mortality or suppress the physiological growth potential. The central thesis of sustainable fisheries is that exogenous mortality through fishing replaces the natural mortality and increases the intrinsic net natural rate of growth by reducing the standing stock — that is the smaller population reproduces at a greater rate and the fish grow faster. Both of these processes are limited and thus limit the potential yield. Harvests that exceed this limit, that is fisheries that generate a mortality that reduces the population below the point of maximum increase in growth, lead to what is termed "overfishing": the long-term yield is less than what potentially could be obtained.

The basic concepts are not unreasonable. They have been demonstrated in some laboratory experiments, and some fisheries have continued for a long time. However, the stability of fisheries has decreased markedly as fishing activity has increased. There also have been many demonstrations that the total mortality rate increases in proportion to fishing effort, and that natural mortality, in the absence of heavy fishing, is relatively low. There is, therefore, some doubt that man can be a prudent predator, taking only what would die or not be produced in his absence.

Table 6. United States fish supply for 1976 (in millions of metric tons).

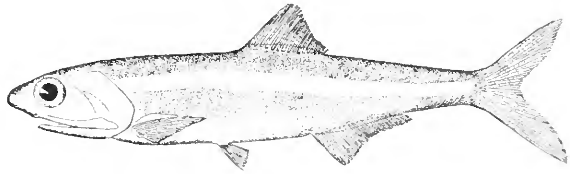
	Domestic	Foreign
Edible	1.3 (37%)	2.2 (63%)*
Industrial	1.0 (73%)	.4 (27%)
Total	2.4(46%)	2.8 (54%)

*40% from Canada and Japan.

South Korean packing worker with fish products packaged for export trade. (FAO/UN photo)

The existing populations of marine plants and animals have evolved an intricate balance between themselves and their environment. This balance is based on population adjustments that provide the optimal reactions of populations to the natural ecological variations. The populations have co-evolved with a wide range of natural changes and are adapted to them. We do not understand the system well enough to predict these changes. Nevertheless, we know the populations can endure them, maintaining themselves in varying composition, but with generally the same productivity.

Marine animals have not co-evolved with man, and our interventions cause changes that are potentially very different from those the natural system has experienced. Man is not sensitive to the effects of these changes because he is not immediately dependent on them for survival. Our technology has developed to the point where we can drive the ecosystem into a state of disequilibrium from which recovery is unpredictable. The control we now exert in managing the populations is based entirely on a pervasive and intense fishing mortality that significantly alters population magnitude. The feedback takes place through our observation of effects and our reactions, both of which are constrained by an economics totally independent of that in the marine biosphere. The time span of changes in the ecosystem is likely quite out of phase with human desires. Our concepts of optimality are very different from nature's. Thus man's continuing activities in the marine ecosystem means that maintaining its productivity and realizing the estimated potential requires considerable restraint to prevent adverse changes.



Striped anchovy *(Anchoa hepsetus)*

The Problems of Projection

The productivity of living marine resources generally is determined by two methods. One is based on estimating primary productivity, the production of protoplasm or carbon by photosynthesis, and then tracing the consumption of this primary food by animals upward through a food chain. Usually scientists begin by estimating the amount of phytoplankton (single-celled plants) in the water, but the figure for the world ocean is not yet very accurate. The conversion process is based mainly on theoretical assumptions of the amount of energy transferred between trophic layers. These trophic layers represent groups of biota that feed successively upon one another. Only a part of the prey's production is consumed by predators, and predator growth increment is only part of the total quantity consumed. The transfer efficiency may commonly vary from 5 to 40 percent; 10 to 15 percent are generally used in calculations.

There are several problems with this method. The estimates of potential depend to a great extent on definition of the trophic layers; how many are used and which groups of species are included. These decisions or judgments can change estimates by factors of 10 or 100. It is not always clear what is assumed; what animals are included in the different levels. Not all of the production in the ocean is available to man. Perhaps something like 30 to 40 percent of the annual production of fish and shellfish can be harvested on a continuing basis. The remainder is needed within the biomass as energy to maintain itself. The most reliable studies based on this approach indicate that the potential harvest is about 150 million metric tons. This includes animals that we are not used to eating and which cannot now be economically harvested.

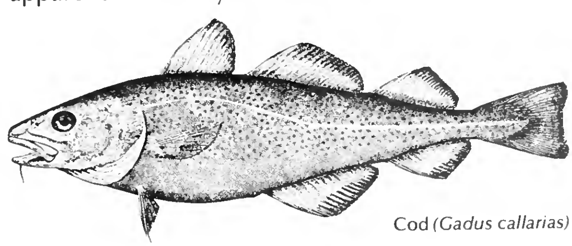
The tropho-dynamic estimates of productivity tend to be higher than those produced by the second method of fishery-based estimates. The former is estimating a resource potential that includes the total organic biomass in arbitrary categories and is not directly restrained by the limitations of practical and feasible fisheries. The latter utilizes observations of actual fishery yields and field surveys of the resources, and incorporates the utilization factors in terms of past performance.

Most of the productive ocean areas have been exploited to some degree. Potential, therefore, can be estimated by examining the available statistics and extrapolating from them. Lack of accurate reports limits the accuracy of such estimates, of course, as does the inference that past performance reflects future potential. Where only experimental surveys of standing stock are available, assumptions must be made about the annual production rate and the proportion available for long-term harvest, similar to the tropho-dynamic approach.

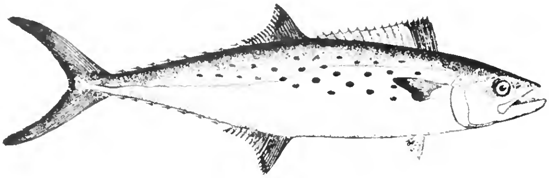
The fishery-based estimate figures have increased with time, a characteristic of trend extrapolation methods. Some estimates assume that past trends could be linearly extrapolated in time, and that laws of diminishing returns (limits of biological productivity) would not apply for some time yet. The more specific estimates often have been based on the concept and method of single-species models and on data from rapidly developing fisheries that were not stabilized to the extent needed for accurate estimates, and which, because of the opportunistic nature of fisheries, were based on short-term, above-average population magnitudes.

Animal populations do cycle, and fisheries seldom are started at population lows. An exceptionally well-documented and perhaps typical example is the mackerel fishery off the east coast of the United States. Americans have fished the population since the early 1800s, with peak annual catches every 10 to 25 years of 50,000 to 80,000 metric tons. The average long-term catch was considerably less than this (Figure 2). In 1967, a very good year class (survivors of one year's spawning) was produced, and the catch, at that time mostly by foreign countries, peaked in 1974 at more than 400,000 metric tons as that year class entered the fishery (Figure 3). This high catch was not repeated because it was based on abnormal annual production, declining to what is obviously more normal levels. Extrapolating trends from data through 1975, which include the peak landing, overestimates the long-term potential.

Improved technology, which has increased catch per days fishing, also has masked real declines in populations, but the possible improvements are limited and the declines have become increasingly apparent in recent years. It also has become



Cod *(Gadus callarias)*



Spanish mackerel *(Scomberomorus maculatus)*

apparent that previously observed highs in cycles cannot necessarily be achieved again after intense exploitation. The potential for a population to react to a favorable environment is lessened after a high mortality has been exerted on it. This appears true, at least, of 10- to 20-year time spans within which the majority of intense fisheries have been developed. This may be caused in part by changes in species abundance triggered by selective exploitation.

Interspecific relations have not been included explicitly in most estimates of potential. It is documented that shifts in species composition have taken place in some intensely exploited areas. Off the coast of California, the sardine population decreased after heavy fishing to be replaced by the anchovy. In the North Sea multiple-species fishery, such changes also have been observed; some of the replacement populations tend to be of the smaller-sized, shorter-lifespan species. In some cases, total yield has been maintained, but often through heavier fishing. In other cases, total yield has decreased, perhaps because species are less desirable and fishing slacks off.

In any event, although fishing has been directed at certain desired species, gear has not been as selective as the taste of markets. The fishing mortality, in many cases, has been directed at large biomass populations, partly because of the development of long-distance, large-vessel fleets, but also because of the search for profit in coastal fisheries. In any mixed-species population, which not by accident occurs in most productive areas, fishing mortality also has been exerted on species caught incidentally, and often has been greater than that which will maintain initial yields. Thus, in general, total area yield, in many cases, has proven to be less than estimates based on individual species assessment. In addition, many estimates include organisms not yet subjected to exploitation, but which are the major food of predators under exploitation and hence in much reduced abundance.

The potential of prey populations is often estimated by calculating the amounts consumed by predators at times in the past when the number of predators were significantly larger — for example, in the case of krill, estimates of potential are derived from calculating whale krill consumption in the past, and matching that figure against the present consumption by heavily reduced stocks, the difference being the surplus that is theoretically available. This system of figuring, however, is questionable, because it is not certain that what was once consumed by predators becomes available to man in the absence of the predator.

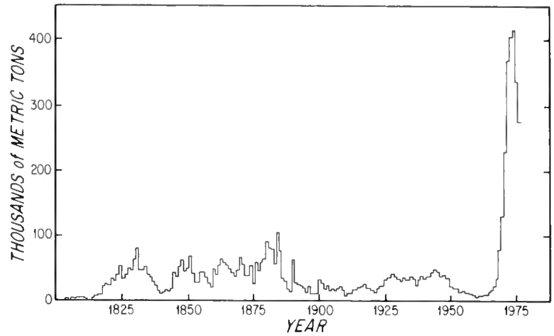


Figure 2. Landings of mackerel from the Northwest Atlantic.

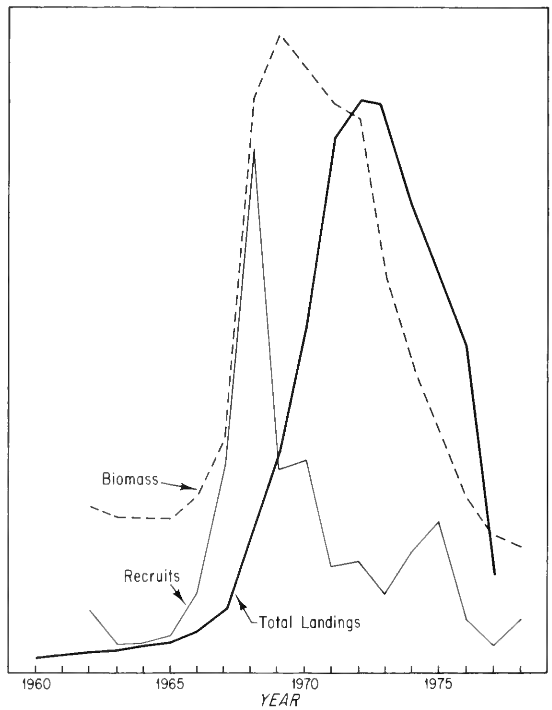
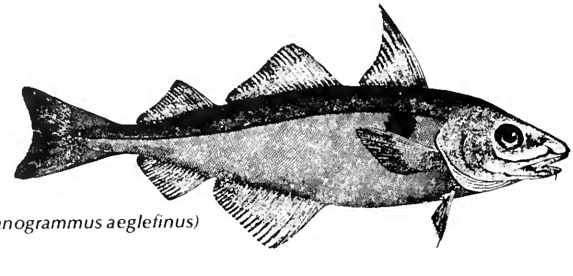
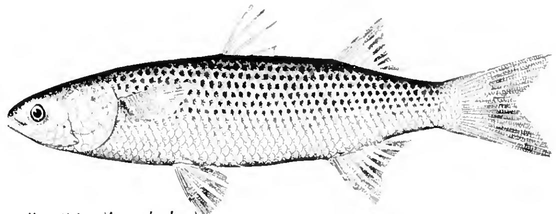


Figure 3. Recent trends in the Northwest Atlantic mackerel population and fishery.

The effect of interaction between species is a rather important aspect most often neglected. The pertinent question is whether the overall productivity of fish biomass is greater than, equal to, or less than the sum of the individual stock estimates of maximum productivity. The problem



Haddock *(Melanogrammus aeglefinus)*



Mullet *(Mugil cephalus)*

arises when traditional single-species methods of assessment are applied to directed-species fisheries. Evidence from fisheries observation, tank experiments, and modeling indicates that present estimates of potential are probably too high because of these inter-specific factors. The most recent estimates based on fisheries data range from 120 to 450 million metric tons. It may well be that maximum potential only will be achieved by utilizing species in general proportion to their natural composition — that is, because of the uncertainty of the effects of intense fishing, the best strategy may be to take fish as they come and not attempt population manipulations.

Several other factors probably will contribute to reduced fishing yields — the first being political. Living marine resources are considered globally as common property to be held and managed in perpetual trust. The scope of commonality recently has been reduced by the extended coastal jurisdictions. Division by national boundaries is totally artificial with respect to the resource and, to a lesser extent, the same is true of the offshore limits. Because of differing concepts of optimality and management, national objectives may be quite differently perceived, even for the same population. The result tends to be further exacerbation of the disharmony between man and nature, which must be reversed if there is to be reasonable utilization of the resource. In fact, national objectives of economic optimization in domestic fisheries already have reduced some foreign fishing within extended coastal zones, and further restrictions probably will be effected. This is particularly significant in temperate water zones where the heaviest exploitation and highest catch now occur, but the effect has been and will be felt elsewhere.

Secondly, up to this time a natural environment has been assumed when estimating the productivity of marine resources. This assumption can no longer be maintained. The effects of man's impact on the environment are much more subtle and probably longer lasting than those of the fisheries.

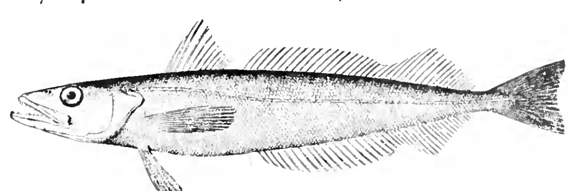
Pollution is largely a result of industrialization and thus most discernible in the Northern Hemisphere. Pollutants are being introduced into the ocean in quantities that are beginning to significantly affect living resources. Productivity is being reduced through change of habitat and bio-accumulation of chemicals, particularly in the estuarine areas of developed countries. Airborne pollution, however, is now detectable even in the open sea. Some pollution occurs in dramatic form — oiled beaches or poisoning by heavy metals. The more important effects, however, stem from largely unnoticed chronic, low-level pollution, a result of society's willingness to regard the oceans — again because of their vastness — as a natural receptacle for man's wastes.

In order to understand how pollutants affect living marine resources, we first must understand the mechanisms behind natural ocean processes, and then be able to predict the effects of a disturbance. It is unlikely that we will reach that point of sophistication rapidly enough to detect and correct our mistakes in the near future. Thus it is prudent to assume, until we know more, that rates of oceanic pollution will increase and that the result will be reduced yields of marine resources.

Resources of the Future

The world catch of aquatic animals and plants is reported annually by the Food and Agriculture Organization of the United Nations with varying degrees of accuracy. Statistics from China (see page 21) and the Antarctic are rough estimates, for example, while those of leading fishing countries for northern temperate waters are much more precise. Examination of these data indicates that most of the traditional fisheries catch remained constant or decreased over the last six years, despite increased fishing activity. In the recent decade, the fisheries have been maintained essentially by shifting to different populations of the same species, or to different species with similar market characteristics. Thus the relatively unfished populations of the broad and productive northwest Atlantic Coast were exploited by long-distance fleets from 1961 through 1972, seeking at first cod, haddock, and herring. Yields from these have decreased significantly in recent years, and probably will not rise again in the near future.

Significant capelin fisheries have developed over the last five years both to accommodate the increased fishing fleet capacity and to replace declining yields of herring. The same has occurred in the prolific North Sea area, where sprat and blue whiting, for example, are being harvested to replace declining herring and mackerel stocks. Crustacean and mollusc catches have not increased much in total amounts. It must be concluded that the productive coastal shelves of the world are being fully exploited, and it is unlikely that a sustained



Silver hake *(Merluccius bilinearis)*

increase of the present traditional fisheries catch of about 60 million metric tons will be achieved in the future. It should be noted that preliminary figures for the 1977 world catch show a decrease of nearly two million metric tons from 1976.

Technological and social developments in the next 25 years, therefore, will not cause an increase in sustained yield of the traditional marine fisheries. Technological advances likely will be needed just to keep the cost of fishing in line with market values. To maintain present yields also will require development of more markets for a wide variety of species in order to take advantage of inevitable cyclic changes in species productivity, and implementation of conservation management practices. Where, then, is the potential for increased yields?

The actual theoretical potential of marine protein is quite large — from 10 to 100 times that provided by traditional fishery forms — if one assumes that plankton and very small vertebrates can and will be utilized. There are a number of serious difficulties involved, supply and demand being the most immediate. A direct comparison of today's fishery efficiencies with the difference in plankton and fish densities illustrates the magnitude of the problem. The most efficient fisheries catch about 50 metric tons of fish per day. The same efficiency applied to zooplankton would produce much less than half a ton per day. Even if the means of harvest can be developed, there are innumerable problems in processing for which no solutions now exist.

Antarctic krill may be an exception (see page 13). Large annual yields could be harvested within the next 10 or 15 years, but there are problems. Recent exploratory expeditions have encountered patchy and variable distributions. The Antarctic weather restricts feasible operations to the summer months. Establishment of a fishery requires a large stern trawler with specialized processing equipment, a vessel at least as large as the biggest trawlers existing today. Krill trawlers easily could cost $10 million each, and it probably would require hundreds of them to meet the minimal estimated potential of 10 million metric tons. Then there is the acceptability of the product; among other things, krill are extremely perishable relative to most fish. They frequently retain green phytoplankton and other food that cause problems in processing. Thus, even assuming an adequate resource, it will require time, technological development, intensive marketing and considerable amounts of money — and luck — to build up a multi-million ton fishery.

There also has been some potential mentioned for developing fisheries on meso-pelagic fishes — for example, lantern fishes (distributed mostly in areas outside national jurisdictions). Again, processing and economic considerations probably will hamper development. They are widely but sparsely distributed. Populations of squid in the open ocean (seaward of the continental shelves) are another possibility. Observations indicate that individual squid are quite large. This could mean that they are old, that productivity is low; we do not have enough information to determine the potential.

In summary, it appears that although fisheries are developing for species not hitherto heavily exploited, these largely replace yields from failing fisheries. The evidence also suggests that further development is quite limited. Given political and economic restraints, it is doubtful that the current marine catch of about 60 million metric tons will be increased much by the year 2000. It may, in the short run, be difficult even to maintain the current yield.

In any event, the potential of world fisheries will be met only through wise management based on a thorough understanding of the ecosystem. The principal ecological research required should deal with the fundamental processes whereby energy is transformed and distributed in the ecosystem, and with the effects of abiotic factors on productivity and species success.

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ANTARCTIC KRILL:

Figure 1. Live krill Euphausia superba, *collected in Antarctic waters.*

Protein of the Last Frontier

by Sayed Z. El-Sayed and Mary Alice McWhinnie

Recently one of us (SZE) received a letter from a free-lance writer, requesting information about a subject that in recent years has attracted wide attention among fisheries biologists, conservationists, politicians, foreign affairs officers, and international lawyers, to name just a few. The subject was Antarctic krill. The writer requested answers to the following:

- *Has the reduction in the whale population resulted in a corresponding increase in the krill population?*
- *What seem to be the most serious obstacles to large-scale krill harvesting?*
- *Prior to the early 1970s only the Soviet Union took much interest in krill; why do you think the Russians were the first?*
- *Some say krill is the largest untapped source of protein in the world; in your opinion, is it worth the time and effort to try to tap it?*

Undoubtedly these questions are on the minds of the professionals and non-professionals alike who are seeking answers to many of the vexing problems that our free-lancer posed in his letter. Seldom in the history of civilization has the development of a new fishery been heralded with the same intensity of concern that now attends the development of the Antarctic krill fishery. This concern stems from the fact that statements have appeared both in the popular press and scientific publications arousing public attention to the harvesting of 100 to 150 million tons of Antarctic krill. To a burgeoning and protein-hungry world population, the prospects of a krill harvest of nearly double the annual world catch of marine fish and shellfish (about 60 million metric tons in 1976) takes on a dramatic aspect.

At the center of all this activity is the shrimp-like crustacean *Euphausia superba* (krill), a 4- to 7-centimeter-long creature that is only one of the some 86 euphausiids species found in the world's oceans (Figure 1). Krill is the key organism in the Antarctic food web upon which all higher species — whales, seals, penguins, winged birds, fish, and squid — depend, directly or indirectly, for their food (see *Oceanus*, Summer 1975, p. 40).

The existence of large stocks of krill in the Antarctic has been known for many years, but interest in their commercial exploitation arose in the early 1960s with the decline of whaling in the Southern Hemisphere. There are several other forces that brought attention to the potential exploitation of krill stocks. Among these are the dwindling stocks of conventional fishes due to excessive harvesting pressure; the recent move by coastal states to establish 200-mile exclusive economic zones, thus forcing long-distance fishing fleets to hunt for harvests outside national jurisdiction (see page 60); and the recent improvements in the equipment required to detect, catch, and process large concentrations of small organisms. These factors, together with human population growth and the increased demand for more animal protein, have led to the search for other potential food sources, and in particular the virtually untouched krill stocks. When these factors are coupled with potential climate changes (see *Oceanus*, Fall 1978), that will most certainly affect quantities and patterns of conventional agricultural production, the urgency to develop a new protein resource becomes even more evident.

The Organism

As a result of the extensive investigations carried out during the British *Discovery* expedition in the 1920s and 1930s, almost all that is known about krill comes from the classic studies of the late J.W.S. Marr of that expedition. Of the 11 species of Antarctic krill, the most important are *Euphausia superba, E. crystallorophias, Thysanöessa macrura,* and *E. valentini.* These euphausiids are located as follows: north of the Antarctic convergence is *E. valentini;* in the pack ice, *E. crystallorophias;* and in open waters south of the convergence, dense patches of the larger species *E. frigida* and *E. superba.*

The largest concentrations of *Euphausia superba* are in the Atlantic sector, particularly in the northern Weddell Sea, the Scotia Sea north of the Orkney Islands, around the South Shetland Islands and west of the South Sandwich Islands (Figure 2). Breeding takes place in at least four areas: the Bellingshausen Sea, the Bransfield Strait, the Davis Sea, and in the vicinity of South Georgia. The number of breeding stocks is largely unknown; however, there is a possibility of at least two separate ones. It is believed that krill spawn once or twice a year (for one or two years); fecundity is between 2,000 to 3,000 eggs per spawning. Longevity is still a matter of controversy; however, there are indications that krill may live for more than four years.

Krill tend to congregate in large swarms of a single age class. These swarms average 40 by 60 meters in size, with a maximum recorded dimension of 600 meters. According to Soviet scientists, krill swarms can extend to depths of 40 or 50 meters, although concentrations most suitable for commercial catch are found between 1 and 10 meters.

The swarming habit makes it easy for baleen whales to feed on these animals, with blue whales preferring adolescent krill, and fin whales favoring adults (see *Oceanus,* Spring 1978). It has been shown that adult and juvenile krill are often found in separate layers, with the juveniles being closer to the surface. The fact that different age groups of *Euphausia superba* swarm separately may be useful for commercial harvesting and fishing management.

The Fishery

The Soviets and the Japanese started experimental krill fishing in 1961-62. In recent years, several other countries have been pursuing this type of fishing, notably Poland, West Germany, South Korea, and Taiwan. In 1974, Japanese vessels reported average yields of 16 tons per day. In 1975-76, the West German trawler *Weser* averaged 8 to 12 tons of krill per hour of towing time, with a maximum catch of 35 tons in 8 minutes (Figure 3)! It is difficult to assess the relevance of these figures or to compare them with those of commercial vessels since much of the time spent in experimental fishing has been devoted to reconnaissance. The technology required to evaluate the extent of the krill resource is still in the formative stage. Nonetheless, available information suggests that, technological impediments notwithstanding, a commercial fishery for krill could develop quickly.

Krill processing, like krill harvesting, was pioneered by the Soviets and the Japanese, who in the early 1960s produced krill meal and krill protein concentrate. Now a large range of krill products is available from more advanced processing techniques (Figure 4). In the early 1970s, the Soviets began marketing krill-butter and krill-cheese spread products. The new brand Okean, currently sold in supermarkets in Moscow at about $1.35 a pound, is recommended, according to *The New York Times,* to enrich such dishes as Siberian dumplings, meat pies, fish balls, salads, paté and deviled eggs. The Soviets also claim medicinal values for krill paste, ranging from treating hyperacidity of the stomach to atherosclerosis.

The Japanese are making a type of fish sausage with 20 percent of the fish replaced by krill, while the Soviets have developed a sausage with coagulated krill paste, structured by an alginate gel. Last year, the West Germans produced a krill mixture with the consistency of a Bruhwurst, containing cooked krill forcemeat, fish, and milk protein.

Despite the recent substantial gains in our

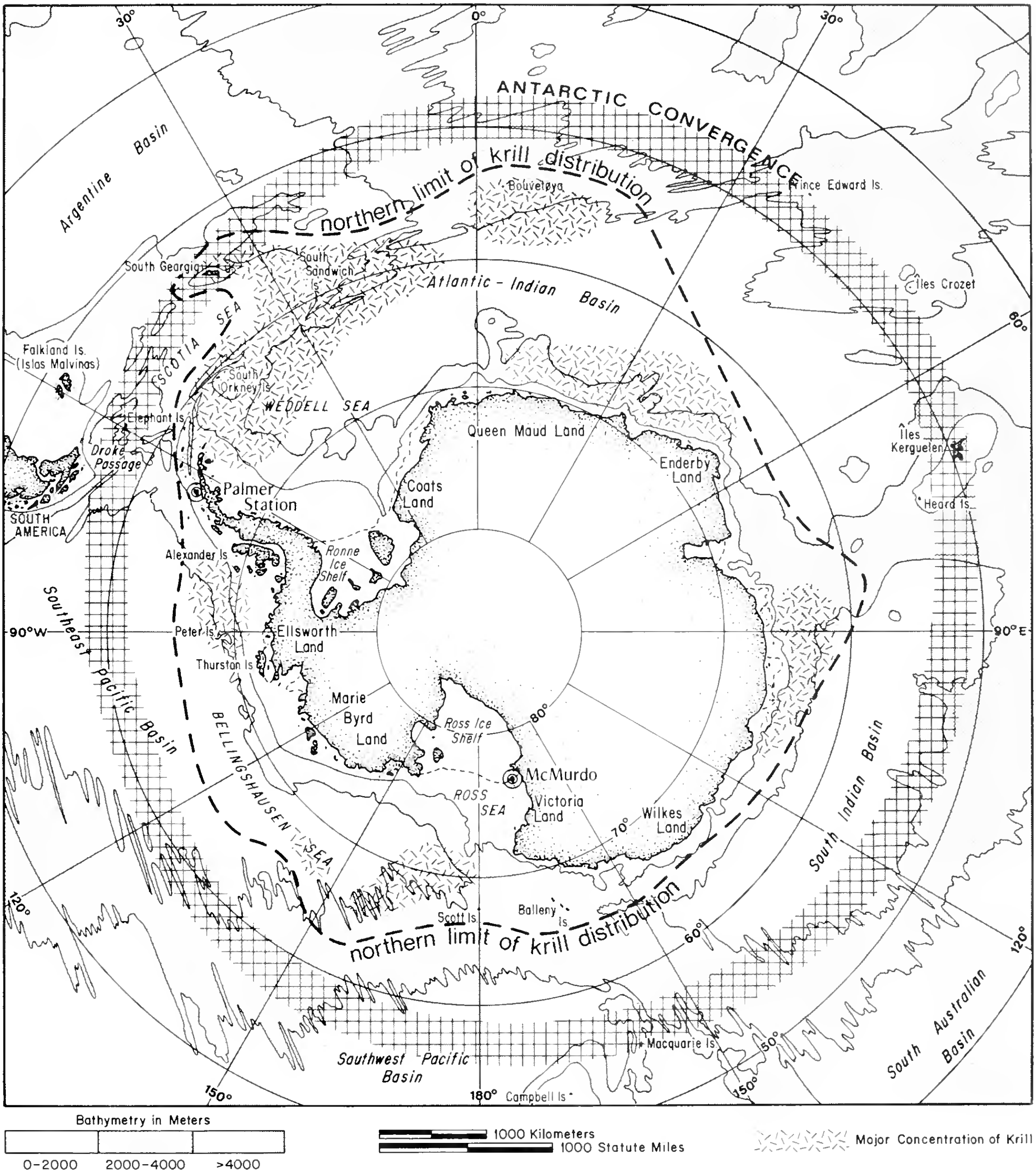

Figure 2. Principal concentrations of Antarctic krill. (Adapted from Mosaic, *September/October 1978)*

knowledge of krill harvesting and processing technologies, these procedures have not been fully developed. The economics of harvesting a remote fishery, the potential salability of krill products, and the development of markets have not been determined. However, it appears unlikely that the landed cost of krill will be less than that of conventional fish and seafood resources.

In the interest of the most efficient management of a living resource, there is a need to know many details of the life history of the species targeted for exploitation. While broad outlines of the life history of *Euphausia superba* were drawn sometime ago (Ruud, 1932; Bargmann, 1945; Marr, 1962; Mackintosh, 1968, 1970, 1972, 1973; Nemoto and Nasu, 1975; among many others), many

Figure 3. The West German trawler Weser *in Antarctic waters.*

fundamental questions remain unanswered, specifically concerning krill biology, distribution, population dynamics, standing stocks, and production. At the present time, Antarctic krill are being harvested at the rate of 80,000 to 90,000 metric tons annually.

Krill Biology

While most aspects of krill biology are under intensive study, definitive answers are needed to questions on growth rates, rate of advance to maturity, longevity, fecundity, and spawning potential. Moreover, as harvesting is underway at several widely spaced sites, it is necessary to know the number of spawning events, temporal and spatial differences within the populations throughout their circumpolar range, and the factors inducing their spawning behavior.

Let us consider the question of krill feeding. Until recently, krill have been considered to be exclusive herbivores and thus primary consumers in the ecosystem. It probably is still true that during the austral summer they extensively graze on the abundant phytoplankton stocks. But McWhinnie and Denys (1978) have reported that krill also have carnivorous, detritivorous, and cannibalistic habits, which will require revision of their annual growth rates and ultimately their longevity, as well as energy transfer throughout the ecosystem. Winter feeding and growth had been considered to be negligible when phytoplankton productivity decreased due to extensive ice cover in the seas adjacent to Antarctica. However, during 12 months of laboratory experiments at Palmer Station, Antarctica, the author (MAM) and co-workers showed that carnivorous and cannibalistic feeding probably continue throughout the year.

Another question involves the relationship between the distribution of krill and their physical/chemical milieu. The Southern circumpolar seas often are considered to be

Figure 4. Advertisements for krill dishes in Japan.

relatively uniform in thermal regime and radiant energy (however, variable seasonally). Their physical oceanographic characteristics have well-known vertical and horizontal variabilities, but these and other environmental parameters have not been fully correlated with krill distribution (Deacon, 1977). Inter-seasonal and inter-annual variations in krill populations also add to the list of unknown factors. British scientists (Bonner, Everson, and Prince, 1978) reported an apparent shortage of krill in the 1977-78 season around South Georgia, a region known to be one of the major feeding grounds of baleen whales. Young Antarctic fur seals showed a corresponding loss of weight, and there was a low survival rate among black-browed albatross chicks and Gentoo penguin chicks compared with earlier years.

Krill Stocks

Estimates of the standing stocks of krill, as well as of the extent of dependence of many species on this food source vary widely. Great discontinuities in the distribution and swarming behavior of krill populations, as well as the diverse methods of estimating standing stocks, are responsible for this high variance. Estimates of krill stocks range from 125 to 200 million metric tons (Everson, 1977; Sahrhage and Steinberg, 1975) to 3.5 to 5 billion metric tons (Bogdanov, 1977), to 6 billion metric tons (Lubimova, *et al*, 1973). The bases from which these estimates were made, coupled with the relatively small areas in which sampling was conducted, render the exercise in determining krill stocks both tenuous and less than useful. However, it is clear that krill stocks are of considerable magnitude. Although seasonal and annual variations are known, they generally have not entered into computations. Nonetheless, inter-annual differences are known to occur (cold versus warm years), with harvesting success being inconsistent on an annual basis (poor, for instance, in 1977-78).

Krill Consumption

Estimates of krill utilization by species in the upper trophic levels — such as whales, seals, and penguins — are as variable as those for the standing stocks of krill. This, too, can be expected when the areal extent of the Antarctic seas (38 million square kilometers) and the dimensions of the coastal areas and their surrounding ice are considered. Moreover, logistic constraints, the character of weather and sea conditions, and the relative brevity of the austral summer (during which most studies are conducted), together account for our limited understanding of this ecosystem.

The most recent estimate of krill consumption by baleen whales, which have an estimated population of about 338,000, is about 33 million tons annually. Crabeater seals, which feed almost exclusively on krill, are the most abundant in numbers — estimated at 25 million; they consume nearly 100 million tons of krill annually. Leopard, Ross, and fur seals also feed on krill, with an estimated consumption of about 4 million metric tons, although their main food sources are fish and squid. At present, crabeater seals appear to consume more krill than any other animals in the system (Figure 5).

The seven species of penguins and the 19 species of winged birds (petrels, albatrosses, and others) have a total population estimated at 188 million, consuming about 39 million tons of krill annually — about equal to that consumed by baleen whales.

We have no reliable estimates on the standing stocks of the other two major consumers of krill — namely fish and squid. There is evidence in the literature that these two groups consume between 100 to 200 million metric tons of krill annually.

Thus, if we combine the estimates of krill consumption by all directly dependent consumer species, it comes to roughly 400 million metric tons annually. It is clear that this total consumption equals or exceeds the minimum estimate for the standing stocks of krill. On the other hand, the total consumer utilization is only 13 percent of the next highest estimate for standing krill stocks — 3.5 billion metric tons.

Annual production is even less well known than the other parameters of the Antarctic ecosystem. Few have attempted computations because data are so incomplete. However, these values range from 13 to 20 million metric tons per year (Rakusa-Suszczewski, 1976), to 75 to 100 million metric tons (Hempel, 1968), to 400 million metric tons annually. Thus it would pose a considerable threat to the Antarctic ecosystem if one were to proceed rapidly toward a large commercial fishery when basic production estimates vary from 20- to 30-fold.

Effects of Man's Krill Harvest

Sooner or later, the problems posed by man's potential harvest of krill must be faced. The Antarctic food pyramid is characterized by large numbers of individual species that make up relatively simple food chains. Krill provide the link between the primary producers — for example, phytoplankton — and the higher trophic levels — fish, birds, and mammals (the latter being consumed by only a few carnivores). It is a peculiarity of the Antarctic ecosystem that one herbivore species, krill, supports five diverse groups, and many species of predators! The ecosystem manages so well because each species exploits a different segment of the krill population, thus reducing competition. Nonetheless, one inherent weakness of the system is its great dependency on a single organism. Therein lies the danger in man's harvest of the creature.

Man is the principal predator of whales. With krill harvesting, he will become the exploiter of both prey and predator! Commercial krill harvesting will likely take place in the areas of greatest krill concentration. These are precisely the areas where whales feed. Because of the annual seasonal migration of whales, the time of year for whale feeding will coincide with the commercial harvesting of krill. The would-be effects on the ecological system as a result of this competition are not clear, but the impact of man's harvest, most assuredly, would cause reverberations in the ecosystem. Because whales are long-lived species, there would be a time lag in the response of the ecosystem to any harvest of krill. It is therefore difficult to estimate what the long-term effects of a large krill harvest would be.

Could the overharvesting of whale stocks have caused a krill surplus? This argument, advanced in recent years, is based on the difference between the amount of krill consumed by the much larger stocks in the 1930s and that of present-day stocks. The surplus is estimated at about 150 million tons. Although there is little firm evidence that such a surplus exists, the increased numbers of seals, penguins, and winged birds counted in recent years could account for additional amounts of krill, which may have been channeled to other consumers as well.

Some fishery experts are advocating a catch limitation on krill that is low enough to provide a minimum risk to the ecosystem. At the same time, they have been urging that an accurate data base be obtained before catch limits are established. They are of the opinion that the harvest of krill should be structured so as to maximize the information gained by catch data.

Biomass: Concepts and Programs

In 1972, the Scientific Committee on Antarctic Research (SCAR) established a small group of specialists to expand the scientific understanding of the Antarctic marine ecosystem. From the beginning of discussions on research needs, SCAR sought collaboration with the Scientific Committee on Oceanic Research (SCOR), the International Association of Biological Oceanography (IABO), and the Advisory Council of Marine Resources Research (ACMRR) of the Food and Agriculture Organization of the United Nations. This group has recently been reconstituted as the SCAR/SCOR/IABO/ACMRR Group of Specialists on Living Resources of the Southern Oceans. The group has worked in liason with the Intergovernmental Oceanographic Commission (IOC), and particularly with its International Coordination Group for the Southern Ocean. The IOC has encouraged SCAR in its development of research programs, which hopefully will provide the scientific information necessary for sound decisions by governments.

In the summer of 1976, the United States hosted the First Conference on Living Resources of the Southern Ocean at the National Academy of Sciences' summer studies center in Woods Hole, Massachusetts. The conference's chief objective was to review the present knowledge of the living resources of the Southern Ocean and to develop proposals for future cooperative studies in the area. The proposals became known as Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS).

The principal objective of BIOMASS is to gain a deeper understanding of the structure and dynamics of the Antarctic marine ecosystem as a basis for future management of potential living resources. The ultimate objective of BIOMASS would be achieved by producing a predictive model for the entire system. It is clear that krill would play a central role in this model, both as the major herbivore and the dominant food for most of the organisms higher in the trophic levels.

At its meeting in Kiel, West Germany, last year, the Group of Specialists proposed an organizational structure consisting of three permanent technical groups — program implementation and coordination; methods; and data, statistics, and resource evaluation — and four shorter-term working parties — on krill abundance, krill biology, fish biology, and physical/chemical oceanographic observations. The austral summer of 1980-81 was chosen for the First International BIOMASS Experiment (FIBEX): as many as 20 ships from 13 countries are scheduled to participate in the multidisciplinary study of the variabilities of ecological parameters in space and time. FIBEX will concentrate on the Atlantic sector, including the Drake Passage and its western approaches. The Second International BIOMASS Experiment (SIBEX) is scheduled for 1984-85, with the overall program lasting between eight and ten years.

International Aspects

While the scientific specialists were occupied in drafting BIOMASS and preparing for the FIBEX experiment, the signatory nations to the Antarctic Treaty were grappling with the diplomatic and resource management problems. And to complicate matters, landlocked and developing countries at United Nations Law of the Sea negotiations began demanding a share in the profits from exploitation of "common heritage" resources, even though they do not have the technology to exploit such resources.

In early 1978, the 13 signatory nations to the Antarctic Treaty met in Canberra, Australia, to begin negotiating a convention on the conservation of Antarctic marine living resources. (Commercial whaling and sealing operations are currently governed by the International Whaling Convention and the Convention on Antarctic Seals.) It had been hoped that the living resources convention would be signed by the end of 1978, but it has been delayed.

It is understood that the convention will provide for comprehensive research into krill ecology, and a monitored quota system, based on

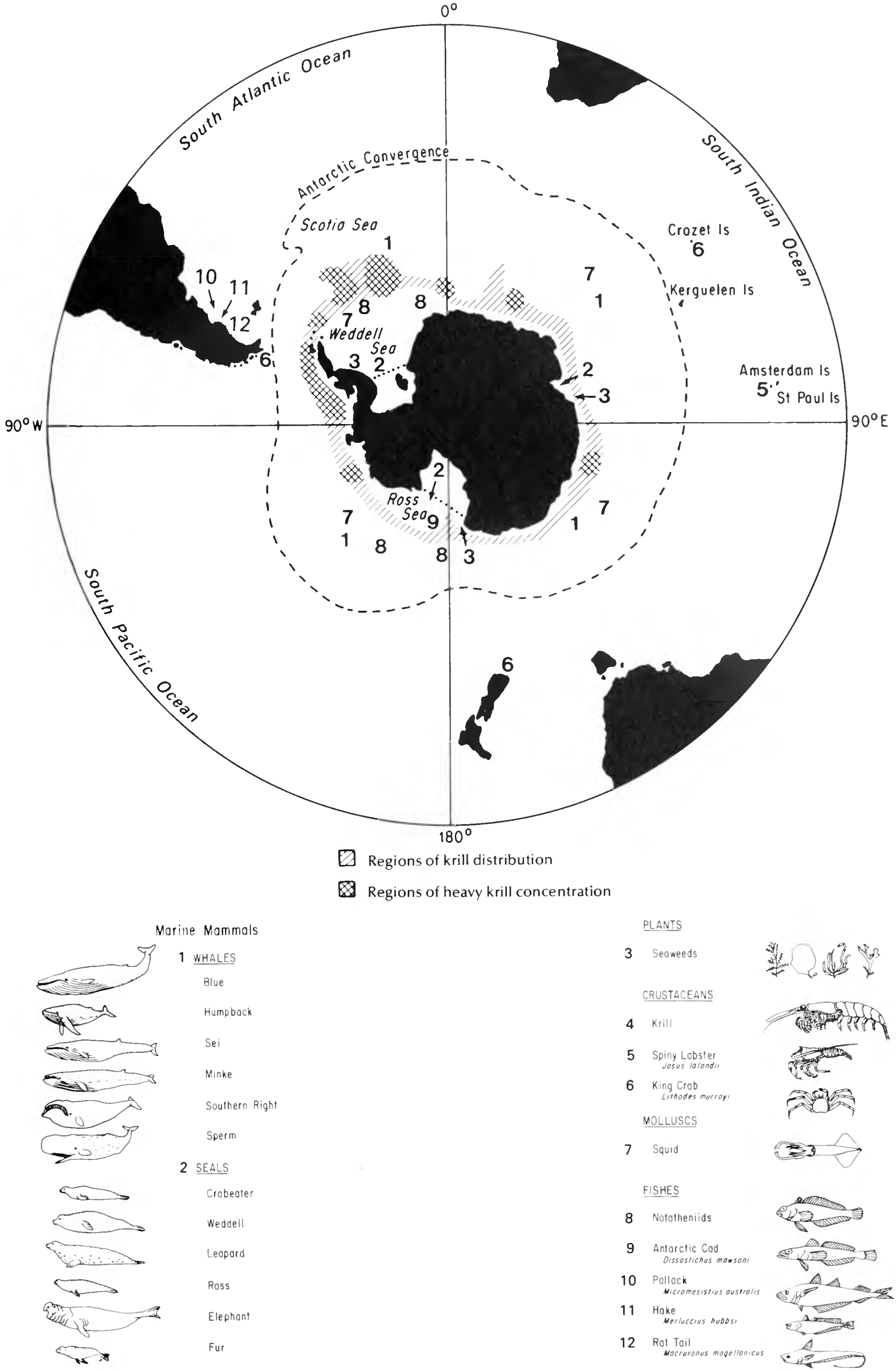

Figure 5. Living resources of the Southern Ocean.

gradually expanding knowledge about krill. The convention will set up a commission to facilitate research, compile and publish data, identify conservation needs, adopt conservation measures, and generally work toward implementing the conservation principles so strongly advocated by the scientific community.

Future Research Needs

The foregoing overview of the possibility of a large krill fishery in Antarctic waters is intended to put the idea into a realistic perspective as opposed to the optimistic view of many, who see it as a panacea for the problem of world protein needs. As present studies show, this ecosystem is not "simplistic"; a great deal of information is lacking in areas of critical concern, such as biology, distribution, and stock assessment, among others.

In any development of a successful fishery, research programs should be designed so as to consider the entire ecosystem. The "species-by-species approach" has, time and again, proven inadequate and faulty. Thus any attempt at harvesting a single species without regard to possible effects on other components in the system may set up irreversible reactions that will result in major changes in the ecosystem. This is especially evident in the Antarctic, where the ecosystem is considered simple, where some of the dominant krill consumers already are under protective conventions, where harvesting comes close to an area that is protected by international treaty, and where long-term nutritional benefits are tightly coupled with conservation goals.

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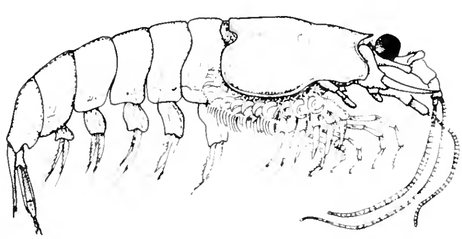

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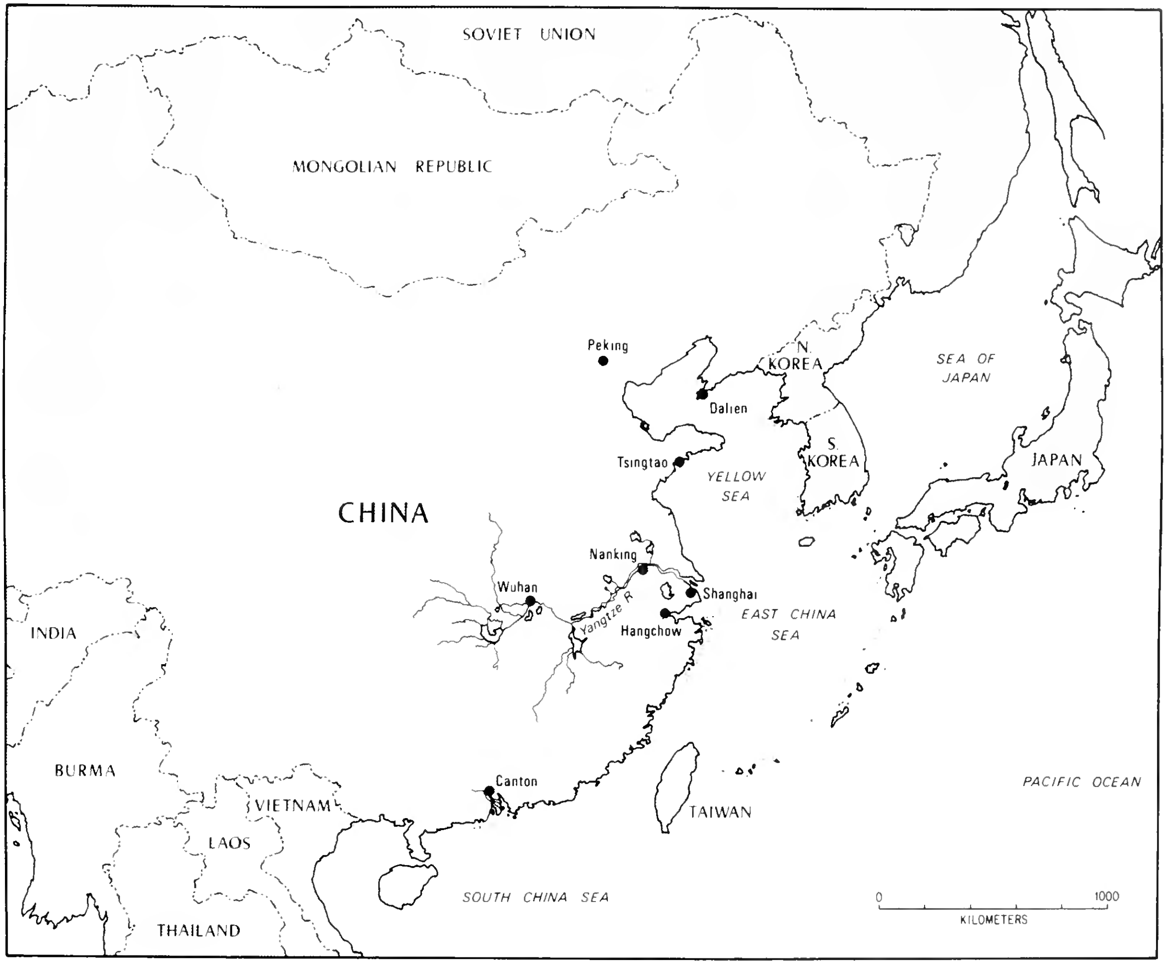
AQUACULTURE IN CHINA



by John H. Ryther

EDITOR'S NOTE: The author visited the People's Republic of China for a month in the fall of 1978 as part of a 10-member delegation of American oceanographers. He traveled to nine locations, including the country's largest oceanographic center at Tsingtao. The following article is based on his visits to both marine and freshwater aquaculture sites.

Freshwater fish production in China probably exceeds that of the rest of the world combined, perhaps by as much as several-fold. The total world production from all forms of aquaculture was recently placed at six million metric tons in a report by the National Academy of Sciences. That figure is unrealistic, however, since no reliable data were then available from the People's Republic of China. In fact, such data may not exist, but some reasonable estimates can now be made on the basis of information recently obtained.

Several independent studies have placed the total area of freshwater in China at about 20 million hectares (50 million acres). About half of that area is suitable for fish culture, and in keeping with the Chinese principle of multiple, intensive use of all natural resources, virtually all suitable waters are stocked with fish and managed to some degree.

About half of the 10 million hectares of managed freshwater consists of large, natural lakes or man-made reservoirs which, because of their size, receive less intensive management than small bodies of water — for example, no feeding, fertilization, disease, or predator control. Annual yields from these larger bodies of water vary widely, reportedly ranging from 50 to 5,000 kilograms per hectare. For example, the yield reported for Tung (East) Lake near Wuhan, which covers an area of 1,500 hectares and is managed by provincial culturists, is 450 kilograms per hectare annually, while that from West Lake near Hangchow, a 560-hectare body of water, is 1,300 kilograms per hectare.

The remaining 5 million hectares of managed freshwater are small, intensively farmed ponds. For the most part, these are managed by agricultural communes, by fish-farming communes, and communes that farm fish as an ancillary activity. In the agricultural communes, fish farming is closely integrated within the total food production system, whereas the fish-farming communities, in addition to fish production, also provide fingerling stocks for the agricultural communes.

The smaller, more intensively managed fish ponds are more productive, yields ranging widely from about 1,000 to 10,000 kilograms per hectare per year, and averaging perhaps 3,000 kilograms per hectare per year. In 1977, the Ching Po Fish Farm outside Shanghai produced 4,600 kilograms per hectare, expected to see a yield of 5,600 kilograms per hectare in 1978, and aspired to an annual yield of 7,500 kilograms per hectare — the reported performance of a nearby farm in Kanus Province.

Estimating yields of the less intensively managed larger lakes and reservoirs at a conservative 500 kilograms per hectare and that of the smaller fish farms at 3,000 puts total annual production of freshwater fish at about 17.5 million metric tons. Clearly this figure — nearly 25 percent of the total annual landings from all oceans — needs verification, but whatever the correct number, it would appear to be significantly greater than earlier estimates of China's freshwater fish production.

This yield also appears to be considerably larger than China's total marine fish landings, estimated at 3.1 million metric tons per year. The latter figure, hitherto unavailable to fishery statisticians, was derived from interviews with fishery biologists located at different points along the Chinese coastline. It is certainly not an insignificant figure — American fishermen only landed 2.3 million metric tons in 1977 — though the marine catch is almost dwarfed by the apparent contribution from aquaculture.

The combined yields from aquaculture and marine fishing — 20.6 million metric tons — is equivalent to a per capita fish consumption of about 45 pounds per year for the one billion or so inhabitants of China. This is not unreasonable for a country that so highly prizes fish as a food and whose other sources of animal protein are severely limited. It is significantly greater than the 17 pounds per year eaten by the average American, but we are not a fish-eating society. The Chinese figure is precisely the same as that of Sweden, and two-thirds that of Japan.

There are nine marine fishing corporations located along China's coastline. The second largest of these, located in Dalien, is an organization that builds, maintains, and operates 150 fishing and support vessels; owns its own freezer, ice plant, net manufacturing plant; and conducts its own processing, packing, sales, and distribution. Much of its annual catch of about 75,000 tons is frozen. Some of the more valuable species, such as shrimp, are exported to the United States and elsewhere. The bulk of the catch, however, is distributed throughout China.

The nine large fishing corporations combined only account for about a half million metric tons, or 16 percent of the total marine landings. The rest of the catch is landed by hundreds of thousands of fishermen in small boats at remote coastal villages that have little or no processing, refrigeration, freezing, or distributional facilities. The catch, therefore, must be consumed quickly and locally.

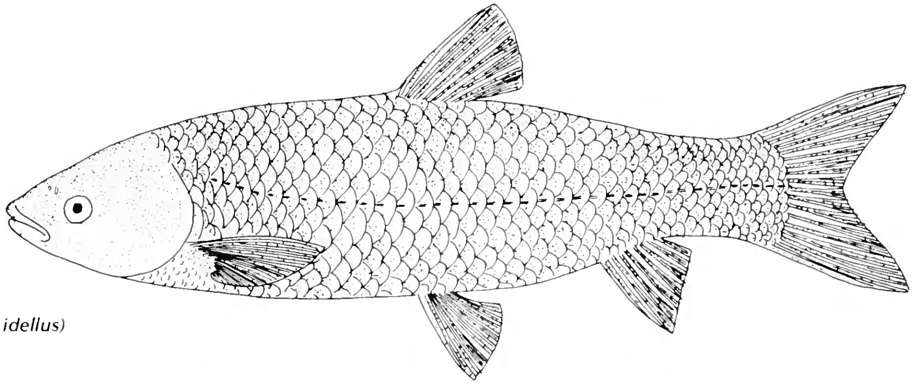
We can see then the importance of aquaculture in providing the large Chinese populace with an abundant supply of high-quality, extremely popular animal protein at reasonable cost. The distribution of farm ponds throughout the country, particularly in the south where water is abundant, makes it possible to market fresh fish without the problems of large-scale processing, freezing, and distribution.

In the size range of two to four pounds, fresh, pond-grown carp sell in the retail market for about the equivalent of 50 cents a pound. Smaller fish sell for about half that price. Chicken, duck, and pork, the other common forms of animal protein, are rationed because they are in short supply, and cost two to three times the price of fish.

How the System Works

Aquaculture in China owes its success to a number of factors. The multiple use of aquatic resources, referred to earlier, is probably the primary one. Reservoirs and smaller farm ponds may be constructed initially for irrigation or domestic water supply, but for the Chinese policy maker it is inconceivable that they not be simultaneously used, and to the limits of their capacity, for fish production.

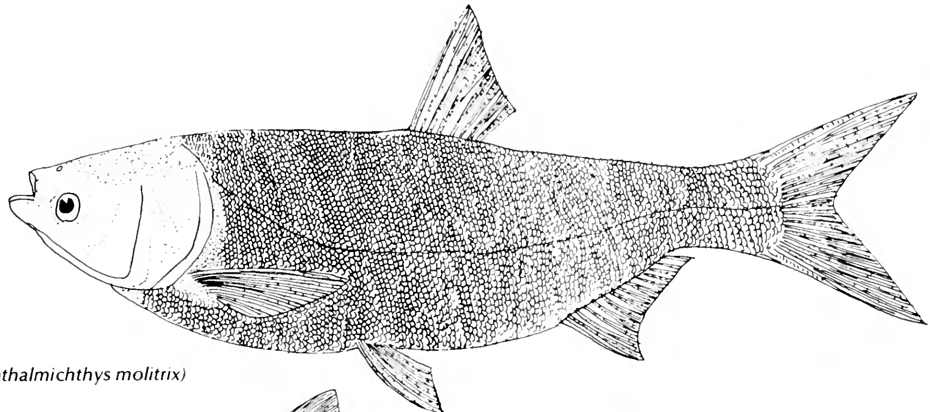
From its beginning, fish pond culture in China has always been considered an integral part of agriculture. The terrestrial and aquatic farms supplement each other in a number of important ways that increase yields of each component part. And mixed species cultivation or "polyculture" is



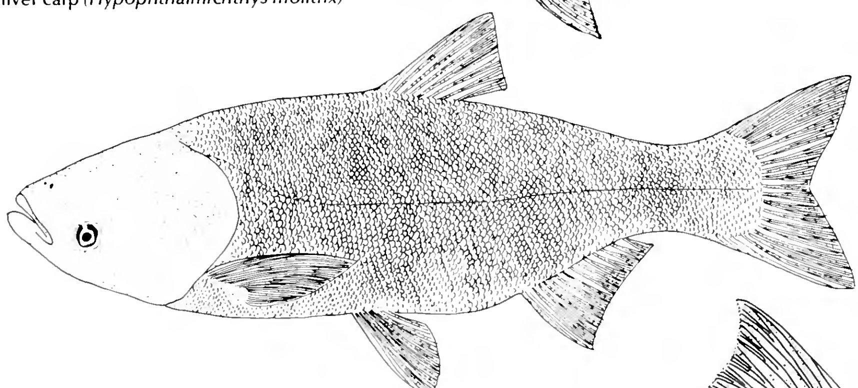
Grass carp *(Ctenopharyngodon idellus)*

universally applied, with particular emphasis on species low in the food chain.

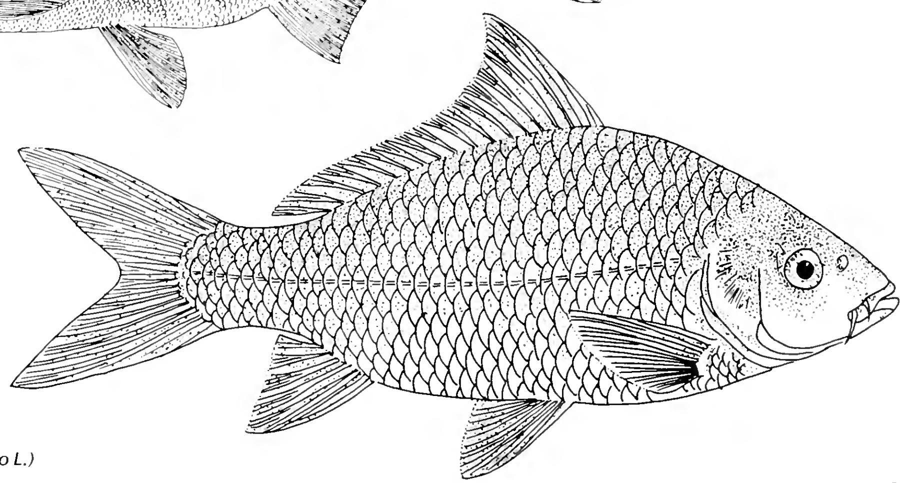
Virtually all of the fish species used in Chinese pond culture are cyprinids (minnows). The four most important and most universally used (the so-called major or Chinese carps or "family fishes") are the grass carp, *Ctenopharyngodon idellus,* the silver carp, *Hypophthalmichthys molitrix,* the bighead carp, *Aristichthys nobilis,* and the black or snail carp, *Mylopharyngodon piceus.* Also used are smaller numbers of mud carp, *Cirrhinus molitorella,* common and mirror carp *Cyprinus carpio,* golden and crucian carp, *Carassius auratus,* and the pond fish *Tilapia* (see page 29).



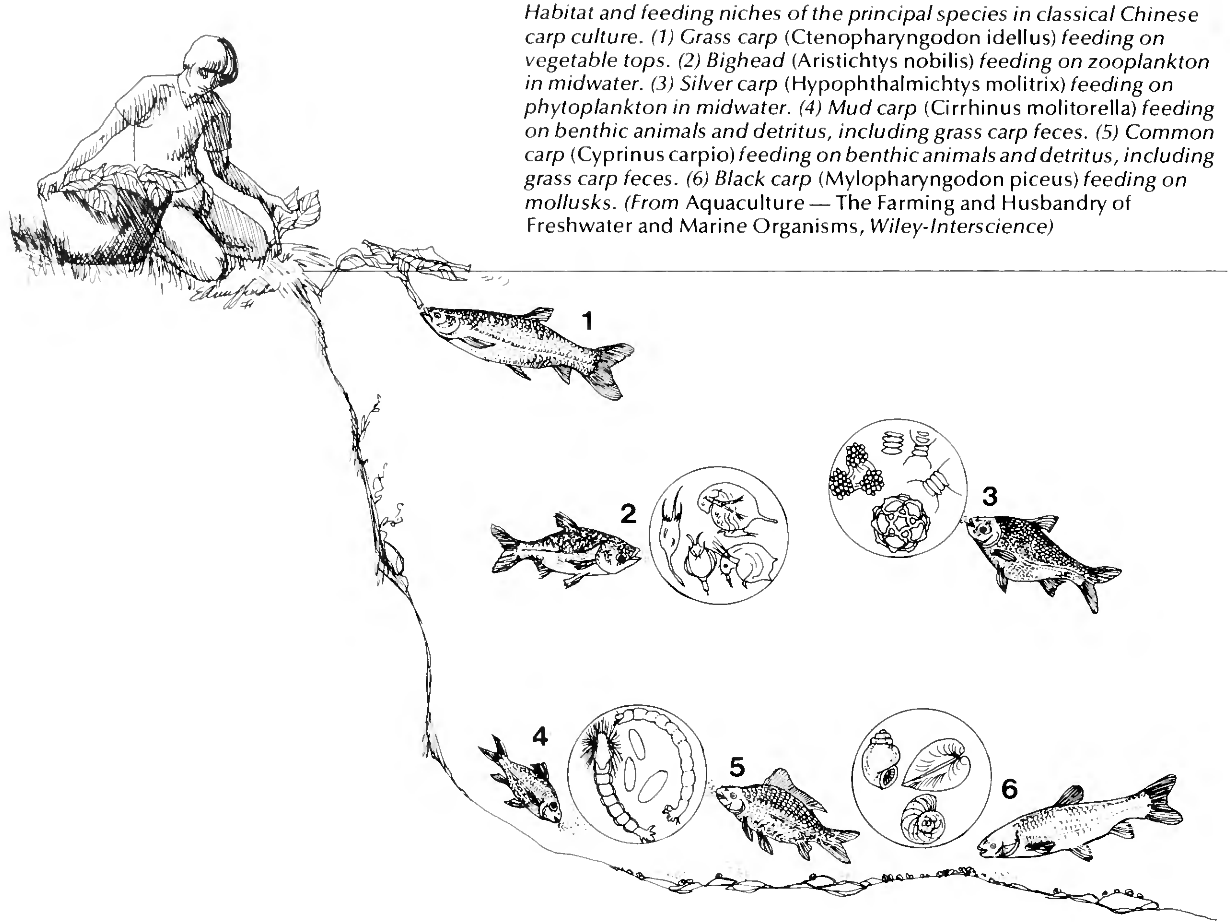
Silver carp *(Hypophthalmichthys molitrix)*



Bighead carp *(Aristichthys nobilis)*



Common carp *(Cyprinus carpio L.)*



Habitat and feeding niches of the principal species in classical Chinese carp culture. (1) Grass carp (Ctenopharyngodon idellus) *feeding on vegetable tops. (2) Bighead* (Aristichtys nobilis) *feeding on zooplankton in midwater. (3) Silver carp* (Hypophthalmichtys molitrix) *feeding on phytoplankton in midwater. (4) Mud carp* (Cirrhinus molitorella) *feeding on benthic animals and detritus, including grass carp feces. (5) Common carp* (Cyprinus carpio) *feeding on benthic animals and detritus, including grass carp feces. (6) Black carp* (Mylopharyngodon piceus) *feeding on mollusks. (From* Aquaculture — The Farming and Husbandry of Freshwater and Marine Organisms, *Wiley-Interscience)*

The grass carp is a herbivore that normally eats aquatic macrophytes (both rooted and unattached and submerged and floating aquatic weed species); it also will feed voraciously on terrestrial plant wastes, such as cut grass and vegetable tops. Although fast growing (5 to 10 kilograms per year, or more), the grass carp is highly inefficient in its utilization of food, producing large quantities of organic wastes. This material settles to the bottom, supporting a community of benthic invertebrates that, in turn, serve as food for the black, common, mud, and golden carps. The wastes also decompose, liberating nutrients that support communities of phytoplankton and zooplankton, which in turn serve as the principal food for silver and bighead carps. The planktonic populations are further enhanced by periodic fertilization of the ponds with fermented pig manure or other organic wastes, such as that from ducks (often raised in the same ponds with the fish). It is the combination of polyculture, which takes advantage of every feeding niche in the pond ecosystem, and utilization of agricultural wastes that results in the low-cost, high-yield achievements of Chinese pond culture.

The major carps normally live in large river systems, and they are unable to spawn naturally in the stagnant farm ponds. Up to 1958, the industry depended on the annual collection of fingerlings from their natural environment, but then an artificial spawning method was developed that involved injecting the fish with common carp pituitary extract or with human chorionic gonadotropin. Today most provinces in fish-farming regions of China have a commune that specializes in hatchery production and rearing of fry for distribution to other communes. The personnel in these specialized communes are accomplished in such fields as controlled induced spawning, selective breeding, larval rearing, disease prevention and treatment, and nutrition — areas normally requiring considerable training and experience in the Western world. At the Ching Po Fish Farm, workers claimed that they usually could diagnose, treat, and cure a disease problem in three days. They added that normal survival rates for fingerlings to marketable adults ranged from 90 to 95 percent. Members of all the fish farming communes take great pride in their ability to solve their own problems — even to conduct their own research as needed, independent of the academic or government research communities. The kinds of research that such production units can accomplish, however, are necessarily empirical, focused on immediate problems.

A bighead carp breeder seined from a fish pond at a fish-farming commune near Shanghai.

Institutional Research Programs

More basic research on freshwater fish culture problems is conducted on the provincial and national levels at a number of universities and institutes. At the Institute of Hydrobiology at Wuhan, for example, both basic and applied research is done on fish breeding and genetics, disease control, and the primary productivity of lakes and reservoirs.

The grass carp, the essential first-stage herbivore in the Chinese polyculture system, is difficult to rear in the early stages of its life cycle, being subject to severe disease problems. Scientists at the Wuhan Institute have successfully brought into culture another herbivore, the Chinese bream, *Megalobrama amblycephala,* which is hardier, perhaps superior as a table fish, and fills the same ecological niche as the grass carp. That fish has now been successfully introduced into 20 of China's provinces.

The same laboratory also has successfully crossbred several closely related cyprinids (for example, different varieties of the common carps) producing hybrids that are fertile, breed true, and grow faster and larger than either parent stock. These also are now available for distribution throughout China.

The ecological unit at the Institute of Hydrobiology studies the productivity of the larger lakes and reservoirs in China, including the 1,500-hectare basin of Wuhan's East Lake, which they selected as a model study area. The objective of this group is to determine the maximum carrying capacity of the lakes and reservoirs so that they can be stocked to that level, thereby achieving maximum potential yield without stunting or stressing the fishes. Other objectives are to determine the proper stocking ratios of different species so as to maximally utilize all feeding niches, and to stock the proper number of grazing and filter-feeding herbivores so as to preserve a desirable level of aquatic macrophytes and phytoplankton for aesthetic purposes, since the lakes also are used heavily for recreation. To achieve these objectives, the staff studies chemical nutrient cycling, primary productivity, and the distribution of phytoplankton and zooplankton, with the ultimate hope of developing a numerical model for predicting potential fish yields.

During the early 1970s, an ovulating agent for induction of spawning by farm fishes was successfully synthesized, tested, and evaluated through a cooperative research project involving the Shanghai Institute of Biochemistry, the Peking Institute of Zoology, and other organizations. The agent (an analog of the nonapeptide LH-RH) is now commercially available, though the extent to which it has replaced the use of carp pituitary (still used exclusively in the United States, and elsewhere) is not known.

Marine Aquaculture

Marine aquaculture is a more recent innovation in China, dating from post-revolutionary times. Many marine species are being grown experimentally along the entire Chinese coastline. These include the seaweeds *Laminaria japonica* (kelp), *Undaria pinnatafida, Porphyra yezoensis, P. quangdongnesis, P. haetanensis, Gracilaria* *verrucosa, Eucheuma gelatinae,* and *Ligera* sp.; the mussels *Mytilus edulis, M. virides,* and *M. smarajdinus;* the oysters *Ostrea rivularis, O. plicatula,* and *Crassostrea gigas;* the clam *Arca granosa;* the scallop *Chlamys farreri;* the sea cucumber *Stichopus japonicus;* the penaeid shrimp *Penaeus orientalis, P. merguiensis,* and *P. monodon;* the pearl oyster *Pinctada martensci;* the crab *Erochier sinensis;* and certain finfishes, including mullet, *Mugil so-iuy,* and milkfish, *Chanos chanos.* Several of these species are already in some form of commercial production, but data are not generally available.

The most important cultivated marine organism is the brown seaweed, *Laminaria japonica,* a cold-water species of kelp originally introduced to China from Hokkaido, Japan. Formerly imported from Japan, *Laminaria* is now grown in more than 3,000 hectares of China's northern coastal waters with a production of some 10,000 dry tons per year, roughly half of which is consumed directly as food and half of which is used for the extraction of alginates. More than 1,000 dry tons per year are now exported to Japan, where production is declining.

Kelp culture is started in one of 15 hatcheries in northern China. Such hatcheries are essentially large greenhouses covering shallow tanks through which fertilized, refrigerated (5 to 8 degrees Celsius) seawater is circulated. Kelp spores attach in the spring to 50-meter-long strings wound on wooden frames that are submerged in the hatchery tanks, the spores developing to 2 to 4 centimeter sporelings during the summer and early fall. When the coastal seawater temperature drops below 20 degrees Celsius, the strings, with the sporelings attached, are removed from the wooden frames, moved outside, and attached to buoyed ropes. During the following six to eight months, the plants are manually thinned, transferred to larger ropes, carefully brushed individually to remove sediments and epiphytes, and fertilized daily. They thus grow to mature sporophytes, ranging in length from 3 meters in the Tsingtao area to more than 5 meters in Dalien, where the water cools more quickly in the fall and the growing season is longer. Annual kelp production in the two areas is roughly 30 and 50 dry tons per hectare, respectively. The wholesale value of dry kelp in China is equivalent to 60 cents a pound.

The cultivation of the red seaweed, *Porphyra,* is a more recent introduction, still undergoing development. Essentially the same technology is used for growing this alga in China as is employed in Japan. Since the latter has been thoroughly documented elsewhere, the practice will not be described here except where there is a significant difference. A recent Chinese innovation is to spread the nets (to which the spores and later the mature plants are attached) under floating bamboo rafts, in contrast to the fixed nets attached to poles driven into the bottom, which are used in Japan. The floating rafts keep the plants permanently at or just below the surface and this has reportedly enhanced yields greatly. Another departure from Japanese *nori* culture is the fertilization of the *Porphyra* beds, accomplished by attaching small plastic bags of fertilizer to each bamboo raft through which the nutrients slowly diffuse as they dissolve.

The small, cold-water species of *Porphyra (P. yezoensis),* which was also introduced from Japan, is grown in northern China, where a yield of about 0.6 dry tons per hectare per year is obtained. In the South China Sea region, the more tropical *P. haitanensis* is grown, reportedly reaching a length of more than 9 meters in contrast to *P. yezoensis,* which grows to about 1 meter in the north. Yields of *P. haitanensis* from large production units are on the order of 8.5 dry tons per hectare per year and those from small, experimental units are reported to be as high as 20 tons per hectare per year. Yields of *Porphyra* in China, though significantly higher than those in Japan, are much less than those of *Laminaria,* but the higher price of *Porphyra,* more than five dollars per pound dry, makes its cultivation popular.

The City of Tsingtao is China's main center for marine research, harboring the Institute of Oceanography (Chinese Academy of Sciences), Shantung College of Oceanography, and the Yellow Sea Fisheries Institute (National Bureau of Fisheries). The Deputy Director of the Institute of Oceanography, C. K. Tseng, is a phycologist who received his doctorate from the University of Michigan, later working at Scripps Institution of Oceanography in California before returning to China. T. C. Fang, Chairman of the Biology Department at Shantung College, is a noted algal specialist. Understandably, then, there is emphasis within the Tsingtao scientific community on seaweed research.

Scientists at the Institute of Oceanography have had considerable success (through X-ray-induced mutation and selective breeding) in developing pure strains of *Laminaria* that grow more rapidly than wild populations, contain more iodine, and can tolerate high temperatures. The latter feature is an important attribute that allows extension of the species' southern range and a corresponding expansion of the *Laminaria* culture industry.

Fang is carrying out interesting and highly original basic genetic studies on *Laminaria.* By treatment with colchicine at low temperatures, he has been able to induce the microscopic female gametophyte of *Laminaria* to develop parthenogenetically into a large, undifferentiated cell mass (callus). Each callus may be considered as a genetically pure clone that can be maintained indefinitely — each cell of which, when isolated and

One of the large greenhouses used as kelp nurseries in Tsingtao.

returned to its normal environment, will develop into a normal female sporophyte (or commercially valuable seaweed plant). This pioneer work in seaweed genetics opens the door to the development of pure-breeding, improved stocks of this important seaweed, following in the footsteps of modern higher plant genetics.

Mussels, Scallops, and Shrimp

In both the Tsingtao and Dalien regions, the same fishing communes that culture seaweeds also culture several kinds of invertebrates. Mussels, *Mytilus edulis,* are grown on buoyed ropes, using essentially the same techniques as those developed in Spain and now widely adopted in many other countries, including the United States. About 18 months is required for the mussels to reach marketable size: there are two crops a year, spring and fall, producing about 480 tons (shells included) per hectare (compared to some 600 tons per hectare per year in Spain for the same species).

Smaller numbers of scallops, *Chalamys farreri,* are grown in the same areas, the juveniles suspended from ropes in layered "lantern baskets." Sea cucumbers, *Stichopus japonicus,* also are released on the bottom as juveniles beneath the *Laminaria* and/or *Mytilus* cultures, where they live on sinking detrital material produced by the plants and animals above. The non-motile animals are harvested by divers two years later when they reach a marketable size of 8 to 10 centimeters. The mussels, scallops, sea cucumbers, and several other species of invertebrates (abalone, clams, oysters) are relatively recent introductions, still largely in the experimental stage. The production units themselves do most of the empirical experimentation, including spawning and larval rearing in their own hatcheries. For example, at the Chin Hsien County Aquaculture Station near Dalien, seed scallop production has increased from 1.7 million in 1977 to 7.9 million in 1978 through the use of improved spawning and larval rearing techniques.

Several of the same species of penaeid shrimp that are grown successfully in many parts of Southeast Asia are also cultivated in the South China Sea coastal area, using essentially the same methods and gaining the same results. But in the East China Sea and Yellow Sea coastal regions, the large "Chinese" shrimp *Penaeus orientalis* is also grown with considerable success. According to Liu Jiu-yu, crustacean specialist and Head of the Zoology Department at the Institute of Oceanography, *P. orientalis* routinely matures sexually in captivity in holding ponds, in contrast to other penaeid shrimp species cultured elsewhere, where gravid females must usually be taken from the commercial fishery to obtain the young. Larval

Multi-layered "lantern" nets used for scallop culture.

stages are hatchery reared as is done elsewhere and post-larvae are grown to more than 15 centimeters (25 grams) in length in less than five months, making it possible to grow the animals to a large marketable size in one brief season.

This relatively temperate-water, easily grown shrimp species would appear to be of potential interest to culturists elsewhere in the world, including the United States. It could be one of the first Chinese contributions to aquaculture in the United States in what one hopes will be a new era of marine scientific exchange between the two countries.

An Example to Learn From

China has long been recognized as both the pioneer and the most successful practitioner of fish farming in the world. What has not been fully appreciated is the magnitude of that success or the broad diversity of new efforts in Chinese aquaculture, particularly in the oceans.

With the field of aquaculture still struggling to fulfill its promise almost everywhere else in the world, it is gratifying to see the Chinese example, and challenging to contemplate how we may benefit from that experience.

John H. Ryther is a Senior Scientist in the Biology Department at the Woods Hole Oceanographic Institution.

The carp drawings accompanying this article were done by Dr. Shao-Wen Ling, appearing in his book *Aquaculture in Southeast Asia,* a University of Washington Sea Grant publication, 1977.

APRIL 1979

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Exotic Species in Aquaculture

by Roger Mann

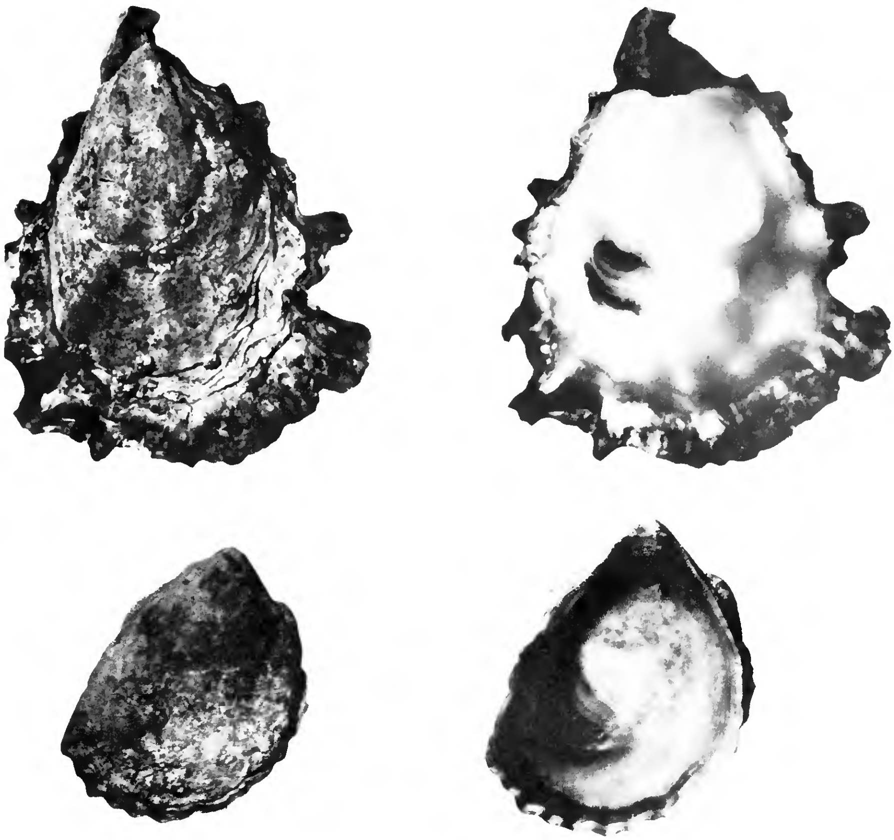
The introduction of an exotic (non-native) species can be a highly unpredictable and potentially harmful act, with results ranging from total failure to reproduce to practically uncontrolled proliferation of the species in the new environment (the freshwater weed *Hydrilla verticillata* is a good example of the latter). Despite the unpredictable nature of such actions, man has successfully transferred large numbers of both terrestrial and aquatic species for such diverse purposes as biological control programs, food sources, soil stabilization, and ornamentation (aquarium species). Table 1 lists a small number of important aquatic food species and their present ranges resulting from introduction programs. There are many more!

An Atlantic salmon of the type introduced into the New Zealand range. (Photo courtesy U.S. Fish and Wildlife Service)

Table 1. Important aquatic food species and their ranges resulting from introduction programs.

Species	Native Range	Introduced Range
MARINE		
Pacific Salmon *(Onchorynchus sp.)*	North Pacific	Chile Tasmania New Zealand Maine New Brunswick Ontario
Atlantic Salmon *(Salmo salar)*	North Atlantic	New Zealand
Shad *(Alosa sapidissima)*	U.S. East Coast	Pacific Coast: Northern Mexico — Alaska
Striped Bass *(Roccus saxatilis)*	Florida Gulf of St. Lawrence	U.S. Pacific Coast
European Oyster *(Ostrea edulis)*	Scandinavia-Black Sea	Maine Nova Scotia California
Japanese Oyster *(Crassostrea gigas)*	Japan Korea Taiwan	Pacific Coast: British Columbia — California Sweden United Kingdom France West Germany Cyprus Israel South Africa Brazil Australia New Zealand Hawaii
Soft Shell Clam* *(Mya arenaria)*	Northern Europe East coast of North America	Pacific Coast of North America
Manila Clam* *(Tapes japonica)*	East Asia: Japan, Philippines	Pacific Coast: California — British Columbia Hawaii
FRESHWATER		
Brown Trout	North America	East Africa
Rainbow Trout	Europe	New Zealand Bolivia
Grass Carp *(Ctenopharyngodon idellus)*	China	Global
"Walking"Catfish *(Clarias batrachus)*	Asia	Florida
Tilapia *(Tilapia mossambica)*	Africa	Southeast Asia

*Often considered as accidental introductions associated with oyster transportations.



Pacific or Japanese oyster, Crassostrea gigas *(top), and native or Olympia oyster,* Ostrea lurida.

From a commercial point of view, man's most successful transplants within the marine environment probably have been salmon species, *Onchorhynchus,* and oysters, most notably the Japanese oyster, *Crassostrea gigas.* In freshwater systems, good examples of widely introduced organisms are carp, *Cyprinus,* and the pond fish, *Tilapia.* These introductions were made to either create a new fishery (salmon in New Zealand), replace a fishery that declined through overfishing or disease (Japanese oysters in the United States and France), or to enhance local food production (carp in Israel and *Tilapia* in Southeast Asia).

Thus there are a mixture of biological, sociological, and economic reasons for the introduction of an exotic species, ranging from a lack of species to culture to the establishment of a new industry or the maintenance of an existing one. The following case histories of introductions illustrate both the uniqueness of each introduction and the long time scale that may be required to get a satisfactory result.

The Japanese Oyster in North America

The native oyster on the Pacific coast of North America, *Ostrea lurida,* grows slowly and to only moderate size. It was first fished in 1850: by 1900, stocks were dwindling. The first unsuccessful attempt to introduce the Japanese oyster to the state of Washington was made in 1902. Subsequent sporadic introductions were made with only moderate success until 1919, when the discovery was made that small, seed oysters survived transit from Japan in much better condition than did adults. Further shipments of seed oysters were obtained, and the oyster industry grew rapidly. Some 2,000 of these oysters were transshipped from Washington to British Columbia in 1925 to enhance those present from previous, small introductions. Meanwhile, oyster growers in California and Oregon also became interested in the Japanese oyster. Importation from Japan continued to increase in volume and, with the exception of the war years and 1978 (when Japan banned oyster exports due to domestic shortages), has continued to the present day. The magnitude of this trade is illustrated by the fact that since 1947 more than 1.3 million cases of oyster seed have been imported to the United States.

A major problem in maintaining the Pacific coast fishery for Japanese oysters has been the

Table 2. Undesirable species introduced accidentally with oysters.

Species	Native Range	Introduced Range
Slipper limpet *(Crepidula fornicata)*	North America, Atlantic Coast	North America, Pacific Coast Western Europe
American oyster drill *(Urosalpinx cinerea)*	North America, Atlantic Coast	North America, Pacific Coast Western Europe
Japanese oyster drill *(Ocenebra japonica)*	Japan	Strait of Georgia
Shipworm *(Limnoria tripunctata)*	Japan	Strait of Georgia
Predatory flatworm *(Pseudostylochus ostreophagus)*	Japan	Washington British Columbia
Seaweed *(Sargassum muticum)*	Japan	Strait of Georgia Vancouver Island
Parasitic copepod *(Mytilicola orientalis)*	Japan	Washington British Columbia

availability of seed oysters for transplanting to areas suitable for on-growing to market size. In British Columbia, breeding is limited to several isolated locations because water temperatures are rarely high enough to stimulate spawning. Successful breeding occurred in 1926, 1936, 1942, 1958, 1961, and sporadically since then. It is probable that sufficient seed for domestic requirements could now be produced within the province; however, attaining this goal has required more than 50 years of continued effort. The industry is presently expanding and could produce more than 6,000 metric tons of whole oysters annually by the early 1980s.

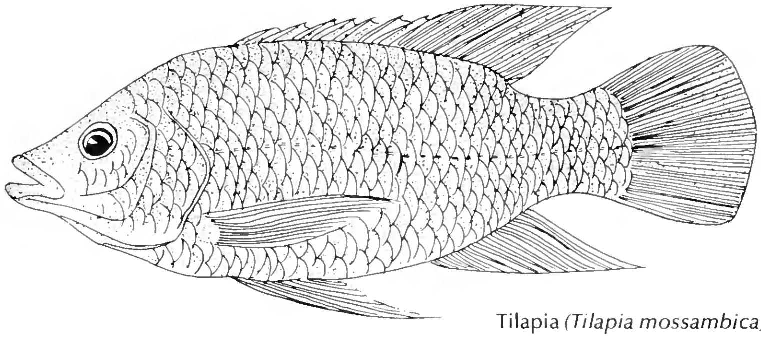
In the state of Washington, domestic seed oyster production areas exist in Willapa Bay and Hood Canal, but oyster growers have continued to import seed from Japan. This practice will undoubtedly decrease in future years as the dollar-yen exchange fluctuations cause prices to rise and Japanese seed production is channeled to domestic use. The role of American commercial shellfish hatcheries in filling the vacated supply will probably increase.

The present domestic Pacific coast oyster industry, which produces more than 6.5 million pounds of oyster meat annually, and that of British Columbia have developed through the efforts of private individuals rather than government agencies. In fact, it is probable that government agencies in the United States and Canada were unaware of the original introductions. Inspection programs for imported seed were not implemented until 1946. Certain undesirable organisms have accompanied introduced seed (Table 2); the overall result of the introduction, however, must be viewed as beneficial in that the economic gains have been substantial.

The Japanese Oyster in France

Before the introduction of the Japanese oyster, the industry in France was based on two species; the European oyster, *Ostrea edulis,* and the Portuguese oyster, *Crassostrea angulata.* During 1970-71, populations of the latter were decimated by an epizoan disease. An immediate severe economic problem resulted, and urgent reparative action was required. The French government had been investigating the growth of small, experimental populations of Japanese oysters in French waters since 1968. Their results were favorable, and a decision was made to import the Japanese oyster as a replacement for Portuguese oyster stocks. The scale of this undertaking is illustrated in Table 3. The Japanese oyster bred prodigiously in the new habitat and now is found in all of the sites formerly occupied by the Portuguese species. In fact, breeding has been so successful that some growth inhibition due to overcrowding is now evident. Further importations of Japanese oysters to France have been forbidden.

The French oyster industry avoided severe short-term economic hardship by introducing the Japanese oyster. The introduction therefore could



Tilapia *(Tilapia mossambica)*

be viewed as beneficial; the long-term impact of the action, however, cannot be predicted.

Tilapia in Southeast Asia

Although the general theme of this issue is harvesting the sea, the case history of *Tilapia* is described because it probably represents the most successful of all introduced aquaculture species in terms of total food production. *Tilapia mossambica* is a native freshwater fish of Africa. It was originally exported to Southeast Asia as an ornamental aquarium fish, and it subsequently escaped. At the beginning of World War II, the traditional collection of milkfish fry, *Chanos chanos,* from coastal waters for stocking culture ponds was prohibited. *Tilapia* was examined as an alternative species. Initial efforts were successful, and the species rapidly spread from Indonesia to Singapore, Malaya, Thailand, Hong Kong, the Philippines, Vietnam, Cambodia, Laos, Taiwan, and China. Today it is the most important pond-cultured fish in Southeast Asia — found in ditches, ponds, canals, reservoirs, and rice fields. It provides a valuable source of protein in these poor nations.

Table 3: Importations of seed Japanese oysters (in millions) by France during the period 1968-77. (500,000 seeds=1 metric ton)

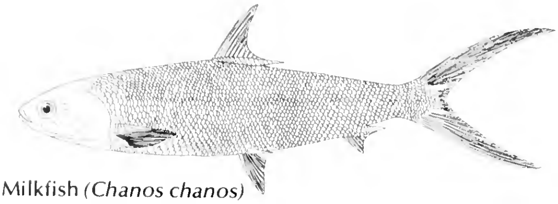
	Japan	British Columbia	Total
Year			
1968-69	*	*	0.15
1969-70	*	*	60
1970-71	*	*	200
1971-72	2,452	1,226	3,678
1972-73	4,826	2,413	7,239
1973-74	729	365	1,094
1974-75	1,930	965	2,895
1975-76	68	34	102
1976-77	10	5	15
Total	10,015	5,009	15,276.15

***No data available on source for 1968-71 introductions.**

Good Versus Bad Introductions

The three brief case histories described thus far generally can be regarded as beneficial introductions in that they alleviated an economic problem and/or provided food and a source of employment. They were not, however, without their deleterious effects; notably the accidental introduction of undesirable species occurring with oyster introductions (Table 2), and the potential of *Tilapia* to destroy the benthic algal mats that are the food source for milkfish. Many introductions result in serious biological problems that negate the advantages associated with the introduced species. It is the compromise of good and bad that must be considered when determining whether or not an introduction has been beneficial. The problem is further complicated by the fact that the introduced species' impact on its new environment may not be evident for a considerable period of time. For example, even after more than 50 years of Japanese oyster culture on the Pacific coast we are still unsure about its future as a self-sustaining species in that region.

Many long-term catastrophes, both aquatic and terrestrial, have resulted from introductions. The most disastrous perhaps have occurred in terrestrial systems — rabbits in Australia, Dutch elm disease in the United States, European rats in the Pacific Islands, and the giant snail, which has spread from West Africa to Madagascar, Mauritius, India, Ceylon, Malaya, Borneo, Hong Kong, Japan, Palau, New Guinea, and, most recently, Hawaii. In the marine environment, the slipper limpet has survived and bred vigorously in locations where oyster stocks — mostly American oysters, *Crassostrea virginica* — have failed (Table 2). In the freshwater canals of Florida, the walking catfish, *Clarias batrachus,* is spreading rapidly following the release of a small number of specimens from fish farms specializing in ornamental fishes. The walking



Milkfish *(Chanos chanos)*

catfish appears to be especially well-adapted to the Florida climate; it breathes air, and therefore can survive periods of drought, has the ability to cross small distances on dry land to find alternative waterways, and has an omnivorous diet that can easily adapt to the availability of different types of food.

Future Introductions: Biology and Policy

The introduction of an exotic organism is, in most instances, an irreversible step with unpredictable consequences. A total ban on the movement of plants and animals is unlikely. Introductions will be made. How then do we review future requests for introductions and, where desirable, effect them? H. J. Turner, a biologist who formerly worked for the State of Massachusetts at Woods Hole, has provided valuable guidelines on the subject of biological criteria for candidate species for introduction. He stated that introduced species should:

1) fill a need – caused by the absence of a similar desirable species in the locality of transplantation;

2) not compete with valuable native species to the extent of contributing to their decline;

3) not cross with native species, producing undesirable hybrids;

4) not be accompanied by enemies, parasites, or diseases that might attack native species; and

5) live and reproduce in equilibrium with its new environment.

The elimination of associated species (item 4 above), especially microorganisms, is difficult. The International Council for the Exploration of the Sea (ICES) has suggested that introduced stock should be imported to a quarantined hatchery for spawning. The original parent stock then would be destroyed, with only the progeny used for introduction. The present state of hatchery technology for marine organisms can provide certain safeguards against the introduction of associated organisms; however, it is not foolproof.

Turner's biological criteria for identifying candidate organisms for culture should be supplemented by a number of social, legal, and economic criteria. A checklist of relevant questions might be as follows:

1) Will the new species require an effort in consumer education to create a viable market?

2) Within the industry using the introduced species, are the potential beneficiaries of the introduction the same ones who will suffer should there be unforeseen problems? (For example, what will happen if the introduced species displaces another commercially valuable species or presents a particular problem to the food processor, but not the grower?)

3) Will a new or supplemental fishery create new employment?

4) Will the introduction result in decreased availability or desirability of the coastal zone for other uses such as recreation?

5) Can autonomous regions outside the area of introduction influence decisions if their own fisheries are liable to be impacted by dispersion of the exotic?

6) How can a compromise be reached between what may be a short-term social and economic gain, but a potential long-term environmental catastrophe?

When an introduction is first considered, many of the problems associated with the action might be minimized if there were a procedural process available to raise relevant questions, thereby identifying potential problem areas. W. R. Courtenay and C. R. Robins, both on the faculty at Florida Atlantic University, presented a procedural model in 1973 for considering introductions. It was based primarily on their experiences with fishes in Florida (more than 75 percent of the tropical fishes imported to the United States enter through Miami and Tampa, with many being transshipped) but is equally applicable to other organisms. The model consisted of seven parts: 1) a rationale for seeking the introduction, 2) the identification of candidate species, 3) a preliminary assessment of impact, using available literature and expertise, 4) extensive public review of the proposed introduction, 5) an experimental research project aimed at answering questions that might be raised by the introduction, 6) a review of the results of the experimental research and, 7) release (assuming the experimental research results are favorable) and continued monitoring of the exotic organisms in their new environment.

The fact that introductions often require extensive time periods to achieve beneficial effects is a desirable characteristic in that it may discourage the introduction of an exotic species. Where a

Walking catfish *(Clarias batrachus)*

Heavily planted seed bed of Japanese oysters in British Columbia.

depleted fishery is the stimulus for an introduction, restorative action should be considered. This may be difficult: in many instances, years of intense fishing with little or no regard for future years has left fishery management planners with tremendously difficult tasks of formulating comprehensive management plans; however, any restorative action to a depleted or depressed fishery is preferable to the introduction of an exotic.

In the absence of feasible restorative alternatives, how should the decision be made to proceed with an introduction? The lead agency charged with making the decision — probably a governmental or regulatory body — should obviously review all of the available data. But more important, it should encourage comment from a wider group of people than just those who are proposing the introduction. This should involve biologists, lawyers, economists, industry and/or fishery spokesmen, as well as state and federal enforcement agencies in the decision-making process. Obtaining and synthesizing viewpoints from these factions is not an easy task. If the various spokesmen are to be effective in communicating their viewpoints to the review board, they must identify the major issues involved in their area of expertise, condense them to manageable proportions, and explain them in a form intelligible to the layman.

If after full review the decision is to proceed, the task of introducing the exotic species remains. As noted earlier, ICES recommends that hatchery stock reared in quarantined systems be used for introductions. Compliance with this would require a commitment of considerable capital investment, high technology, hatchery systems, and the time necessary to produce a sufficient amount of progeny to supply a depleted market. Initial efforts probably would be the responsibility of government agencies, since few private industrial concerns would be willing to make such a long-term capital investment. Efforts should be made to incorporate a selective breeding program into the introduction program. The introduced species should be carefully observed following release, and the resulting data used as part of this selective breeding program to produce superior stocks for distribution to the new fishery as it develops. Throughout the whole introduction procedure, the utmost care should be exercised to avoid introducing associated pests, parasites, and deleterious microorganisms.

In conclusion, introductions should be discouraged due to their unpredictable nature, especially in situations where a native species is available as an alternative. Where there remains no alternative, they should be effected with extreme care.

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Drawings by Shao-Wen Ling, from *Aquaculture in Southeast Asia,* a University of Washington Sea Grant publication, 1977.

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Developing Countries and the New Law of the Sea

by John Gulland

The new regime of the seas, as it is emerging from the United Nations Conference on the Law of the Sea (UNCLOS) and — perhaps more clearly and decisively — from a series of national actions taken by countries to extend jurisdiction over their coastal fish resources, is having a profound effect on many aspects of world fisheries. It is, however, only one of a series of actions that are restructuring many aspects of international transactions. Of somewhat wider interest is the call for a new international economic order. This arose from the realization that the effect of many economic market forces is to increase the already serious gap between rich and poor countries. For example, manufacturers in the richer countries usually can control their prices, taking into account increases in costs; whereas primary producers — and many poorer countries depend on one or two primary products — are at the mercy of the open market. Such factors gave rise to a hope that the new Law of the Sea would lead to a redistribution of the benefits of ocean fisheries between rich and poor. Many thought that the fisheries of the poorer countries had been suffering from the activities of long-range fleets, and that under the new regime the developing countries would be able to take much greater advantage of their coastal resources.

Of the other forces leading to the development of a new regime of the seas, the most significant is the now fairly general acceptance that all fish resources are limited. The idea of completely unlimited access, implied in the traditional concept of freedom of the seas, has become inappropriate. The conservation and rational management of fishery resources requires some control over the amount of fishing. In the past, effective controls have been placed on the exploitation of a few high-seas fisheries (for example, on yellowfin tuna in the Eastern Pacific, and on whales). Generally, management measures were introduced, and the necessary administrative machinery set up, only after it was more or less universally agreed that action was needed. Naturally this meant that some measures were taken too late; as was the case with some issues of the International Whaling Commission during the 1960s. The limits on fishery resources and the increased rate of exploitation call for a reversal of this principle — any large-scale exploitation of a resource should take place only after it is clear that the resource can sustain the exploitation. Some entity must have clearly defined authority over each resource and its exploitation.

For some resources, this authority is becoming identified. Coastal states have full authority within their territorial sea; and they have very considerable authority as far as 200 nautical miles from baselines. The draft texts emerging from the Law of the Sea Conference — which have changed little in the recent rounds of negotiations — set limits on this authority by giving rights of access (under certain conditions) to non-coastal states when the coastal state does not fully utilize the resource. However, many of the conditions are open to various interpretations so that in practice, coastal states are likely to have full control, allowing foreign fishing only under their own conditions.

This clarity of authority does not extend to all resources. Some species (such as tuna and whales) are harvested, at least in part, beyond 200 miles, and many fish that never go beyond 200 miles do migrate along the coast between the areas of jurisdiction of two or more coastal states. The UNCLOS texts call on states to collaborate in conserving these resources, but do not specify how matters will be arranged to ensure that actions taken in different national zones, but affecting the same resource, will be consistent.

Effects of Extended Jurisdiction

The most striking effect of the new ocean regime is the coastal states' jurisdiction over a wide band of water. However, drawing this 200-mile band on a map gives a poor impression of its impact on fisheries. On a global scale, the effect is underestimated. Although there is a large area of high seas, very few fish are caught in these waters. Present catches beyond 200 miles (mostly tuna) are about 1 percent of the total world catch of marine fish, and even these stocks also occur within 200 miles, so that some coastal states will have a special concern in their rational utilization and management.

Considering the distribution within 200 miles, however, a quick glance at the map might lead one to overestimate the impact. The productivity of the oceans varies from region to

Table 1. Catches in major sea areas in 1976 and 1972, and for the latter year (one of the last years before extension of limits) catches by non-local fisheries.

Area	Total Catches (thousand metric tons) 1976	1972	Catches by non-local fisheries All Species (1972)	Tuna
North West Atlantic	3,461	4,327	2,292	10
North East Atlantic	13,329	10,699	3,667	1
West Central Atlantic	1,566	1,488	143	5
East Central Atlantic	3,557	3,111	1,930	180
Mediterranean, Black Sea	1,276	1,165	40	—
South West Atlantic	1,206	805	24	12
South East Atlantic	2,872	3,013	1,771	29
West Indian Ocean	2,111	1,809	201	67
East Indian Ocean	1,176	821	88	36
North West Pacific	17,232	14,531	2,936	—
North East Pacific	2,409	2,774	2,254	—
West Central Pacific	5,430	4,770	479	114
East Central Pacific	1,463	982	287	274
South West Pacific	380	275	199	100
South East Pacific	5,646	5,539	48	13
Total	63,114	56,109	16,359	841

region — it is much higher over the continental shelves than in the open ocean. The width of the shelf varies, but is generally less, and often considerably less, than 200 miles. Therefore, the outer part of the 200-mile zone is usually much less attractive to fishermen than the inner part. If the shelf is narrow, extending a coastal state's jurisdiction to 200 miles from, say, 12 miles, may only barely increase its fishery resources, instead of increasing them eightfold (see map page 38).

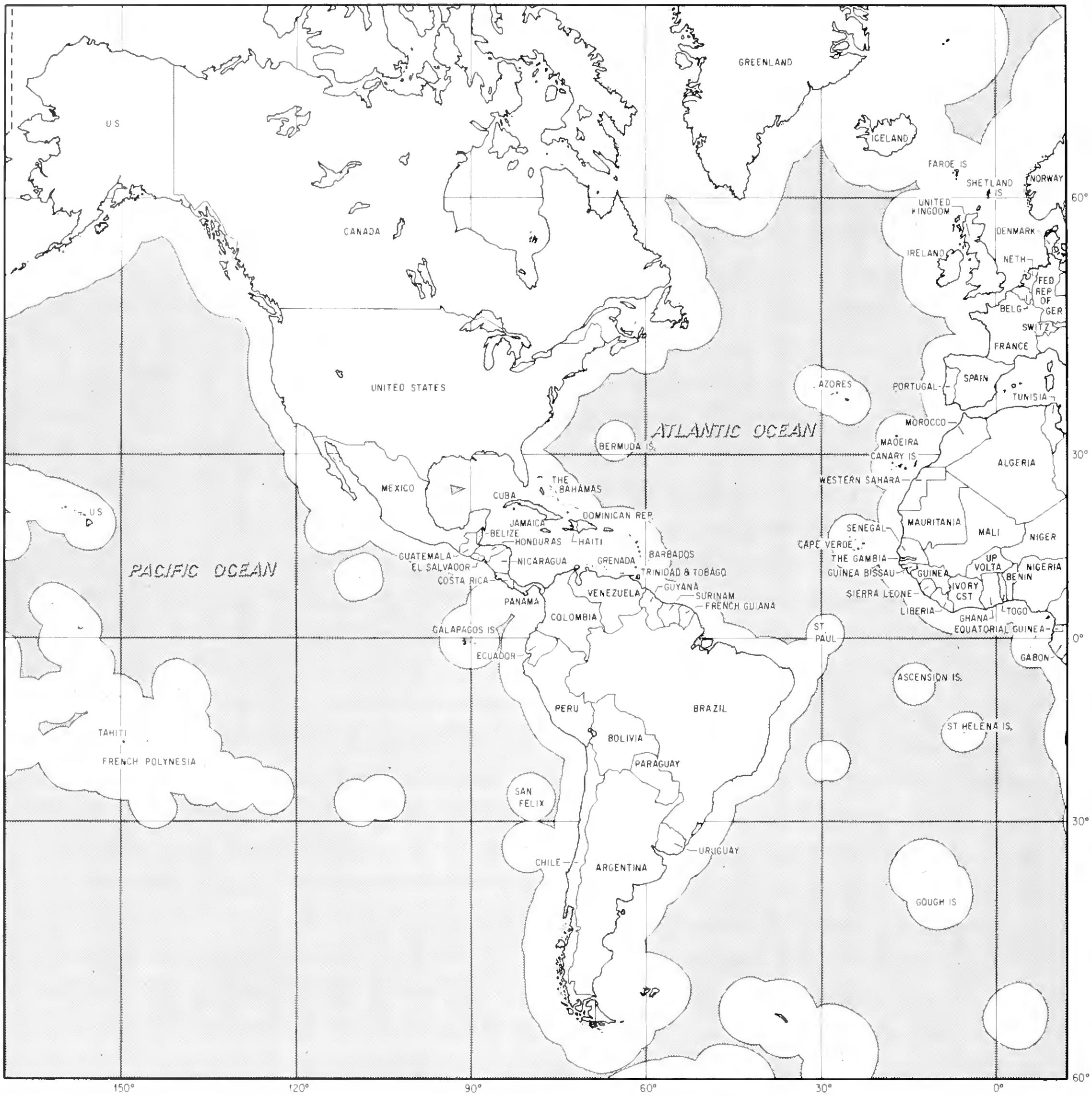
Also, there are substantial differences in the magnitude and nature of the fish stocks in the zones off various countries. Particularly striking is the high productivity in the upwelling areas off the western coasts of Africa and America. These areas are especially productive in shoaling pelagic species (such as anchovies, sardines, and mackerel), but some areas — for example, off Northwest and Southwest Africa — also produce large bottom-dwelling resources (such as hake and sea breams).

In other shelf areas, the distinction is as much in the variety of the fish species as in the magnitude of the productivity. In tropical areas, large numbers of species are found — perhaps 50 or more in a single trawl haul, with no single species or even group of species accounting for a large part of the total. In temperate and subarctic areas, the range of species is smaller, and a single species can support a major fishery.

The only immediate concrete effect of the new ocean regime is the ability of the coastal state to control the activities of medium- or long-range fishing vessels from foreign countries. These vessels need substantial economic returns to make their long journeys worthwhile; this requires good catches of reasonably high-valued fish. The result is that non-local fishing is concentrated in certain clearly identifiable areas. Table 1 shows the total catch and the amount taken by non-local fisheries for each of the major regions of the ocean. Only in the North Pacific and North Atlantic, and off West Africa does non-local fishing represent a significant part of the total, but in these regions the long-range fisheries are important. These are the valuable single-species fisheries of high latitudes (notably cod in the North Atlantic, and Alaskan pollock in the North Pacific) and those in the upwelling areas off Northwest and Southwest Africa. In addition, the larger species of tuna concentrate the productivity of most warmer waters into economically attractive units, and are exploited by long-range fleets of long-liners in all oceans, and by purse seiners in the Eastern Pacific and Eastern Atlantic. However, these tuna fisheries account for only a small proportion of the total catch of all species in the region in which they operate.

Some countries also have medium-range (or middle-water) fisheries off the coasts of adjacent countries that have less developed fisheries, or less local demand for fish. Such fisheries used to be common in the Northeast Atlantic (for example, Scottish trawlers fishing off the Faroe Islands), but also occur off West Africa (where there is a severe mismatch between where the fish are — largely off desert or semi-desert coasts — and where the demand for fish is) and in Southeast Asia, where Thailand has built up a thriving middle-water fishery

Global Effect of 200-Mile Claims



NATIONAL FISHING MARITIME CLAIMS

in Nautical Miles, as of January 3, 1979

(TERRITORIAL SEA CLAIMS IN BRACKETS)
(200-MILE ECONOMIC ZONES IN PARENTHESES)

3 Miles — 5 Countries

Bahrain [3]
Jordan [3]
Qatar [3]
Singapore [3]
United Arab Emirates [3]*

6 Miles — 3 Countries

Greece [6]
Israel [6]
Lebanon [No Legislation]

12 Miles — 37 Countries

Algeria [12]
Australia [3]
Belgium [3]
Bulgaria [12]
China [12]
Cyprus [12]
Djibouti [12]
Dominica [3]
Egypt [12]
Equatorial Guinea [12]
Ethiopia [12]
Fiji [12]
Finland [4]
Honduras [12]
Indonesia [12]
Iraq [12]
Italy [12]
Jamaica [12]
Kenya [12]
Kuwait [12]
Libya [12]
Malaysia [12]
Monaco [12]
Nauru [12]
Rumania [12]
Saudi Arabia [12]
Sudan [12]
Syria [12]
Taiwan [3]
Thailand [12]
Trinidad and Tobago [12]
Tunisia [12]
Turkey [6]
Western Samoa [12]
Yemen (Sana) [12]
Yugoslavia [12]
Zaire [12]

15 Miles — 1 Country

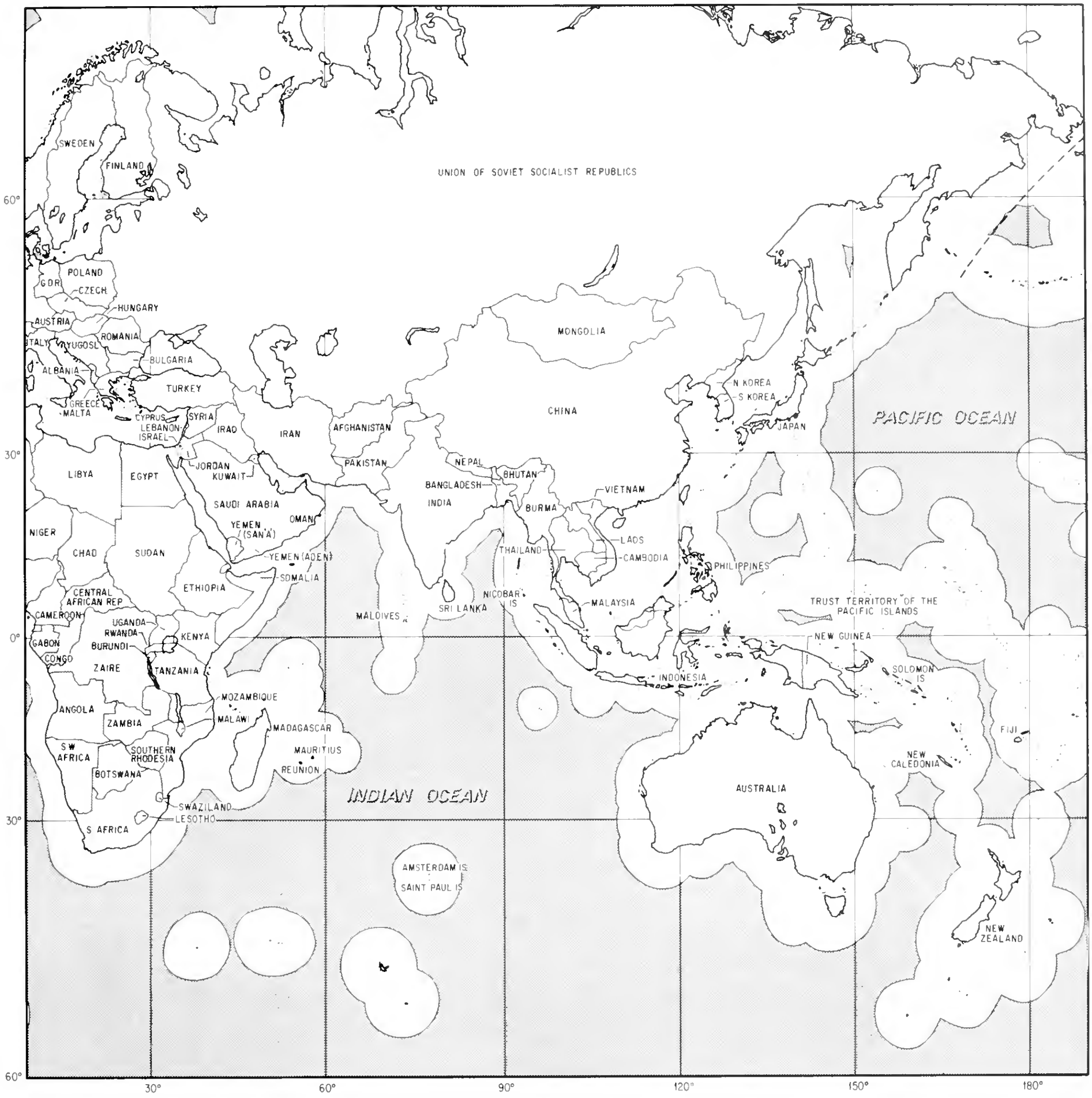
Albania [15]

25 Miles — 1 Country

Malta [12]

*Except for Sharjah, which has a 12-mile limit.

Source: U.S. State Department, Office of the Geographer.



50 Miles — 4 Countries

Cameroon [50]
Iran [12]
Gambia, The [50]
Tanzania [50]

70 Miles — 1 Country

Morocco [12]

150 Miles — 2 Countries

Gabon [100]
Madagascar [50] (200)

200 Miles — 76 Countries

Angola [20]
Argentina [200]
Bahamas, The [3]
Bangladesh [12] (200)
Barbados [12] (200)
Benin [200]
Brazil [200]
Britain [3]
Burma [12] (200)
Canada [12]
Cape Verde [12] (200)
Chile [3]
Colombia [12] (200)
Comoros [12] (200)
Congo [200]
Costa Rica [12] (200)
Cuba [12] (200)
Denmark (plus Greenland and the Faroes) [3]
Dominican Republic [6] (200)
East Germany [3]
Ecuador [200]
El Salvador [200]
France [12] (200)
Ghana [200]
Grenada [12] (200)
Guatemala [12] (200)
Guinea[200]
Guinea-Bissau [12] (200)
Guyana [12] (200)
Haiti [12] (200)
Iceland [4]
India [12] (200)
Ireland [3]
Ivory Coast [12] (200)
Japan [12]
Kampuchea [12] (200)
Liberia [200]
Mauritania [70] (200)
Mauritius [12] (200)
Mexico [12] (200)
Mozambique [12] (200)
Netherlands [3]
New Zealand [12] (200)
Nicaragua [3]
Nigeria [30] (200)
North Korea [12] (200)
Norway [4] (200)
Oman [12]
Pakistan [12] (200)
Panama [200]
Papua New Guinea [12] (200)
Peru [200]
Poland [12]
Portugal [12] (200)
Sao Tome & Principe [12] (200)
Senegal [150] (200)
Seychelles [12] (200)
Sierra Leone [200]
Solomon Islands [3]
Somalia [200]
South Africa [12]
South Korea [12]
Soviet Union [12]
Spain [12] (200)
Sri Lanka [12] (200)
Surinam [12] (200)
Sweden [4]
Togo [30] (200)
United States [3]
Uruguay [200]
Venezuela [12] (200)
Vietnam [12] (200)
West Germany [3]
Yemen (Aden) [12] (200)

Rectangular/Polygonal Claim — 3 Countries

Maldives (200)
Philippines
Tonga

in the Indian Ocean and in the South China Sea.

Thus it is possible to classify some countries as "gainers" under the new ocean regime, some as "losers," and some as not directly affected. The gainers are those countries that now control the foreign fishing off their coasts, whereas the losers are those nations doing substantial fishing outside their own waters. These terms should not be interpreted too strictly; for instance, many long-range fisheries have suffered badly because of failures to introduce effective management measures. Extended jurisdiction should result in more profitable fishing, and should benefit non-local fisheries — at least when the coastal state cannot, or does not wish to, take all the available catch itself.

A single country, of course, might be a gainer in some respects, and a loser or unaffected in other instances — for example, the United States. The New England fishermen fishing on Georges Bank are benefiting from the strict controls on foreign fishing (though this does not mean that their own operations can go completely uncontrolled); further south, the menhaden fishery is virtually unaffected; and the United States tuna purse-seine fishery operations off Central America, and possibly off West Africa, are likely to be more severely controlled.

Some of the major gainers and losers can be identified. In northern waters, the main gainers are Canada and the United States (on both coasts), though several other countries in Western Europe, the Soviet Union, and Japan have some foreign fishing off their coasts. Further south, the principal gainers are in West Africa — from Morocco through Mauritania and Senegal to the Cape Verde Islands in the north, and Angola and Namibia in the south. In the central and south Pacific, the main gainers are the island territories in the southwest Pacific; the foreign tuna fisheries in the adjacent waters are large compared to local fisheries, even if not exceptionally large by world standards. Australia and New Zealand also stand to gain. There is little non-local fishing in the Indian Ocean other than tuna, so there are no major gainers; though, as in the Pacific, the island states may benefit because of the smallness of their local fisheries.

The losers are predominantly the more advanced fishing countries, notably Japan and the Soviet Union, as well as several other European countries; some (such as Spain and Portugal) with a long history of cod fishing off the North American coasts, and others (for example, Poland) with more recently developed, but very substantial, long-range fishing. In addition, several developing countries stand to lose significantly; these include South Korea (with important tuna long-line and trawl fisheries), Cuba (which takes significant catches off Southern Africa), and Thailand.

However, the greatest impact in terms of both gaining and losing will be felt by the richer developed countries, whereas the developing countries taken as a whole are clearly gainers. This is shown in Table 2, which sets out the total catches of non-local fisheries during 1972 (the last typical pre-Extended Economic Zone year) divided between developed and developing countries, according to both the country doing the fishing, and the country off whose coasts the catch is taken.

This direct impact, resulting from the control of foreign fishing, is not the only effect of the new regime of the sea. There is also a great psychological and political impact. Until the new Law of the Sea discussions, little was heard about fisheries or ocean affairs in general, and the fisheries department was the Cinderella of most governments. Now ocean affairs are much in the public eye, and governments are paying full attention to the problems of fisheries. Whether this will prove to be a good thing for fisheries remains to be seen. There is a danger that great attention will give rise to great expectations, and possibly rash promises, especially by those looking at charts of large expanses of sea without realizing that the usable fishery resources may be concentrated in a small area along the coast. What is certain is that within most countries there is an opportunity for a careful look at national fisheries — their problems and the actions needed to deal with them — at a level of government and with a degree of attention that generally has not occurred in the past, and may not occur again for some time. Much depends on how well this opportunity is used for drawing up plans for the future rational utilization of fishery resources.

Actions by Developing Countries

How developing countries react to the new Law of the Sea regime will depend on whether they are gainers, losers, or unaffected by its immediate impact. Initially, each country must take a careful look at their own fisheries at all stages — from an assessment of natural resources to the catching, marketing, and ultimate consumption.

The problems of the losers are discussed by Wlodzimierz Kaczynski in this issue (see page 60); he examines the impact of the new regime on the large fleets of developed countries, such as the Soviet Union and Japan. The problems of less-developed countries, such as Cuba and Thailand, are much the same. They have to make the best deal that they can, bearing in mind that the coastal states they fish off have most of the power. In some respects, the smaller states have fewer advantages in their negotiations with coastal states than do the larger countries, such as Japan; they have less advanced technical assistance, or often, less of an access to markets to offer to outside fisheries. However, they do have other advantages.

Table 2. Catches (thousand metric tons) by non-local fleets in 1972, according to nationality of fleet, and location of the catch.

		Nationality of Vessel		Location	
	Total	Developed	Developing	Developed	Developing
North Atlantic	5,959	5,955	4	5,813	146
North Pacific	5,190	4,854	336	4,804	386
West Africa	3,701	3,532	169	271	3,430
Others	1,510	947	562	259	1,251
Total	16,360	15,288	1,071	11,147	5,213

Many governments may be more suspicious of large fleets from the Soviet Union or Japan fishing off their coasts than they would be of vessels from a small developing country. Also, they often can provide the small fleets with useful technical assistance. For example, Burma has little interest in knowing how to operate large factory trawlers of the type used by the Soviet Union, but could learn much from the ships of Thailand and apply it immediately to its own fisheries.

More developing countries, however, will be negotiating as coastal states and potential gainers. This is the mirror image of the situation discussed by Kaczynski. Each country, depending on whether it is a gainer, loser, or unaffected, will try to either maximize the benefits they can gain from the resources, or (at least in the case of the long-range fleets) minimize the reduction in the benefits arising from the new legal situation. Since the types of benefits that the gainers and losers are seeking are not the same, the opportunities for successful bargaining are large. There would be a complete and direct conflict between the two groups only if one erroneously assumed that a country's sole benefit from a fishery is the gross weight of the catch taken by its national fleet.

Generally, the distant-water countries are interested in the supply of fairly high-quality fish (the economics of the high-volume, low-price fisheries for fish meal largely have discouraged any long-range fishery based solely on this product), the employment of moderately advanced technology, and large-scale capital investment. Distant-water fishing is not an attractive form of work — shore jobs are basically more attractive, and indeed, some distant-water fishing countries, such as Japan, are finding crew shortages a major problem. On the other hand, many developing countries see fisheries as providing employment and economic aid — often these countries have a serious shortage of foreign exchange. Perhaps rather surprisingly, the possible contribution to national food supply from the stocks currently fished by foreign fishermen is not always a major consideration. This is partly because the types of fish may not be attractive to local markets, but often the potential supply would swamp local demand. As already noted, many of the catches by long-range fisheries (other than those in the North Atlantic and North Pacific) are off the semi-desert, sparsely inhabited, coasts of Northwest and Southeast Africa. At the extreme, the total catches off Namibia (in Southwest Africa) are equivalent to more than 5 kilograms per day for everyone in Namibia!

Therefore it has not proved difficult for coastal and long-range fishing countries to reach agreements, and a large number of these are in force. The terms vary: they may include a continuation of foreign fishing, with merely some payment of license fees; a greater involvement of the coastal state in what remains to be principally a foreign-based operation (for example, under certain types of joint venture); or a full phasing out of foreign fishing and its replacement by local fisheries, though often with foreign involvement in, for example, marketing or technical training.

So far these arrangements have been handled on a case-by-case basis, where a coastal state deals with each foreign fishery separately, even when several countries are fishing off their coasts. Attention has been given to what are the optimum benefits that can be obtained by the coastal country from each group of foreign vessels. Comparatively little attention has been given to considering what should be the optimum level of the total foreign fishing. An exception to this trend is evident in the United States, where the Fishery Conservation Act calls for the determination of the optimum yield from each stock. If the local fishermen cannot take all of it, the surplus is allocated to foreign fishing. But one must consider the fact that if the stock is fairly heavily exploited, approximately the same yield can be taken at very different levels of fishing effort. If effort is held at a relatively low level, the catch per boat will be high as will the profits and the ability to pay substantial license fees. Therefore, if a coastal state wants to benefit from license fees from foreign vessels, its view of the optimum yield, and optimum level of effort, may be one that keeps effort low, but license fees per vessel high; on the other hand, if the objective is high catch, more or less regardless of cost, or full employment for local fishermen, the optimum level of effort may be much higher.

This is just one example of the more complex policy issues that can and should be taken into account under the new legal regime of the sea. Policy makers in coastal states must be supplied with much clearer and broader fishery advice than in the past. Such advice is necessary whether a policy has to be determined for foreign fleets or not.

Using The New Authority

Strictly speaking, of course, changing lines on a map makes no difference to fishery problems. If there is no foreign fishing, the ability or inability of local fishermen to go out and catch fish successfully and economically will not be affected by changing lines from 12 miles or 3 miles to 200 miles. If fishery resources are to be well used — neither neglected, nor over-exploited — firm decisions need to be made, backed up by clear authority, and reached on the basis of adequate information. Most resources have not been used wisely in the past because one or more of these elements were missing — often all three; because in the absence of clear authority, little research had been done, and therefore few decisions were made. Under the new regime of the sea, authority (except for highly migratory species) is clearly vested in the coastal state (or a group of adjacent states working together). This new authority, and the greater awareness of marine fishery issues by national administrations and the public, is bound to result in a demand for clearer scientific advice on the fishery resources, and how they should be exploited. This demand is similar to those arising from the general public's concern over the rational management of the environment. Although environmental concern originally was a matter for the rich, developed countries, the developing countries are increasingly aware of the problems, and of the need to avoid making the same mistakes. The result of these converging demands is that the worldwide scientific community will need to find out much more, in a quantitative sense, about the nature, distribution, and magnitude of fish stocks, and how they react to fishing.

We can now return to the question posed in the opening paragraph. A few developing countries — for example, Mauritania — will gain substantially from the new ocean regime. The immediate practical effect on most other countries will be comparatively small, but the impetus that is being given to the scientific study of ocean resources, and to the need to make a careful determination of the best national policy to make use of these resources, should be of real, if unquantifiable, benefit to all developing coastal states.

John Gulland is head of the Marine Resources Service in the Fishery Resources and Environment Division of the Food and Agriculture Organization of the United Nations, Rome, Italy.

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Oceanography Assembly Planned

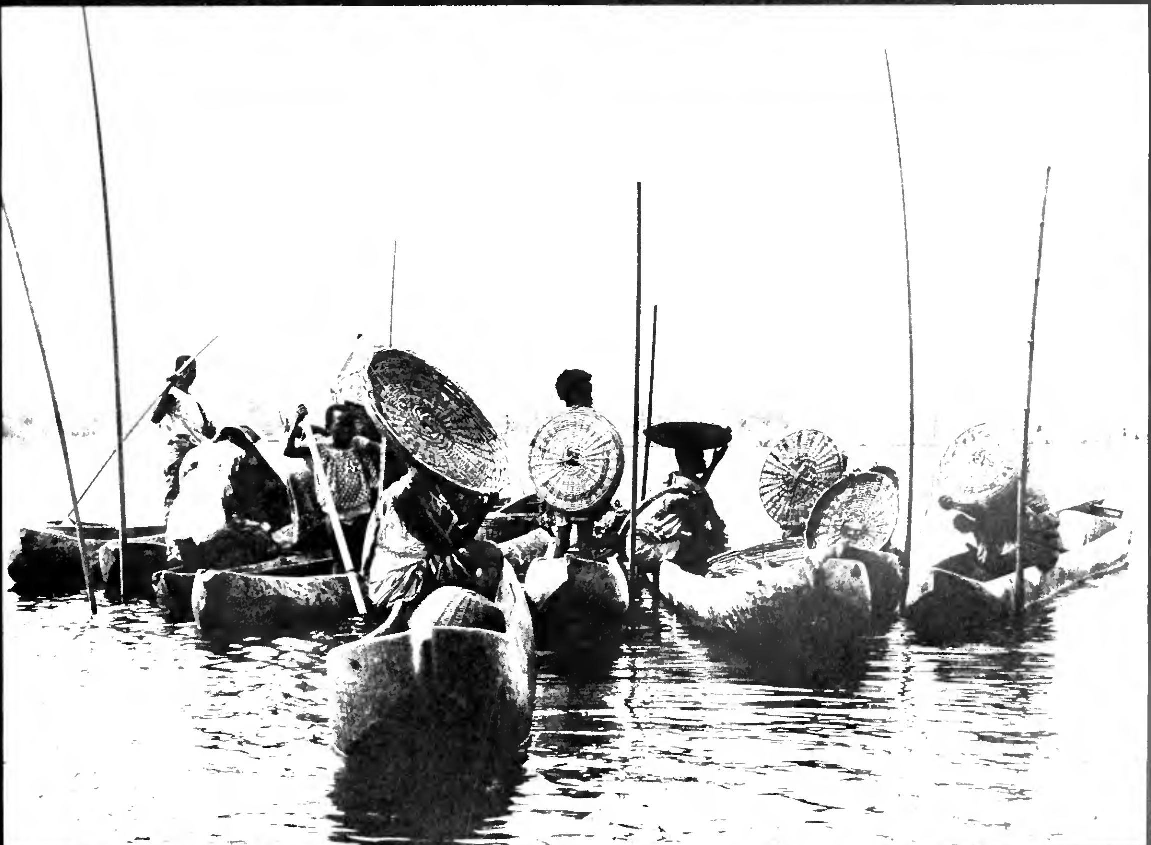
A public assembly on future and present trends in oceanography will be held in Woods Hole, Massachusetts, from September 29 to October 3, 1980, to mark the 50th anniversary of the Woods Hole Oceanographic Institution.

The assembly will consist of invited papers on all aspects of oceanography, including scientific, technical, social, and institutional affairs, with particular focus on future development in these fields.

The assembly will follow the Third International Congress on the History of Oceanography (September 22-26), which also will be held in Woods Hole. For further information, contact: Dr. Peter G. Brewer, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543. Telephone (617) 548-1400, ext. 2552.

Fishing in the Third World

A Photo Essay

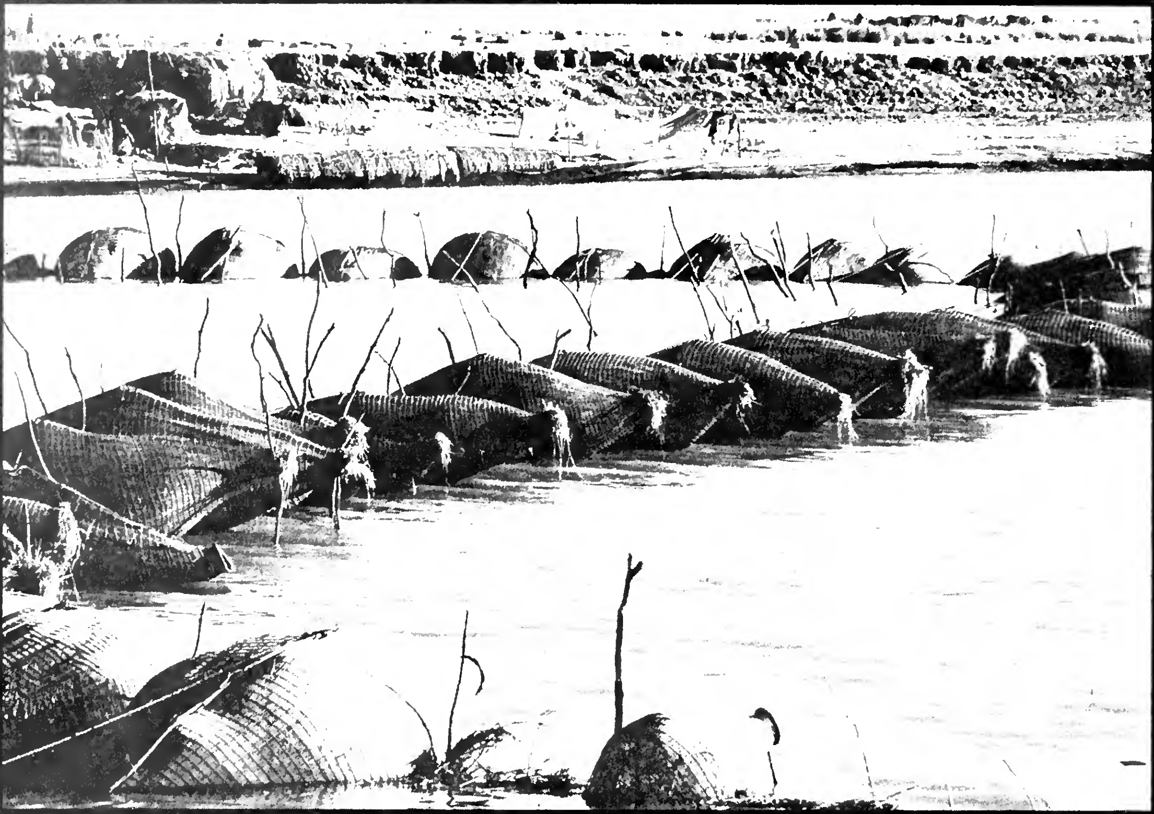


Women waiting to buy fish, Lake Ahémé, Benin. (FAO photo by Banoun/Caracciolo)

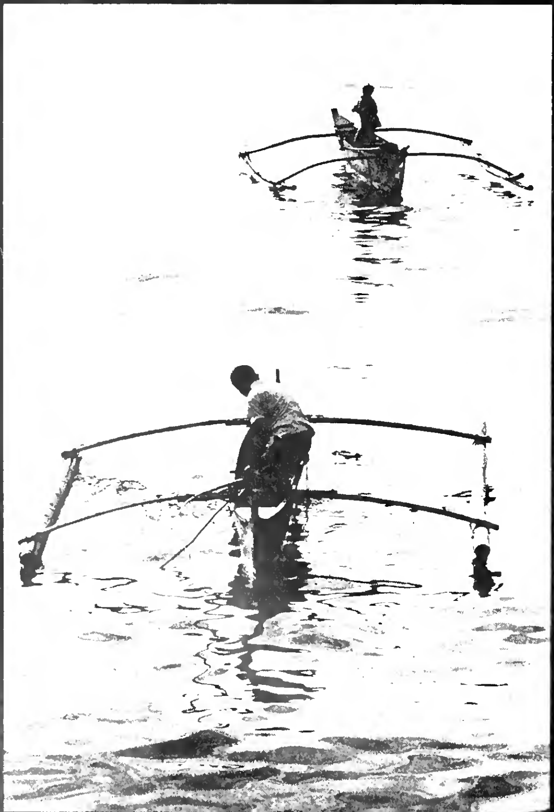
Canal fishing, Vietnam, (Photo by Inger McCabe, PR)

Trapping fish in Zaire rapids. (Photo by Georg Gerster, PR)

Fishing on stilts in Sri Lanka.
(Photo by Georg Gerster, PR)



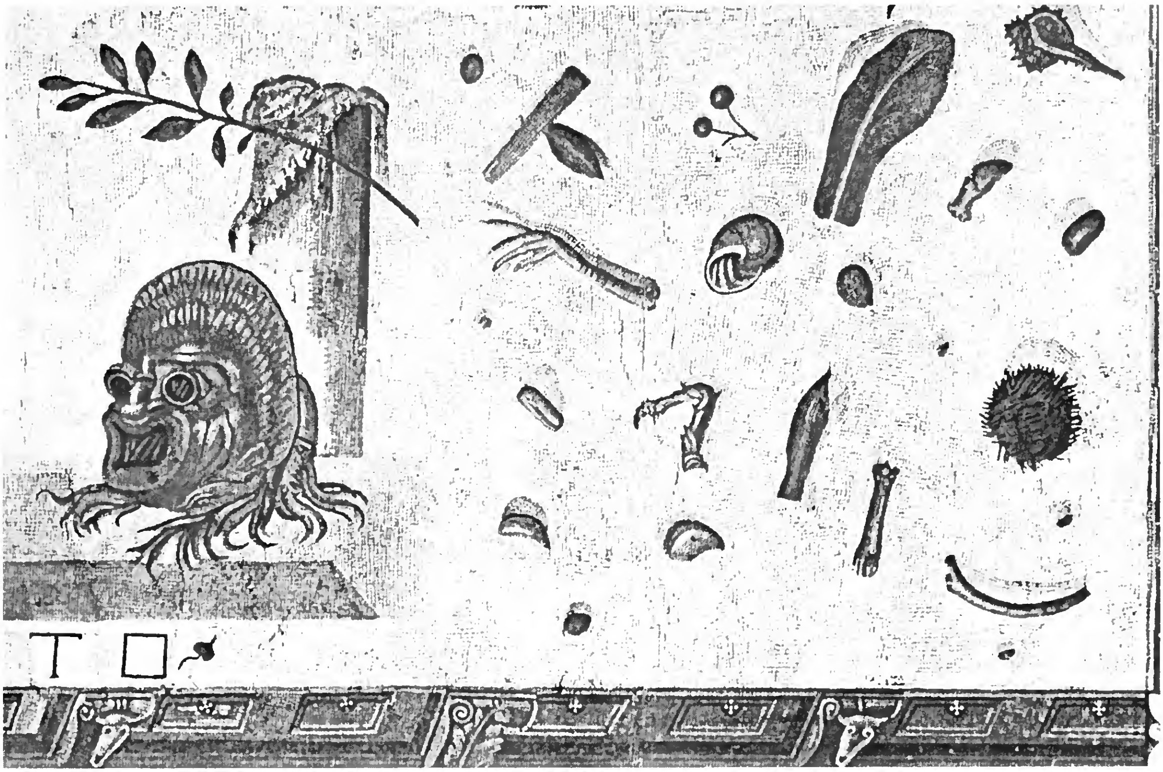
Fish traps on a tributary of the Niger, Mali. (Photo by Georg Gerster, PR)



Philippine fishermen in outrigger canoes. (Photo by Allan Price, PR)

Bringing smoked and dried food to market. (Photo by Georg Gerster, PR)

Reducing Postharvest Losses of Fish in The Third World



Mosaic floor detail found in Rome, Italy, in 1833, now in the Museum of the Vatican. This type of decoration, found in houses of the rich, was fashionable in antiquity between the 2nd century B.C. and the 1st century A.D. It became known as the "unswept floor mosaic," representing scattered food leftovers – many of aquatic origin – which, having fallen to the floor in the course of a banquet, remained there undisturbed, overnight, as an offering to the ghosts of the departed relatives or friends of the party.

by E. R. Pariser

Nearly 25 million tons of fish, or about 35 percent of the known world fishing catch that is destined for human consumption, is lost annually during processing procedures — that is, at various points between the boat and the consumer. The people who are hurt most by this tremendous wastage are probably the fishermen and small communities in the less-developed countries, or what has been termed the third world.* Fish to these people are an extremely important source of food and protein, not to mention income. They can ill afford to lose a large percentage of their catch. But reducing the postharvest losses in these regions is a complex problem — one that requires in many cases fundamental social and cultural changes in addition to an infusion of new technology, instructors, and currency.

The United States began to take a hard look at this problem shortly after the World Food Conference convened in Rome more than four years ago. At that time, the President of the United States wrote to the President of the National Academy of Sciences (NAS) asking for an assessment of the global problem of hunger and malnutrition. The President asked that the NAS develop "specific recommendations on how

*The term *Le tier monde* (the third world) was first used by a number of French writers in the 1950s. To them, the Capitalist countries constituted the "first" world, while the "second" consisted of nations living under Communist regimes. Thus the newly independent nations of Africa and Asia were termed the third world, with some South American states, for little reason, also included in this category.

research and development capabilities can best be applied to meet the major challenge." This resulted in an investigation — the World Food and Nutrition Study — which concluded that as many as 450 million to a billion persons in the third world may not receive enough food for normal growth and development, and that this number would probably increase significantly by the end of the century.

The NAS study, in reviewing the traditional strategies that many governments have adopted to deal with the problem — attempts to slow population growth and to increase food production — found that an important avenue had not been sufficiently explored. This was the reduction of food losses during and after harvest due to spillage, contamination, and attack by microorganisms, insects, birds, and rodents. Many observers believe that a reduction of local food losses might greatly lessen, perhaps even eliminate, the need of some countries to import large quantities of food. To encourage such an effort, the United Nations General Assembly at its seventh special session set a 50 percent reduced global postharvest food loss — possibly exceeding a half billion tons per year — as a target to be achieved by 1985. This action prompted the U.S. Agency for International Development (AID) to request that NAS undertake a study of postharvest food losses in developing countries.*

The study determined that postharvest fish loss, especially in less-developed countries, is the result of a vicious circle of cause and effect. Once fish are dead and out of water, their biochemical nature makes them susceptible to particularly rapid decomposition. Consequently, they are difficult to sell, being suspected of staleness. The fish merchant, especially in warm climates, has been known since ancient times to use various subterfuges to convince the customer of his wares' freshness. The customer, on the other hand, has often discovered that the fish are indeed of poor quality, and the monger a cheat. Historically, this has resulted in the notion that fish merchants are untrustworthy and therefore second-class citizens. In some societies, fishermen have been ostracized, even isolated from the rest of the population, their fish regarded as inferior food — frequently evil-smelling, obnoxious, and disease-provoking (see page 67).

In many countries, the consumer has insisted on personal inspection of the whole fish to insure its freshness, evaluating its eyes, gills, and other parts. Consequently, the food processing industry has had little incentive to develop techniques similar to those evolved for many other food staples that would make it possible to utilize fish components in the manufacture of new products, especially those in which the identity of the raw material would be lost.

The processing of fish, with the exception of canning, has not progressed for at least 2,000 years, fishermen in the ancient world having developed such preserving methods as salting, pickling, sun drying, and smoking. I believe this technological stagnation is reflected in the practices followed by fisheries all over the world, resulting in large postharvest losses.

Let us define the boundaries of this article. We will not discuss the losses that occur in large-scale industrial fisheries in third world countries, nor those in the fish export businesses operating there: the more careful handling, processing, and transporting of large quantities of fish tend to reduce losses, as does the profit incentive. Furthermore, it is unlikely that loss reduction in the industrial sector would directly benefit the malnourished and poor in these countries. We will concern ourselves only with the problem of postharvest food losses that are suffered by artisanal subsistence fisheries.

What Do We Know?

In most countries, attitudes toward food in general vary widely from place to place and from population group to population group. Hardly any edible produce exists that is not utilized as food in one place and considered inedible or abhorrent in another. For some people, only cooked food is "real" food. Depending on one's viewpoint, food that is moldy or fermented may be either delectable or inedible. The same attitude applies to loss of food: for example, many ethnic groups offer specially prepared foods to the spirits of departed friends and relatives, gifts that the living often can ill afford. In the strict sense, of course, this is a food loss, but the belief is widespread that without these offerings disaster would surely befall the individual family or community. Similar attitudes are widespread in areas of food loss where people fear and worship certain vermin, such as rodents, insects, and birds, which are known to destroy food wholesale.

The existence of such deeply engrained, varied attitudes makes an accurate assessment of food losses and the implementation of corrective measures extremely difficult. We know in general:

1) that huge gaps exist between what is being planted, produced, or harvested as food, and what is actually being consumed;

2) that the disappearance of food (its nonutilization, spoilage, and consumption by animals) is regarded by societies in varied ways and not necessarily as loss of food;

3) that there is little ready willingness to reduce the gap between harvested and consumed food;

*The author was chairman of this study, which issued a report through the National Research Council in December, 1978, entitled "Postharvest Food Losses in Developing Countries."

Sorting fish by species and size in the fishing port of Abidjan, Ivory Coast. (Photo by Bernard Pierre Wolff, PR)

4) that the poor usually resist changing traditional methods of processing a particular commodity; and finally,

5) that when the willingness exists to adopt a new strategy for protecting the harvest, there is seldom any assurance that the farmer's or fisherman's additional effort will accrue to their own benefit and not be eroded by the government or landlord taking away the increased food.

We know that fish provide about 17 percent of the total animal protein consumed by humans. In many coastal areas, fish is the *only* source of animal protein, representing a sizable proportion of the caloric intake as well. We also know that attitudes toward fish as food in many societies range from outright avoidance of fish to willingness to consume only a small number of the available edible varieties.

There are no reliable hard data concerning postharvest losses in either the large-scale or the artisanal fishing enterprises in less-developed countries, nor is there hard information on the losses sustained by individual fishermen who operate independently. The Food and Agriculture Organization of the United Nations (FAO) estimated that the postharvest fishing losses in some countries are among the highest of any commodity — in some instances exceeding 50 percent of the landed fish. (By comparison, a conservative minimum estimate of yearly losses of cereal grains and legumes on a worldwide scale would be 10 percent by weight, and about 20 percent by weight of nongrain staples, such as perishables.)

We should note that staggering food losses occur in both industrialized and developing countries, although for different reasons and at different places in the food chain. In the United States, for instance, about 20 percent of all the food produced annually is lost. This amounts to 137 million tons of food, valued at $30 billion. Take frozen fish as an example: 15 percent by weight is lost in supermarkets alone due to poor storage. In Britain, the situation is even worse. The Ministry of Agriculture, Fisheries, and Food has estimated that 22 percent of the total food traded in the nation is lost during distribution, or in the home.

Findings of NAS Study Group

The NAS study group concluded that because of the difficulty of obtaining hard data on fishing in less-developed countries "it would be a waste of time and resources to attempt quantitative assessment of postharvest food losses for fish in different regions." Instead, it was determined that efforts should be concentrated toward understanding the technological and social organization of different fisheries, working toward improving the handling and processing techniques in those stages where the most important losses occur and where the greatest loss reduction can be achieved. In general, the critical stages were identified as follows:

- *Serious food losses occur immediately after harvest on board ship because of the absence of appropriate means to preserve the catch until landed.*
- *Large losses are sustained due to enzymatic spoilage and insect infestation as the catch is landed, processed on the beach, and awaits transportation to market.*
- *Losses occur due to primitive handling methods, preservation, transportation, and exposure at market.*

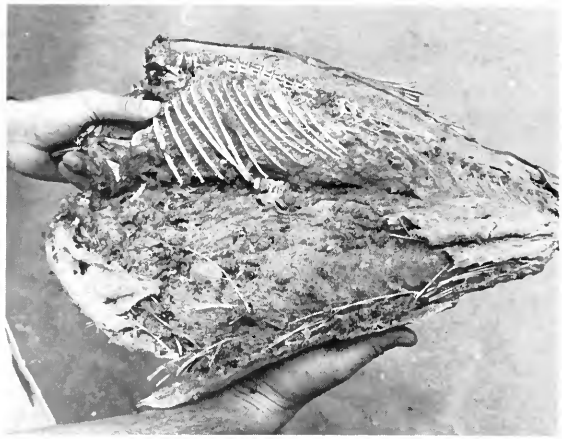
Traditionally Processed Fish Products

The fishing industry in third world countries can be generally divided into two categories — that dealing with fresh fish (including chilled and frozen), and traditionally processed fish (including dried, salted, smoke-dried, and fermented products). We will concentrate in this article on the latter category because this is where it is believed that the major losses occur, although it is acknowledged that considerable losses of fresh fish also occur aboard ship, especially in warm climates, due to poor handling and lack of refrigeration. It should be noted, however, that even stale or spoiling fish are often processed.

The simplest and most widely used technique for preserving fish is sun drying, in which the landed fish are spread out on the beach, or on a mat, and dried in the sun. Under these conditions, the wet fish are subject to attack by blowflies, mainly *Chrysomyia* spp., whose larvae burrow into the fish. Apart from the physical damage to the fish and the associated spoilage, the blowflies also are a major source of disease, particularly since the beaches they infest are widely contaminated with human feces as a result of limited public sanitation facilities. Dried fish are also subject to attack by *Dermestes* beetles. If this infestation is allowed to proceed, the beetles consume the fish.

Losses due to *Chrysomyia* and *Dermestes* vary from area to area and from season to season. Hard data on these losses are difficult to obtain. For example, estimates of losses in Malawi during the rainy season one year due to blowfly larvae ranged from 2 to 40 percent.

Salting is a technique that is often used to enhance the quality and acceptability of naturally dried fish. This is accomplished by either stacking the split fish with dry salt between the layers, or, preferably, by immersing the fish in brine, which serves to speed up the removal of water from the flesh and to reduce the time necessary for air- or sun-drying. In the case of oily fish, such as sardines, prolonged drying leads to discoloration and rancidity.



Dried body of fish in Mali, West Africa, infested with insects. (FAO photo by J. Chevalier)

Salting is also a chemical method of controlling bacteria and insects. Flies will not attack fish that have been brined before drying, and the rate of attack by beetles is inversely proportional to salt concentration. One of the most difficult problems with salted dried fish is controlling reabsorption of moisture from humid atmospheres. Proper packaging is therefore essential.

Smoke-drying is another technique used to deter insect infestation. In West Africa, a variety of foodstuffs are handled in this fashion. In the Lake Chad area, for example, fish may be partially dried in the sun, then covered with grass or papyrus, and set on fire. This forms a scorched and blackened hard protective outer surface on the fish.

This method, however, offers only minimal control against insects, which often deposit their eggs in the flesh before and during drying. During smoking of thick-bodied fish, the insects are deterred by heat and smoke, but the larvae already present in the fish penetrate into the deeper parts of the animals where the heat and smoke have only a minimal effect. The loss in this type of processing may be as high as 15 percent. In addition, physical and economic losses result during storage and distribution. Dried fish are a fragile product, and, if roughly handled in transit to the marketplace, or vibrated on overloaded trucks on poor roads, crumble into a powder.

Strategies for Loss Reduction

In most cases, any attempt to reduce food losses between harvest and consumer in less-developed countries requires fundamental social change — obviously a difficult undertaking. The fishing industries in these countries are by and large fractionated, poorly organized, independent, and oriented toward maintaining a subsistence-survival level. For any postharvest food loss reduction strategies to have a chance of success, they must be

Sun drying of fish in Mali village. (Photo by Georg Gerster, PR)

adapted to the local cultural, economic, and political situations existing in the individual country. Introduction of new technology alone will not overcome the problem. Cooperation between members of the local fishing industry (those who harvest, process, sell, buy, preserve, store, package, transport, and purchase fish for sale in the marketplace) only can be achieved if:

1. A communications link is established between the fishing people and the rest of the community.

2. Incentives for loss reduction efforts are developed and implemented.

3. Government support is assured.

4. Social, religious, and cultural patterns are understood and respected (including reasons for fish avoidance).

By nature, fishing people are isolated geographically (and often socially) on their boats and on the beach. One of the most widely distributed, and usually misused, products of high technology could play an important communication and education role — the transistor radio. In addition to dispensing entertainment and political news, these instruments could be used to impart useful information to the fisherman, such as weather conditions and explanations of the advantages involved in reducing postharvest food losses.

The Academy study group concluded that "no postharvest food loss reduction strategy would be successful unless the members of the artisanal food fishing industry were convinced, and could see for themselves, that there was an advantage for them, individually and collectively, to make the extra effort to change their traditional methods of handling the harvest. This fact, too often forgotten or neglected, may be more important and perhaps more difficult to introduce than all the other plans and implementations put together."

Nearly all artisanal fishermen would benefit from improved storage conditions on their boats, reducing the deterioration of fish prior to landing. But here we should remember that many have very small boats; the problem of appropriate scale should be examined carefully. Many potential improvements may be beyond the resources of the individual fisherman. There is need of considerable research and development in this area. Low-cost cooling devices would be particularly helpful to artisanal fishermen. In many areas, if seawater could be cooled by several degrees, it would greatly retard spoilage of certain species. Of course, the use of ice would be better.

In general, improved postharvest food handling methods during storage, preservation, transportation, and dehydration processes are closely connected with the availability of energy sources. It is now possible to produce small amounts of energy very *inefficiently* but very *inexpensively* from sturdy wave, wind, and other motion generators. These can deliver enough power to cool water by a significant number of degrees, and also can produce small amounts of freshwater from saltwater by reverse osmosis. Thus high-level technology can be utilized to produce long-lasting generators that will provide small amounts of energy. These may be inefficient to some extent, but they also will be inexpensive and therefore attainable in these particular societies.

Preparation of the Fish

Poor-quality fresh fish make poor-quality dried fish. Thus less losses are likely to occur when the fish are cleaned thoroughly and, if possible, chilled before drying. Dried fish products, after all, are an

Fish-smoking process in Abidjan, Ivory Coast. (FAO/UN photo)

alternative to fresh fish. Attention should be given immediately to keeping insects away from the fish and also reducing the time necessary for drying by raising the catch off the ground. These objectives can be accomplished by constructing simple racks from local material, utilizing wire mosquito netting fastened to the wooden legs. It also is desirable to cover the drying fish, protecting them from rain. This can be accomplished with plastic sheeting, which is impermeable, cheap, and generally available. The sheeting is more efficient than moving the fish undercover from the racks by hand.

Larger fish should be tied up by the tail on the racks. The fish should be sorted roughly by size before being hung, and hung sufficiently far apart so as not to touch or impede the flow of air around them. Fish that are hung touching each other have a tendency to stick, stain, and dry more slowly. The racks should be staggered in their construction so that the fish do not drip on each other. The lowermost rack should be at least 2.5 meters from the ground to reduce the chance of contamination. The ground in the vicinity, meanwhile, should be dry and clean. Overall, the fish should be dried well away from any activity that might contaminate the product.

Chemical Control of Insects

There are two types of insect infestation — one short-term, involving flies that infest the fish when they are wet, and the other long-term, involving flies and beetles that infest the fish when they are dry.

The literature contains a number of suggested chemical treatments, but stresses that these contain potential hazard to the consumer. In fact, there are no chemical means of controlling insects that can be recommended at the present time without health hazard to the consumer. In less-developed countries, different insecticides are produced, transported, distributed, and used by many people with little knowledge of the hazards.

The use of contact insecticides should only be considered as a last resort when:

- *No other means of dealing with the pest infestation is practical or economical.*
- *The techniques employed are simple and foolproof.*
- *The treatment uses insecticides of low mammalian toxicity at dosage rates that leave residues within tolerance limits set by the Food and Agriculture Organization and the World Health Organization.*

For short-term fly control of wet fish prior to drying, brief immersion in a pyrethrum solution (0.125 percent weight per volume [w/v]) with 1.25 percent w/v piperonyl butoxide has been recommended. This is not effective, however, against *dermestids,* which requires a further immersion of the dried fish in a water emulsion containing 0.018 percent w/v pyrethrins and 0.036 percent w/v piperonyl butoxide. Provided the fish are properly dried before treatment and drained afterward, they do not become too moist for storage nor unacceptable to consumers. This technique is reported to be effective for eight to twelve weeks.

Wherever possible, indirect chemical methods should be employed before resorting to direct contact control of insects. For example, insects can be controlled by treating fish containers with insecticides, or treating places where fish are handled, rather than the fish themselves. More research is needed on new products of low toxicity before insecticides can play a more important role in direct contact control.

Policy, Training, and Assistance

The Academy study concluded that aid to artisanal fishermen in less-developed countries should come through projects in the general areas of technology, extension (training), and infrastructure (public works and capital investment).

It recommended that technological aid be administered through government research and development institutes rather than through universities, finding that educational institutions tend to "focus too finely on a small aspect of a broad and pressing problem." It also stated that "prospects should be considered for linking into or strengthening" the programs of the FAO in regard to regional collaboration in fish technology research. These programs — underway in Asia, Africa, and Latin America — establish links between institutes within individual regions to work on common problems.

The report also recommended that a number of other technology projects be considered. One such project would entail the establishment of containerized chill stores within fishing communities, which would be supplied with ice from central locations. A central storage plan also could be devised for dried fish, which would offer protection against infestation. Other projects would involve new methods of drying by improved smoke-drying ovens or by designing and introducing solar driers.

In the training field, the report urged that more women be brought into extension programs. "Although extension services exist on paper in many countries," the report stated, "extension links are weak throughout the third world." It noted that "women are the economic power in the fish business" (particularly in Africa), and that "extension work is unlikely to succeed unless this is recognized."

The report warned that the transfer of technology by extension links would likely fail unless there also was provision for investments that would improve the quality of life, such as new port and landing facilities. It recommended capital investment to upgrade fish marketing and storage areas, water supplies, sanitation, and sewage facilities. In addition, it said that postharvest food losses could be substantially reduced through the provision of newer trucks and better roads.

A Look Ahead

It is extremely difficult to forecast the impact that a large postharvest loss reduction would have upon malnutrition in less-developed countries. Our ability to make such a prediction would depend upon answers to a number of questions, such as:

At what points between harvest and consumption do losses occur?

What is the volume (at least approximately) of fish actually lost?

What are the reasons (agents) responsible for the loss?

What are the governmental, financial, technical, and labor resources available to implement and enforce loss reduction strategies?

What is the social context within which the fishery operates?

What place does fish as food occupy in the food system of the particular society?

This list of concerns, of course, is far from complete; I list them mainly to point out that although specific technological advances can make significant contributions to food loss reduction, the most formidable obstacles are nontechnical — changes in social customs, attitudes, food habits, and prejudices. To bring about such changes is an undertaking for which we do not yet have the tools or skills. Policy makers in less-developed countries (and those who want to assist them) still have to learn how to select appropriate, socially acceptable technologies; to elicit the will of the fishing people to adopt new methods; and, especially, to insure that incentives are available and implemented to make the reduction of food losses profitable for those who invest in the extra effort.

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Fishing Technology for Developing Countries

by Joachim Schärfe

The desire on the part of developing and less-developed countries to better exploit their resources within newly established extended economic zones is leading to a demand for increasing sophistication in respect to fishing boats and their gear. In many instances, this increased sophistication could be obtained through the creation of a national fishing technology service, which, in addition to serving the needs of fishermen directly, could also advise government authorities on various investment, loan, and subsidy programs, as well as regulations governing fisheries, certification, and other matters. Most of the large industrialized countries already have such a service or institution for research and development of fishing technology.

Fishing technology — as the term implies — deals with the ways and means of fish capture. This involves the whole range of fishing gear and methods, the related features of vessels, instrumentation, fishing strategy and tactics, as well as biological and environmental aspects that have a direct bearing on fish capture. Compared with sister disciplines — such as fisheries biology, hydrography, fish utilization, and processing technology — fishing technology got off to a late start in the 1930s, gaining more general recognition in the early 1950s. There are many countries today — among them the United States, Japan, Poland, West Germany, and the Soviet Union — where the subject is taught at university level.

In many developing countries, the functions that would normally fall under a fishing technology unit or service are being handled in an ad hoc manner by government officers, who often have limited expertise in fishing matters. Sometimes these countries hire outside consultants or accept technical assistance projects to solve specific problems. But these approaches lack comprehensiveness and continuity; while the immediate problem may be solved, there may be negligible long-term evaluation and follow-up, undermining the original solution to the point of collapse.

Figure 1. A typical small shrimp trawler operating off the southwest coast of India. There are some 12,000 of these boats fishing in Indian waters, which has put heavy pressure on shrimp stocks. Opportunities for diverting part of the fishing effort to other stocks are being investigated. (Photo by author)

Outside consultants often are not well versed in the cultural, social, and economic aspects of the local fishing situation, so they are often unable to offer meaningful solutions to problems. And because the government officer in charge of fishery operations may not have full subject matter competence, there is often a gap in understanding on both sides contributing to an unsuccessful transfer of technology.

This is not to say that there have been no spectacular successes in technical assistance programs to developing countries. There have. One example is the small-boat shrimp trawling fishery in India, which was started through the efforts of a master fisherman from the Food and Agriculture Organization of the United Nations (FAO). The fishery subsequently drew further FAO support as well as bilateral aid from Norway. It now employs many thousands of boats and tens of thousands of fishermen and shore workers in addition to being an important source of foreign currency (Figure 1). Another example is the development of bottom trawling in Thailand, which was initiated through bilateral aid from West Germany and then taken up by private enterprise. More recent programs have involved small-boat purse seining with light attraction for species of small pelagic fish in the waters off Sri Lanka, and purse seining for tuna in waters off the Philippines.

Unfortunately, there also have been a good number of costly and frustrating failures — mainly due to attempted introduction of overly sophisticated technology combined with a lack of understanding of local cultural, social, and economic concerns (see pages 36 and 67). The recognition of these past mistakes has led to widespread agreement that future technological aid must be both appropriate and acceptable to the target community.

The general criterion for appropriateness is the extent to which the innovation can contribute to long-range development targets — for example, increased production, improved efficiency, foreign currency earnings, employment opportunities, and better working conditions and safety, to name just a few. Technical considerations include simplicity, reliability, sturdiness, and ease of operation, among others. Decisive economic factors involve loan plans and the cost of equipment for long-term operations, including spare parts. Cultural and social concerns apply to acceptability of the innovation within the traditional life and working pattern of the individual, his family, and the community as a whole.

An example of the organizational structure needed for a national fishing technology service is indicated in Figure 2, while Figure 3 shows the main interrelationships between disciplines and services. Fishing technology in developing fisheries initially should concentrate on applied research and development, with emphasis on the transfer of appropriate technology. Investigations into vessel design and construction, the hydrodynamics of fishing gear, the use of acoustics for fish detection and stock assessment, and fish reactions to gear and other stimuli should be left to institutions serving advanced fisheries. The results of such investigations, however, should be fully utilized within the framework of technology transfer.

As we have indicated, the decision to establish a fishing technology service in a developing fishery should be based on a careful identification of present conditions and development opportunities. This implies a meaningful dialogue with the fishermen, fishing operators, fishery administrators, market vendors, marine scientists, and those in supply and other supporting industries. The importance of these contacts cannot be overstressed. To facilitate this close contact with the fishery, the location of the fishery service (or unit, as the case may be) should be close to the main fishing center. And in order to reduce competition for funds, the technology service should be on an equal level with whatever sister institutions exist, such as a biology facility. This should not exclude the common use of premises or facilities where this is desirable for economic or other reasons.

In the development of programs, one of the first orders of business should be to decide whether the main emphasis will be on promoting small-scale or industrial fisheries, or both. In larger developing countries, governments often want to develop both simultaneously, which in turn substantially increases the demand for fishing technology services.

The introduction of small-scale improvements in fishing techniques involves a gradual, step-by-step process of modest innovations. Examples include mechanization of existing craft, introduction of fish detection and attraction techniques, expansion of fishing operations into deeper water, better exploitation of under-utilized known resources with modified gear, and better treatment of the catch during and after fishing (storage on board).

The promotion of industrial fishing requires more complex approaches. The main fishing techniques in this instance are trawling, purse seining, long-lining, and pole-and-line fishing. These methods usually require specially designed vessels and fishing gear. Thus the development of medium-distance offshore fishing for under-utilized resources often involves creating loan plans for fishermen, or financially aiding joint ventures. In the latter case, the financial risk for both partners, as well as any loan-extending agency, clearly demands attention to the technical details of the endeavor.

To be effective, the fishing technologist has to cooperate closely with his customers, the fishermen. He must not conceive of himself as a white collar worker, for to be effective, in addition to his office and laboratory tasks, he must constantly communicate and work with fishermen in their own environment (at sea and ashore). He must gain their confidence, which he can do only by proving that he has something worthwhile to offer — that he knows what he is talking about. This involves hard, practical work during experimental, exploratory, and demonstration fishing, often under severe weather conditions. It is sometimes difficult to train such a staff in countries where only the white collar status is afforded esteem.

The technical competence that is available in developing countries is oriented predominantly toward other fields, such as biology. Prospective fishing technologists therefore require special subject matter training. Some large, developing countries already provide courses in fishing technology in the curricula of fisheries training institutions, or in universities. These, however, are

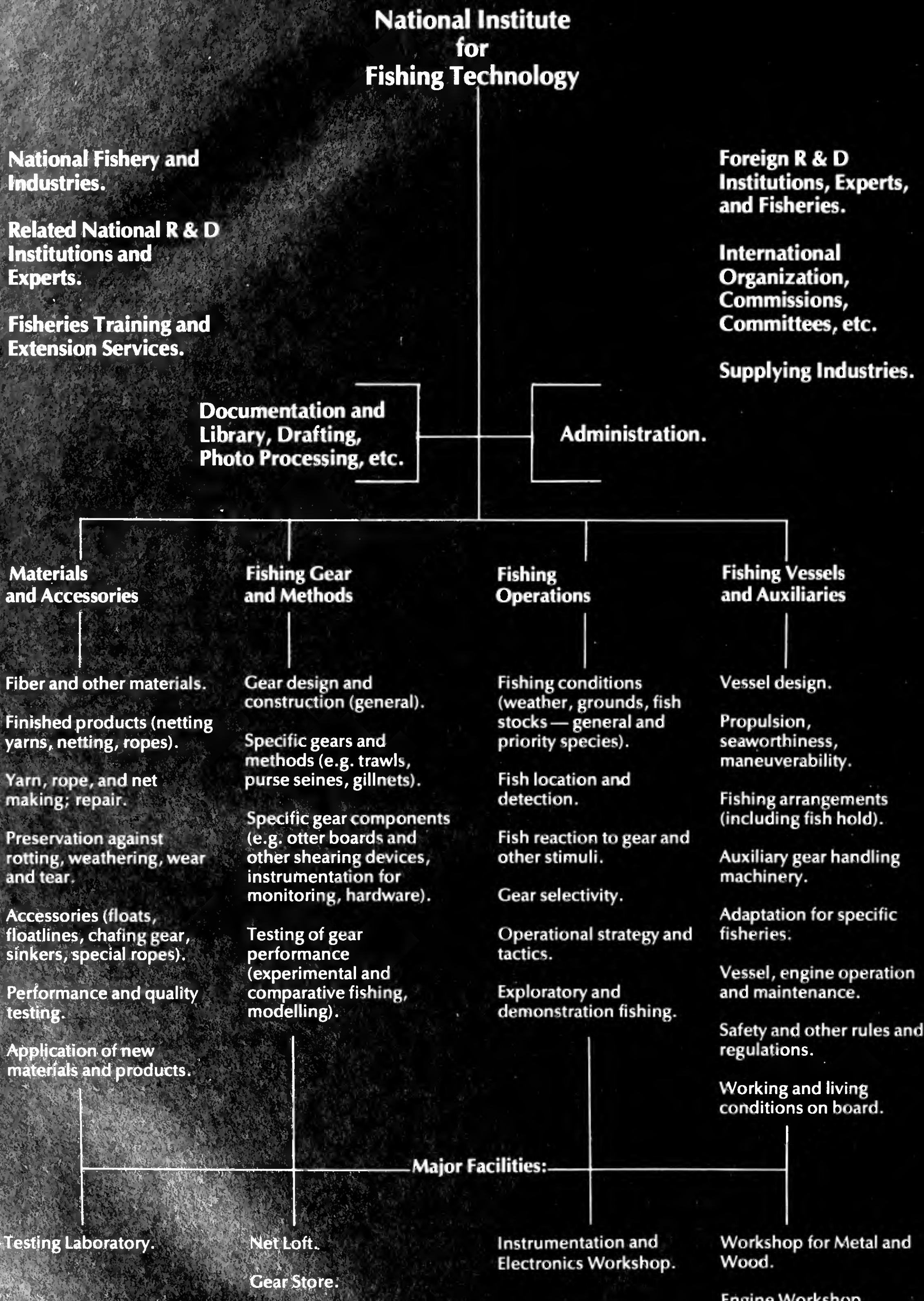

Figure 2. The organizational structure of a possible national fishing technology institute.

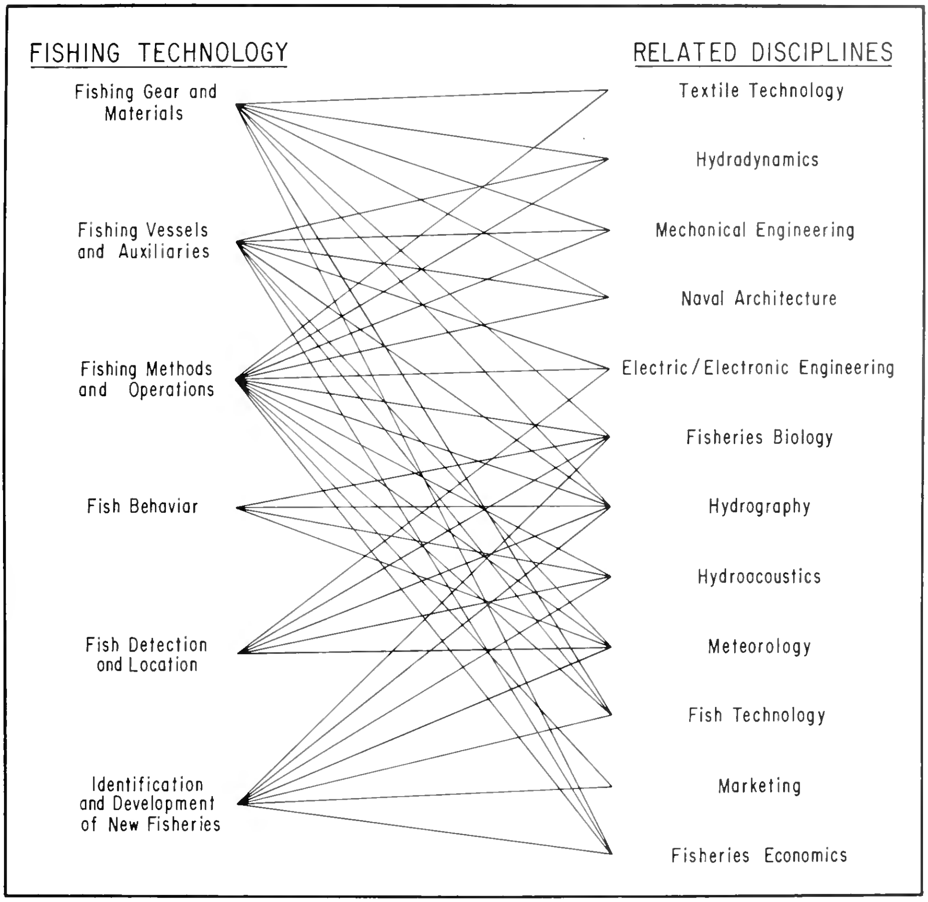

Figure 3. The main interrelationships between fishing technology and related technical and scientific disciplines. (Courtesy FAO, FIIT)

either on the operator's level — skipper, mate, engineer — or too theoretical. Foreign technical assistance agencies are trying to overcome this shortcoming in practical fishing experience by providing study tours and fellowships for would-be technologists from developing countries. In some instances, they also are offering regional introductory courses.

Fishing Technology in Developed Nations

In advanced, industrialized nations, fishing technology has attained considerable sophistication. Mathematicians, physicists, engineers, naval architects, and economists have joined with fishery scientists to provide a wealth of knowledge about fish behavior, the design and operation of various fishing gears, comparative performance testing, modelling, vessel features, operational concepts, and so on. This has led to some remarkable achievements. Some examples are sonar-guided purse seining, aimed trawling (Figure 4), and the development of major latent resources, such as Antarctic krill (see page 13) and oceanic squid. Other examples of successful fishing technology include the introduction some years ago of synthetic fiber materials for nets and ropes and the gradual development of echo-sounding for fish detection. A more recent innovation has been the development of an automated trawling system (Figure 5), which utilizes electronic data processing to integrate the major aspects of the fishing experience. It finds the fish, steers the boat, lowers the net, captures the fish, and returns the catch shipboard, even aiding in the processing procedure — in effect relieving the trawler skipper's brain "computer" of many of its former burdens. The computer system thus more readily guarantees that a given trawl will capture targeted fish even under adverse conditions, such as rapid fish movements, or strong winds or currents. Also receiving increased attention is the development of remote-sensing devices that can provide environmental data related to fish distribution, such as temperature probes.

More prosaic improvements in fishing technology also have occurred in respect to fishing gear and operations. Among these have been the introduction of monotwist monofilament for gillnets (more pliable and easier to handle than the older monofilament line), automated long-lining for bottom fish (saves on labor), parallel ropes for midwater trawls (replaces netting in the mouth of the trawl, considerably reducing drag), new otter board designs (lower drag, better performance),

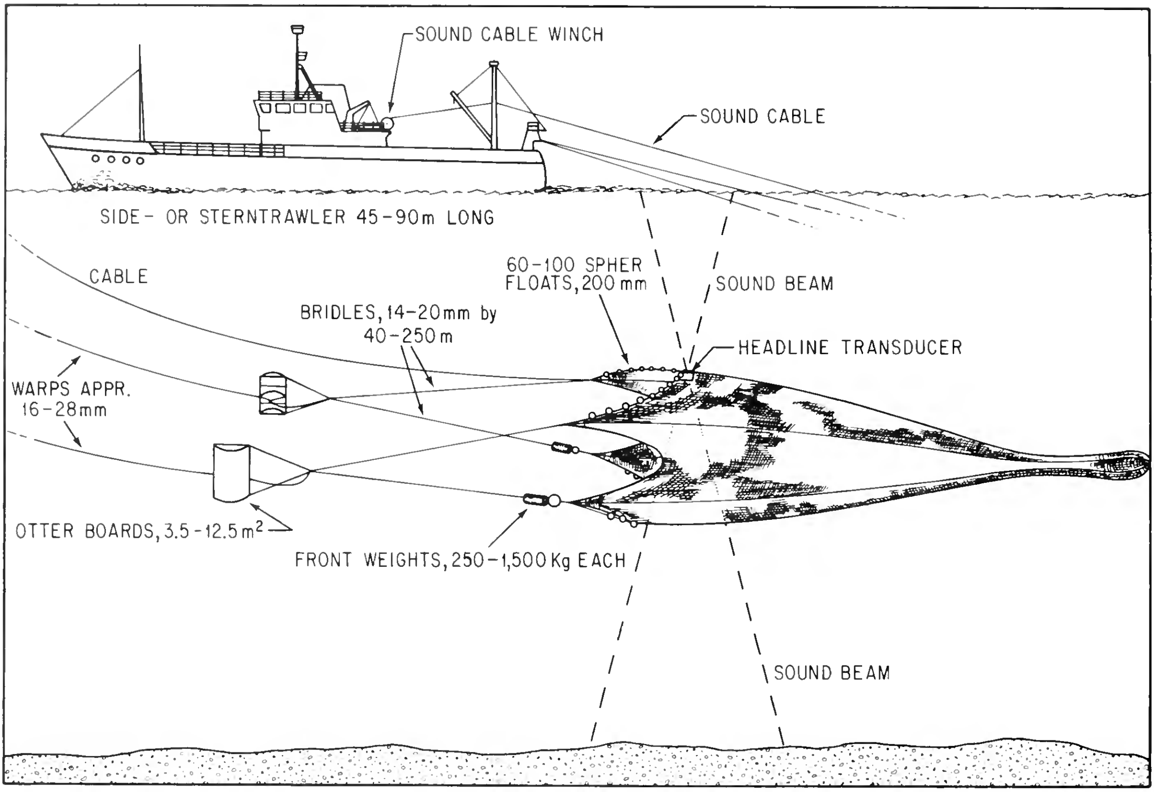

Figure 4. Aimed midwater trawling — an example of large-scale industrial fishing. A special feature is the monitoring of fish in and above the net mouth by an echo-sounding device.

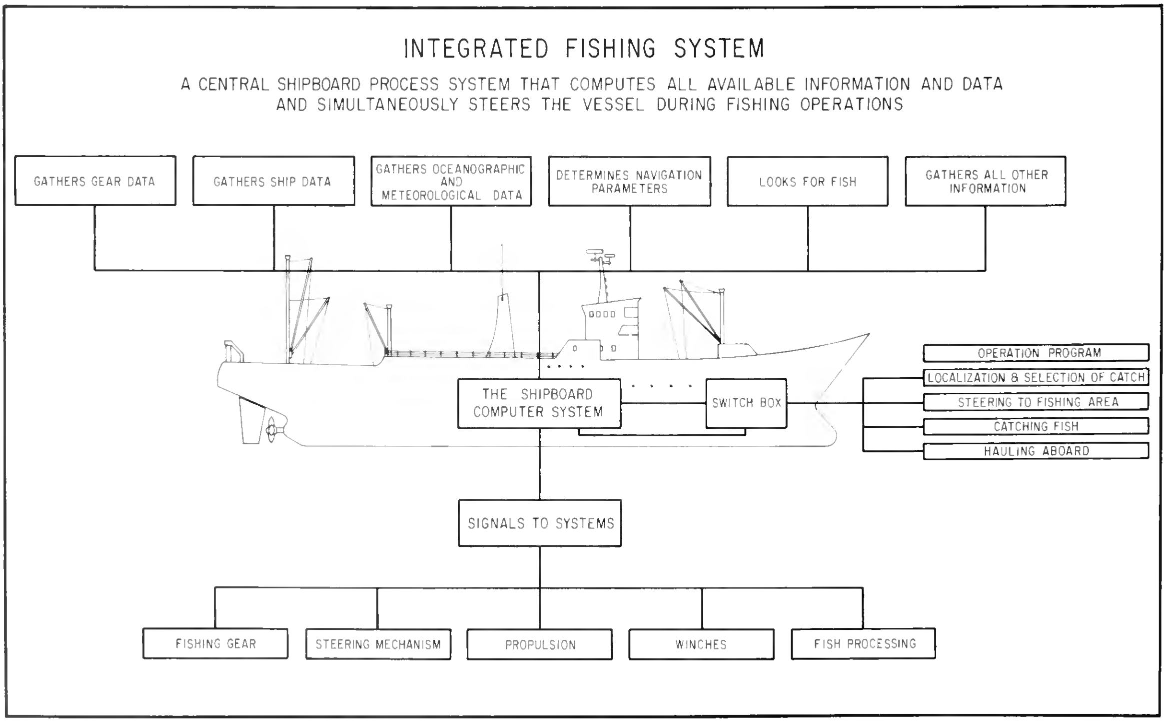

Figure 5. An automated trawling system, similar to those being developed in several large industrial fisheries. The system integrates data from a number of sources, allowing for automatic decisions in the fishing process, including control of the vessel.

Figure 6. A ferro-cement trawler on Lake Victoria, East Africa. The vessel was built as a prototype and operated by the Food and Agriculture Organization of the United Nations under technical assistance projects. (Photo by author)

hexagonal meshes for purse seines and trawls (less wear), and new, longer-lasting materials for vessel construction and repair, such as ferro-cement (Figure 6) and plastic reinforced with fiberglass.

The majority of these improvements, while having been developed for advanced fisheries, are relevant to developing fisheries. They serve to illustrate the partnership that is needed between advanced and developing fisheries if there is to be a successful transfer of technology. Fishing is essentially the hunting of wild animals that live in a changing environment. Thus there is a close relationship between fishing technology and the disciplines of marine science (many fishing technologists are former marine biologists). Certainly one can see that the advances in fish detection methods are indebted to the pioneering underwater acoustic studies of marine scientists.

Moving Ahead

We have seen that fishing technology is an integral part of any well-balanced fisheries development. Therefore fisheries in developing and less-developed countries that desire accelerated growth should consider establishing (or upgrading) their own national capacity in the form of an autonomous institution, service, or unit. To initiate such a project, aid should be sought (multi- or bilateral) from more advanced fishing nations, preferably in subject matter expertise and equipment, until national competence is fully developed. The next best alternative, although much inferior, would be for the developing country to seek consulting services to assist their national staff.

In developed countries, there is a need for fishing technology institutions to include the problems of developing nations in their programs, specifically by making specialists available as consultants. In certain instances, they also can alert their national technical assistance agencies to specific needs of fisheries in the third world.

We should mention as a final note that there is considerable opportunity for developing nations to exchange fishing expertise within their particular regions. These efforts should receive the fullest attention and support from all concerned parties.

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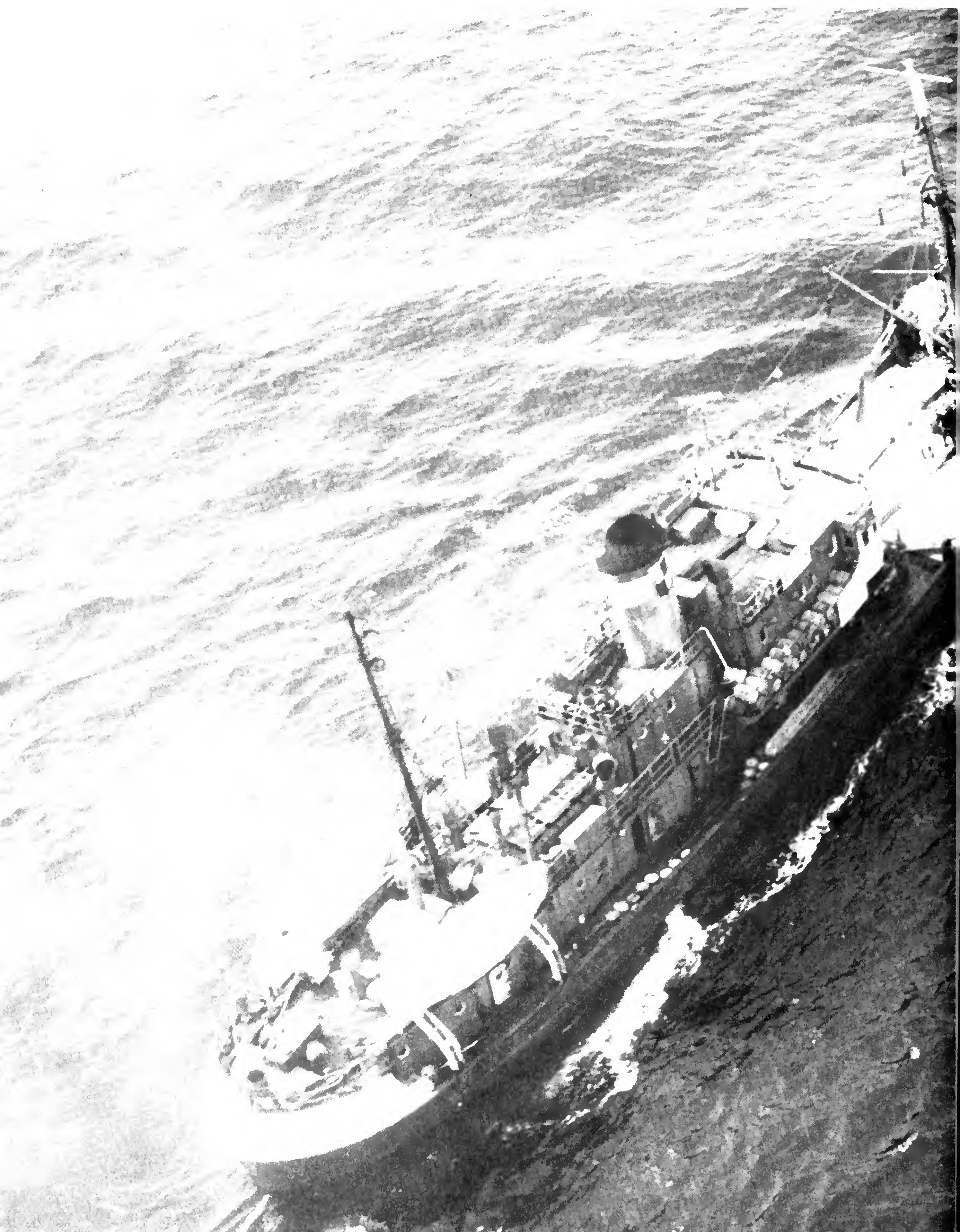
Problems of Long-Range



Fisheries

by Wlodzimierz Kaczynski

The operators of long-range fishing fleets presently are re-evaluating their position because of the stringent regulations imposed on them by coastal states in the wake of extended jurisdictions out to 200 nautical miles. In addition to reassessing expansion plans, they are seriously considering developing alternative fisheries in open-water areas where their fleets still can operate freely. It has become only too clear to these operators that they based their initial fishing programs on what has now become mainly the highly restricted resources of the more developed countries, such as the United States, the Soviet Union, Canada, Australia, New Zealand, and those of Western Europe. The long-range fleets began to notice a crimp in their operations in the early 1970s, when harvests began to decline due to fishing restrictions that were largely a result of unilateral, bilateral, and multilateral actions by developing coastal nations.

At one time, the long-range fleets — coming from such countries as the Soviet Union, Japan, Poland, and Spain — were highly successful in their fishing efforts off developing and less-developed countries, substantially increasing their overall catch from year to year. The most prolific areas were in the Southwest, East Central, and Southeast Atlantic (see map pages 6 and 7).

In fact, foreign fishermen have been taking a significant part of the total catch in nearly all parts of the ocean (Table 1). In 1976, for example, they took about 52 percent of all fish harvested in the Southeast Atlantic, 56 percent in the East Central Atlantic, and 74 percent in the Northeast Pacific. Only in the Northeast Atlantic (exploited mostly by Western European nations) were foreign fleet operations considerably less intense, accounting for only about 11 percent of the catch.

Fishing Off Patagonia and West Africa

In 1967, Argentina introduced a 200-mile economic zone, which took effect after four years of heated negotiations. Prior to its implementation, the abundant Patagonian Shelf resources (mainly hake) were open to foreign fleets. Large-scale fishing operations led to high catch rates: long-range fleets took nearly 22,000 metric tons in 1965 and 686,000 metric tons in 1967 (Table 2). With the Patagonian Shelf waters now closed to foreign fleets, the Argentine government is initiating ways to better utilize its enormous fishery resources. They are considering joint ventures with a few carefully selected partners who will gain access to the area, as they think this will be more profitable than license payments or surplus quota allocations. We will return to the subject of joint ventures later.

In the coastal zones of West African nations, where there are considerably less restrictions,

Soviet factory ship Trudovaya Slava, *one of the mother ships of the large Soviet-bloc fishing fleet, working off the Virginia coast. (Photo courtesy U.S. Coast Guard)*

Table 1. Distribution of domestic and foreign catch in the major world fishing areas (in thousands of metric tons).

Fishing Areas		1967	%	1969	%	1971	%	1972	%	1973	%	1974	%	1975	%	1976	%
Atlantic Northwest	Domestic	2,080	52	2,110	48	2,119	49	2,041	47	2,039	45	1,926	47	1,846	48	1,978	57
	Foreign	1,950	48	2,250	52	2,246	51	2,289	53	2,452	56	2,130	53	1,973	52	1,483	43
Atlantic Northeast	Domestic	9,063	87	9,251	92	9,216	88	9,275	86	9,860	87	10,337	87	10,592	87	11,822	89
	Foreign	1,281	13	769	8	1,253	12	1,415	14	1,425	13	1,480	13	1,549	13	1,507	11
Atlantic East Central	Domestic	748	49	782	38	1,096	39	1,238	40	1,327	38	1,589	42	1,454	41	1,741	44
	Foreign	782	51	1,288	62	1,745	61	1,907	60	2,148	62	2,184	58	2,071	59	2,227	56
Atlantic Southeast	Domestic	1,978	75	2,289	74	1,541	62	1,789	60	1,882	60	1,955	67	1,583	61	1,403	48
	Foreign	662	25	801	26	939	38	1,214	40	1,273	40	975	33	1,004	39	1,535	52
Pacific Northeast	Domestic	476	46	391	38	464	20	521	19	531	28	486	21	780	22	616	26
	Foreign	569	54	643	62	1,844	80	2,255	81	1,352	72	1,831	79	1,761	78	1,793	74

Source: 1967-1969. Gulland, J. A. 1973. Distant-water fisheries and their relation to development and management. Technical Conference on Fishery Management and Development, Vancouver, Canada. 1971-1976: Food and Agriculture Organization. 1977. Yearbook of Fishery Statistics, 1976. Rome: FAO.

distant-water fisheries are growing. Full-scale fishing activities have expanded on the rich fishing grounds of nations that possess underdeveloped fishing capacity, or are unable to develop these resources at the present time.

Also contributing to the development of long-range fisheries in this area is the existence of two international fishery management bodies covering North West and South West African coastal waters: the CECAF — Commission for East Central Atlantic Fisheries, and the ICSEAF — International Commission for South East Atlantic Fisheries. In both organizations, non-African members play an important role in the decision-making process; their position cannot be overlooked when yearly quotas are allocated to foreign fishermen in this region.

In the CECAF area — adjacent to Nigeria, Senegal, Morocco, Ghana, Zaire, and others — the total yearly catch during the 1970 to 1976 period grew from more than 2.7 million metric tons to almost 4 million metric tons. During that period, the total share of non-African nations increased from 47 percent to more than 56 percent. The Soviet Union had the largest fleet, increasing its catch two-fold (along with Bulgaria, Cuba, Poland, and Rumania), whereas the Western countries' catch rates remained relatively low. Japanese catches in this area have decreased steadily over the last seven years (Table 3). The total harvest of the Eastern European fishing nations in this area is more than twice as large as that of Western long-range fleets, approaching the level of catch registered by all coastal Northwest African fishing states.

Table 2. Patagonian Shelf fisheries (domestic and foreign) before and after implementation of 200-mile economic zone (in thousands of metric tons).

Country	1965	1966	1967	1968	1969	1970	1971	1972
Argentina*	192.3	240.6	227.3	212.1	191.9	209.0	222.7	231.4
Bulgaria	—	—	—	6.4	—	0.9	0.8	—
Taiwan	—	—	—	0.7	11.8	8.9	10.1	10.0
Cuba	—	0.4	—	1.6	2.1	—	—	—
East Germany	—	0.2	—	—	—	—	—	—
West Germany	—	—	2.0	—	—	—	—	4.0
Japan	21.9	11.1	4.4	5.7	12.2	14.8	3.0	3.3
Soviet Union	—	73.3	677.7	189.8	92.6	420.6	262.2	4.6
Total foreign nations	21.9	85.2	685.7	204.7	116.6	445.2	276.1	22.9

*Total catch of Argentina.
Source: FAO. Yearbook of Fishery Statistics, Rome, 1973.

Table 3. Catch in CECAF area (1970-1976) by coastal and distant-water fishing nations (in thousands of metric tons).

	1970	1973	1976	% change in 1976 1970=100
Coastal nations				
Nigeria	384.1	409.8	494.8	128
Senegal	187.2	315.8	260.9	139
Morocco	250.7	399.9	281.4	112
Ghana	171.5	223.7	237.7	139
Zaire	136.6	156.9	117.9	86
Other African nations	316.5	340.1	348.4	110
Subtotal	1,446.6	1,846.2	1,741.1	120
Distant-water fishing nations				
a) *Eastern European countries*				
Bulgaria	35.0	19.9	25.4	72
Cuba	22.1	10.6	10.7	48
Poland	31.2	34.3	129.4	415
Rumania	4.8	43.9	35.8	746
Soviet Union	612.5	942.7	1,315.4	215
Subtotal	705.6	1,051.4	1,516.7	215
b) *Other nations*				
Egypt	9.0	13.8	15.0	167
France	54.1	49.3	64.1	118
Greece	32.4	33.4	23.9	74
Italy	62.9	42.4	25.0	40
Japan	142.9	113.2	65.2	46
South Korea	—	64.2	105.0	—
Portugal	70.4	28.2	26.9	38
Spain	219.7	367.2	384.8	175
Subtotal	591.4	667.8	709.9	120
TOTAL	2,716.6	3,564.8	3,967.7	146

Source: FAO. Yearbook of Fishery Statistics, Vol. 42, 1976.

Most long-range fishing in the Southeast Atlantic is concentrated in the Namibian area, where there are important hake fisheries. Foreign fishermen have increased their share of the total catch in the ICSEAF area from 34 percent in 1970 to 54 percent in 1976 (Table 4). Here, as in the CECAF area, the Soviet Union has the largest share of overall catch, and its catch in 1976 was higher than the combined harvest of Angola and Namibia. As a whole, Eastern European nations took 1.1 billion metric tons in 1976, and their growth rate between 1970 and 1976 was the greatest of all other nations fishing in that area. In contrast, the total catch of the African nations is steadily decreasing.

There are three main reasons for the increasing pressure of the long-range fleets on the West African fishery resources:

1) The close proximity of these grounds to the foreign fleets' homelands. (It only takes 10 to 14 days to reach Northwest African areas, and another week to reach South Angolan or Namibian coasts.)

2) High concentrations of commercially important species, which are only partially harvested, at best, by the neighboring African nations (such as Spanish Sahara, Mauritania, and Sierra Leone).

3) Better access to the resources due to fewer restrictions on fishing.

Also, West African nations are seeking international cooperation in fisheries as a means of accelerating their own development. In numerous

Table 4. Catch in the Southeast Atlantic area (1970-1976) by coastal and distant-water fishing nations (in thousands of metric tons).

Country	1970	1973	1976	% change in 1976 1970=100
Coastal nations				
Angola	367.2	470.3	153.0	42
Namibia	711.2	709.7	574.1	81
South Africa	572.7	708.8	636.6	111
Subtotal	1,651.1	1,888.8	1,363.7	83
Distant-water fishing nations				
a) *Eastern European nations*				
Bulgaria	40.4	22.9	45.7	113
Cuba	21.4	54.0	44.8	209
East Germany	—	—	4.9	—
Poland	—	49.9	113.0	—
Rumania	3.4	—	7.9	232
Soviet Union	422.6	648.6	841.2	199
Subtotal	487.8	775.4	1,148.0	235
b) *Other nations*				
France	—	1.2	—	—
West Germany	0.6	1.8	12.6	—
Ghana	—	71.9	32.0	—
Israel	5.3	7.3	6.9	130
Italy	—	0.5	11.8	—
Japan	84.8	142.0	118.0	139
South Korea	—	—	1.8	—
Portugal	20.8	37.6	20.4	100
St. Helena Island	0.2	0.2	0.2	100
Spain	246.0	217.2	200.7	82
Zaire	13.7	11.5	7.5	55
Others	9.7	14.7	14.8	153
Subtotal	371.4	505.9	426.7	115
TOTAL	2,510.3	3,170.1	2,938.4	117

Source: FAO. Yearbook of Fishery Statistics, Rome, 1973 and 1976.

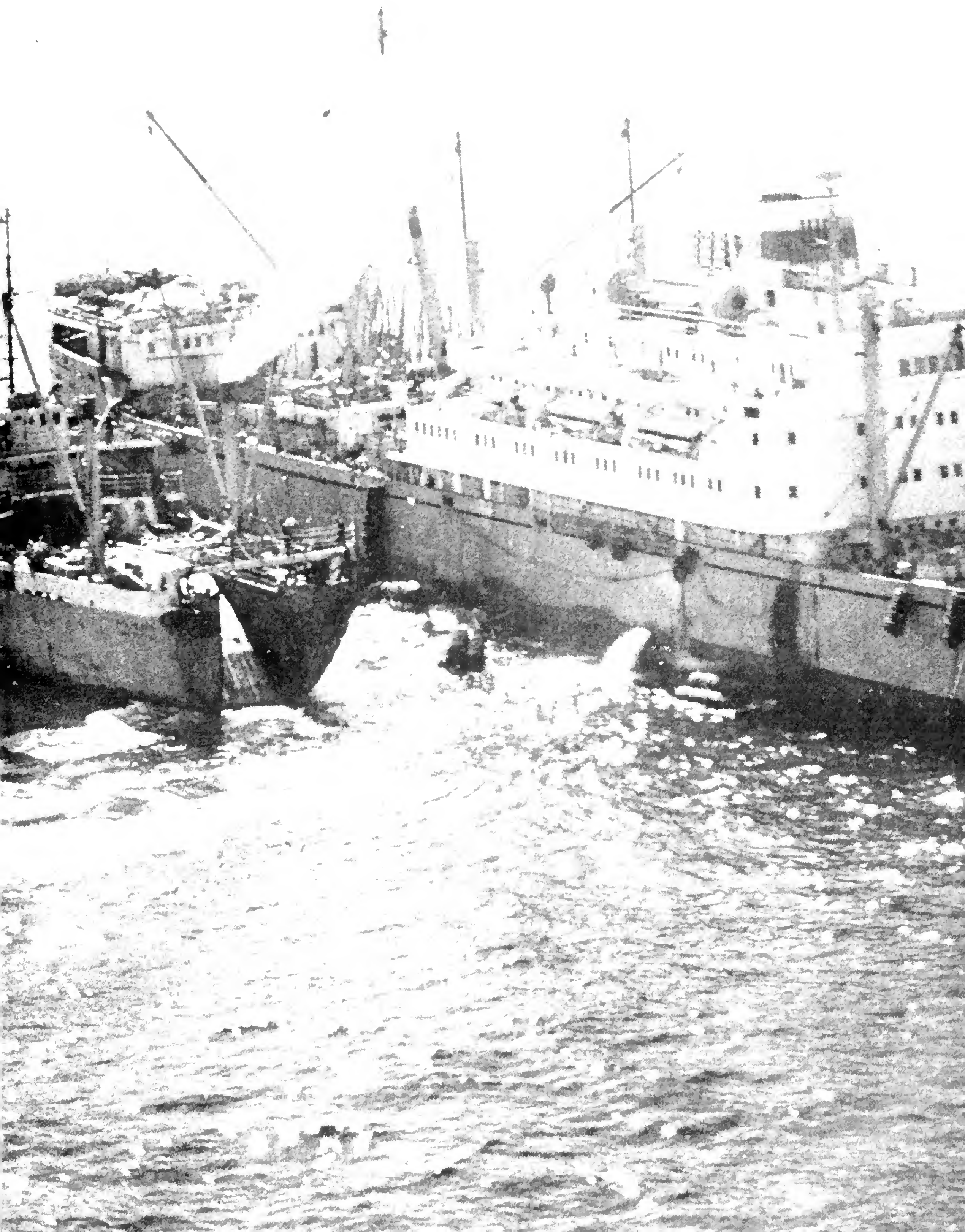
bilateral agreements, foreign countries are allowed to harvest coastal resources because they supply fishing vessels, land installations, or training to the coastal nation. Foreign nations also have undertaken cooperative fishery research operations to better determine the potential of the coastal fishery resources.

The importance of the West African fishing grounds to the foreign fleets should not be overlooked. The Soviet Union's total harvest in this region was more than 2,130 metric tons in 1976. This means that CECAF and ICSEAF area catches contribute 20 percent to the total Soviet catch, which was slightly over 10 million metric tons that year. The Spanish catch in African waters in 1976 was 585 thousand metric tons, providing the greater part of their total long-range catch. Polish catches at that time in this area represented more than 30 percent of their overall harvest. Japan, taking 183,000 metric tons in 1976, and South Korea, taking more than 100,000 metric tons, are other important long-range fishing nations operating there.

Joint Ventures

For foreign fishing operators, joint ventures with developing countries not only provide access to the local resources and employment opportunities, but they also generally are less expensive in terms of manpower and vessel operation. Japan, for example, has been a part of joint ventures with many developing countries for years—with nations in Africa, Latin America, and others. By 1976, Japan had established about 200 companies in foreign (mainly developing) nations. Such operations contribute to the Japanese fishery economy, because some of the fish food produced goes to

Right, Soviet stern trawler about to offload catch onto factory ship. (Photo courtesy NMFS, Woods Hole)



their own consumer market.

However, many long-range fishing nations use large factory trawlers, and there are problems using them in joint operations. Some of the major difficulties are as follows:

1) The use of factory trawlers excludes the possibility of land processing, since they are equipped with processing plants on board. This means that the developing coastal nation cannot use the technology or gear from these vessels in developing its own harvesting and processing potential. On the other hand, the foreign operator saves money by not having to build plants on land.

2) Operation costs of these vessels have proven to be very high, often more than $1.2 million per vessel per year. Thus the output of marketable fish food products also should be high. This is extremely difficult if the land facilities (ports, cold storage, transportation) are inadequate to support full-scale, highly industrialized coastal fisheries, with local markets unable to absorb the quantities produced.

3) Only a few developing countries can offer adequate support for large factory trawlers, which must therefore return every year to their home shipyards for repairs and maintenance.

Since most developing countries require smaller vessels, generally without processing installations on board, foreign fishermen should make available much simpler and less expensive short- and middle-range fishing boats that can operate from adequate land support facilities in these coastal states.

Future Operations

Many distant-water fishing nations already have realized that future fisheries development requires that they adjust their internal maritime economy to include the cost of harvesting fish in coastal zones of developed and developing countries. They may have to pay license fees, or finance joint ventures or other foreign aid projects. In addition, they must look for alternative, open-ocean areas where new fisheries can be developed. The long-range fishing nations that have not developed cooperative links with the developing nations, or have not replaced their large fishing vessels with smaller ones for inshore operations, are suffering economically because of the reduced fishing opportunities.

Cooperative arrangements with coastal states are considered by many long-range operators to be temporary solutions, since coastal nations eventually will develop their own fishing capacity. In Africa, South America, and Asia, developed fishing nations are offering their services via technology transfer proposals to help expand the coastal fisheries of less-developed nations (see page 54). The eventual self-sufficiency of the developing nations' fisheries is a factor that should not be overlooked by distant-water fleet managers.

It is clear that distant-water activities in coastal zones of other nations must be preceded by negotiations to determine quotas and fishing effort levels for foreign fleets. This situation creates a climate of uncertainty for long-range operators. They are unable to project their future shipbuilding programs and properly adjust the composition of their fleets to the ever-changing terms of access.

This applies particularly to the Eastern European nations, which developed an independent fishery model, based on large fleets supported by auxiliary vessels. To maintain this model of ocean fisheries management, these nations must continue using the port facilities of developing nations to assure logistical support for their factory trawlers and other ships operating in remote areas of the Southern Hemisphere or open-ocean waters. The Soviet Union, for example, has created a network of fishing bases in the Canary Islands, Singapore, Cuba, Mauritius, and other countries. The dimension and composition of their fleet and those of other Eastern European nations suggest that they will be interested mostly in independent, long-range fishery activities in both the open ocean and continental coastal zones for many years, since this type of operation is much more manageable than other alternatives, including joint ventures.

Open-ocean fishery resources utilization will require large, modern fishing vessels able to operate in tropical and subantarctic areas. Such vessels are under construction in Eastern European, Japanese, and other shipyards. This trend could contribute to the further deterioration of long-range fishery activities, but some developed fishing nations perceive the costs of this expansion to be low compared to other alternatives.

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Cultural Deterrents to Use of Fish as Human Food

by Frederick J. Simoons, Bärbel Schönfeld-Leber, and Helen L. Issel

In various parts of the modern world, but especially in Africa, South Asia, and the American Southwest, there have been strong, traditional cultural deterrents to eating fish. In any effort at increasing the consumption of fish among the cultures involved, it is important that we understand the nature of these deterrents, which are part of what sociologists call the "foodways." The foodways of a society — those thoughts, feelings, and behavior relating to food that are common to the group — determine which of the available food resources are consumed and which are not. In some cases, foodways can readily be modified, whereas in others strong feelings exist against change, against accepting new foods. Such feelings may be implicit or explicit. They often relate to religious belief, or to concern with social status, or other aspects of society and culture. A foodway may be followed by all members of a group, or restricted to a particular class, caste, sex, age, or other subgroup. It may be practiced at all times, or observed only at particular times of the year or periods of a person's life, such as during a woman's pregnancy. In trying to understand the foodways, including those that restrict the consumption of fish, one is led to a position of "cultural relativism" — the view that understanding can be best achieved within the framework of an individual culture, that broader generalizations may be useful but not universally applicable.

In trying to determine the origins of a particular foodway, the social historian may encounter insurmountable problems. For one thing, it may have roots so far in the past that little empirical evidence can be found to shed light on how it developed. A further problem is that a foodway may not have had a single origin, but multiple ones. This forces one to be skeptical of general theories of origin, especially those that reflect our own cultural tendency to favor explanations in terms of economics, health, and disease.

In this brief article, we seek to establish the broad boundaries of the problem, to identify a range of cultural behavior that has deterred people in widely scattered areas from utilizing more fully their aquatic food resources. It should be noted that one cannot always separate foodways relating to freshwater fish species from those of saltwater. A general rejection of fish, for example, applies to fish of all sorts, whatever their habitat. This is the form of fish rejection to which we turn first, what has been called ichthyophobia — general rejection of fish as food.

Ichthyophobia

Western observers have long been surprised that the Tasmanian Aborigines, hunters and gatherers (extinct since late in the 19th century) who lived south of Australia on a mid-latitude island with abundant fish in the surrounding seas, apparently did not eat scaled fish, though they did eat shellfish, crayfish, and sea mammals. Some observers have said that the Tasmanians regarded scaled fish with disgust, and would rather starve than eat them. Recently, Rhys Jones, an archeologist, reported, on the basis of findings from excavations, that the Tasmanians quit eating such fish, which had previously been important in their diet, about 3,800-3,500 years ago. In the absence of plausible explanations in terms of disease, or ecological or technological change, Jones concluded that the Tasmanians abandoned fishing and fish eating because of an "intellectual decision," one which reduced "their ecological universe." This is the best example of archeological evidence being brought to bear on the origins of a foodway relating to the sea.

The Tasmanians, however, were an isolated group of fish-avoiders. As we mentioned previously, there are three large regions of the modern world where strong traditional feelings have existed against eating fish. All these regions include some arid and semi-arid sections where fish are relatively scarce, and others where they are plentiful. One is in Africa; a second, in Asia, stretching from Turkestan to India; and a third, in the American Southwest. The first two of these regions of fish avoidance have been studied as to geographic limits, cultural associations, and possible origins of the avoidance, but the third has not.

Africa

The greatest number of modern African fish-avoiding groups are found in Northeast, East, and South Africa (Figure 1). It is believed that such avoidance existed in early times among the Cushites, the original inhabitants of Ethiopia and adjacent lands of Northeast Africa. Some parts of that region have considerable fisheries potential — for example, the Red Sea and Indian Ocean. Some

Cushites merely express ignorance of how to fish, or smile at the notion of eating fish. Others consider fish eating to be shameful, and regard fish as dirty snakes. There is one report that Beja — Cushitic pastoralists of the Red Sea borderlands of Egypt, Sudan, and Ethiopia — often feel so strongly that they reject fish even when in great need. Similar attitudes — that fish are unclean food, that fishing and fish eating are low-class practices, and that one's social status is enhanced by refraining from them — are found also among Nilotes and Bantu in East and South Africa. Some scholars suspect that these attitudes were diffused southward by the Cushites, others that they may have evolved independently under ecological conditions similar to those of the Cushites. Though modern influences have caused many African fish-avoiders to abandon traditional views, such views continue to deter development of the fishing industry. One example is former French Somaliland (now Djibouti), which possesses an abundant and varied marine life, but where very little fishing is done except for rock lobsters, shrimp, and crabs.

Why fish avoidance became so widespread in northern and eastern Africa, but was virtually unknown along the Guinea Coast and in Central Africa, remains a mystery. It may be significant that northern and eastern Africa are arid and semi-arid regions. Perhaps fish avoidance there had its roots in rejection of a relatively scarce and unfamiliar food. Another possibility is that negative attitudes toward fish use in northern and eastern Africa originated in the contempt pastoral nomads often exhibit toward agricultural folk and their customs. Fishing would have been less important, even unnecessary, for such nomads, whose herd animals ordinarily provide an abundance of animal protein. Such nomads, moreover, were vigorous and aggressive fighters — in an excellent position to inculcate their attitudes toward fish and fishing among agricultural folk. In keeping with the latter hypothesis is the reluctance of some Bedouin Arabs to eat fish except in times of need. Also relevant is the occurrence of many fish-rejecting pastoral nomadic groups in the arid lands from Turkestan to northwestern India, within the Asian zone of fish avoidance.

South Asia

In India, a major fish-producing country, it has been estimated that nearly a third of the population does not eat fish. There are reports, from Madras, of resistance even to utilizing fish meal as cattle feed. Among practicing Jains (of all the Indian sects perhaps the most concerned about what they eat) fish are not consumed at all. Within the dominant Hindu religious community, however, it is usually only certain Brahmin or priestly castes *(jatis)* and other castes of superior ritual standing that refuse to eat fish, for most Indian fish avoidance stems from religious concepts, especially *ahimsa* (nonviolence to living creatures), which is central to Jain and Hindu thinking. Ahimsa also is the basis for widespread vegetarianism, not only among Hindus and Jains but among Buddhists and adherents of other religions of Indian origin.

Another reason advanced by Brahmins and members of other high castes for their refusal to eat fish is that fishermen are untouchables and that they, as upper caste members, would become ritually polluted if they ate fish. In Hindu India, fishing is a lowly occupation, often looked down on even by humble castes. One caste from Bengal, the Kaibarttas, divided into two separate castes because one section of the group began to practice fishing. In previous centuries, the Hindu concept of transmigration of souls also contributed to fish avoidance. This occurred when an illustrious person along the Malabar Coast died; then all fishing and fish-eating stopped for several days to give the person's soul sufficient time to choose its new habitation in a fish. Also contributing to the avoidance of some, but not all, fish in India is the Hindu belief that certain waters are sacred (for example, temple pools and sections of holy rivers) and that sanctity is imparted to fish living in them.

American Southwest

In pre-Columbian North America, there were notable regional differences in the quantities of fish available and the amounts consumed by native peoples. In some places, as among the salmon-fishing Indians of the Pacific Northwest, average annual fish production was from 800 to 1,000 pounds per square mile. Fish in these parts were the most important food staple. By contrast, in much of the continent's western interior, average annual production was less than 50 pounds per square mile. In the American Southwest, the Navajo, Apache, Zuni, Hopi, and other various Indian tribes refused to eat fish altogether. Among the Pueblo Indians (the Zuni and Hopi), water was viewed as sacred, and fish and all other water-living creatures shared in that sanctity. There is no record of a general fish taboo among the northern Athapascan relatives of the Navajo and Apache; in fact, they live on fish for a considerable part of the year. This suggests that Navajo and Apache rejection of fish developed only after they migrated to the Southwest several hundred years ago, perhaps through the influence of Pueblo Indian groups with whom they had contact. In any case, early accounts of the Navajo report a fear of eating all food originating in water, including frogs, crabs, eels, snails, turtles, clams, and waterfowl. One Navajo explanation given was that these creatures are "people of the water," offspring or servants of the water monster who resides in the ocean and controls the waters of the land as well. Navajo believed that the water monster would punish those

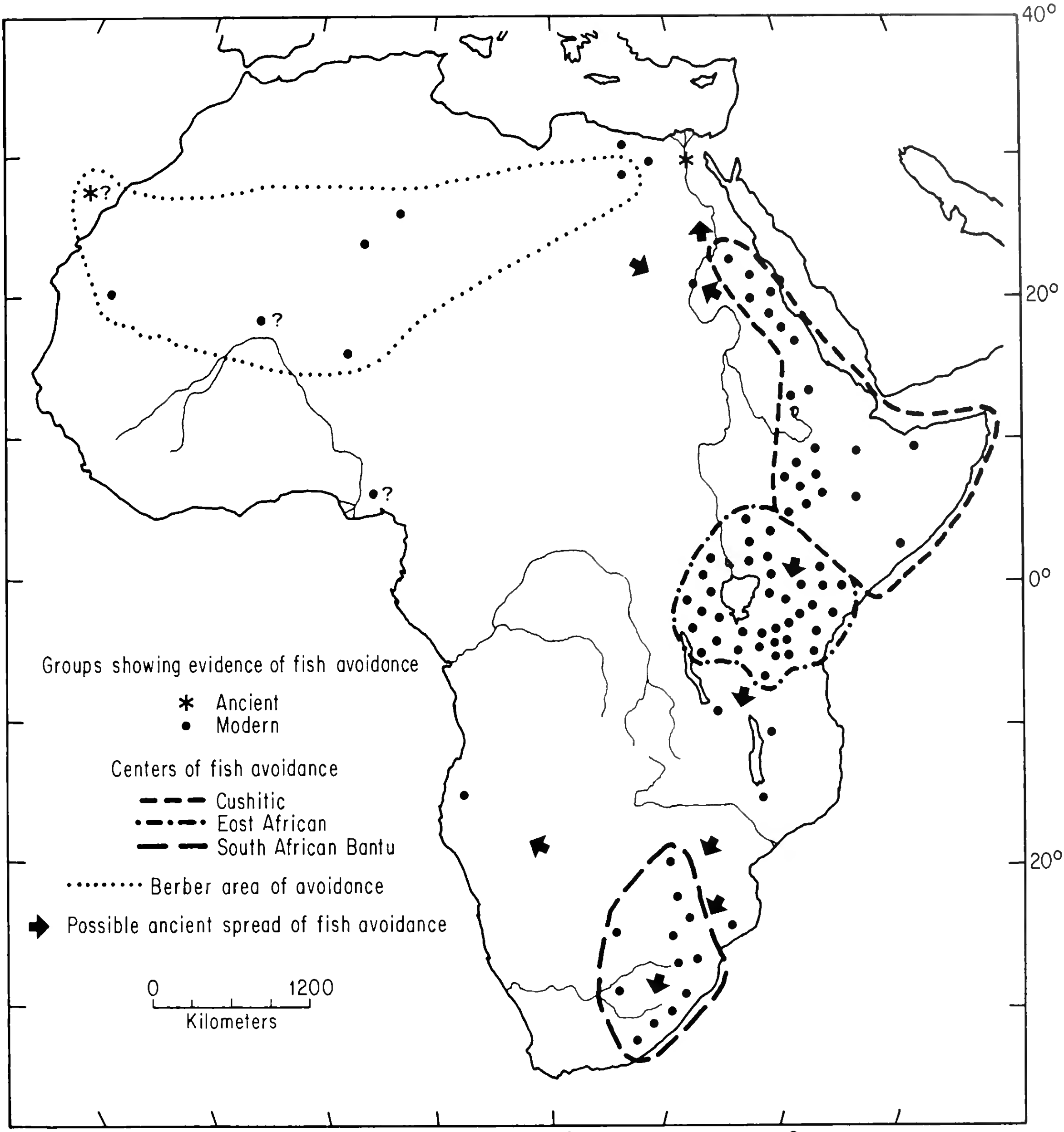

Figure 1. Areas in Africa where tribal groups show evidence of fish avoidance.

who ate his creatures. Observers noted some Navajo who reacted to fish as a pollutant whose consumption required purification ceremonies. Certain Navajo refused even to touch fish or to eat candy shaped like fish.

Through contact with Spanish- and Anglo-Americans, the Navajo and other Indians of the Southwest largely have abandoned their traditional attitudes toward fish. Among the present-day Navajo, sardines and other canned fish are popular trading post items. Frozen fish also are popular. Some, however, mainly older people, still find fishing and fish eating distasteful.

Nevertheless, the traditional fish ban of the Navajo and other Indians of the Southwest provides an interesting parallel to that of the arid and semi-arid lands of Africa and Central Asia. In the American Southwest, however, the avoidance cannot have derived from pastoral contempt for farmers and their ways. The Indians of the Southwest had only

These you may eat, of all that are in the waters. Everything in the waters that has fins and scales, whether in the seas or in the rivers, you may eat. But anything in the seas or the rivers that has not fins and scales, of the swarming creatures in the waters and of the living creatures that are in the waters, is an abomination to you.

They shall remain an abomination to you; of their flesh you shall not eat, and their carcasses you shall have in abomination. Everything in the waters that has not fins and scales is an abomination to you.

Leviticus XI. Old Testament

the turkey and dog as domesticated animals and, before the Spanish conquest, pastoralism did not exist as a way of life. The avoidance may have developed among farmers as a reaction to scarce, relatively uncommon forms of life that lived in waters regarded as sacred.

Rejection of Particular Forms of Fish

Malnutrition is widespread in India. Some people, therefore, might expect the pressures of hunger to have led Indians to consume a broad range of edible seafood as has been the case in the Far East and Mediterranean. That this is not so has been shown by David Sopher, a geographer who traveled along India's east coast. He observed that many beds of edible oysters existed, but no use was made of them. Nor was there any use made of *Holothuria,* the *bêche-de-mer* of Chinese soups. Local fishermen, in fact, were amazed to learn that this species was eaten by peoples elsewhere. Squid also was not consumed, except in one locality. Lobsters and eels were not popular, and sharks and skates were eaten only by the poor. (Others have observed that many coastal Indian groups also rate tuna low because the red color of its flesh resembles that of meat. In some fishing villages, tuna is simply thrown away.)

E. N. Anderson, a sociologist, has noted that even among the boat-dwelling fishermen of Hong Kong, who are practical and very knowledgeable about fish and fisheries, some sea creatures (for example, sturgeon, sawfish, and whales and porpoises) are classified as sacred, and not caught. If they are captured alive, they are returned to the sea. If not alive, they are carried to a temple, where they serve as sacrifices.

The failure of the peoples studied by Sopher and Anderson to use many readily available seafood resources seems to be characteristic of other cultures as well. Yet virtually nothing has been done to map the patterns of rejection of individual fish species, or of fish that fall into a particular category. For example, widespread interest in the Jewish ban on fish without "fins or scales" (*Leviticus* XI: 9-12), has not led to the study and mapping of similar bans among other ethnic or religious groups. It is known that many Moslems observe such a ban. We are told that this is why most shellfish caught in Pakistan, a Moslem country, are not consumed domestically, but are exported. In parts of India, there are reports of Hindus refusing to eat fish without scales. Though this indicates that such refusal extends well beyond the Near East, its precise geographic limits have not been determined.

In establishing patterns of acceptability of fish as food, one must be sensitive to variations within a religious group. In Islam, as is true of other Near Eastern religions, great concern is expressed about the way in which an animal dies, and by whose hand, though differences of opinion exist as to what is acceptable. Some Moslems believe that fish should not be eaten if they are dead when removed from the water. Others say that if a Moslem removes a dead fish from the water it can be eaten. And some say that all fish caught by non-Moslems are forbidden unless they are alive when taken from the water and then killed, with a proper benediction by a Moslem. Moslems also differ as to the particular types of fish they accept. Sharks, for example, are caught and eaten in the Arabian peninsula, birthplace of Islam. Yet one reads of an Arab vendor not far from Medina trying to sell a young shark to a Malay, presumably a pilgrim, who refused to buy on the grounds that sharks eat men.

Also deserving further investigation are the geographic patterns relating to interior peoples' preference for river and lake fish, and their downgrading of fish from the sea. Most Indian and Pakistani interior groups far prefer freshwater fish. The reasons advanced are that fish from brackish and saltwater lack fat, or have a more pronounced fish odor. In India, an experiment introducing brackish water and sea fish to inland fish consumers was undertaken a few decades ago in Orissa, where fish were sold at half their usual market price. Even at that price, very small amounts were sold and the program finally was abandoned because the subsidy was too costly. At last word, thought was being given to providing free supplies of sea fish to children in schools in an effort to gain acceptability.

Open Research Area

We have seen that deterrents to eating fish date back to antiquity, that frequently their origins are obscure, and that little has been done to establish the present-day geographic patterns of avoidance. Even within specific areas where an extensive literature is available, our knowledge is fragmentary, woefully incomplete. It is clear, however, that great variation occurs from culture to culture, a situation that must be taken into account by the student of foodways whose goal is to increase the use of food from the sea.

One can dispute the reasons for our ignorance of foodways relating to aquatic food resources. Certainly Westerners in general tend to dismiss as curiosities the foodways of other peoples and thus they are not stimulated to undertake serious study of them. American disinterest also may be related to the minor role of fish, as compared to meat, in our diet. Whatever the reasons, neglect in this area offers exciting possibilities for the enterprising investigator.

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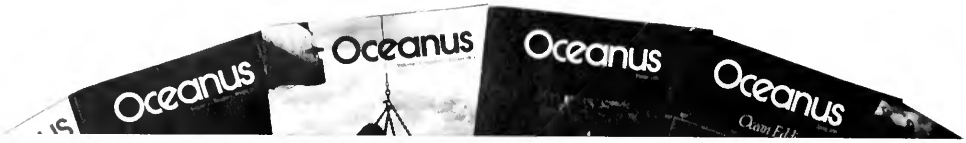

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