14

Fishes

Among all the biological resources of the sea, fishes have always been the most important. Compare them with marine mammals—whales, porpoises, and seals. They are much more abundant, more widely distributed, and less elusive. The average fisherman in most parts of the world with his modest vessel and apparatus stands a far better chance of catching a few tons of fish in a day's fishing than an equivalent quantity of mammals, and the fish are generally easier to dress, preserve, and market.

Compare fishes with the familiar commercial invertebrates like shrimps, crabs, lobsters, oysters, and clams. They are more densely concentrated in volume, and yield more pounds per unit of labor. A tuna boat takes around ten or twelve tons in a day's fishing; a shrimper does well to take one fifth of that quantity. Thus even the expensive varieties of fishes are cheaper than most invertebrates, which for the most part are too costly for anything less than the luxury trade.

Consequently, when people concerned with world food problems consider means of expanding the use of ocean resources for the humbler human needs, it is fishes on which they set their great expectations. They count on increasing greatly the quantities which fishermen now harvest and market. For purposes of this discussion, let us minimize the human problems involved in accomplishing such an increase. Let us presuppose unlimited supplies of skilled labor for fishing, unlimited capital for buying equipment, unlimited markets, unlimited demand, and unlimited preserving, storage, and transportation facilities. Economics, technology, and sociology are not the province of this chapter. In this section we are concerned with the fishes—cold-blooded, aquatic, backboned animals with gills and fins, excluding such other marine animals as mammals, mollusks, and crustaceans. If the exploitation of the sea is to be increased, where could the additional quantities of fish come from?

In searching for answers to these questions it is necessary to keep in mind the rather exacting limits of human needs and fishing capabilities, for not every kind of fish is usable. The total commercial value which a species contributes to a country's economy depends on the extent to which it possesses the qualities listed below:

Abundant, i.e., voluminous, in the sense of being capable of yielding large volume

Aggregated in dense concentrations, or easily concentrated

Regular enough in their habits that fishermen can depend on finding them year after year at about the same places and times

Accessible to fishermen; that is to say, not so deep as to be beyond range of fishing vessels and their gear, not inhabiting unworkable ground, not so elusive as to make the cost of catching prohibitive

Accessible for a long enough season to permit attractively profitable returns for the necessary investment in vessels, gear, and labor

Comestible, palatable, and nutritious

Aesthetically acceptable

Firm-fleshed, and therefore well-keeping during the time of transportation from fishing grounds to port

Amenable to preservation by such methods as salting, pickling, smoking, freezing, canning, or keeping alive in tanks until needed *

These qualities are not absolute. They must change with the technological advances and according to economic conditions and human tastes.

In general (there are some localized specific exceptions such as the ipon fishery of the southern Philippine Islands, which depends on the fry of gobies) the foregoing requirements severely limit the range of choices of fishes that may be exploited largely for human use. Indeed, they rule out at once the majority of species. They rule out most of the kinds of fishes that are too small to be worth anything, like the little blennies and sculpins that live in tide pools; many queer-shaped, slender, relatively fleshless ones like sea horses, pipe fishes, and snipe eels; some poisonous ones, like porcupine fish; all those that live permanently beyond fishable depths, like the grenadiers; and many fishes that evidently do not school and, as far as anyone can tell, are rare.

Thus it looks as though only a few kinds of fishes can be used. As it is, out of all the sea fishes which are known in the world, not

* See note 1, page 307.

more than 6 per cent are ever used, and not more than 2 per cent are used very much. The great majority of commercial species are in less than a dozen of the three or four hundred families. About a third of the total catch of all sea fishes reported in catch statistics of the world are herrings and their relatives (sardines, menhaden, and anchovies); about a quarter are cods and their relatives (hakes, haddock, and pollack); about 9 per cent are mackerel and their relatives (bonitos and tunas); and about 3 per cent are flounders. The remainder, almost a third, is made up of rockfishes, basses, snappers, weakfishes, and a miscellaneous assortment of other groups.

Fishermen have arrived at this narrow selection by generations of experience at catching and marketing fish. The machinery of their industries, creaking and cumbersome though it may be, is geared to dealing with those kinds of fishes which they have learned how to catch regularly and in large quantities, and which the public has become accustomed to seeing and therefore conditioned to accepting. Were markets now to change radically, calling for enormous increases in catch, existing fisheries could not produce them without changing in some way. What might they do? They might intensify exploration of the relatively unknown regions of the sea and subsequently generate fisheries for such bizarre creatures as they found which people had never before known. Or they might expand their fishing radius to include distant grounds which, although fairly well known, have so far remained almost untouched. Or they might harvest the less valuable species which they have hitherto avoided—familiar enough species living on or near the old, well worked-over fishing grounds. Or finally, they might advantageously manipulate rates of fishing, and the times, places, and techniques of fishing in order to enlarge the harvests of stocks which they already exploit.

The most hoped-for among these possibilities is to find and exploit something completely unknown. This would be difficult, for during the course of many scientific expeditions over the past hundred years or so, ichthyologists have collected specimens the world over with all sorts of gear ingeniously contrived to take fish wherever they occur and whatever their habits may be. However, it must be admitted that their sampling has been spotty. It has been most thorough where there are well-developed fisheries and fishery research laboratories and nearby university or governmental museums having study collections of fishes and competent curatorial staffs. Elsewhere, it has depended mostly on sporadic collecting expeditions. Thus, ichthyologists know a great deal about the species of fishes living on the plateaus of most of the shelf areas of north temperate latitudes, less about those living on the steeper slopes, and very little about those living on large stretches of shelf in equatorial and southern latitudes. They know least about the fishes of the deep sea.

Knowledge of the relative quantities of a species usually is in some proportion to the size of the fishery for it. Where knowledge depends on specimens brought back from expeditions, as it does for most species of fishes, its quantitative value is negligible. Thus, in general, ichthyologists are not in a very satisfactory position to offer authoritative a priori advice as to what kinds of fishes will yield large returns in underdeveloped areas, and therefore as to how much money people ought to hazard in new fisheries.

Up to now ichthyologists have collected and named more than 25,000 species. Judging from the rate at which they are discovering new ones, this number comprises a large part of the total; and judging from the kinds of discoveries which they are making, it probably includes most of the species of large populations. Thus it seems unlikely that many large stocks of fishes remain unknown to scientists. Scientists, however, usually communicate their discoveries only to other scientists, and in their own specialized language. Thus their knowledge about fish faunas is not easily available to average fishermen. But is it possible that fishermen, even with their very specialized gear, know more about fish faunas than their landings indicate? It would look as though their knowledge must be severely circumscribed. Most fishermen cannot go far from shore in search of new fishery stocks. They are more or less tied to the land, for the distances which they can travel and the things they can do are limited by the small size of their vessels, the simplicity of their equipment, and the driving necessity of earning a continuous living. Fishermen of highly advanced mechanized fisheries, on the other hand, are able to go much greater distances, but even they are not so independent of land as it would seem. Fishermen balk at spending long periods at sea unless they are exceedingly well paid. Moreover, it is not good economy to spend more time at sea than is absolutely necessary to get pay-loads. Such factors limit the range of oceanic fisheries and selection of fish to a few species like cod and tuna, which have special qualities that bring a high enough price in the market to make such fishing profitable.

While fishermen cannot often afford to explore far afield, they do cover ground which many fishes inhabit or visit, and they see many kinds of fishes which they do not catch and in some regions catch many kinds which they do not bring to port. Indeed, many more species of fishes than are exploited occur within the orbits of fishermen. Thus, about two thirds of all the known seafishes, that is, something like 17,000, live on continental shelves in depths of less than 100 fathoms. Continental shelves being narrow, for the most part, the majority of species of marine fishes live within twenty miles of land. Moreover, there is a tendency among shelf fishes to move into shallower water and toward shore in summer. Not only is this true of sedentary bottom-dwellers, but also of many pelagic, surface swimmers which, on the whole, never see the bottom during most of their lives. Some species of shelf fishes move in toward shore to spawn; others move offshore for that function. With either pattern, however, the young of certain species (particularly herring-like fishes) spend the first months of life close to the beaches, in estuaries or sloughs, and even far up in fresh water. As they grow larger they go out to sea, but not many species of these sea spawners go far beyond their continental shelf, for the spawning grounds are located in such relation to currents as to provide for transport of the young to their shoreward nursery grounds. Some of the pelagic fishes, notably the tunas and spearfishes, are not bound to the coastline as are the shorefishes, but occur on the high seas wherever temperature conditions are favorable. Nevertheless, they too, often touch inshore zones to feed.

Thus have fishermen had ample opportunity to acquire at least some acquaintance with many kinds of fishes that represent a much larger area than is encompassed by the limited radius of their small local fisheries. They may see only an occasional specimen belonging to a very large stock; they may not know where to seek the main body of the stock or be equipped to reach it. They may even have no name for these occasional visiting species, but from long-continued fishing experience, they do know of their existence.

Since generations of fishermen have thoroughly explored their coasts in the course of day-to-day work with many kinds of gear, they have had ample time and opportunity to learn what is there. Thus it seems unlikely that there could be many stocks of coastal fishes which are quite unknown to them. There are several that are underfished, certainly, but few that are unknown.

If there were to be any extraordinary increase in production of sea fishes, it would have to come partly by stepping up the rate of fishing the known species and partly by exploiting some of the seven thousand species which roam far below the surface of the sea outside the present range of fishermen.

While most of the familiar species occur near coasts, there are probably no parts of the sea except perhaps in the deepest depths (below 7,000 meters) which are quite devoid of fishes.[1] On the other hand, no species is found in all oceans or at all depths. Most marine fishes have more or less restricted ranges, and it is the exception rather than the rule to find identical species on the coasts of such widely separated regions as New Jersey and France.

Temperature is the most important factor determining the distribution of fishes, but it is not the only one. Depth and geology of bottom are others. One bottom-living species, for example, may be restricted wholly to coarse sand, another to mud, still another to broken shells, and another to rocks. Some species may be found only in the intertidal areas, in tide pools, while others may range from surface to bottom in open water. Wherever biologists have been able to observe the activities of shorefishes in their native habitat, as modern diving apparatus permits, they find that fishes, like land animals, occupy particular situations. A species may be absolutely confined to a habitat as restricted, for example, as an area in which are found colonies of a certain species of coralline alga, but only between the depths of 15 and 30 feet and only where the temperature never goes above 63° or below 55° F. Temperature and depth barriers may limit the fish to only a fraction of the range of the alga while colonies of the same species of alga in somewhat shallower or deeper water may harbor a closely related but quite distinct species of fish. Judging from such studies as have been made on fishes in their natural habitat, the occurrence of many species, perhaps of most of them, may be peculiarly and severely restricted, and often by a complex system of factors. Obviously, knowledge of such influences must have great bearing on where, how, and for what men fish.

Fishes vary greatly in size, from tiny gobies, adult at half an inch, to swordfishes of 14 feet or more. Sharks reach a far greater size, the basking shark to 25 or 30 feet and the whale shark to 50 or 60. However, most fish species are small. If we could average the adult length of all existing kinds of fishes we would probably arrive at an "average fish" of about 6 or 7 inches.

The saying, "big fish eat little fish," is generally true. Some commercially caught fishes, such as the herrings, sardines, and menhaden, feed directly upon plankton, but the majority of fishes, including food fishes, prey upon smaller fishes and other organisms which may themselves be one or two food-steps away from a basic plankton or plant-feeder.

It has been pointed out in previous chapters that in a simple ecological food pyramid, the ultimate predator is usually the largest species in individual size. He feeds upon a smaller species, the latter upon a still smaller one, and so on. Each step down on this "pyramid of numbers" means not only smaller size but also more individuals. Still more important in relation to the productivity of the sea, each step down means a tremendous increase in total bulk or weight of protein. In other words, with each ascending step towards the ultimate predator, there is a tremendous loss of protein. To produce one adult sea bass takes many times his weight of small fishes.

Those familiar with terrestrial food-chains may remark that this system does not hold so neatly for land animals, among which many large species, such as cattle, antelope, deer, and elephants, feed directly on vegetation, while the natural predators of these large herbivores (wolves, lions, leopards, and so forth) are often smaller than their prey.

However, as shown in Chapter 5, the ecology of the sea differs sharply from that of the land in many particulars, perhaps the most important being the distribution of vegetation. Light penetrates the sea for only a short distance, and plants need light. They live only near the surface of the oceans, and the great bulk of sea plants are microscopic, unicellular organisms such as diatoms. Although the zooplankton feeds on them, there are few truly herbivorous fishes. These are mostly specialized forms living on attached algae along shore. Most plankton-feeding fishes eat diatoms, but most of them also depend to a still larger extent upon animals for food. Few plankton-feeding fishes reach more than 12 or 15 inches in length and the majority are under 10. The only very large fishes in the seas which live directly and wholly on plankton are the two largest sharks, the basking shark and the whale shark. Practically all the large true fishes are active predators on smaller fishes. The ocean sunfishes, which are believed to feed principally on jellyfish, are the principal exception.

It is clear, therefore, that most kinds of fishes must be small. It is also clear that there is a much greater bulk of small fishes than of large. Yet most of the fishes utilized as food by man in Western Europe and North America (where high industrialization of the fisheries is accompanied by an effort to maintain the yield at high levels) are larger species, reaching from 10 or 12 inches to a yard in length.

If we except the plankton-feeding sardines, herrings, and menhaden, most of the food fish we consume are larger predators. This means, by and large, that we are losing the tremendous amount of protein that disappears with each step up the "pyramid of numbers."

Another phase of fish abundance is both directly and indirectly correlated with temperature and latitude. Observers familiar with the vast quantities of herring, cod, and other fishes on northern continental shelves have remarked on the absence of such tremendous numbers of fishes in tropical areas. Moreover, it is well known that the cooler, murkier waters of the north are considerably richer in all sorts of plankton than the clear waters of the tropics. As richness of plankton has proved to be an excellent indicator of richness of fishes in these northern waters, it has been quite generally assumed that sea fishes are simply less abundant in the tropics than in cold waters.

However, one cannot be certain on this point, for no satisfyingly quantitative comparisons have yet been made. Moreover, there are certain facts to consider that are often overlooked: on approaching the equator from the poles, the number of fish species increases prodigiously. On cold North Atlantic coasts there may be no more than 50 to 200 species at any one locality, while at Amboina, in Indonesia, it is probable that 1,500 to 2,000 will eventually be recorded from one small area.

Evidently tropical species can seldom be as abundant individually as cold-water species. Possibly, however, some continental shelf areas in the tropics produce as great a total weight of fish life as an equal area of, let us say, the North Sea. This may seem like rank heresy to marine biologists, but it may still be true. For one thing, the extreme diversity of the fishes in the tropics and the nocturnal or cryptic habits and small size of so many may easily mislead even a trained biological observer.

However, the most abundant of all fishes do not seem to be confined to the continental shelves at all. The discovery that pelagic organisms concentrate in layers (the "deep scattering layers") throughout all oceans at depths of 150 to 450 fathoms and rise toward the surface at night, gives point to some known ichthyological facts. Towed within the depth limits of the scattering layer, plankton nets bring up an abundance not only of small shrimps and other invertebrates, but also of small fishes. Many of these are lanternfishes (Myctophidae) of diverse species, some of which are already known to make vertical migrations toward (or quite to) the surface at night. But the most abundant of all fishes in these nets are a few very small, transparent, luminescent fishes of the bristlemouth family (genus *Cyclothone*). These fishes apparently occur by the billions within the depth limits of the deep scattering layers. The few species (chiefly *Cyclothone signata* and its close allies) must be the most abundant of all fishes—certainly in numbers and quite possibly in weight.

In general, mankind uses the fish resources of the sea poorly. Only on the coasts of western and northern Europe and on the north temperate coasts of North America and Asia are the sea fishes exploited according to modern knowledge and practice, and these areas form but a small part of the seas of the world.

Elsewhere, with the exception of only a few small areas, the marine fishery resources do not appear to be exploited to anything near capacity. Generally, only a small proportion of the more easily caught fishes are taken, the kinds obtained depending principally on primitive local fishing methods available and on local tastes and prejudices.

However, information on the extent of utilization of fishes in any area is peculiarly difficult to obtain. For some areas we have more or less reliable catch records but almost nowhere do we have accurately quantitative information on the *abundance* of the species caught, to say nothing of those that are not caught or that are discarded. We can piece some of this information together if we are familiar with the species representation at a given point and know something about the usual abundance of similar or identical species in other areas, but this is only a poor substitute for firsthand local knowledge. The truth is such information does not exist for nine tenths of the coasts of the world, let alone for offshore areas.

We know that there are long stretches of continental shelves, rich in fishes that could be easily caught, that are but lightly fished. One such area is the relatively broad shelf off the Atlantic coasts of Uruguay and Argentina, another is the west coast of Africa from Angola to French Equatorial Africa (see Figure 1, page 15).

We know that the bathypelagic fishes (and indeed all the deep water species) are untouched, for no one has yet devised a method of catching these animals in large quantity, or of sorting them out of the mass of planktonic invertebrates, some of which may be inedible or even poisonous. If such methods are devised, a supply of fish protein unrivaled by any existing fishery might become available.

We know that the offshore bottom faunas on the deeper parts of the continental shelves are rich in edible fishes, and that fisheries for these kinds are few and scattered (off Cuba, Portugal, the Azores, Japan, and South Africa).

We know that the more extensive coral reef areas of the world support large populations of many of the finest edible fishes, but that methods of catching them are difficult to devise and seldom very efficient.

We know that tunas and other pelagic fishes must occur in quantity in many tropical parts of the oceans, for example, in the South

Atlantic, Indian, and the mid-Pacific where there has not until recently been any important fishery for them, and the mid-Atlantic.

We know that sardine-like fishes are found in enormous numbers around almost all continents, and that far greater numbers could be caught of most species than are now obtained.

However, we also know that local customs, prejudices and economics often have far more effect on the utilization of these fishes than does knowledge of their existence, of their availability, or of means of catching them.

A study of the geography of fish distribution discloses an order from which it is possible to predict about what species may be expected to occur in any given locality. For, like other classes of animals, fishes fit into a distributional pattern in which may be distinguished several major zoogeographical regions, delimited by hydrographic and land barriers. Within each region there is an essential homogeneity of fish genera and families, and although a number of species range throughout an entire region, most of the included ones do not. Rarely does a species of shorefish occur in more than one of the major regions. In considering how and where to increase exploitation of the fishery resources, therefore, it is essential to take these patterns into account.

From a fishery-scientific viewpoint the *Indo-Pacific* is the most important of these zoogeographic regions, since more kinds of fishes live there than in any of the others. This zone extends from the Red Sea and Madagascar eastward half way round the world to the Marquesas and Tuamotu Islands. Its northern and southern boundaries are rather close to those of reef-forming coral. It reaches northward to southern Japan and Hawaii and southward to southern Queensland and the southern boundaries of Polynesia. Not only are the species numerous in the Indo-Pacific region—more than a third of all known sea fishes occur there—but they are remarkably unvarying and widely distributed. Many of the larger species of shorefishes—jacks, snappers, sea basses, and surgeonfishes, for example—occur throughout this vast region and nowhere else. No rule can be written about this, however, for some species are very restricted in their range. Myers has called the Indo-Pacific the "great mother fish fauna of the tropics." [2] Other tropical regions are only minor, relatively poor segregates of it, defined principally by the Indo-Pacific families and genera which they lack.

The other tropical regions are the *West African,* extending from Senegal to Angola; the *West Indian,* extending from Key West and Yucatan to Bahia or Rio de Janeiro; and the *Panamanian,* reaching from the Gulf of California to Ecuador and including the Galapagos

Islands. In kinds of fishes, all of these regions are far poorer than the Indo-Pacific. The West Indian is richest of these smaller regions, the Panamanian next, and the West African poorest of all. Each of them has a homogeneous shorefish fauna, which is almost totally different in species from all the others. Nevertheless, these faunas are more similar to each other than to any of those of the temperate regions to the north or south.

The two polar regions are poorest of all in species. However, we still know relatively little about them. The limits of the *Arctic* region differ considerably depending upon what criteria one employs. Dunbar in 1951 defined arctic marine areas ". . . as composed of arctic water only . . . subarctic areas as composed of a mixture of arctic and non-arctic water . . . and boreal or temperate areas as bounded to the north by the line south of which there is no admixture of arctic water." [3]

Arctic water masses possess many characteristics inherent to high biological productivity and these factors seem to be limited only by low temperatures. As a consequence, at the northern subarctic border or where arctic water mixes with other water masses, part of this temperature barrier is removed and high productivity results. The arctic marine fish fauna contains few species, and in fact is most easily distinguished from that of the subarctic by what it lacks in comparison.

The *Antarctic* region, bounded on the north by the 6° isotherm, consisting of the waters surrounding the antarctic continent and a few of the most southerly island groups, has a poor fauna, which is dominated by a single family of large-headed, rather sluggish, bottom-living fishes called Nototheniidae. Among 76 species of fishes in one collection from the Antarctic, 68 belong to this family; 6 are eelpouts (Zoarcidae), and 2 are sea-snails. In addition there are one or more species of the flabby, gelatinous member of the cod family, *Muraenolepis*. Most of the Nototheniids are rather small, growing to lengths between three and nine inches. A few reach larger sizes up to an extreme of about five feet. Although most of them live on the bottom, a few are pelagic or semipelagic.

One of the most striking features in the economy of life in the antarctic seas is that few fishes have the form and swimming powers to utilize krill (planktonic crustaceans) as a source of food. The evolution of pelagic types of nototheniid fishes has been limited, and it is the warm-blooded animals, the whalebone whales, crab-eater seals, and penguins, which make most use of krill. In oceanic circumpolar waters, a number of small bathypelagic fishes feed particularly on krill and are often to be found with the latter in the stomachs of whalebone whales. These fishes, however, would hardly repay commercial exploitation.

The bottom-living species feed largely on crustaceans (especially on amphipods and isopods), polychaete worms, small lamellibranchs and fishes. While Dr. Marshall was stationed at the Falkland Islands Dependencies Survey base at Hope Bay, Graham Land, over 1,000 nototheniids, mostly of one species, were caught by line through holes cut in the ice, or at the ice edge. Even in the winter months the stomachs of these fishes were nearly always packed with freshly eaten and partially digested isopods and amphipods together with small fishes, mollusks, and pieces of seaweed. Further indication of their bottom-living habit is the fact that the fishes would not take the bait until it had touched, or was very close to, the bottom.

Knowledge of the abundance of the coastal fishes of the antarctic continent is sketchy. The National Antarctic Expedition led by Captain R. F. Scott set fish traps at McMurdo Sound and caught up to 105 fish in one haul. The Australasian Antarctic Expedition (1911–1914) from time to time caught nototheniids by hand line. Part of the Swedish South Polar Expedition stranded at Paulet Island near the northeast coast of Graham Land fished through holes cut in the ice during the winter months. A day's catch could amount to about 100 small fishes and over 14,000 were caught in this way. Dr. Marshall writes that when he was at Hope Bay, Graham Land, he baited lines with pieces of meat, fish, or bunting, and from June until September fresh fish (mainly *Notothenia coriiceps*) of excellent flavor and weighing ½ to 2 pounds each were a frequent part of the diet. The fish could be caught quickly, the rate being set by the time required to take a fish off the hook and rebait and lower the line.

The cool-water *North Pacific* region, extending from northern Japan to the Bering Sea and Puget Sound, is exceedingly rich in endemic species and genera of sculpins, rockfishes, eel-blennies, and other related groups. Large flatfishes abound, and anadromous salmon which mature at sea and spawn in fresh water form a conspicuous and important element.

The cool-water *North Atlantic* region, reaching from New York to Iceland, to the English Channel, and Scandinavia, has fewer shore species than the North Pacific. It lacks the great variety of sculpins, rockfishes and eel-blennies of the North Pacific, as well as some endemic Pacific groups. There are a few more true cods than in the Pacific. Otherwise the two faunas are similar although few species occur in both regions.

The areas between the North Pacific and North Atlantic and the tropical regions to the south of them are, in general, transition zones. The coasts of North America between New York and Florida, and between Puget Sound and Lower California, are excellent examples. Many species and some genera are confined to these transition zones, but most of the shore fishes present are related directly to either more northerly or more southerly types. In the eastern Atlantic, there is more reason to delimit a major intermediate region because of the Mediterranean, which has a recognizable group of fish genera and species of its own. These extend north to the Atlantic coast of France and south to Morocco.

South of the tropical areas, fishes are less well known and the regions harder to define. The best marked one is the *South African* region, containing a large number of cool-water shore fish genera and species found nowhere else, and many others that appear elsewhere only on the coasts of southern South America and Australia. The South African region extends from just south of the southern boundary of Angola around the Cape perhaps as far east as Port Elizabeth.

The *South Australian* region probably has more species than the South African, but its limits are less easy to define. It is a relatively cool-water fauna that shows its nature best in Tasmania and the South Island of New Zealand.

The *Patagonian* region, south of Chiloé in Chile, and extending up an unknown distance on the Atlantic side, is very poorly studied. We have little knowledge of its extent or size, and only a general idea of the composition of its fish fauna.

We know too little about the vast area of the *deep sea* to divide it into geographic regions. The sea cools rapidly with depth. Below 2,000 meters it varies within a narrow temperature range—between 4° and —1° C., from the equator to the polar seas. Thus the deeper water fishes meet fewer temperature barriers than do the shore fishes, and some of them range widely over most of the oceans. These being the most difficult fishes to reach, they are the ones we know least about. We know little of their habits, the characteristics of their environment, or of the barriers that limit their distribution.

The deep pelagic fishes are mostly small, but some of them, as remarked above, such as the bristlemouths, of which little is known, are the most numerous of all fishes. Somewhat larger than the bristlemouths, but still small, are the exceedingly abundant lanternfishes, which also are obtained at present only with plankton nets. These are remarkable for their oil content, owing to a most interesting specialization. The lanternfishes possess the hydrostatic "air-bladder" typical of bony fishes, but many species of them make nightly vertical migrations, often to the surface, undergoing a change of pressure which would rupture a bladder filled with gas. The air-bladder is completely full of fat, thus retaining its hydrostatic function but without the dangers of an expansible gas. About 24 genera and about 175 species of lanternfishes have been named, varying in adult size from about an inch to over a foot. The average species reaches about 3 or 4 inches. They are characterized by luminous organs along the lower part of the sides arranged in patterns which vary with species, and which, in some species, differ with sex.

The opinion that bristlemouths and lanternfishes are abundant is based on the fact that marine biologists catch them everywhere in their deep plankton nets. Furthermore, lanternfishes are one of the most important items in the diet of fur seals feeding along the coast of Japan, and of tunas in the counter equatorial current of the Pacific.

Other bathypelagic fishes are legion, but the two groups already mentioned are the most numerous and possibly the only ones save the macrourids that would repay any efforts to utilize them for food.

The deep-sea fishes of the sea bottom are mostly found so deep that the efficient working of gear to catch them in large numbers imposes great obstacles to economic exploitation. The most important group are the grenadiers (Macrouridae), deep-sea relatives of the cods. The numerous species of this family range in length at adult size from 8 inches to 3 feet. A few occur in shallow enough water to be taken in some of the deep offshore, continental-shelf trawl fisheries. These are the only ones likely to be within reach of commercial fishermen.

The oceanic currents, typified by the Gulf Stream, the Kuroshiwo, and the counter equatorial currents, provide environment to tunas, dolphinfish, swordfish, and certain of the larger mackerels and jacks. These valuable pelagic species occur in two types of faunas. One, characterized by yellowfin tunas, skipjack, and dolphinfish, lives in the tropics; the other, characterized by bluefin tuna, swordfish, and albacore, lives in temperate waters. These seem to be more independent of land masses than any other species of marine food fish. Several of them are said to belong to world-wide species. However, these species are probably composed of many relatively small, more or less genetically independent stocks of overlapping distribution.

It is not possible to learn from published statistics how each of these regions contributes to the world's catch. Fishery statistics are obtained in various ways, sometimes from the complete, honest recording by literate fishermen in their log books, sometimes by divination. Consequently, accuracy of published catch data varies from near perfection to zero. It is highest for countries of the North Atlantic and North Pacific, and for a few in the southern hemisphere such as Australia and South Africa. Tables 14-1 and 14-2 suggest how the world catch of fish is probably divided among the various geographic regions.

TABLE 14-1. ESTIMATED CATCHES OF MARINE FISH BY GEOGRAPHIC REGIONS, 1956

Region	Millions of Metric Tons
Coastal Forms	
Indo-Pacific	2.8
South Australian	0.1
North Atlantic (combined with Atlantic Arctic)	10.3
Northeast Atlantic—Transitional	1.5
Northwest Atlantic—Transitional	0.6
Southwest Atlantic—Transitional	0.1
Patagonian	0.1
West African	0.6
South African	0.6
West Indian	0.2
Panamanian	0.7
North Pacific (combined with Pacific Arctic)	5.5
Northeast Pacific—Transitional	0.2
Northwest Pacific—Transitional	1.4
Oceanic Pelagic Forms	
Eastern Pacific	0.2
Western Pacific (exclusive of Indo-Pacific)	0.4
South Australian	<0.01
Indo-Pacific	0.6
Eastern Atlantic	0.4
Western Atlantic	<0.01
	26.3

Of all the great geographical regions, the North Atlantic and North Pacific are the most intensively fished, the most heavily exploited area being around Japan. Here alone almost all the kinds of fish that can be caught by existing methods are used by man. However, Japanese fishery conservation is still in a relatively early stage of development and little control is put on the industry. Indeed, much opposition must be expected to such control, for Japan produces little meat, gets most of its animal protein from fish, and has a great over-population problem.

In the North Atlantic, the North Sea continues to support a heavy fishery, and can probably continue to do so indefinitely, largely because of the regulations fostered by the bordering nations through the Permanent Commission. The western Atlantic is heavily fished but also will probably sustain its maximum productivity as a result of conservation action agreed upon by the nations belonging to the International Commission for the Northwest Atlantic Fisheries.

Outside the North Atlantic and North Pacific regions, the areas of the continental shelf which support very intense fisheries are small indeed, although for many reasons exact information is peculiarly hard to get and more difficult to evaluate once obtained. For example, in New Zealand some local areas are said to be highly overfished while others within reach are barely touched, the difference being due mostly to refusal of the fishermen to work more distant or "difficult" bottom, despite the much more lucrative returns to be gained. The relatively secure economic position of the fishermen and wages set by law at a high level operate here to determine the

TABLE 14-2. PERCENTAGE DISTRIBUTION OF FISH CATCHES BY GEOGRAPHIC DIVISIONS, 1956

Geographic Division	Percentage
Asia	39
Europe	30
North America	16
South America	3
Africa	5
U.S.S.R.	7
Northern Hemisphere	89
Southern Hemisphere	11
Pacific Ocean	41
Atlantic Ocean	54
Indian Ocean	5

pattern of fish resource utilization. Again, in the vicinity of Rio de Janeiro, in Brazil, certain local species and areas, as well as several quite distant ones, seem to be overfished, while intermediate localities and fish supplies lie relatively untouched. This is the consequence of a complex of prejudices among fishermen and the general public. Areas adjacent to Cape Town and other South African ports, to Sydney in Australia, to Singapore, to Buenos Aires, to Shanghai, and to other large metropolitan centers are said to be very heavily fished, while other nearby areas lie relatively fallow.

Although specific local information is lacking in most points, it seems likely that the catch of fish on continental shelves of most of the world could be increased with standard fishing methods of one kind or another. In some areas there would be special difficulties to overcome, as in the tropics, where the abundance of coral would preclude trawling and the diversity of species might necessitate devising new gear.

Almost everywhere in temperate and tropical seas we have enough information to say that there will be found, on the deeper parts of the continental shelf, a rather diverse assemblage (exact composition still to be discovered) of usable fishes, many that can be trawled and many others that can be fished with long lines. This assemblage is fully exploited in only a few areas.

About smaller islands and on many coasts, coral reefs form a rather narrow fringing area fairly close to shore, and although their length may be great, their width is not, and the total area is therefore small. In other places, notably on the coasts of Queensland and New Caledonia (the Coral Sea), the width may be great and the area large (see Figure 16). Near Nouméa, for example, one can sail for hours over water 10 to 50 feet deep where the bottom is covered with growing coral. This coral is not uniform, but occurs in patches of differing species or groups of species. The immediately observable fish population is very large, even though we know that but little of it is visible at any one time, especially during daylight hours. The abundance of fishes varies widely from one spot to another in a reef area. As Vernon Brock's surveys in Hawaii have shown, quantities range from 7 to 2,118 pounds per acre.[4] But the tremendous variety of fish species, each requiring a somewhat different catching technique, the obvious difficulty or impossibility of working normal fishing gear (even hooks) in such places, and lack of knowledge of the edibility of the species make utilization of coral reef fishes a rather complex business. Nevertheless, in some places, for example Hawaii, reef fishes have long been heavily exploited, perhaps even past the point of optimum utilization. Elsewhere, however, reef fishing techniques are adapted for the most part to catching only a few of the larger fishes in commercial quantities, and careful exploration of the means of catching large quantities of the other species has not been made. Nor is it likely that these means will be developed by fishermen steeped in traditional northern fishing methodology. A more promising line of attack would probably be to improve native fishing methods, or perhaps to utilize electronic, chemical, or other modern technological means of enticing fishes out of the impenetrable maze of coral.*

Meanwhile, little is known about the fish faunas in most of the coral reef habitats in the world. Few such habitats have been intensely explored ichthyologically. One of them is a small area at Dry Tortugas, Florida, which W. H. Longley studied for many years.

* At the same time, it must be remembered that reef fishes seem to be nonmigratory; some of them are believed to be slow growing and they may be particularly vulnerable to overfishing.

Another is in Hawaii where Vernon Brock conducts quantitative surveys. A third is at Bikini Atoll, where Vernon Brock, Earl S. Herald, and Leonard Schultz have collected extensively under water.[5]

Great tropical river estuaries, such as those commonly found in Indonesia, often support much larger fish populations than the rivers themselves or equal areas of the non-estuarine coast nearby. That this is due at least in part to the nutrients brought down by the rivers is unquestionable, but aside from the fact that such places do support extensive fisheries for certain types of brackish-water or mud-bottom fishes, we know comparatively little about them. Croakers, threadfishes, and many others are especially abundant in such places (see Chapter 9).

While there is no doubt that the fishes of the world can supply a greater amount of human food than they do now, it is peculiarly difficult to say exactly how and where. There is neither enough dependable information recorded about the fisheries or about the fishes. Knowledge of the fisheries comes mostly from fishermen who are usually untrained as observers (see page 64) and from fishery scientists and fishery officers who are trained, but whose opportunities for extensive observations are often limited. Much of this knowledge never becomes recorded in print. For some very small parts of the seas, such as the North Sea, the North Atlantic Banks, the Sea of Japan, and the Pacific coast of North America, our information is relatively abundant and well recorded. For most areas, it is astonishingly and exasperatingly scanty and undependable. Special scientific studies of habits, ecology, and life history have been made on relatively few species, even in the best known areas, and on none in most places (see Figures 17–19).

Hence, any attempt to evaluate the production or potential production of the fisheries of the world is very difficult, if not impossible, except in the most general terms. For even though existing knowledge of fish and their general distribution may enable us to give probable answers to some questions, the almost complete lack of knowledge of the abundance of any one kind at any one place for most of the world makes a precise answer impossible.

It seems obvious that any program designed to increase the contribution of the fisheries to the food supply of man must be based upon much more secure and exact information than is now available. No conference of fishery men, steeped in the traditions of their own homelands and differing profoundly in outlook and understanding, can produce that information. The only solution would appear to be to permit a group of men, with a united viewpoint, harmonious understanding of the needs, and broad knowledge of the world's marine animals, to examine the world's fisheries and fishery records at first hand in sufficient detail to permit answers to specific questions.

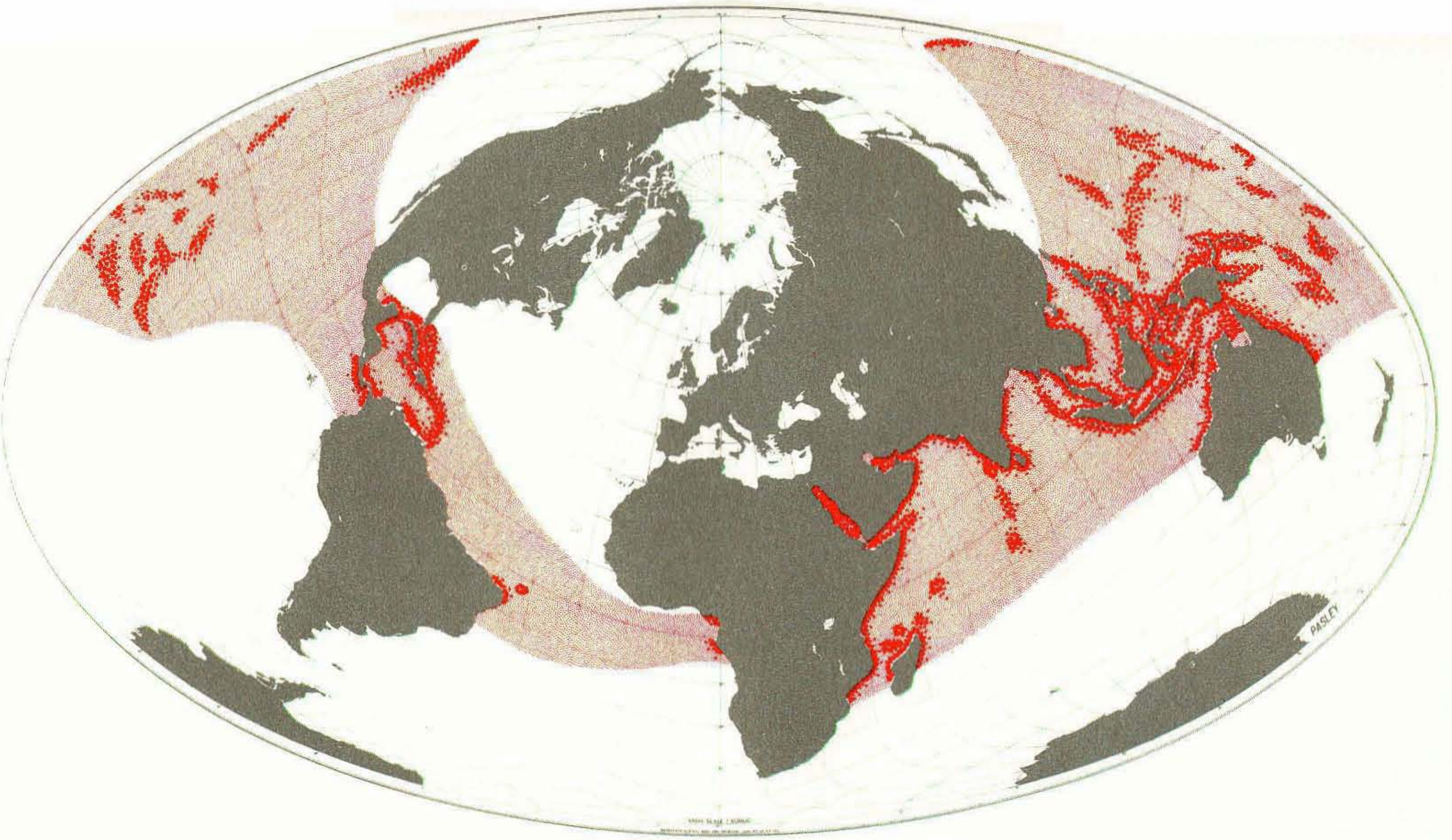

FIG. 16. Reef coral. Extensive coral reefs, of interest because of the important associated fishery resources, occur within the lightly dotted zone. The principal areas occur along the coasts and around the islands marked with larger dots. Data given by George S. Myers.

Discussion of Figure 17

Figure 17 is essentially a map of ignorance. It began with a survey of the world's marine fish faunas, some of the first very rough results of which, for the Pacific, were presented by George S. Myers in 1940.[6] It continued with an estimate of the total number of known species and, by a process of extrapolation, of the still unknown species of each of these areas and of the world. To this had to be applied a general knowledge of the rough ecological classification of the species into littoral, shore, pelagic, bathypelagic, and benthonic divisions.

A large number of geographical points were then selected. The number of species recorded from within each quadrant having one of these selected points as its center was then plotted against the total number of species to be expected in that quadrant, and the result expressed as a percentage. The areas between points were then filled in by careful judgment of the extent of knowledge of them as compared to the main points.

The result is a rough but probably reasonably accurate assessment of existing knowledge of the occurrence of marine fishes within any 10,000-square-mile quadrant of the sea. The principal error will be in regard to smaller bathypelagic species found at greater depths than 100 fathoms (roughly 200 meters). These are very little known and poorly recorded everywhere save in parts of the North Atlantic and the Mediterranean.

The user of this map should realize that most marine fish species are either littoral or shore fishes found on the continental shelves but that these shelves have been adequately fished only in a few areas. Off the continental shelves, the fish fauna of no part of the sea is really well known.

This map clearly indicates that knowledge of the kinds and distribution of fishes is still in its infancy and that a tremendous amount of collecting and identification must be done, even in relatively well-known areas, before our knowledge of the fish resources of the sea is sufficient for really intelligent use.

Local fishery officers (who are usually not ichthyologists) may object to this chart as not properly representing their areas. Our sole defense is that local fishery officers frequently realize neither the richness of the nearby fish fauna nor the percentage of it that is still unrecorded, if not totally unsuspected, including many species possibly of great food value. Actually, the error will almost always be found to be in recording too high a percentage for any area.

This map records merely the finding of species within one local area (10,000-square-mile quadrant). It records nothing of abundance, of knowledge of habits and life history, or of the number of species existing in any area. But it does indicate vast ignorance of the most simple fact we can have about the fishes of an area—the mere occurrence of the species that general knowledge of fish distribution as a whole tells us will eventually be found to occur in that area.

Finally, the number of species increases very greatly toward the warmer regions, and the only areas where knowledge of the composition of the fish fauna is reasonably complete are the temperate or colder regions, where the number of species is relatively small, and where knowledge of the composition of the fauna is therefore relatively easy to obtain. Moreover, it is chiefly these temperate and colder waters that have been scientifically investigated actively and continuously for a long period of time. Knowledge of the sort here mapped will be much more difficult to obtain in the tropics, where the difficulty of the job is far greater and the scientific centers small and few. In general, no information subsequent to 1957 is included.

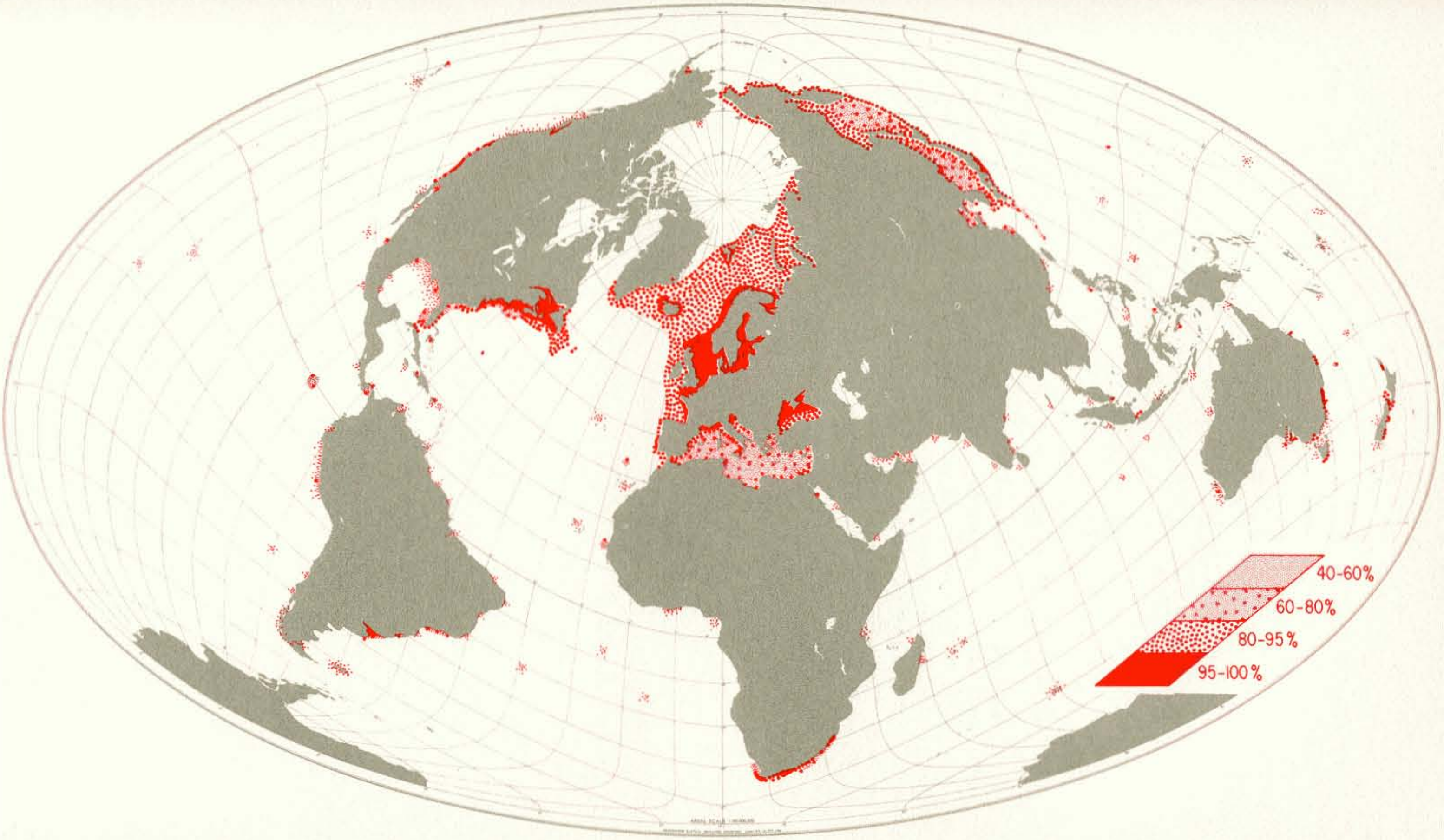

FIG. 17. Knowledge of species of fishes. The intensity of shading indicates the percentage of species (out of the total number occurring or expected to occur) which have been recorded in each 10,000-square-mile quadrant of the sea. Compiled by George S Myers.

Discussion of Figure 18

This map is based upon a reasonably complete knowledge of what has been done in the study of the habits, ecology, and life histories of marine food fishes in different parts of the world. In no area is it believed that sufficient information is available for more than 60 per cent of the food fishes actually present to permit reasonably sound regulation and utilization of the resource. Among areas where the percentage is over 50 are the coast of the North Atlantic States of the United States, the North and Baltic Seas, and the coast of Iceland.

The map implies the almost total lack of knowledge of the habits, ecology, and life histories of most of the world's food fish species.

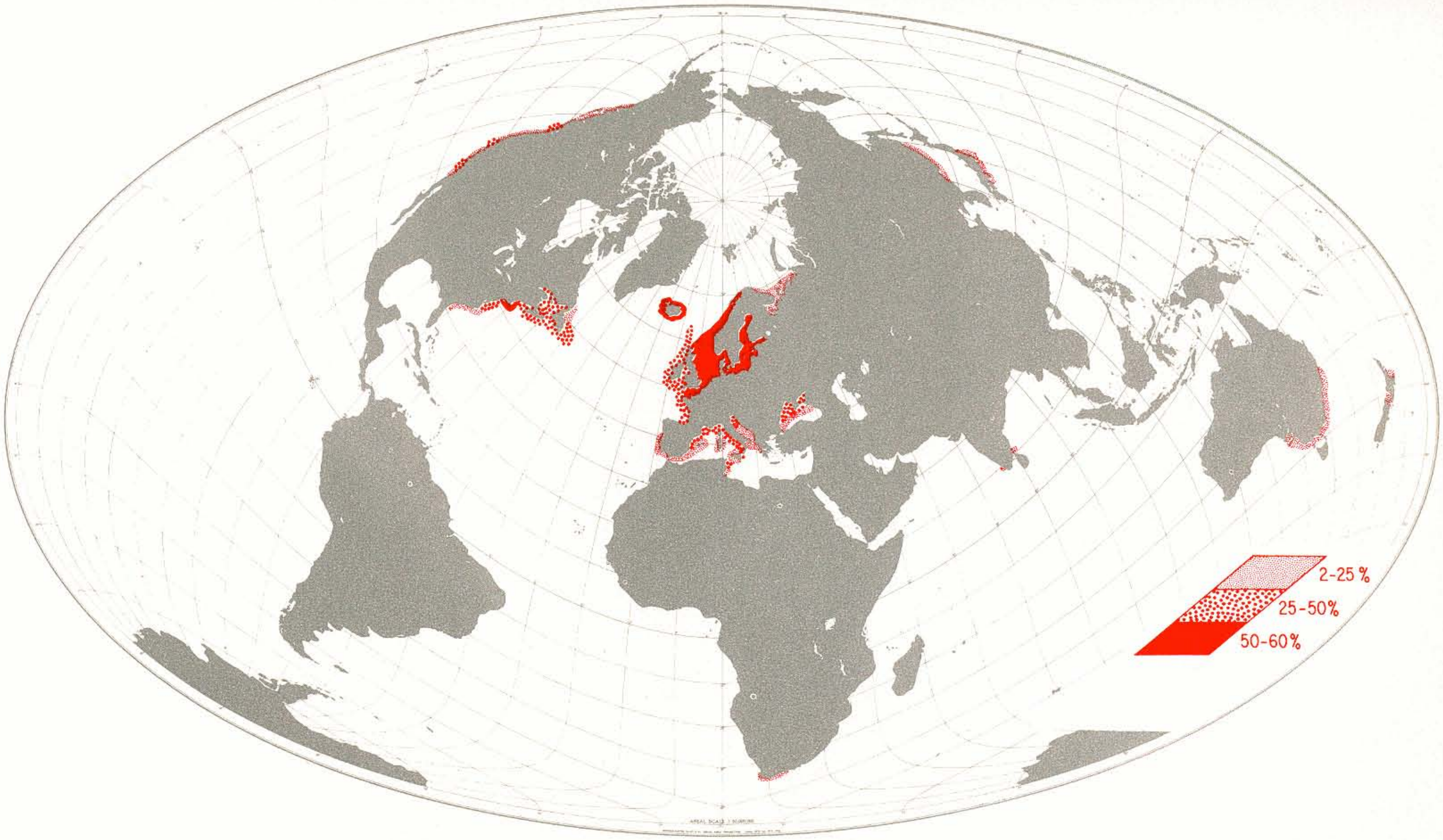

FIG. 18. Knowledge of habits of marine food fishes. The state of knowledge (1951) of habits, ecology, and life histories of marine food fishes of all seas is indicated by increasing intensity of shading. Compiled by George S. Myers.

Discussion of Figure 19

This map is based upon some of the surveys made for Figure 17, in addition to an estimate of the larger or more abundant species available to the fisheries along most of the world's coasts. It omits bottom fishes found at depths of more than 150 fathoms as well as pelagic and bathypelagic species. It is especially useful to indicate the relatively few species upon which the fisheries must be based in cooler regions, and the very numerous species upon which they must be based in the tropics.

Fisheries depending upon relatively few species which are very abundant, as in the cooler plankton-rich seas, are far easier to exploit than fisheries which must depend on large numbers of species, few of them exceptionally abundant, such as occur in most tropical coastal areas. For example, bottom trawling, which is so successful in the North Sea, is seldom or never of great importance in the tropics where much more diversified gear has to be employed, because of the composition of the available food fish fauna and of the rugged or coral-strewn bottom.

In general, areas of equivalent temperature range are equally rich in species, but the picture is not always so simple. The West African tropical marine fauna is not nearly as rich in different species as the Indo-Pacific fauna which occurs on the eastern coast of Africa. The species composition of the food fish fauna of the Pacific coast of the United States is enriched by the excessively large numbers of a single genus (*Sebastodes*) found on it. The Guiana and northern Brazilian coast of South America is poorer in number of species of food fishes than it would be were it not for a solid mud-and-mangrove-swamp coast for 1,500 miles, a type of shoreline that is notably conducive to a species-rich fauna.

The coasts about which we have the least information in regard to number of food fish species (outside the polar areas) are those of Chile and south-western Africa. The latter is a cooler area of upwelling and perhaps is quite as rich in species as the Peruvian coast, which has between 190 and 200 species now utilized for food (in addition to an estimated 25 species of potential food fishes still unreported).

It must be emphasized that this map is based not only upon the food fish species now utilized; it also includes carefully estimated numbers of other food fishes (i.e., species of reasonably large size and abundance) that are present but unutilized. Larger sharks are included; rays are not.

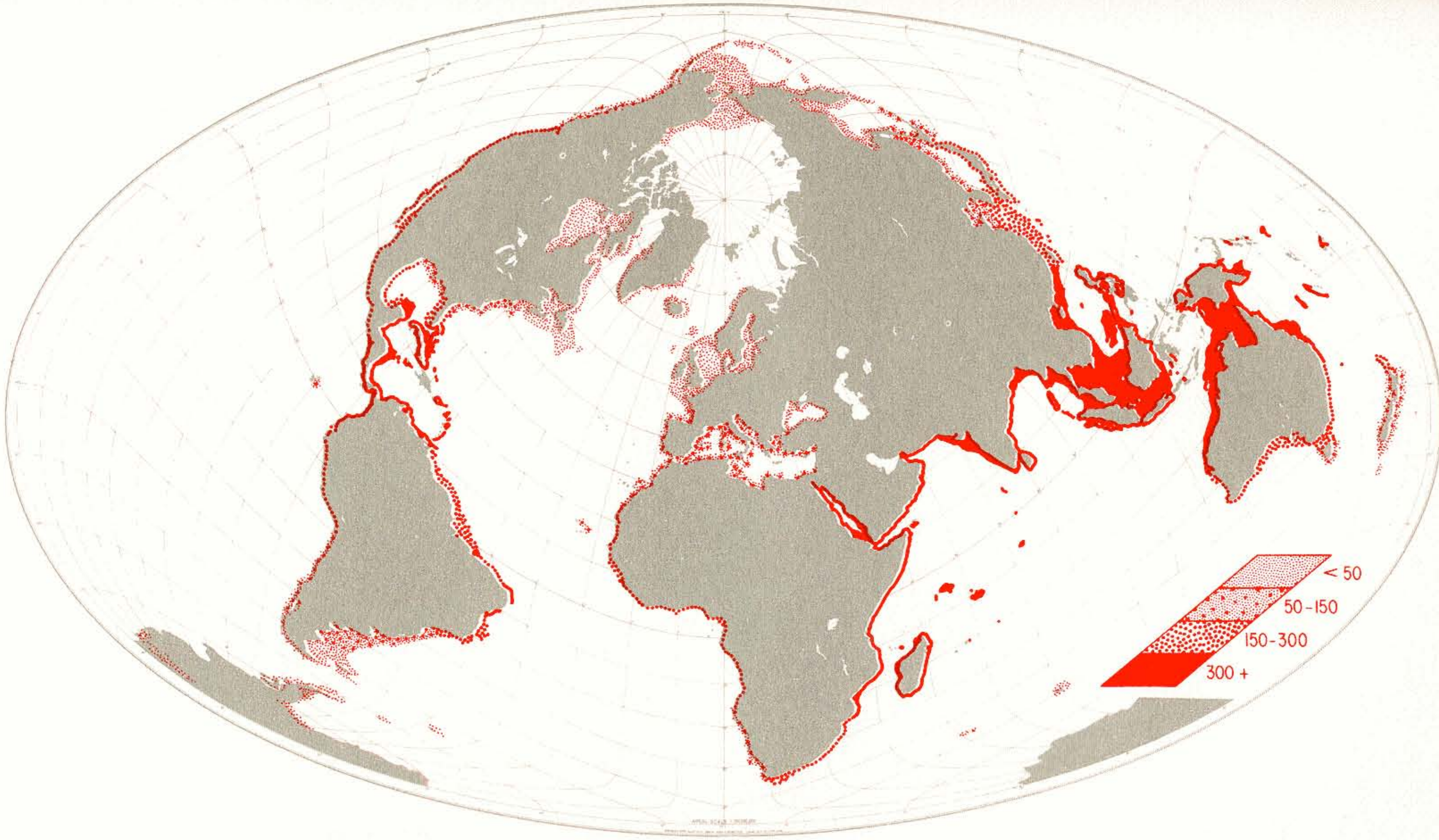

Fig. 19. Species composition of marine food fish faunas. The numbers of species of marine food fishes (1951) available (not necessarily in use) in coastal and shallow waters are indicated by relative intensity of shading. Compiled by George S. Myers.