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SOME PROBLEMS AND PROSPECTS FOR THE HARVEST OF LIVING MARINE RESOURCES TO THE YEAR 2000

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THE value of the global harvest of living aquatic resources in 1968, taken at an average price of $160 per metric ton to the fisherman, was a little more than $10 thousand million (10 billion, U.S. style), on 64 million metric tons. In the neighbourhood of nine-tenths of this came from living marine resources, or diadromous fishes dependent upon the sea (FAO, 1969a).

As will be developed below, there is reasonable expectation that supply and demand will create a global harvest of living aquatic resources of a little less than 100 million metric tons in 1975, nearly 175 million tons in 1985, and a little more than 400 million tons in 2000 (Table 1). There is no reason to think that the proportion of marine and fresh water production will change markedly during that period of time. Presumably the value of production will increase in rough relation to volume of production (Chapman, 1970a).

As will be developed below, production by the developing countries has grown much more rapidly than that for the developed countries during the last decade, and slightly exceeded it in 1968 (25.3 million metric tons, developing ; 24.9 metric tons, developed). Production in the centrally planned economies increased at a rate between that of the developed countries and the developing countries during this period and in 1968 (13.8 million metric tons) was a little more than half that of the developing countries. There is reason to expect that these trends can be continued during the period under consideration under existing institutional and jurisdictional methodologies, properly supported and applied (FAO, 1969a).

At present levels of production the value of the harvest of living marine resources is roughly double that of all minerals (including petroleum and gas) from the sea and the seabed (Fye, *et al.*, 1968).

By far the largest part of mineral resources (at least value) known, or reasonably expected, to be economically capable of harvesting within the next thirty years are within national jurisdiction (continental shelf) or in nearby area disputed as to

† We regret to announce that Dr. W. M. Chapman passed away on 25-6-1970.

jurisdiction (continental slope and continental rise) (LaQue, 1970, Schaefer, 1970). These resources are fixed geographically (excepting dissolved salts which are so ubiquitous as to be capable of being disregarded from a jurisdictional standpoint). Those that are not clearly within national jurisdiction border it geographically. Technologies in existence and under development are such that harvesting them economically requires, in the great majority of cases, logistic support from facilities in the adjacent land. For this purpose practical arrangements require to be made between the harvester and the adjacent sovereign regardless of jurisdictional aspects, and it is not to be expected that the adjacent sovereign will permit their harvest without exerting sufficient jurisdiction to protect its interest from pollution, navigation, public health, security, and customs reasons, aside from other economic and political reasons (Blake, 1970).

TABLE 1

Production of fish and shellfish in the world by year 2000 A.D. at rates of increase of 4%-6% and 8% compounded annually, in metric tons computed from a base of 60.5 million metric tons actual production in 1967.

Year	4%	6%	8%
1968	63	64	65
1969	65	68	71
1970	68	72	76
1971	71	76	82
1972	74	81	89
1973	76	86	96
1974	80	91	104
1975	83	96	112
1976	86	102	121
1977	89	108	131
1978	93	115	142
1979	97	122	153
1980	101	129	165
1981	105	137	178
1982	108	145	193
1983	113	154	208
1984	117	163	225
1985	122	173	244
1986	127	183	263
1987	132	194	284
1988	137	205	307
1989	143	218	331
1990	148	231	358
1991	154	245	376
1992	160	258	407
1993	167	274	439
1994	173	290	474
1995	180	307	512
1996	187	326	563
1997	195	345	608
1998	212	366	657
1999	210	388	710
2000	218	411	767

These fixed mineral resources of the relatively shallow seabed (shelf, slope, and rise) are distributed very broadly around the world ocean margin, off the coasts of developed as well as developing and socialist countries, and irrespective of marine capabilities at harvest. The technologies for their harvest are readily available for hire to all countries under mutually agreeable terms established essentially by the give and take of the world economy and market (United Nations, 1968b, c, d).

The debates in the General Assembly, in the First Committee, and the Seabed Committee over the past three years have indicated no disposition on the part of those countries, either developing or developed, which have reasonable likelihood of harvestable seabed resources on the continental slope and rise adjacent to their continental shelves to turn over the revenue raising capabilities, or other controls of harvesting, of those resources to an international agency, or anyone else (United Nations, 1968d).

Since such known resources are so widespread in the developing and developed world it is certain that more than one-third of the nations represented at any Law of the Sea Conference (or General Assembly) will have the likelihood of substantial income from such resources in the foreseeable future. Accordingly it is unlikely that the jurisdictional situation over these resources will be affected materially in the near future, unless it is to confirm jurisdiction over the resources of the adjacent continental slope and rise to the adjacent sovereign (Chapman, 1969a).

As Schaefer (1970) and others have pointed out :

(*a*) The only consequential resource of the deep-seabed likely to come under practical harvest in the reasonably near future is ferro-manganese nodules ;

(*b*) These are so abundant over such enormous areas that property rights over them in a particular geographic area is not of much value ;

(*c*) The environmental factors in any technology presently envisioned for harvesting ferro-manganese nodules are such that economies of scale will require to be used in order for any such operation to be economically feasible. The scale of operation thus required will be so capital-intensive, and the minimum economical output from any single such operation so large in relation to available world market, that it is extremely unlikely that there would be more than a few such operations at work in the whole world ocean by the year 2000, or that any of these would be in the hands of small countries or companies (LaQue, 1970). Even this much production would likely flood the world market for those metals, reducing economic incentive, which is very light presently at best.

(*d*) Existing Law of the Sea clearly makes such resources the property of him who first reduces them to his possession (Chapman, 1968b, 1969b). Adequate such resources are known more than 1,000 miles from any land. It is unlikely that any sovereign under whose flag such a large capital-venture was organized would tolerate interference with such an operation on the high seas so far removed from land by another sovereign.

(*e*) There is no technology presently developed that would yield any net profit on the harvest of ferro-manganese nodules from the deep-seabed anywhere, and thus there is no such harvesting. This may develop during the next decade, but there is not likely to be enough net profit yield from all such harvesting during the next thirty years for nations to quarrel about very much (LaQue, 1970).

When the balloon of talk about the value of marine resources outside national jurisdiction is punctured there is not much of consequence to come within the purview of the United Nations except living marine resources, or, more bluntly put, fish (including vertebrates and shellfish jointly within that generic term). The value of this resource from the monetary and nutritional standpoints is large enough, and the international problems related to its harvest are sufficiently trouble-making and complex, that it is a suitable subject for much international concern and action (Jackson, 1967). The rest of this paper is confined to that subject.

Fortunately the ubiquitous phrase 'for the benefit of mankind' also gives no more than modest trouble in this aspect of marine resources affairs. The developing countries already are faring much better at the harvest of the living resources of the sea than either the developed countries or the socialist countries. For natural economic reasons this trend is likely to continue if not interfered with by new Law of the Sea rules. With adequate safeguards, which are well-known and capable of application (Chapman, 1967b, 1968a, 1968b), this situation can be maintained at least during the period covered by this paper.

A. The Nature of Living Marine Resources

Several factors related to the harvest of living marine resources are functions of natural processes, which cannot be modified by political activity. Among these are :

1. *They are renewable.* Each population of such animal, under each set of environmental conditions in which it occurs, can produce a crop of certain size so long as (*a*) fishing pressure is not permitted to exceed the level corresponding to this maximum sustainable yield, and (*b*) the environment does not change, or is not changed (Schaefer, 1957, 1959, 1968).

The scientific methodology required to determine the level of fishing effort corresponding to maximum sustainable yield is well-known and the nations are in agreement on this criterion of fishing as the international norm for regulation of effort (Convention on Fishing and the Conservation of the Living Resources of the High Seas). All that is required is the money and time to do the required research, and the obedience of the sovereigns to their agreement on this subject.

2. *They are migratory.* Schaefer (1970) and Kasahara (1970) have given examples of the migratory nature of these resources either in their harvestable or pre-harvestable stages. Many more could be given. Relatively few such resources supporting, or likely to support, major fisheries stay within twelve miles of land and those that do (as well as many of those that do not) migrate laterally alongshore at some life history stage, to the extent that few substantial living marine resources spend their time totally within one national jurisdiction (Cushing, 1968).

3. *They are not distributed uniformly in the ocean.* Areas like the north central Peru coast, the South-west African coast, the central West Indian coast, and the South-east Arabian coast, are tremendously productive every year. This is more or less true whenever there is regular vertical upward circulation in the ocean. Areas like the coast of Kenya and Tanzania, the North-east coast of Brazil, most of the Mediterranean Sea, the Grand Bahamas, the open ocean outside the California Current off Baja California, and the Sargasso Sea are steadily impoverished because there is

no upwelling of nutrients from below the photic layer, or run-off of nutrients from land. Artificial upwelling is not economically feasible and is unlikely to become so in the time period under consideration. Accordingly some parts of the ocean are rich, and some are poor, and man cannot practically change these situations (FAO, 1970 ; Fye, *et al.* 1968 ; Cushing, 1968).

4. *They are often affected greatly in abundance by natural environmental changes of a seasonal or longer period nature.* A variation of two or three times over a period of a few years in year class abundance is felt to be rather stable for a major fishery resource. Variations by a factor often are not unknown (Cushing, 1968).

5. *Their concentration into commercially catchable aggregations is frequently changed by environmental factors.* Many such resources concentrate at particular times and places for particular purposes, such as spawning or feeding, or in regular migratory routes between feeding and spawning places. It is upon these concentrations that successful fishermen work. Changes in oceanographic conditions may keep the fish spread out so they do not concentrate, shift their areas of concentration by some miles or hundreds of miles from where the fishermen expect them, or keep the schools below the surface, or off the bottom, where they cannot be detected or caught easily, or otherwise disturb the availability of the stock to the fishery (Cushing, 1968).

6. *They are quickly perishable.* The fish begins to spoil immediately upon death. This will occur from growth of bacteria in or on the fish and native to it, from the effect of the natural enzymes of the fish (particularly its digestive enzymes), which keep working after death ; or by the body fats becoming rancid through oxidation of the normally polyunsaturated natural oils of the fish. Fish must be eaten fresh soon after capture, or quickly stabilized (preserved) by stopping these three activities, either by drying, salting, heating, chilling, pickling, canning, removal of the oil and water, or otherwise. Few foods have such delicate and attractive tastes as ocean fresh fish ; hardly anything is more objectionable than a really stale fish (Chapman, 1965 ; 1967a ; 1970a).

7. *The nutritive value of all fish is about the same.* The amino-acid and balance of fish muscle protein, and thus its nutritive value, is approximately the same in anchovy or sardine that bring the fisherman $10 to $20 per ton at the dock as is that of salmon, tuna, or shrimp that may bring him $2,000 to $4,000 per ton. It is taste, texture and appearance that give the fish or shellfish its monetary value ; the nutritive value of all is about the same. Even rather thorough bacterial, enzymatic or rancidity changes in fish flesh do not change its nutritive value materially, if at all. In some sections of the world the strong tastes of spoiled fish enhancas its attractiveness to the consumer, and a good many substantial fishery products in many parts of the world are permitted to spoil purposely to a certain stage (which may even be liquid) before being stabilized by salt or otherwise (United Nations, 1968 ; PSAC, 1967).

B. The Nature of Demand for Fishery Products

Different markets in different countries have widely different demands and prices for fish products. Squid are among the most delicious and underutilized creatures of the sea. They are regarded as staple food items in Japan, elsewhere in the Orient, and in the southern European countries. They are viewed with repulsion in most of North America. The porbeagle shark caught by Norwegians off New England brings a particularly high price in Italy and no price at all in New England. Large, dark-coloured tuna bring high prices in Italy and Japan, and are not acceptable for canning in the United States. Shrimp are practically never bought with their heads off in Europe, and practically never sold with heads on in North America. Albacore tuna is thought to be too tasteless and soft by the Japanese, who sell most of their catch to the United States where it is the highest priced tuna. Ocean redfish (*Sebastes*) are a choice product in Germany, and a drug on the market in England. Hake is a high priced delicacy in Spain, and the Spanish fishermen go as far as South Africa and Patagonia for it; west coast of North America fishermen avoid hake when possible, and dump it at sea if caught accidentally, because there is no market for it on the American west coast. Spiny lobsters bring $3 per pound in the United States where they are scarce, and are not eaten in India where they are rather abundant etc., etc.

In consequence of these varied tastes for fishery products in different parts of the world a large world trade in them has grown up. It has grown very rapidly in recent years and is still doing so. The recorded value of world imports of fishery products was $1.2 thousand million in 1958 and $2.4 thousand million in 1967. The trade is not just between developed countries or from developing to developed countries. For example, in the first six months of 1969 Peru exported fish meal to 43 countries, of which 25 were developing. The United States imports shrimp from upwards of 40 countries. Japan is the second largest fish producer in the world. In 1967 it exported 464 thousand tons of fish and fish products worth $254 million, but imported 263 thousand tons worth $146 million. Its exports go to most countries in the world, and are growing steadily. It expects to be a net importer of fish within five years, and to consume much more fish than it can catch within fifteen. Aside from the great diversity in the trade in fish and fishery products that affects almost all nations in the world (FAO lists the imports and exports of fishery products for 150 countries in its *Yearbook on Fisheries Statistics for* 1968, vol. 27), and the sharp growth in the volume and diversity of this trade over the last decade in particular (which is continuing), there are changing trends in the general nature of the form in which fish have been used and traded over the past thirty years that are useful in indicating trends that will likely exist over the next thirty years. The reason is that the trends have been so steady and persistent since 1938 that their persistence well toward 2,000 can be anticipated (FAO, 1969b).

The overwhelmingly largest change in trend of usage over recent years has been as raw material for fish meal and other undifferentiated protein production. In 1938, 8.1% of world production was used in this form, and by 1968 this had reached 35.6%. Actual use grew from 4.3 million tons in 1958 to 22.8 million tons in 1968.

Fresh marketing is still a very large user of fish, but a continuously decreasing proportion of total production is used in this fashion. In 1938, 52.9% was used fresh, and in 1968, 28.9%. Actual fresh use was 14.8 million tons in 1958 and 18.5 million tons in 1968.

The old, traditional ways of preserving fish for later use (drying, smoking, pickling, salting, etc.), have fallen steadily in favour. In 1938, 27.1% of production was used in this fashion, and in 1968 only 12.7%. Actual cured use was 7.3 million tons in 1958 and 8.1 million tons in 1968.

Aside from fish meal and other undifferentiated protein, the other steady increase in proportional use has been in the frozen form. None was recorded used in this form in 1938 by FAO (probably because it was below the 50,000 ton per year level). In 1968, 12.7% of world production was used in that form. Actual use in this form was 2.8 million tons in 1958 and 8.1 million tons in 1968.

The proportion of fish and shellfish used for canning (which produces a product that is rather expensive, relatively, in much of the world) has held rather constant during this period. In 1938, 7.1% of production was used in that form and, in 1968, 8.5%. It had reached a height of 9.5% in 1956 and 1957. Actual use was 3.0 million tons in 1958 and 5.5 million tons in 1967.

C. The Effects of Animal Size on Fish Use Form

By and large the greatest volume of fish used for direct human consumption has been of animals ten inches long, or longer, and this is still the case. As noted above, this has nothing to do with nutritive value, because all fish flesh is substantially the same in this respect. Also it has little or nothing to do with original intrinsic taste of fish. Most kinds of fish, raw and fresh, are pleasantly bland in taste, with each kind having a faintly distinctive flavour which is relished by connoisseurs, as noted in the Japanese shops that specialize in serving raw fish flesh cut from freshly killed specimens. The taste of preserved or cooked fish of any kind bears little relationship to original taste, raw and fresh from the water.

The essential reason for using relatively large sea animals for direct consumption is because they are easier and more economical to handle, process, and preserve between catching and consumption to the taste, texture and appearance characteristics that consumers want and will pay sufficiently high a price for to warrant the work.

The effect of this preferential use of larger sea animals for direct human consumption is to limit the volume of sea food available for direct human consumption. The reason is that, by and large, the larger sea animals are higher in the food chain than the smaller. They are mostly carnivores that live on carnivores, or carnivores that live on them. For instance, yellowfin tuna eat bonito, bonito eat anchovies, anchovies eat either tiny plants or animals (that eat tiny plants). There is a loss in conversion of 80% to 90%, or thereabouts, at each step in the food chain. Therefore it may take as much as 10,000 tons of phytoplankton to produce one ton of the sort of sharks that live on yellowfin tuna. The situation is much more complex than that, but the example is illustrative. The situation is the same, essentially, as when there were more buffalo than wolves on the Great Plains, more antelope than lions in Africa, and more deer than tigers in India. The closer the food chain is to basic plant production for food, the more animals of that kind there are (Chapman, 1967a).

The size of animals that feed directly on plants in the ocean goes right down to single cell animals of microscopic size, and animals of this size are enormously abundant in the ocean. At times they are so abundant that they colour large areas of ocean brown, or red, or yellow, or green, although the individuals are so small they cannot be seen by naked eye. This is the zooplankton that some ocean scientists have looked to as a source of food because of its enormous abundance. The trouble is that, even where such small zooplankton is thickest, the cost of removing the water from it is so much greater than any useful product that could be made of it would be worth that no technology presently envisioned appears close to being able to economically harvest it.

There are animals of literally all sizes in the ocean, however, from these microscopic kinds to the great blue whale and giant squid. Nearly all of them congregate at particular times and places so that they are more cheaply caught then than otherwise. When the individual animal gets to be about an inch long, and occurs in schools or swarms so they can be caught in terms of several tons per hour, they are capable of forming a resource base for a commercial fishery. While knowledge of living marine resources is far too scanty to make a reasonable estimate as to the volume of such small animals between the length of 1 to 10 inches there are in the ocean. I do not believe any knowledgeable marine biologist would challenge the statement that there are at least ten times the weight of animals in the sea between the lengths of 1 to 10 inches long as there are more than 10 inches long.

It is in this size area that most of the controversy among marine biologists as to the volume of animals that is capable of being harvested per year from the ocean exists. Almost none are now of the opinion that catches cannot be increased several fold from present levels, or to about 200-250 million tons per year (Schaefer, 1968 ; Kasahara, 1967a, 1967b). Others, however, contend that production can reach possible sustainable levels of 1,000 to 2,000 million tons per year (Chapman, 1965 ; Schmitt, 1965). The former are talking in terms of the sorts of animals which present technology can take and process for use economically. Most are thinking in terms of those used for direct human consumption, and mostly those that are ten inches or longer in size. Those who talk of limits between a billion and two billion tons per year are talking about the full range of animals of the sea that are one inch or longer in size, and that concentrate at times and places into commercially catchable schools or swarms. Examples of these smaller things are the krill (not only of the Antarctic, but of many other parts of both the northern and southern ocean) (Kasahara, 1967b), the red crab of the Mexican west coast (and similar species at similar latitudes elsewhere in the world), the lantern fishes, the deep-sea smelts, the sand-lances, the anchovies, etc., etc.

The reason why Schaefer and Kasahara suggest that the difference between those who claim upper production limits of 200 million tons per year for world ocean sustainable fish catch, and those who contend for 2,000 million tons, is not as great as the two sets of numbers would indicate is just this : The two groups of experts are talking about two different groups of animals. Those who contend that the upper production limit may be in the neighbourhood of 2,000 tons per year are talking about all the animals in the ocean one inch long or longer, and nobody contends that of the 'conventional' fish ten inches and longer, anywhere near that volume can be taken in a sustainable fashion. Perhaps 200-250 million tons per year of fish of that size is a quite reasonable upper sustainable production limit.

One of the reasons why so much fuss is raised over this point among marine biologists is the conservation factor, which will be dealt with more fully below. Sovereigns are hard enough to get to force their citizens to abide by conservation regulations as it is, and overfishing on 'conventional' fish is already a major problem in many areas of the high seas. Some feel that if sovereigns suspect the upper limit of sustainable production from the sea is 2,000 million tons per year instead of 200, the sovereigns will never enforce conservation regulations and there will be great damage and loss of productivity in the stocks of 'conventional' fish that now produce most of the fish used for direct human consumption, and most of the total value to fishermen (FAO, 1968a).

D. Fish Meal and Undifferentiated Protein

For a long while the scrap and trimmings resulting from the processing of fish for direct human consumption (for instance canning, filleting, etc.) has been dried, had the excess oil pressed from it, and, as fish meal used to feed chickens and other animals. Between the two world wars special fisheries were developed to catch raw material for this processing (California sardine, Atlantic menhaden, etc.). After World War II, the science of animal husbandry was developed rapidly and the application of nutritional concepts to all sorts of animal raising was brought to a fine art, particularly in the United States. In 1946 broiler chickens were raised in the United States to an age of 90 days with a feed conversion rate of 4 pounds of feed to one pound of meat, at a cost of .33*c* per pound. In 1968 broilers of the same weight were brought to slaughter at an age of 52 days, a feed to meat conversion rate of 2.1, and a price per pound at the farm of .15*c* (Wittwer, 1970).

While breeding, housing, care, and several other factors went into this sharp improvement in poultry and egg production, the chief ingredient was carefully planned, efficient feeding. Fish meal played a part in this, and still does. Its role in the diet was to provide a balance of amino-acids in the diet so that the chicken could efficiently use the proteins of grains that were deficient in one or more amino-acids. While poultry production has been the main beneficiary of this nutritional efficiency revolution, the same sort of thing has applied to other livestock except for ruminants, and balanced diets containing fish meal for this nutritional purpose also are now used for calf starters.

This revolution in poultry (and swine) production, particularly, spread throughout Western Europe and Japan, and now is spreading throughout the world, particularly through the developing countries. The result is low cost meat and eggs which people of substantially all societies accept readily, and which can be produced so close to market that processing, preservation and transportation costs are at a minimum.

Coincident with this revolution in animal husbandry efficiency, and inextricably connected therewith, came an expansion in fish meal production and use. In 1948 about 589,000 tons of fish meal were made and 1.5 million tons of fish were used for this purpose, aside from scrap and trimmings. By 1968 about 4.7 million tons of fish meal were made in the world and nearly 23 million tons of fish (better than a third of all fish caught in the world) were caught and used particularly for this purpose. Peru became by far the largest producer. First its production went to North America and Western Europe. As the poultry revolution spread through the world so did fish meal and use. As noted above, in the first six months of 1969 Peru exported fish meal to 43 countries on all continents, 25 of which were developing nations. There is every reason to expect that fish meal production and use for this purpose will continue to grow as the poultry revolution expands throughout the developing and socialist worlds.

This has become the strongest force in world fish trade and development, and is likely to continue to be so for the rest of this century. Because of the fact noted above that the flesh of all fish has essentially the same amino-acid balance, and therefore nutritive value, any fish, large or small, can be used to make fish meal. The product is priced on the basis of so much per protein unit, not on taste, texture or appearance. The consequence is that the small things of the ocean that are so abundant have come into use. They could not be brought to market economically for direct human consumption, but as fish meal they can be caught and brought economically to market for indirect human consumption as poultry meat, eggs, bacon and hams. The anchovy of Peru, Chile, South Africa and California have come into production and use, or are in the process of doing so. Anchovy feed partially on phytoplankton and partially on zooplankton, and are thus close to the base of the food chain and very abundant. One can readily anticipate other known anchovy stocks in the Gulf of Mexico, off North-west Africa, and in the Indian Ocean coming into production in the near term.

Other small fish which were otherwise unused, such as capelin of the Arctic and sand lance of the North Sea, have become substantial raw material sources for fish meal in North-west Europe. These are abundant and still unused off Canada (Aiken, *et al.*, 1970), and Greenland and also in the North Pacific. Larger fish which can be produced cheaply but which are too abundant to all be consumed by the direct human market are used for fish meal. Examples are herring, sardine, mackerel, Alaskan pollock, and blue whiting. Lantern fishes are just beginning to be used for this purpose in South Africa. Experimental fishing for krill in the Antarctic is under way, and the known available stocks of krill there alone are sufficient to double present production of living marine resources on a sustainable basis.

Fish meal is undifferentiated animal protein. It is acceptable for direct human consumption in many areas where rice, casava, and bananas are the staple calorie providers in the diet, but it is not used much there in this form. Where the heavy taste and odour of rancid fish oils are an attraction rather than a detraction, dried fish are used, or sauces and pastes are made of fish.

If, however, substantially all of the fish oils are removed during the processing, and the latter is done under hygienic conditions suitable to human food preparation, one gets a substantially tasteless, odourless, light coloured powder which is fish protein concentrate. It can be included in pastas, breads, gruels, beverages, etc., in sufficient quantity (as in the chicken feed) to allow the human body to use the proteins of the grain which are deficient in one or more essential amino-acids, or to provide the whole protein requirement of the diet, in an undetectable manner and at a low cost (U.S. Bureau of Comm. Fish., 1966). It is the dream of many nutritionists and humanists that this cheap source of well-balanced animal protein can one day soon be one of the means by which protein malnutrition in humans can be eliminated from the world.

It is noted that any fish suitable for making fish meal is suitable for making fish protein concentrate, and that unused stocks of fish are known that are more than adequate to produce all of the animal protein requirement of a human population considerably larger than exists in the world today (Schaefer, 1968). It is also noted that all vertebrates, including chickens, pigs, lizards, and humans, have the same nutritional frailty. They require on an almost daily basis certain amino-acids in their diet that their bodies cannot synthesize. Those must come from plants either directly or indirectly. Ruminants, and some other vertebrates, have digestive systems (either extra stomachs or longer intestines, or other arrangements), so they can digest green plants in sufficient volume to get enough of the essential amino-acids to permit growth and health. Chickens, pigs and humans cannot.

Undifferentiated protein products other than fish meal, fish protein concentrates, pastes and sauces are becoming important in Japan, and are likely to spread elsewhere. Artificial hams and sausages in which flesh from a variety of fishes (and whales) formed the meat ingredient zoomed into importance in Japan during the 1950's and have made their place in the Japanese diet. 134,000 metric tons were produced in 1969 (Suisan Keizai, Feb. 11, 1970). Kamoboko, or fish cake made of carbohydrates and fish flesh with flavouring has long been a part of the Japanese diet. The invention in recent years of a simple machine that can debone small and medium-sized fish cheaply aboard ship has led to the production of 'surimi' which is deboned fish meat pressed into cakes, frozen aboard ship, and used later for incorporation into fish cake. Such fish as Alaska pollack, Atka mackerel, capelin, and other things that were used only for fish meal production ten years ago are now used for making 'surimi' for direct human consumption, to the tune of several hundred thousand tons per year. The trade is still increasing rather sharply. 198,300 metric tons of this product was used in Japan in 1969, up 36% from 1968 (Suisan Tsushin, Feb. 13, 1970).

Thus new techniques, methodologies and products are opening up the use of fish and shellfish of all sizes to use directly or indirectly as food for man. The great breakthrough in fish meal production has used fish in vast quantities (anchovy, sand lances, and crangon shrimps) down to four and five inches in length, and it is only a matter of time and growing demand for smaller, even more abundant, things to come to harvest. As the demand for animal protein in the world continues to grow so will the production of food from the sea. Whatever fish are suitable for fish meal production can serve the same nutritional need for humans directly through fish protein concentrate, pastes, sauces or fish cakes.

E. Impediments to Fishery Development

The chief impediment to producing increased yields of food from the sea is cost. The subject is too extensive and complex, as well as being variable from country to country, to be considered adequately here, but some general comments may be useful by being illustrative.

A general rule is that fishermen who work at sea, and particularly those that stay at sea for some days or months, require to earn somewhat more than the same labour and skills can earn on shore. Otherwise the labour will not go to sea, where working conditions are naturally worse than on shore, except under duress. Not only does this extra profit on labour need to be assured before the operation is viable, but special incentives must be supplied to ensure diligence at sea. For this reason payment for labour in sea fishing is based on share of production in all successful fisheries, whether in socialist, developing, or developed countries. Examples could be given of developing countries where attempts have been made to stimulate fishery development through payment of straight daily, hourly, or other wages, and have all failed.

Another general rule that is often overlooked is that the fishing vessel and gear must be able to earn enough profit so that the capital invested in them will earn at least as much as if it were invested in shore industry. With the application of science and technology to fish production both vessel and gear have become generally more capital-intensive. Risks at sea are generally higher than ashore, whether from weather, fluctuations in abundance or availability of stock being fished, or otherwise, and therefore the profit margin in the operation for the vessel and gear must normally be higher than for the capital invested ashore to cover the cost of this extra risk.

If there is any general rule that is violated generally in developing fisheries, always with disastrous economic results, it is that of not calculating into the operation adequate margins for the capital invested in vessel and gear. Only if this is done can a fishery be self-generating. A frequent tendency in developing countries is to provide capital for vessel and gear to build a fishery without providing profit margins for it to earn. In consequence the fishery is not self-generating, and when the original vessel and gear are worn out the fishery disappears again unless more such subsidy is pumped in. This is a particularly important point because most land people (bankers and government officials particularly) generally do not understand that in a modern, efficient fishery the capital invested in the vessels and gear is always a large fraction, and normally the largest fraction, of the whole capital investment required from ocean to consumer to make the fish supply operation viable. If the vessel and gear do not make a profit the fish stay in the sea.

Another general rule is that a vessel in which the key crew, but particularly the skipper and engineer, makes a considerable part of total earnings from ownership in the vessel and gear is more efficiently operated, and catches at a lower cost per ton, than a vessel which is owned by absentee investors, whether individual, corporate, or government. Without going into detail it is simply stated that this empiric rule has been demonstrated time and again throughout the world. A wise corporation or government wishing low cost raw material from the ocean gets ownership of vessel and gear into the hands of the fishermen-operators as soon as possible through provision of easy credit, selection of appropriate skipper-operators, assistance in the management of the business aspects of the matter, training, or otherwise.

A corollary to this is that access to capital is often the single greatest impediment to fishery development. Land people (particularly bankers and government officials) have difficulty in differentiating between an efficient skipper-operator, who may be uncultured and crude, and an incompetent fisherman who can speak in a cultured tone. Accordingly in broad sections of the world, and particularly the developing countries, access to capital by fishermen-operators is difficult and expensive, and very frequently in the hands of money-lenders whose interest rates trap the fisherman in bondage for life and stifle development.

Another corollary to this is that in all societies some skipper-operators are greatly more efficient than the average. If the profit margin is pegged to make the average vessel operator profitable these extra-ordinary skipper-operators get rich. This is almost always resented by land people, and particularly company management or government servants whose earnings are not so large. These then attempt to limit the earnings of these extra-ordinary men and in doing so always damage the economic viability of the fishery. The general rule is that only rich fishermen make money for others in the chain of supply (whether corporate or government) and any fishery which does not have a few rich fishermen-operators by local standards is not likely to be economically viable. A safeguard to this, from the standpoint of social standards, is an almost universal fallibility of successful owner-operators. They almost always plow back profits into new, more efficient, vessels and gear.

Another general rule is that one never uses a larger or more sophisticated vessel than necessary to maximize net earnings. The larger and more sophisticated the vessel the greater the costs. When a government planner sees a large, sophisticated foreign fishing vessel operating off his coast the almost universal reaction (in the United States as well as in the poorest developing country) is to seek vessels of the same size and sophistication for his country. This ignores the facts that (*a*) labour at sea is always more costly than labour ashore, (*b*) the chief cost in the final price to the consumer is ordinarily that of locating, catching, and delivering the fish to shore, and (*c*) the chief economic waste in all fisheries is the time spent running to and from the fishing grounds, with consequent lack of earning to the vessel and gear.

Fishing vessels and gear are highly specialized investments designed to fish, and when they are not fishing they are not earning. It also ignores the fact that if the owner of the large, sophisticated vessel had a harbour nearer the fishing grounds to which he could economically take his catches for processing and distribution to market, he would be using a smaller and less sophisticated vessel, and by doing so cutting his costs per unit of production.

It follows from this that the chief advantage developing countries adjacent to rich fishing grounds have is not just cheap labour, but the proximity to the fishing grounds. The living resources of the high seas being open to all gives a powerful economic advantage to the coastal country adjacent to the fishing ground. Given equal assistance in the application of science and technology to fishery development, access to market, and access to resource, the short-range fishermen will eventually run the long-range fisherman out of the market and off the fishing ground because his costs are less. This is one of the prime reasons why fish production by the developing countries has been going forward more rapidly in the past decade than has that of the developed countries or the socialist countries. If the rules were now to be changed so as to raise his costs relative to those of the big vessel, long-range operator, this advantage would decline.

A chief impediment to fishery development throughout the world is government regulation to protect the inefficient fishermen from the efficient fishermen. This is not only the source of much friction as between countries, but is almost uniform tendency within countries as between their own citizens. The tendency is as fully developed in the richest as it is in the poorest countries. The elimination of traps and fish wheels from the salmon fisheries of the United States is a particularly apt example, but literally dozens of equally good examples could be cited from other countries on all continents and at all stages of economic development. If production of food from the sea is what is wanted then efficient fishermen require to be protected and encouraged to become more efficient. If social and economic equality is what is wanted then fish production will suffer.

Another chief impediment to fishery development, for which dozens of examples of importance in the developing world could be cited, is the protection of local industry, or the protection of foreign exchange balances, by heavy tariffs or other trade barriers affecting what the fisherman needs to work with. The high price of diesel fuel in India has prevented the modernization of its fisheries for many years, and is only now being modified. Barriers to importation of foreign built fishing vessels are common, hindering the development of fisheries in the United States and Australia as well as in Brazil, Argentina, India, and many other countries. Tariffs on tin-plate to protect local steel industries, or to raise revenue, hold back the development of fish canning industries in Chile, Peru, India, Philippines, and other countries where fish suitable for canning is readily available. Synthetic webbing and ropes, engines, spare parts, electronic equipment, and all of the modern paraphernalia of the trade that a fisherman needs to be efficient, and to modernize his production facility, are generally subject to trade barriers that block imports entirely or raise costs to the fisherman sufficiently to inhibit development. Fortunately a good many developing countries are beginning to realize this, and that frequently the loss of foreign exchange by permitting fishermen access to supplies and equipment he needs is often met or exceeded by gains in foreign exchange that can be made from the export of his product, if he is permitted to become competitive in the world market.

This is by no means a comprehensive account of the impediments to the increased production of food from the sea. It is only some examples which government at the international and the national level can take into account in their efforts to enhance such production. The general point to be made is that the chief impediment to increased production of food from the sea is neither demand nor supply, but the cost of getting the fish out of the sea to the consumer in a form he will accept and at a cost he will pay.

This is particularly apparent in the fisheries supporting fish meal and undifferentiated protein products, from which a very large part of future yield of food from the sea can be expected. For instance, when the delivered price of fish meal in Hamburg is $150 per ton the market for it keeps increasing sharply. At prices between $180 and $190 per ton market growth levels off. At $220 per ton the market is shrinking. Such close supply-demand relationships can be demonstrated for such luxury products as crab, shrimp, lobsters, scallops, and for such medium range products as ground fish and tuna, as well as they can be for the cheap fish meal type fish. As cost goes down market increases. The demand for animal protein, as well as its need, is so great in the world as a whole that if price can be kept down within the consumer's reach fish landings will continue to expand steadily.

F. The Changing Fishing Patterns

The statistics in this section are taken from *FAO Yearbook of Fishery Statistics for* 1969, volume 26, the most recent world-wide data available (FAO, 1969a). They include all living aquatic resources, marine, freshwater, and diadromous because they are used to illustrate trends, rather than to be specific. As usual the total figures are composed of about 90% marine and diadromous fish dependent upon the sea. In 1967 13.6% were freshwater and diadromous fish; 77.6% marine fish; 7.4% crustaceans, molluscs and other invertebrates; and 1.4% 'other' (seals, miscellaneous aquatic mammals, miscellaneous aquatic animals and residues, aquatic plants).

The total catch rose from 33.2 million tons in 1958 to 64.0 million tons in 1968. That for Africa rose from 2.1 to 4.2 million tons; for North America from 4.0 to 4.6 million tons; for South America from 1.6 to 12.9 million tons; for Asia from 15.0 to 24.3 million tons; for Europe from 7.7 to 11.8 million tons; for Oceania from 110 to 210 thousand tons; and for U.S.S.R. from 2.6 to 6.1 million tons.

The countries with developed economies (Canada and U.S. in North America; Western Europe including Yugoslavia; Australia and New Zealand; Israel; Japan; and South Africa) increased their landings during this 11 years from 17.2 million tons to 24.9 million tons. The developing countries increased their joint catches from 8.2 to 25.3 million tons; and the centrally planned economies (Mainland China, North Korea and Viet Nam, Mongolia, U.S.S.R. and Eastern Europe) increased their catches from 7.8 million tons to 13.8 million tons. The statistics for the Asian centrally planned economies are exceedingly suspect, and largely composed of those for Mainland China. Thus what credence to put on the 4.9 million ton level for 1958 or the 6.9 million ton level for 1968 is debatable. The increases from 2.9 million tons in 1958 to 6.9 million tons in 1968 for U.S.S.R. and Eastern Europe are as sound as any of the other statistics.

Canada and the United States did little better than hold even for this period, their joint catches rising only from 3.7 to 3.9 million tons. The European Economic Community did not do much better, with its catches rising from 2.0 to 2.2 million tons. In both instances the consumption of fish in these areas increased sharply, with imports coming chiefly from the developing countries. The other countries of Western Europe increased their catches from 5.5 million tons to 8.7 million tons. Israel increased from 12.6 to 26.1 thousand tons; Japan from 5.5 to 8.7 million tons; and South Africa from 419 thousand tons to 1.1 million tons.

Canadian fishing continued to be restricted to North American waters, and chiefly off its own coast, with the exception of three or four tuna vessels that fished off Latin America in the eastern Pacific and off West Africa.

Most of the United States catch also was taken off the coast of the United States and Canada except for the tuna fishery off Latin America in the eastern Pacific and the shrimp (and a little other) fishing off Mexico in the Gulf of Mexico, and down along the Caribbean coast to central America somewhat. The tuna fishery thrived during this period but did not extend its area of activity until in 1968 a few boats fished off West Africa, to be followed by 24 doing so in 1969.

Fishing by the European Economic Community countries remained in the North Atlantic except for Italy and France, whose fishing expanded south along the West African coast. In the case of Italy, in particular, this was encouraged by government subsidy for the stated public purpose of economizing on foreign exchange.

The other Western European countries also did not expand their fisheries out of the North Atlantic, to speak of, excepting Spain, like Italy, undertook a sizeable fishing vessel subsidy programme during this period, also for the stated purpose of economizing on foreign exchange. In consequence its catches grew from 845 thousand tons to 1.5 million tons during the period and its vessels began working rather steadily along the West African coast as far as South Africa, and to some extent even on the Patagonian shelf off Argentina, as well as in the North-west Atlantic and off Europe. In this group, also, the Danish catch grew sharply from 598 thousand tons in 1958 to 1.5 million tons, and its vessels intensified their fishing off Scotland and Greenland, but not outside the North Atlantic.

The fisheries of New Zealand and Australia remained off their own coasts during the period as did the South African (counting South-west Africa). The Israeli extended their fishing out into the Atlantic off North-west Africa, and somewhat down the Red Sea off Ethiopia (the eastern Mediterranean being very poor in fish production).

The Japanese continued to expand their fisheries quite literally to all parts of the world ocean where fish stocks were sufficiently large to warrant commercial fishing. Their world-wide long-line tuna production reached a peak during this period and fell off toward the end upon meeting competition in most parts of the world ocean from South Korea and Taiwan. Their trawlers worked throughout the Pacific, Atlantic and Indian Ocean either steadily or on an exploratory basis. Their whalers continued to work Antarctica and the North Pacific. Their fishing spread from the Bering Sea down throughout the Gulf of Alaska. Their trawlers worked steadily off North-west, West, and South-west Africa, and explored into the North-west Atlantic and off the east coast of the United States. Still, however, the great bulk of their total catch continued to come from the area of the home islands, which is quite rich, and is worked intensively, as it has been for a long while.

Among the developing countries the tripling of landings took place mostly in their own territory or directly offshore, but this was by no means entirely the case. In South Korea and Taiwan long-line tuna fleets were built up which ranged completely through the Pacific, Atlantic and Indian Oceans. Their trawlers ranged newly down into the South China Sea to Indonesia. Taiwan fish production doubled from 230 to 527 thousand tons. Korean production also doubled from 404 to 841 thousand tons. In Africa, Ghanese vessels expanded their fishing area north to Mauretania and south to South Africa while tripling catches from 31 to 102 thousand tons. Cuba expanded its fishing through the Caribbean into the Gulf of Mexico, up the east coast of the United States to Nova Scotia and the Grand Banks, and down the coast of South America to Argentina, while tripling catches from 22 to 66 thousand tons.

While the big producer in this group was Peru, whose catches rose from 961 thousand tons in 1958 to 10.5 million tons in 1968, there were other countries that made great increases both in total tonnage and relative production. Chile went from 226 thousand tons to 1.4 million tons. Argentine catches went from 84 to 223 thousand tons. Brazil from 212 to 420 thousand tons. Venezuela from 78 to 126 thousand tons. In Asia, aside from Taiwan and South Korea, Thailand production jumped from 196 thousand tons to 1.1 million tons. South Viet Nam went from 143 to 410 thousand tons (despite steady war), Philippines went from 447 to 944 thousand tons, Malaysia from 140 to 407 thousand tons, Ceylon from 41 to 144 thousand tons, India from 1.1 to 1.5 million tons, Pakistan from 284 to 424 thousand tons, and Indonesia from 691 thousand to 1.2 million tons. In Central America, Mexican production rose from 164 to 366 thousand tons, in Panama from 7.0 to 72 thousand tons, and in El Salvador from 3 to 14 thousand tons. Even the tiny Costa Rican catch jumped from 1 to 5 thousand tons, and that of Trinidad and Tobago from 4 to 13 thousand tons.

Among the socialist countries U.S.S.R. made tremendous expansions in its sea fisheries with those of Russia proper registering the greatest gain (Suisancho Nippon, Feb. 13, 1970). Like Japan, it expanded to all parts of the world ocean and in an even more dramatic way as it developed its methodology of groups of vessels moving together with specialized research, supply, processing, and transport ships in the group. Its catches increased from 2.6 million tons in 1958 to 6.1 million tons in 1968, and its vessels worked both sides of the Atlantic from the Arctic to the Antarctic, both sides of the North Pacific to Japan on the West and California on the East, and in an exploratory way in the South Pacific and Indian Oceans on both sides. Aside from whaling in Antarctica (and experimental krill and fish fishing there) most production was still from the Arctic, North Atlantic, and North Pacific. Substantial production came from West Africa from Gibraltar to the Cape, and there was some fishing on the Patagonian shelf.

Among the eastern European countries there was other strong sea fishery development. Polish production went from 145 to 407 thousand tons and its vessels expanded their area of operation out of the Baltic as far as the North-west Atlantic. East German production went from 93 to 295 thousand tons, with a similar geographic expansion. Romania began fishing in the Atlantic as well as the Black Sea, and Bulgaria had begun fishing the Red Sea area before the closure of the Suez Canal.

This 11 year period was thus marked by a steady increase in production of food from the sea (and to a less extent from freshwater) that grew at a rate at least three times that of the human population increase, and much more rapidly than production of food from the land. The greatest rate of increase in production came in the countries with developing economies and the developing countries ended up the decade producing at an actual annual volume somewhat larger than the developed countries, if the countries with the centrally planned economies are left out of the reckoning. If they are taken into the reckoning, and the Eastern European called developed, and the Asiatic called developing, the same is still true.

G. Assistance to Development

The countries of the developing world had, and have, certain natural advantages that spurred on the great development in their sea fisheries that has taken place in recent years. Among these have been, and are:

1. Demand for animal protein and particular kinds of fish and shellfish, in the world as a whole.
2. Proximity to large fishery resources that had been little fished previously.
3. Relative ease from a technical, educational, training, and capital viewpoints in getting into fishing.
4. Freedom of entry, as contrasted with land resources that are owned by individuals or governments and have institutional barriers normal to property rights.
5. Rapidly developing new technologies relatively easy to apply such as synthetic webbing, marine diesel engines, freezing and chilling ashore and afloat, fish finders, etc.
6. Desire of peoples and governments to assist them in their development, etc.

To these natural advantages has been added much practical assistance that can be briefly noted:

International

In the United Nations family responsibility for fisheries rests in the Food and Agricultural Organization (FAO) of the United Nations. FAO has had a Division of Fisheries since its organization in 1945. During the first half of the last decade this structure was broadened and strengthened to become, in 1965, a Department under an Assistant Director-General, with two Divisions (a third being created in 1970). Funding for the regular programme of this Department has also been gradually increased, being $2.3 million for the 1964/65 biennium, $3 million for the 1966/67 biennium, and $4.4 million for the 1968/69 biennium (estimate). Several intergovernmental regional bodies for fisheries have been established over the years under the FAO Constitution to further assist member countries, and promote co-operation in fisheries among them. These are the Indo-Pacific Fishery Council with 18 members, established in 1948; General Fisheries Council for the Mediterranean with 17 members, established in 1952; South-west Atlantic Fisheries Advisory Commission with 3 members, established in 1961; the Fishery Committee for the Eastern Central Atlantic with 15 members, established in 1967; and the Indian Ocean Fishery Commission with 20 members, established in 1967. The general function of the Department is to promote national and international action with respect to the development of the world's fisheries and the rational utilization of the living resources of marine and inland waters (FAO, 1968b).

Over and above this regular programme of work is the fishery aspect of the United Nations Expanded Programme of Technical Assistance [EPTA, now UN Development Programme (TA)], executed by the FAO Department of Fisheries. Under this programme single (or occasionally more) experts in particular subjects are sent to countries, upon their request and at the total cost to UN, to make particular studies, give advice on particular subjects, or execute particular tasks. Such projects may be of a few weeks or months duration, or even a few years under exceptional circumstances. Since the first fishery project was initiated in 1950 under the EPTA programme (and until 1968) FAO has issued 140 EPTA reports relating to marine (and 57 inland) fisheries based on the work of nearly 100 technical assistance experts who worked in 60 countries. This programme is on going and much used by developing countries (FAO, 1968b).

In 1958 the Special Fund of the United Nations was established on a quite different philosophic basis than the above. Member nations were not assessed to support it but voluntary contributions were solicited from them. It was dedicated to making pre-development studies that would lead to industrial growth in developing countries. The recipient country was expected to put up matching funds in kind or otherwise, and ordinarily about equal to the sum granted by the programme. Only good sized projects were considered (over about $200,000 in total cost) and the projects were reasonably long-term (two or three years at the start, now often for four or five years). The fishery projects of Special Fund [now combined as UNDP (SF) with UNDP(TA) in the United Nations Development Programme] have all been executed by FAO, and in recent years this has developed into the main work of its Department of Fisheries.

The UNDP(SF) programme grew rapidly since 1960. As at January 31, 1969, 48 such projects had been involved costing $111 million, of which $48 million was provided by UNDP(SF) and $63 by the recipient countries. This list included 4 projects already completed ($6 million), 29 projects in operation ($81 million), and 13 projects approved but not yet started. At that date the Department was participating in 12 other UNDP projects in which another Department of FAO had prime responsibility, and 18 other fishery projects were under consideration by UNDP. This work is on going and can be expected to increase, and become even more effective, over the next few years (FAO, 1969d).

These projects are tailored to particular country need and cover large ranges of fishery needs: fishermen training, resource surveys, establishment of continuing research and administrative institutes, fishery development, education of experts, fish culture training, etc. The projects are scattered quite literally throughout the developing world, and cover freshwater as well as marine situations. Most are individual national projects but a few (such as Central American, Caribbean, and West African) are regional, serving a number of countries.

The rapid growth of the Special Fund Programmes in fisheries during the first half of the last decade almost swamped the FAO fishery function and the resultant stress was one of the reasons leading to the reorganization, broadening and strengthening of the FAO Department of Fisheries in 1965. A main problem was that the new load of work brought on by this rapidly expanding field programme over-loaded the regular programme of FAO to the point where it nearly broke down and could not function properly. This situation began correcting in 1964 as Special Fund began allowing more overheads to the executing agency, and all parties, including the executing agency, Special Fund, and the member countries, became more familiar with the techniques of operating such programmes. There is probably no other single factor presently acting as effectively in the world as the Special Fund—FAO programmes in assisting the development of sea fisheries by developing countries in all parts of the world. If this can continue to grow and the World Bank group puts forward needed credit, fishery development in the developing countries should continue to expand in a healthy fashion through 2000 A.D. with great advantage to all mankind (FAO, 1968c, Chapman, 1970).

Bilateral Programmes

There has been a good deal of effort and funds devoted by a number of developed and socialist countries to assist particular countries develop their fisheries through bilateral assistance programmes. The result has been a mixed bag. The German programme of introducing trawling into Thailand was a smashing success. The assistance to Pakistan by the U.S. in building the fishery harbour at Karachi proved quite useful, although that harbour has now been outgrown. The Russian assistance to Cuba has been productive. The Norwegian project in India started poorly, but has become quite effective. On the other hand, both East German and West German fishery aid projects in Guinea produced little, and both Russian and U.S. projects in Somalia produced substantially nothing. Bilateral fishery development aid to Indonesia has produced little practical results. Japan, U.K., France, Germany, United States, Russia, and a number of other nations still undertake fishery development projects to assist particular nations, but the projects are often rather short-term and generally have not been as productive as aid given through multi-lateral sources. A reason is often lack of continuity and clear-cut, well rounded, objectives. Bilateral assistance in the form of fellowships, training courses, and similar activities has appeared to be more effective overall than bilateral assistance in field projects.

Private Industry

A good many developing countries do not want foreign industry to come in and have equity ownership in firms developing their fisheries. If they do permit such activities they often do so under conditions which make the operation economically unviable. On the other hand other countries have welcomed foreign firms in, and in some cases even given incentives to the firm. Malaysia is an example of the latter. Peru, Chile and Equador are examples where foreign firms have been welcomed on normal business terms that led to rapid fishery development and the simultaneous growth of native industry. Peru, in ten years time, thus built not only the most productive fishery in the world, but one of the most sophisticated. Great technical assistance came from foreign firms that moved in with full-blown technology from home, but foreign ownership has never been more than thirty or forty per cent of the industry, and native Peruvian firms have developed that are as competent and successful as the foreign firms. Shipyards, net and fibre factories, machinery manufacturing firms, etc., have grown rapidly in Peru to support this thriving industry.

The United States fish industry has promoted much fishery development in the developing world not only through wholely owned firms and joint ventures, but through providing credit, firm market, technical assistance on quality control, etc., without equity ownership. Japanese fishing industry has worked in many parts of the world through joint ventures with local capital, or even joint ventures with foreign firms and local capital. In recent years there has been a growth of independent experts and firms specializing in technical assistance who hire out for management fee with, or without, equity participation to assist in the development process.

By and large a great variety of expertise, skill, and know-how is available from these many sources to countries desiring assistance in the development of their sea fisheries. New technological developments are available almost simultaneously in all parts of the world through trade journals, trade representatives, FAO and other governmental publications, and the general intelligence networks that permeate every aspect of the world's fish business. International traders and brokers diligently seek new sources of supply in the furthest corners of the world with which to fill their world markets.

Where development goes slowly the reason is more apt to be the nation's, or people's inability, or lack of desire, to use assistance than the lack of it being available.

H. The Conservation Problem

The theory of fishery conservation is simple.

Each homogeneous stock of animals is provided by nature with some surplus reproductive vigour. In a state of nature all such stocks are in balance with each other and the environment, producing just enough young each year so that on average each male and each female begets one male and one female in the succeeding generation. In aquatic mammals this may be one or two pups a year, or every other year. In some sharks, and rays, this may be a few young every year, or every other year. In Pacific salmon this may be a few thousand young every two to five years, depending on species and race. So it goes on up to things like cod and tuna in which each female may produce several million eggs in a spawning, and spawn every adult year of life. In nature there is always surplus production available in order to hold even.

As far as the fish stock is concerned, deaths to it from fishing are no different than deaths due to environmental change, predation, or otherwise. As fish catch from the stock increases, the average weight and age of the individuals in it decline, the total number of individuals and total biomass in it decline, and the remaining individuals have more room for survival in their ecological niche.

This all goes on as fishing pressure increases until a point is reached where the level of fishing corresponds to the maximum sustainable yield which the reproduction vigour of that stock of animals can support. If fishing effort continues to increase beyond that level either yield does not increase (if reproduction is fishery independent) or declines (if reproduction is fishery dependent). In any event, cost per unit of production goes up sharply as fishing effort increases beyond the level corresponding to maximum sustainable yield (Gulland, 1968).

As a matter of fact maximum net economic yield always occurs at a level of fishing effort somewhat less than that corresponding to the maximum sustainable (physical) yield (Schaefer, 1957, 1959). This has led economists to propose that means be devised whereby fishing effort can be limited to that level corresponding to maximum net economic yield (Gordon, 1954, and others). The natural corrollary to this is that a form of property right needs to be established in the resource, as well as a machinery of government devised to protect the rights, and enforce the regulations that would ensue. To carry it to its logical extension, and this has been recommended (Christy and Scott, 1965), there would be required an international body (undoubtedly in the UN family) with powers to assign rights of entry to fish particular fish stocks in the area beyond national jurisdiction, establish and enforce required regulations, do the scientific and management work required, etc.

While there is a certain logic to this it has been, to this point, all talk and little action, and that condition is likely to persist over the next many years. There are a good many reasons for this, too complex to cover in detail at this time, but some prominent ones are :

1. Under current international law and practice entry into fisheries beyond national jurisdiction is open to all, and the fish are the property of him who first reduces them to his possession. The individual fisherman operates in the fishery under no right pertaining to him under international law but under rights that pertain to the sovereign whose flag his vessel wears. Individuals frequently are the objects of international law, but only sovereigns are its subjects. Thus, in effect, the independent sovereign nations hold jointly the property rights in the living resource beyond national jurisdiction (Chapman, 1968b).

2. Few, if any, sovereigns show much, or any, interest in maximizing net economic yield from their high seas fish. Their objective appears rather uniformly to be maximizing the physical yield by their national fishermen, with a view to improving their nutrition and industry without the expenditure of foreign exchange, or to earn foreign exchange, or both.

3. Sovereign with sea fisheries show little more, or no, interest in turning control over them to any international body, and certainly not in losing revenue or business deriving from them. They show a marked reluctance even to take cases arising from jurisdiction disputes to the International Court of Justice or arbitration (Department of State, 1955). They drag their feet as long as they can, normally, in resisting application of conservation regulations to their fishermen even after they have agreed to prevent physical overfishing.

4. The machinery required to establish and enforce such objectives, even were it acceptable to sovereigns, would likely cost more to operate than the net economic yield gained, and probably cause more dissention among nations than it would cure. It would certainly take a fundamental reorganization of the United Nations to equip it, or any body associated with it, with the powers and financial resources required to handle this complex and enormous task.

What the sovereigns have agreed to, in the 1958 'Convention on Fishing and the Conservation of the Living Resources of the High Seas', (U.S. Senate, 1965), is to prevent their fishermen from overfishing in the physical sense any living resource in the high seas, and to co-operate with other nations in such prevention. This was done within a framework that protected the interests of all, both coastal and distant, both large and small, both poor and rich. It provided an arbitral system for solution of disputes. It was endorsed by overwhelming vote at the 1958 Conference on the Law of the Sea, has not been objected to very strenuously by anyone since, and is generally looked to as a statesman-like solution to the conservation problem, and rather a model of its kind. The only problem has been that, once having voted for its adoption, the sovereigns have inclined to ignore it, and gone about their fishery relationships by other means (Chapman, 1970b).

It must be pointed out that there are two problems involved. One is the actual prevention of physical overfishing by conservation regulation, when needed, and the other is the division of the profits (fish) that result from the conservation practices. All hands are agreed on the necessity of the first; all hands want to bargain, with every weapon they have, to get the largest share possible of the second.

The way, the sovereigns handle this problem is that when an overfishing problem becomes so flagrant that it can no longer be brushed under the rug they initiate amongst themselves (the ones whose fishermen are actually involved) a convention which ordinarily establishes a joint commission, on which each is equally represented, to deal with the problem. The Commission so established may be funded to hire its own scientific staff, or it may only correlate the scientific results from investigations done by national agencies. However, this is done, the research is generally funded on a niggardly basis, all hands resist as long as possible the imposition of conservation regulations on the grounds that the scientific results (from poor fundings) are inadequate to the conclusions, and in the end do not ordinarily act until the industry of several go broke, or until they are shamed into acting by public opinion or the threat of force (Chapman, 1970b).

As examples, the North Pacific fur seals were almost exterminated before a conservation system was established; the North Pacific halibut industry of both Canada and the United States was on the rocks before corrective action was taken; the whale fisheries of the Antarctic were brought to very low level before adequate regulations were adopted last year; the salmon resources of both sides of the North Pacific were in bad shape before three such conventions came into force to deal with different aspects of the problem; there is general agreement that the cod take from the Barents Sea could be doubled if the fishing effort by all hands could be cut in half; the Atlanto-Scandian herring stock of the Norwegian Sea is obviously overfished, as is the haddock stock on Georges Bank off New England, and in both cases adequate conventions are available to attend to the problem and there is agreement amongst scientists as to what should be done (Chapman, 1967b).

Despite the demonstrated cupidity, intransigiance, and dilatory habits of sovereigns respecting conservation of their sea fisheries (and it does not seem matter much whether they are developing, developed or socialist as to economics, or rich or poor, or large or small) this clumsy system of attending to these international fishery conservation problems muddles along and works pretty well in the long run. In spite of dire prediction no living resource has been permitted to be fished to extinction since the Bering Sea sea-cow 200 years ago, and there is little likelihood of this happening. It is presumably possible in slow reproducing animals like whales, porpoise, seals, etc., that have high individual value, but in fish it is not even presumably possible. The industry goes broke from slow catches before the fish stock does.

Also it needs to be kept in mind that total production continues to hold up in the two areas of ocean (North Sea and Japanese home islands) where total fishing has been most intense for the longest time. Furthermore, it is not certain that protection of carnivores at the third or fourth trophic level, because they taste good and bring high prices, will always be the international norm. It is conceivable that in the future, as lower trophic level animals come to harvest more importantly, there will be a desire to keep down predator abundance at sea as is done on land, where wolves and coyotes are kept at low level to protect calves and lambs. A case in point is the competition between man and guanay birds for anchovy off Peru (Schaefer, 1967).

In any event there are enough successful international fishery commissions at work in diifferent parts of the world to indicate that this system can work. In those cases where the economic as well as the conservation sides of the problem can be agreed to as a solution, it works quite well. Solving the conservation side of the problem tends to lessen friction over the economic side, mitigates economic damage to all, and leads in the direction of solving the economic side of the problem.

In the case of the North Pacific fur seals not only was sealing at sea stopped entirely in 1911 but conservation regulations responsibility was put in the hands of the sovereigns that owned the rookeries. In response these sovereigns, pursuant to treaty, were required to give a share of the harvest to the sovereigns who had stopped sealing. The convention came into force in 1911, and with modest changes is still in effect. The seal herds rebounded to normal size in a few years and the harvest has been in the vicinity of the maximum sustainable one for many years (Tomesevitch, 1943).

The sockeye salmon resources of the Fraser River were taken in hand by an international commission in 1938, the annual harvest divided equally between Canadian and American fishermen under treaty, and the stocks rebuilt under very careful joint regulation and other action. This worked so well that pink salmon conservation responsibility was added to the convention later. The North Pacific halibut stocks rebounded to normal levels soon after regulations were initiated by the International Pacific Halibut Commission in the early 1930's. The Inter-American Tropical Tuna Commission has so far prevented any noticeable overfishing of yellowfin tuna in the Eastern Pacific. The International Whaling Commission, at long last, has secured agreement from the remaining Antarctic Whaling countries to lower their catches below the replacement rate so that rebuilding of stocks will begin, and also secured agreement to cut back sperm whale take in the North Pacific. The nations involved in the Arctic cod fisheries, and those in the great Atlanto-Scandian herring fishery, at last are engaged in serious negotiation at this writing to put into effect adequate catching regulations. A protocol to the International North-west Atlantic Fisheries Convention designed to correct haddock overfishing is in an advanced stage of adoption.

Thus, despite the frustrating slowness of action under these international fishery conventions, and the interminable wrangling over scientific fact and injustice of regulation application to different nations, the system does work. Furthermore the major damage that arises from the slowness of action is to the nations who delay action, whose industries suffer economic loss and whose consumers pay higher prices or go without. Resources, so far, have not suffered permanent damage and have always responded to eased fishing effort rather quickly. Examples of major overfishing in individual nations (including the United States) can be cited that are worse than those in the high seas, and that leave one with the feeling that these problems are generally handled better, and quicker, in the international area where there is criticism from outsiders than they are when they are totally within national jurisdiction.

The surprising thing is that, despite the acrimony that often develops in these meetings and activities of regulatory international fisheries commissions, problems get worked out, none of the commissions has ever gone out of business because of abrogation of the establishing convention, nations who resign have come back or continued to co-operate as well as they did when members, and non-members have frequently (if not ordinarily) abided by regulations that were established.

Furthermore, despite sharp differences in social and economic theory, and practice, U.S.S.R. and the countries of Eastern Europe belong to international fishery conservation conventions with countries of the western world in all parts of the world, participate and co-operate thoroughly in the scientific work and meetings, and abide by regulations that are jointly adopted as obediently as anyone else does. As a matter of fact the Black Sea Mixed Commission, composed only of socialist countries, operates about the same way as these other international fishery conservation commissions do and, to an outsider, without much more, or less, wrangling and tensions among national delegations as occur there.

A particularly interesting example is the International North-west Pacific Fisheries Commission, to which only Russia and Japan belong. Those two countries have wrangled over their joint fisheries in that area steadily since at least 1905, and had serious annual meetings every year, when war between them did not intervene, since about 1925. In 1956, when a state of war still nominally existed between them, Russia actually imposed a fishery treaty for the area on Japan by threat of force, under concepts that were not yet to be agreed to in international treaty practice until the 1958 ' Convention on Fishing, etc.,' which Russia agreed to, but never has ratified (neither has Japan).

The Japanese complained bitterly about this high handed action, but complied because they had no suitable alternative. A joint Commission was formed and has met every year since then to exchange scientific results, set quotas for the catch of particular species needing regulation for the coming year, and assess permitted catches by the fishermen of each nation. There was always the threat of Russian force if agreement was not reached. Frequently the disputes at the annual meeting have been so bitter that the Commission delegates themselves could not resolve them, and they have had to be bucked up to the diplomatic level. On two or three occasions the issue had to be resolved at the Prime Minister level, with the full panoply of diplomatic relations between the two countries brought to bear.

Yet when the original ten-year period of the convention expired, and Japan could abbrogate with one year's notice, the Foreign Minister of Japan announced publicly that the convention was working satisfactorily and usefully as far as Japan was concerned, and that despite differences of opinion from time to time between the countries over fishery problems, Japan had no intention of abrogating the convention.

A similar, and related, question exists on the other side of the North Pacific under the ' International Commission for the North Pacific Fisheries,' to which only Japan, United States and Canada belong. Russia does not, although it fishes the area heavily. Under the ' abstention ' provision of this convention Japan abstains from catching salmon or halibut in the convention area. It has stated repeatedly that it does not agree with this ' abstention ' principle, which was imposed on it while a state of war still existed, and that it has a perfect right to fish for salmon and halibut on the high seas in the area. On the other hand it enforces its fishermen to abide by the terms of the treaty, and when the original period of the convention expired a few years ago giving Japan the right to abrogate on a year's notice, it did not do so, and still shows no inclination to do so. Furthermore Russia has proclaimed repeatedly that the 'abstention' principle is unreasonable and it would never agree to a convention containing it. It fishes the area catching more fish therein now than do American and Canadian fishermen combined, but its fishermen carefully refrain from catching salmon and halibut commercially in the area.

Russia fishes very heavily off both coasts of the United States and by doing so excites exactly the same bitter resentment and political reaction among affected American fishermen and their Congressional representatives as would happen if the United States were the poorest nation in the world and starving for lack of animal protein. This normal tension is exacerbated by abnormal tensions of high moment between the nations. Yet the United States each year negotiates separate annual agreements with Russia applying to the Pacific and Atlantic areas, in which the United States grants some privileges to which both agree Russia does not have under ordinary international law, and Russia gives up some privileges that both agree she has on the high seas under international law. These are not nice, polite, negotiations. Both sides hammer out hard bargains. But the peace is kept, and, actually, a good deal of co-operative spirit appears to develop.

In an even more curious category are annual negotiations respecting king crab catches on the Alaskan continental shelf, whose fishery grew rapidly in the 1960's to the point where conservation regulations were required. The United States claimed the king crab were creatures of the continental shelf under the 1958 'Convention on the Continental Shelf' and were the subject of its sole jurisdiction. Russia, which had fisheries for king crab in the area, agreed. Japan, which also had, did not agree that king crab were creatures of the continental shelf. Both, however, separately negotiated agreements with the United States which restricted the catches of king crab in the area by their fishermen, and renegotiate those agreements to lower catch levels from time to time, as the American catches increase. The matter of legal right is set aside, as is often the case in international fishery agreements, for argument in other forums so that practical problems can be attended to (Windley, 1969).

One last peculiarity of the North Pacific is that South Korea has made economically unsuccessful attempts to enter the Bering sea salmon fishery, from which Japan is excluded by treaty, and from which Russia abstains to keep the peace. Japan and Russia are publicly opposed to the abstention principle. Russia is publicly opposed to the existence of South Korea. The United States is the public protector of South Korea. Yet all four countries (U.S., U.S.S.R., Japan and Canada) diplomatically oppose South Korean entry into the North Pacific fisheries with some energy and success.

The point of all of this is that the present system of independent fishery commissions composed of nations whose fishermen operate in a particular high seas fisheries, operating under convention among them, works slowly and often badly, but the system does work and can prevent overfishing of high seas resources that is of serious, or permanent, consequence. It can, if pressure is strong enough, also compose the economic differences between the nations that arise from the conservation regulations that ensue.

As a part of the reorganization of FAO in 1965 that resulted in the creation of a Department of Fisheries under an Assistant Director-General, and the broadening and strengthening of this work, there was also formed the intergovernmental Committee on Fisheries within the Department. COFI consists of senior fishery officials representing 34 members of FAO, which are elected by the FAO Council. It meets annually to review the work of FAO Department of Fisheries (first meeting, June, 1966) (FAO, 1966). Although only 32 members of FAO are members of COFI, there is rotation of membership so that opportunity is available to all. Furthermore, observers have the opportunity to participate in the debates and work of the session, and do. There are ordinarily representatives of somewhat more than 50 nations present and participating, as well as representatives of international agencies involved in related work. It is noted that Russia, not a member of FAO, sends a representative and participates in an observer status in COFI work.

As one of its first duties COFI undertook to review the situation of sea fisheries on a world basis, and keep them under review, to see where overfishing situations might be developing in the world ocean where there was not appropriate international machinery to prevent or deal with it. Based on recommendations arising so far from COFI and for this purpose, there have been formed the new 'Indian Ocean Fisheries Commission', the 'International Atlantic Tuna Commission', and the 'International Commission for the South-east Atlantic Fisheries'. Additionally the 'International Council for the Exploration of the Seas' and FAO jointly are undertaking studies preparatory to dealing with overfishing problems that are developing off North-west Africa (FAO, 1968d; 1969e).

The institutional framework for dealing with existing overfishing problems in the world ocean is in fairly good shape, and, with COFI keeping a watchful eye on developing problems of this nature on a global basis, one may reasonably expect that other such problems elsewhere, as they develop, will be called to public attention so that any extra machinery that is needed will be developed. If the senior fishery officials of 34 nations, assisted by substantial international staff and qualified expert observers in fishery management from 20 to 30 other nations, cannot develop methodology for dealing with overfishing problems as they come along, there is probably no other group of people who could do better (FAO, 1969f).

A major problem is with money to do the science and the management, as well as with the shortage of trained scientists and managers to do the work.

Shortage of funds with which to do the necessary scientific research is a problem with all national fishery agencies, and with the international fisheries commissions that do their own science. With the international fishery commissions that are now developing in the tropics and sub-tropics (the developing world) the situation will be critical. The developing countries simply do not have the money with which to fund the needed research. The developed countries show no tendency (aside from the United States in the Inter-American Tropical Tuna Commission) to fund the commission work on an adequate enough basis to make up for the shortfalls in treasuries of developing countries. Developing countries, by and large, want the research required to be done for the purpose of framing conservation regulations done by their own scientists as a first choice, and by scientists of an international agency as a second choice. They distrust, and with some justification, the results of studies made by national agencies of developed countries.

To meet these needs developed countries, FAO, UNESCO, UNDP and other funding sources have developed extensive programmes for training fishery scientists and administrators in developing countries. Considerable progress has been made in the past twenty years, and much more is to be expected as time goes on (United Nations, 1968b, 1969). In particular, quite a number of capable fishery administrators are now at work in the developing countries, but there is still a vast shortage of scientists native to those countries.

It turns out to be more difficult, and more time-consuming, to develop competent scientists than competent administrators or managers. Also the developing countries are almost unanimously more interested in developing their fisheries than in managing them to any rational standard. The consequence, generally, is that when a fishery scientist returns home from his academic training he finds that there are no funds available for research related to conservation management, and personal career opportunities lie either in developing fisheries or administering them. Accordingly they go into those lines of work, or are absorbed elsewhere into the governmental or educational machinery of their homeland because they are educated, and educated people are scarce for all positions requiring it.

The nations do not fund FAO in its regular programme to do research itself, nor to subsidize research in developing countries. UNDP (Special Fund and TA programmes, both) pick up a good deal of slack by supporting such research when it is requested by the recipient countries as a part of a specific programme, or even fudging a little in that direction when need is great and criticism against doing so is not strong. Ordinarily recipient countries do not request support for conservation research as a part of a fishery development project from UNDP because their desires are centred on the short term benefits of development, not conservation and rational management of resources. Neither staff of UNDP or FAO, although they recognize the problem, are able to do much about it. Also the UNDP Governing Council, composed as it is, has not faced up to this problem with much vigour heretofore.

The consequence of this is that one can anticipate with some degree of confidence that the new international fisheries bodies in the tropical and sub-tropical world are not going to be able to detect, measure, and frame measures to prevent, overfishing problems as rapidly as they develop over the next thirty years. The consequence, inevitably, will be exacerbated fishery jurisdiction problems not only between long-range fishing nations and coastal nations, but between neighbouring nations in the developing world whose fishermen harvest the same migratory resources. Such problems have already occurred between Mexico and Guatemala, Chile and Peru, Venezuela and Trinidad and Tobago, Guinea and Ghana, Thailand and Cambodia, Thailand and Burma, Singapore-Malaysia and Indonesia, Philippines and Malaysia, Taiwan-Korea and Philippines, etc.

It may be stated rather categorically that in all cases where conservation problems in international fisheries have been brought under control (as noted above) this has always been where there was reasonably good agreement reached on the scientific facts underlying the problem, prefaced by quite solid (and expensive) research. In the absence of agreed scientific bases for dealing with the conservation aspect of jurisdictional fishery problems there is only force or diplomatic coercion left as means of dealing with them. In those instances where agreement has been reached on the economic aspects of fishery jurisdiction problems, this has always been preceded by competent scientific inquiry that laid the factual basis for the diplomatic agreement.

I. The Environment Problem

Reference has been made above to the guiding criterion of the maximum sustainable yield in reaching agreement on the management of the use of resources supporting international fisheries. Non-professional observers dealing with this problem often gain the impression that the maximum sustainable yield is a finite, reasonably easily determinable, and reasonably constant and steady fact of life. This is very seldom the case, and never quite so (Hela and Laevastu, 1970).

Changes in the environment bring related changes both in the actual abundance of each living marine resource, and to the availability of that resource to the fishermen. It is normal for the size of the year class entering the fishery each year to vary considerably from year to year in a manner not related to the fishery but related to changes in the environment. This variation may be of the order of two or three times over a period of a few years, or it may be of the order of ten or more times. The variations may follow a reasonably steady pattern over a few years, or a few dozen years, or a few hundred years, in rhythm with large scale changes in the circulation of the ocean, or there may be a sudden, unexpected, and sharp change lasting a year or two, reflecting a similar local change in the ocean environment (Gulland and Carroz, 1968).

Aside from the effect of these changes in ocean condition on the actual abundance of the resource, similar, but different, effects may be noted in the distribution of the resource and its availability to the fishery quite separately from its actual abundance, and occasionally contrary thereto. The commercial concentrations expected may occur a few miles, or a few hundred miles from where the fishermen expect them. Or the resource may stay so broadly distributed in the water column that fishermen cannot find commercially adequate concentrations even though actual abundance has not changed. Or the concentrations may occur out of sight below the ocean surface, or up off the bottom, where the fishermen cannot locate them, or where his gear cannot catch them, irregardless of actual abundance (Cushing, 1968).

It is frequently the case that these environmental changes affect in a material way the availability or abundance of a particular resource differentially as respects the high seas off particular nations. For instance, in warm years yellowfin tuna are more catchable in the northern and southern end of their eastern Pacific range (off Peru and Chile to the south, and Mexico to the north) but in colder years off Central America and the tropical area. In years when there is strong upwelling sardinella are abundantly available to Ghanese and Dahomey fishermen. When there is no upwelling Dahomey fishermen lose out because they are not equipped to fish deep. In warm years the fishermen of North Chile and South Peru do well on bonito and anchovy. In cold years, the Chileans do not do so well.

Great scientific effort has been devoted by fishery agencies to elucidating and attempting to predict, the effects of these environmental changes on the abundance and availability of particular resources, and it has been, so far, quite frustrating. Obviously the level of fishing corresponding to the maximum sustainable yield of a particular resource is quite different when the resource is $\times$ size large than when it is $3\times$ or $5\times$, and variations of this magnitude are not unknown, or even uncommon. If one cannot predict reasonably well the size of the population one cannot predict the quota limits required to prevent overfishing very well either.

In higher latitudes most resources supporting major international fisheries are supported by several year classes. In such situations the variation in abundance of one year class may compensate for a reverse variation in the size of other year classes in the fishery to the extent that average abundance can be predicted that are pragmatically useful in preparing regulations.

In lower latitudes it is more normally the case that only one, two or three year classes support the fishery, and in these cases the situation is that much more difficult to deal with. When fishing intensity grows to the level corresponding to the maximum sustainable yield the number of important year classes in the fishery is always reduced so that the effect of one extra-large, or extra-small, entering year classes is of the greatest importance to the success of the fishery, or the precision with which the level of fishing effort corresponding to the maximum sustainable yield can be estimated.

The national agency, or the international agency, having the responsibility of making the estimates, in the absence of ability to predict the environment and its effects on fish abundance and availability, can make only the best informed guesses it can based on the best information and theory available to it. When this affects the distribution and employment of tens of thousands, or tens of millions, of dollars invested in fishing vessels and gear, the fishermen being regulated are not very happy about the resultant lack of precision. This is the main reason why sovereigns are so slow in enforcing conservation regulations until the need becomes great and generally obvious.

In cases where availability is particularly good even when abundance is low (a not abnormal situation) the fishermen assume that the scientists and administration are completely crazy, maliciously set on driving them out of business, or have sold out to their competitors.

This explains the urgency of the interest of fishery scientists and administrators in environmental science, and why they spend so much of their scarce research funds in this pursuit.

But most fishery scientists and administrators, unfortunately, are dealing with particular fishing problems within particular, finite, geographic areas and the environmental changes which affect their results and judgements may be, and often are, originating elsewhere completely outside the area where they are making measurements and observations (Bjerknes, 1969).

It has only been within the past decade or so that understanding has gradually dawned on scientists that the ocean and the atmosphere are parts of one interdigitating heat engine, the processes of one of which cannot be understood without understanding the related processes in the other (ACMRR/SCOR/WMO, 1969). Something like 90% of the solar energy driving the atmosphere, for instance, does not come into the atmospheric process directly from the sun, but is absorbed into the ocean, circulated by it elsewhere, and then back radiated, or otherwise dispersed, into the atmosphere to drive it. The interaction of all parts of the liquid and gaseous phases of the engine are intimate and complex, and tremendously dynamic and restless.

Only a good glimmering of understanding of these processes is yet available. Whether the great swings in environmental change that are observed are the results of harmonic relations in energy flux between air and sea, or whether they are triggered by variation in incoming radiation, or both, are not clearly understood. It is even doubtful that measurements of the sort required and adequate to elucidate such problems are yet being undertaken. As a matter of fact it is not clearly certain yet what sorts of measurements need to be taken, where they need to be taken, and what precision is required. The one thing that is gaining considerable agreement is that these are processes of large dimension, ocean-wide at least, and probably global in extent. In any event, it seems hopeless to predict very precisely fish abundance and availability of particular resources off Peru, off West Africa, off California, or off Arabia from measurements taken within those areas themselves.

Inquiry into environmental change is mostly handled by different machinery than inquiry into fishery abundance and availability change in both national and international agencies.

In the international field meteorology, atmospheric, and weather co-operation has grown through the World Meteorological Organization of the United Nations and its antecedent organizations, which predate the United Nations by nearly a hundred years. In recent years WMO has developed the World Weather Watch, through whose mechanism atmospheric measurements in all parts of the world are transmitted quickly (increasingly in real time) to all parts of the world so that all meteorologists and weather forecasters everywhere can have all of the data there are from everywhere (WMO, 1967). Even more recently WMO and the International Council of Scientific Unions have formed the Global Atmospheric Research Pro- gramme to plan and carry out large scale experiments in air-sea interaction particularly. Fortunately for the fishery people, it is the tropical area, where many of their newest and most urgent problems lie, that the most urgent problems of the meteorologists also occur.

In the international field, responsibility for co-ordination of general oceano- graphic research among nations lies in the Intergovernmental Oceanographic Com- mission of UNESCO. It was established as recently as 1961, and the growth of environmental science and understanding in recent years has been so great and rapid that it has really never got its feet under itself. It is currently in the process of funda- mental reorganization as to governing management, funding, operational programme, and statutes—as well as membership (steadily growing), and relation with other agencies of the United Nations family, as well as intergovernmental organizations outside the family (IOC, 1969a).

A basic problem is that the research required to elucidate these fundamental energy fluxes between sun, atmosphere and sea are very expensive. Observation stations must be established literally all over the world, and the measurements made at them transmitted to data storage points where they can be archived, analyzed, and recovered readily for study. The observation stations are expensive in themselves, the transmission facilities are expensive, the computers required for storage, analysis and retrieval of data are not only very expensive, but computer facilities of the sort and capacity required are available at only a few points in the world yet.

Oceanographic research vessels suitable for taking such observations at the number of places they are needed, and with the regularity needed, are simply too expensive to use for this purpose by anyone for very long periods of time. For this reason great planning reliance is being placed on buoys that can be moored un- manned at ocean stations (U.S. Coast Guard, 1969), take the observations automati- cally, and transmit them electronically to shore stations (NAS-NAE, 1969). For this purpose IOC is developing the Integrated Global Ocean Station System (IGOSS) in the closest relation with WMO, because WMO's World Weather Watch and IOC's IGOSS must be closely integrated to be maximally useful. This is all still in the project stage and the basic technology is still being developed and tested (IOC, 1969b).

In the long run it is likely that a large part of the basic observational load must be carried by earth orbiting satellites. As Werner Braun has said 'The initial cost of getting a satellite into orbit is considerable, but after two or three orbits the cost per mile of operation puts a Volkswagen to shame.' It was only the coming of the earth orbiting satellites that gave the environmental scientists an opportunity to see the whole world frequently in a single glimpse, and measure changes in the environment at all places on the globe with almost any frequency desired. It is only the rapid development of computers that has come as a necessary corrollary of space research that has given the memory and analytical capability required to handle the enormous multitude of data required to elucidate problems of global environmental variability.

While there is little doubt that great dependence must be placed on results from earth-orbiting satellites to bring in the data required to deal with these problems of environmental change on which prediction of fish abundance and availability ultimately rest, the total resources of all national and international fishery agencies are entirely inadequate to deal practically with these processes of large, or global, dimension. Furthermore it is unreasonable to think that situation will change in the reasonably near future (Laevastu and Johnson, 1970).

Accordingly, the only practical avenue for the fishery people is to co-ordinate and collaborate with the environmental people as closely as possible. Since the oceanographers and meteorologists have essentially the same limitations of funds relative to problem size, they also are literally forced to collaborate and coordinate among themselves, and with the fishery people, in order to have sufficient resources jointly to deal with these large problems that all three sorts of people have. It is for this reason that FAO, WMO, and UNESCO (together with some other international agencies having related responsibilities, such as IMCO, IAEA, IHB, UN) are in the process of reorganizing IOC and broadening its support so that it can serve all of them more effectively.

There are basic political problems connected with this that must be faced realistically, and will not go away simply by being blinked at.

So far only the United States and U.S.S.R. have been prepared to devote the resources required to mount substantial space programmes and the technological base required to operate them. In the near future it is unlikely that many more nations will be prepared to do so. Among these Germany, Japan, France, Australia and South Africa are the only likely contenders, although the European Economic Community as a group may possibly be able to get its joint space programme off the ground.

When it comes to basic ocean research and research in air-sea interaction, the situation is much the same, and for much the same reason, relatively enormous in costs. Russia and America are the giants in this field as well, and the other substantial contributors are Japan, U.K., Germany, Canada, France, Australia, and South Africa, although in this field useful contributions are available from Italy, Spain, the Scandinavian countries, India, Pakistan, Brazil, Peru, and a few others.

The problem is that there are relatively few developing countries who are competent in any substantial way to deal with these large and expensive problems in environmental science, nor expect to be in the near future, or even much desire to be. Their direct interest is in immediate economic and social improvement, and the slender scientific resources they have to devote to oceanography or meteorology are pretty well devoted to what appear to be quick pay-offs in fishery development and weather prediction. In their projects to UNDP they emphasize application and include only as much science as is absolutely required for application. They support FAO Department of Fisheries strongly, and Intergovernmental Oceanographic Commission lightly, if at all. In FAO they support efforts in direct development and training, with as small a science component as is possible.

Since the developing countries are not heavy in basic science, and few can afford to be, and the industrialized countries are, the former are not very effective in IOC and they resent the controls that U.S. and U.S.S.R. exercise in these activities, which derive from the relative size of effort, if from no other cause.

A further area of suspicion arises from the fact that a large part of the funding support for oceanography, meteorology, and space activities comes from military budgets in the two military giants, but to some extent also in the other industrialized countries with competence in these fields.

Arising from this suspicion and inability to control, guide, or often even to understand and use results from these scientific and technological outputs of the specialized agencies in the United Nations family, there is a current trend to bring all controls over international collaboration and co-operation in the environmental sciences within the purview of the General Assembly, where the small nations have the required votes to control, and where they have trained diplomats who can deal on a basis of personal equality with the diplomats of larger countries.

The tendency of this trend currently is to impede the ability of the two giants in the environmental sciences working together on these large and expensive projects through United Nations channels, which is not easy even without such a trend. It makes increasingly difficult co-operation and collaboration among those nations that have the resources and trained scientists to deal with these problems in a practical manner.

In the fishery field, in particular, development is retarded. Investments are not made because of uncertainties in size and variability in resource abundance and availability. This is particularly the case in the large pelagic fisheries of California, Chile, Angola, West India, and South-East Arabia-Somalia. It will be increasingly the case as dependence increases for supply on those very productive areas of the ocean in the tropics and sub-tropics, and Antarctica, where variation in productivity is so dependent on variation in environment, and where the whole food chain is so fragilely connected with sudden change in the environment.

J. The Juridical Problem

There are several sorts of sea water, juridically, as far as the harvest of living marine resources are concerned :

1. *Internal Waters.*

The internal waters of a nation, and contained resources, are as much the exclusive property of the sovereign as the land, with some minor navigational exceptions.

2. *Territorial Sea.*

The living resources of the territorial sea are under the exclusive jurisdiction of the sovereign.

3. *The Contiguous Fishery Zone.*

While a relatively recent concept, it is now rather broad international practice to claim exclusive jurisdiction over the harvest of living marine resources within twelve marine miles of internal waters.

4. *Continental Shelf Resources.*

Living marine resources that are in constant contact with the continental shelf during the harvestable stage are taken to be within the exclusive jurisdiction of the sovereign having jurisdiction over the shelf. The refinement of this concept on a species by species basis is still proceeding in the practice of nations.

5. *High Seas.*

The living resources of the high seas are the property of him who first reduces them to his possession. Entry to the fishery is restricted only by treaty obligation of the sovereign whose flag the vessel wears, and general tenets of international law.

There are three general classes of proposals now under consideration to govern the fisheries beyond national jurisdiction. They are :

1. To continue building and strengthening the currently used system described above in which FAO, and intergovernmental organizations outside the U.N. family, handle the management of the use of these resources, supplemented by bilateral or multilateral arrangements made separately among the directly affected nations, in general accordance with the broadly agreed norms set down in the 1958 'Convention on Fishing and the Conservation of the Living Resources of the High Seas' (U.S. Senate, 1965).

2. To create within the United Nations structure, or otherwise, an intergovernmental agency which would have responsibility for managing the use of living marine resources beyond national jurisdiction (Pell, 1968 ; Danzig, 1968 ; Borgese, 1968). And,

3. Extending the territorial sea, or contiguous fishing zones, of each coastal state as far to sea as that nation felt to be necessary to protect its interest from time to time, or to 200 miles or to some other arbitrary distance which would give the coastal state monopoly over the use of these international resources (MacChesney, 1957).

Some problems connected with the first two solutions have been mentioned above, and treated by numerous authors. Some problems connected with the third are mentioned here.

1. *Navigation.*

No satisfactory legal means have yet been devised by which a sovereign can give up rights that pertain to freedom of fishing in an area of the high seas without affecting his right to navigate in, on, or over the high seas area affected. This is the nub of the extended controversy between the United States, on the one hand,

and Chile-Equador-Peru on the other. It comes down to this : If the agreement is reached between the parties it will be accompanied by regulation. If a vessel is apprehended in the area under agreement and accused of violating the agreement, in whose court is the case to be tried? If it must be tried in the court of Chile-Equador-or-Peru and the vessel is wearing the United States flag, it was not on the high seas, because United States citizens are entitled to a trial in an United States court for crimes committed on United States territory, which a U.S. flag vessel on the high seas is. If the trial must be in a court of the United States, then the vessel was on the high seas and not within the exclusive jurisdiction of Chile-Equador-or-Peru as the case might have been [Dept. of State (U.S.) 1955].

2. *Restriction in living marine resource development.*

Great animosity toward Russia and Japan, in particular, exists in a good many countries because of their long-range fishing. Yet the long-line tuna fishery of the world would not have been developed by others than the Japanese, or not so soon. Nobody besides the Russians and Japanese have yet any economic use for the large yellowfin flounder resources of the eastern Bering Sea. Only Japan has use for the squid off Mauretania and the North-east United States adequate to justify harvesting them. Only Russia had enough economic use for the herring on Georges Bank to warrant the beginning of their harvest. Only Japan has a 'Surimi' market which justifies the large scale harvest of Alaska pollack and Atka mackerel for direct human consumption. Examples could be multiplied.

What is said about Russia and Japan is more broadly relevant to other countries. Germany can use ocean red fish; U.K. does not want them. Denmark can use the sand lance economically; Scotland does not yet want them. Ghana needs the mackerel off Mauretania with which to feed its people; Mauretanians do not like fish. The United States can economically harvest tuna off Peru; Peru cannot economically harvest them and compete in the United States, Japanese, or European tuna markets.

A great deal may be said for reasonable restraints on long-range fishermen, but a good deal can be said on their side to the effect that substantial amounts of food from the sea now available in the world market, or for the internal nourishment of the catching country, would not be available if the efforts of long range fishing were curtailed. The corollary is that the extension of national jurisdiction does not ensure that the extending nation will be able to economically harvest the resources and get them to any market.

The shoe pinches the developing countries that have narrow coastlines and the ability to fish if jurisdiction by neighbouring states is extended into the sea. Such action will deter the present success of the developing countries in expanding production of their sea fisheries.

3. *Conservation.*

The extension of national jurisdiction to ensure conservation of the resources is not a very good excuse. National sovereigns have not been any better at protecting living resources within their unique jurisdiction than they have been when operating jointly through intergovernmental arrangements. As a matter of fact, the odds seem to be a little better under the latter system where outside criticism and public opinion play a more restrictive role (Chapman, 1970b).

Even 200 mile zones would not eliminate, or even much reduce, need for intergovernmental arrangements of the sort now used and being developed, because of the migratory nature of these resources both along shore and even across oceans.

4. *Cost.*

The main effect of fencing off resources from use by others would be to protect inefficient fishermen from more efficient fishermen (from developing as well as developed countries). The result would be to raise the cost per unit of production. This would act in the direction of slowing down development of food production from the world ocean. The added cost would be to consumers the world over.

As a matter of fact, there is not much likelihood of the nations agreeing either to splitting the living resources of the sea up among themselves, or establishing the machinery that would be needed within the United Nations to turn over the whole job of managing the use of the living resources of the high seas. The cost and the disadvantages to the whole world community are too obvious.

K. Summary and Suggestions

1. There are sufficient stocks of living marine resources known to support likely world demand through the year 2000 and beyond, on the basis of sustainable yield (Chapman, 1970a).

2. Demand by the year 2000 for living aquatic resources may be as much as 400 million tons per year, or six or seven times as great as in 1968.

3. Value of global living marine resource production is running about twice the total of all other resources extracted from the ocean combined.

4. Fisheries jurisdiction yields large and complex international problems which cannot be avoided because of the migratory nature of the resources. International machinery has been in the process of being developed and used for the resolution of those problems over the past 70 years, with the result that much practical experience has been had. This effort should be broadened and strengthened, and not discarded for a new and untried panacea.

5. For the past decade fishery development has been moving more rapidly in the countries with developing economies rather than in developed nations, and in 1968 surpassed it in total volume (FAO, 1969a). There is a reason to believe that this trend can be continued under existing international machinery.

6. There is in existence international machinery and experience to bring assistance to the developing countries in additional fishery development. It requires some regular augmentation in funding as time goes on and problems become more complex. This can be secured by diverting more funds through the existing international machinery of the United Nations Development Programme and the Department of Fisheries of FAO.

7. A major problem of developing countries in this field presently is insufficient funds and insufficient trained scientists available to them so they can hold up

their end in international fishery conservation bodies. They will need added funds and scientific assistance from multilateral sources for this purpose over the next several years, and UNDP and FAO, neither one, has sufficient funds, or latitude in the use of those funds, to fill those needs.

8. A great underlying need in fishery development and management on a global basis is greatly expanded work in environmental science, both oceanographic and meteorological. Fishery science cannot be expected to be funded adequately to the task, nor can oceanography or meteorology. No single nation presently is prepared to fund adequately this global research, and therefore machinery and funding are required in the international field to provide co-ordination and collaboration between national and international agencies. WMO, FAO, and UNESCO (with other agencies) are in the process of broadening and strengthening the Intergovernmental Oceanographic Commission of UNESCO to serve them jointly in these matters. This effect deserves support of large and small nations alike. The Secretary-General of U.N. has made extensive recommendations in this field to ECOSOC (E/4487. 24 April, 1968)—'Marine Science and Technology: Survey and Proposals'. His proposals deserve better support from the nations than they have had to date, and particularly the funding support.

9. There is much controversy now respecting the Law of the Sea. This is centering on problems of mineral development of the deep-seabed, which are distant in time, and those of the continental shelf, which are within national jurisdiction. The really important juridical questions concern the jurisdiction over fisheries in the high seas, both from economic, diplomatic, social and conservation viewpoints. Confusion between these ocean problems concerning fishery jurisdiction, and the essentially land problems connected with seabed jurisdiction, prevented successful conclusion of both the 1958 and 1960 Law of the Sea Conference, and the trend is now repeating.

10. The existing juridical system for handling fishery jurisdiction problems is considerably better from the standpoint of mankind as a whole than any other system that has been proposed. Substantial, and successful, international experience has been had under it for the past 70 years. As a matter of fact, there are no existing problems in jurisdiction over the harvest of the deep-sea mineral production that do not appear to be more susceptible of satisfactory solution under the fishery system of governance than under other systems proposed.

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