ARTICLES

OCEANOGRAPHY'S ROLE IN DEVELOPING MARINE RESOURCES

By James H. Johnson*

Natural resources are developed in response to a present or projected need. Future economic and social needs for natural resources are strongly conditioned by the expected increase in world population. An examination of past statistics and projected trends in world population is sobering. In 1600, world population was about 350 million; by 1800, the figure had doubled; by 1900, it had doubled again and stood at about 1.5 billion. And again since then, the world's population has doubled itself. Within the next 35 years, if this rate of increase continues, there will be over 6 billion persons on earth. Though it has taken all the vast reaches of time to arrive at today's population of around 3 billion, it may take no more than 35 years to add the next 3 billion.

Clearly, if the world population continues to rise as projected, the demand for natural resources will intensify. It is not clear, however, just how much of the demand will be satisfied from resources in the marine environment. This environment, however, appears likely to play a significant role in supplying food, mineral, water, and recreational resources.

In general, the development of marine resources follows a similar pattern: Location - Description and Assessment - Extraction - Processing - Marketing.

This paper outlines future demands for food and describes some kinds of oceanographic data and programs needed to develop marine food resources. Emphasis is placed on the location, description and assessment, and extraction phases, though certainly processing and marketing are of equal importance for full development of the resource. Also, economic factors must be considered in all phases of development.

World Protein Shortage

Today, the limited quantity of food--in calories--is a great concern to many parts of the developing world, but the nutritive value--protein--is even more crucial. Supplies of protein are particularly scarce and costly in the poorer nations. The recent report of the President's Science Advisory Committee on the World Food Problem1/ concludes:

"It is imperative for programs designed to alleviate protein deficiency to produce big results in a relatively short time. Since even the most vigorous efforts probably will fall short of the goal, work should be initiated promptly on any program which shows promise of possible significance."

Certainly none of the steps taken to date to solve this problem has been effective enough to halt the worsening trend. No adequate solution is in sight. President Johnson recently warned that the shadow of starvation and impending famine has grown even darker. He said it was necessary for the United States and other nations to make a massive effort to help the less fortunate of the earth help themselves.

The urgency of this problem can be demonstrated by the following factual highlights:

1. World population is expected to increase at a frightening rate.

2. Even today, at least 20 percent of the 2.25 billion people living in less-developed countries receive too few calories, and about 60 percent have diets inadequate in nutritional quality.

3. If present growth rates continue until 2000, there will be more than four times as

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many people in the less-developed countries than in the developed ones.

4. If similar foods are consumed in the next 20 years, estimated protein and calorie needs mean that the world will need 50 percent more food in 1985.

5. The population-control effort does not offer much hope for solving the food supply problem in the near future.

6. Recent rates of growth in food production in the developing countries have been slower than those of consumption.

7. Poor distribution systems within and among countries make the situation even more disturbing.

In recent years there also has been a growing demand for fish and fish products in the United States, edible and non-edible. The per-capita use of fish and fish products increased from 42 pounds (round weight) in 1950 to 62 pounds in 1966. An estimate based on projections of population, income, and per-capita consumption is that total use of fish and fish products in the United States will increase to 28.1 billion pounds in the year 2000. This is 134 percent over the 12 billion in 1966.

Estimates of Potential Harvests

When one examines the rapid growth of fishery activity since World War II, and the expected increase in this activity to supply world demand, he wonders what the upper limits of fishery resources are that can be taken year after year. Over the past twenty years, production of living aquatic products has increased from about 20 million metric tons to about 50 million metric tons (Figure 1).

Estimates have been made in recent years on the possible sustained production from the oceans. These estimates are essentially of two types. One extrapolates present trends and success in areas now heavily exploited to like regions of the oceans yet unexploited. The other is based on food-chain dynamics--on the amount of phytoplankton produced naturally in the ocean, and the flow of energy through the food web to fish. Both have shortcomings. The former approach appears, on the average, to give estimates much below those of the latter.

At the Second Annual Marine Technology Society Meeting in Washington, D. C., June 1966, W. M. Chapman of Van Camp Seafoods, estimated that the ocean produces about tw billion tons of marine animals each year tha are large enough and useful enough to form th basis of a practical commercial effort.

Schaefer (1965) has estimated the harvest able crop from the net rate of photosynthesis of organic matter and its transfer through th food chain. He concludes that a minimum 200 million metric tons of fishery product can be taken on a sustained basis--and th the figure appears reasonable and probabl conservative. This agrees closely with th estimate in a 1962 publication of the Nationa Academy of Sciences--National Researc Council of 190 million metric tons that coul be taken annually--or about four times tha now taken.

On the conservative side, estimates mad by some scientists at the International Conference on Fish in Nutrition, 1961, Washington D. C., suggest that we may be approaching th upper limit of sustained production faster tha we realize.

There is much need for further study on th processes governing ocean productivity to refine the estimates now being made. At present however, the consensus seems to be that production from the sea can be increased significantly.

The greatest increases in catch are expected to come largely from the lower trophi levels. This expectation is already borne ou by production figures of the last two decad (Figure 2) which show the greatest growth i fisheries from herringlike fishes. Peru' catch record provides an outstanding exampl of how the harvest of lower trophic level forr can catapult a nation into prominence in worl fish production (Figure 3).

Oceanography's Role Increasingly Importan

The role of oceanography in development o food resources will become increasingly important. Results of oceanographic survey will provide understanding of ocean processe needed for more efficient means of locatin new resources. Follow-up programs will b directed at stock assessment, including th determination of effects of environmenta change on abundance and distribution of stocks an understanding of which will lead to fisher forecasts. Concurrently, ocean engineerin programs will be pursued for developing efficient harvesting techniques.

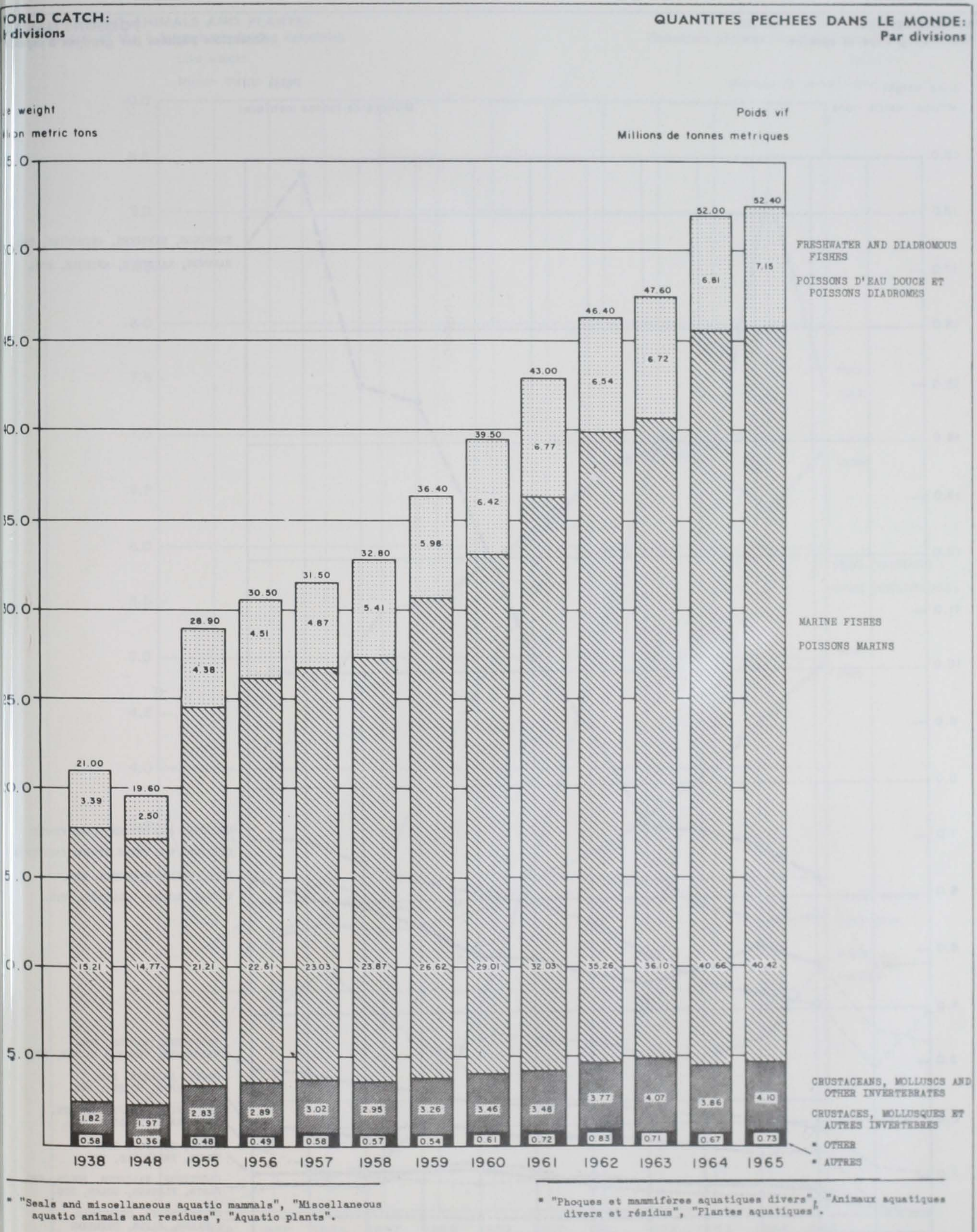

Fig. 1 - World catch of aquatic products (FAO).

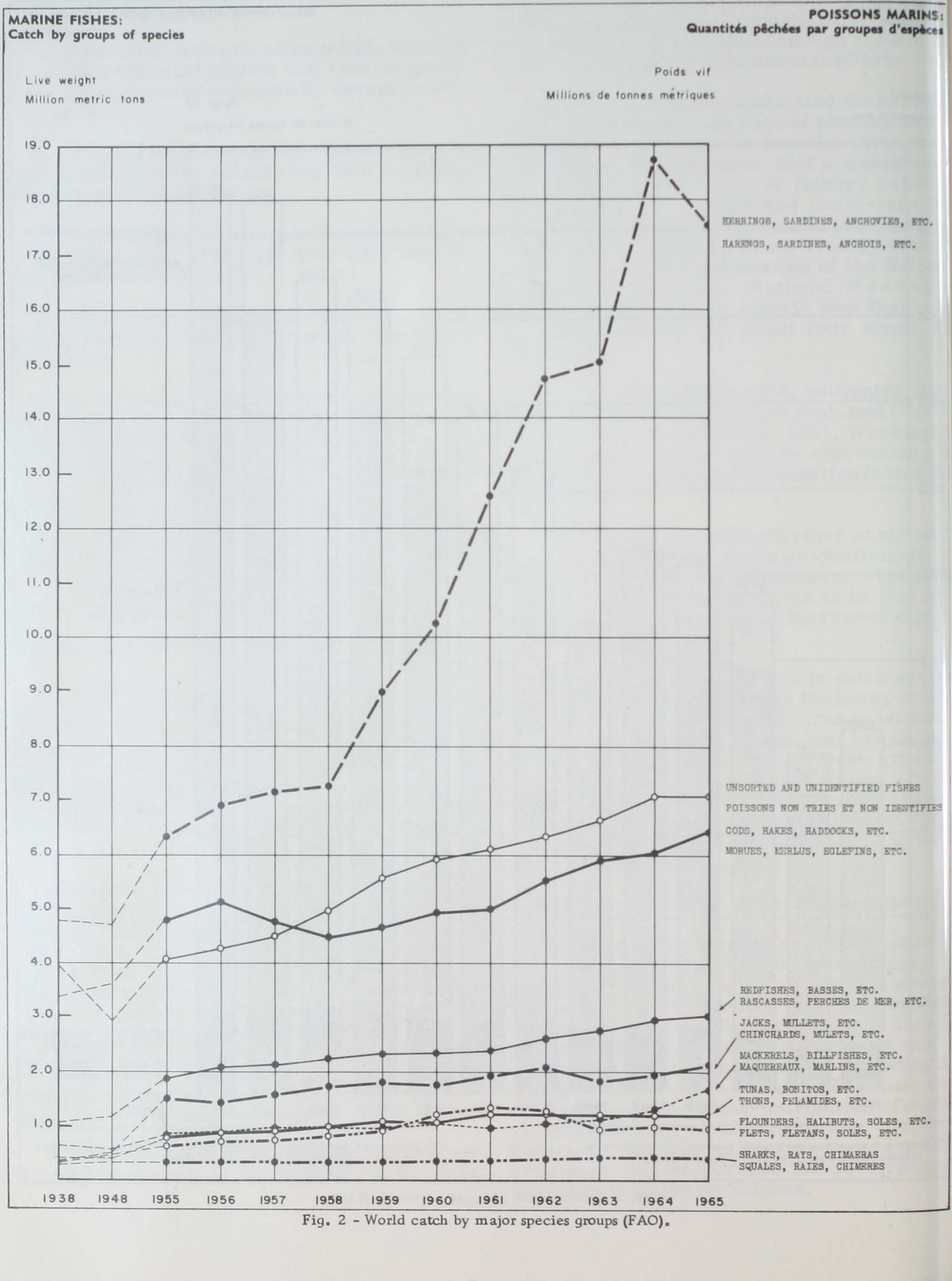

Fig. 2 - World catch by major species groups (FAO).

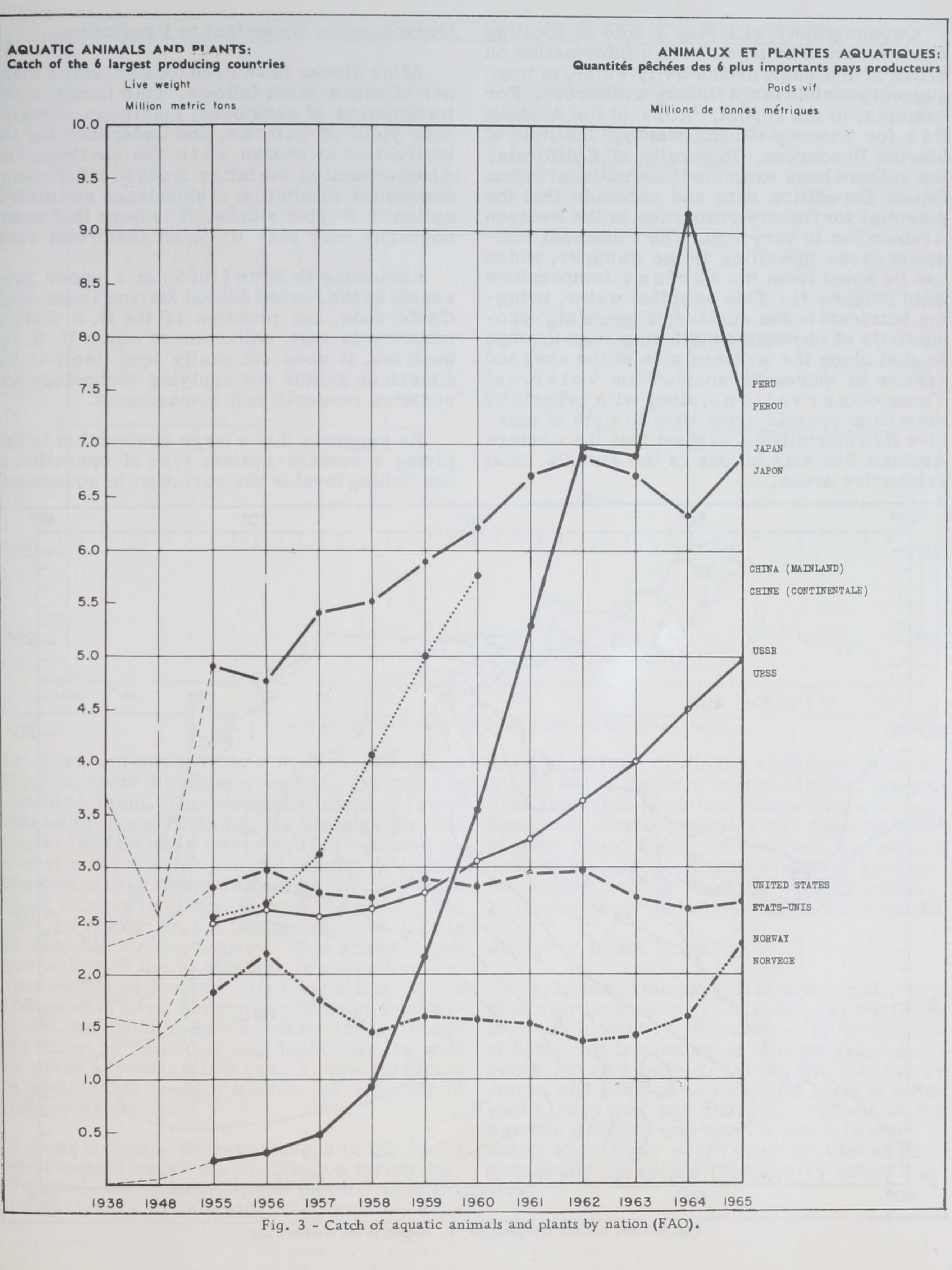

Fig. 3 - Catch of aquatic animals and plants by nation (FAO).

Oceanography will play a role in locating new resources by providing information on areas of high basic productivity which, in turn, suggest possible large fishery resources. For example, in the report, "Atlas of the Arabian Sea for Fishery Oceanography," Institute of Marine Resources, University of California, the authors have examined International Indian Ocean Expedition data and conclude that the potential for fishery resources in the western Arabian Sea is very high. The southwest monsoons cause upwelling in the summer, which can be noted from the surface temperature field (Figure 4). This upwelled water, bringing nutrients to the surface, triggers high productivity of phytoplankton during June through August along the western side of the sea, and results in increased zooplankton volumes. These observations, along with reports by merchant vessels from time to time of massive fish mortalities, suggest that the western Arabian Sea may be one of the world's most productive areas.

Oceanography Important to Prediction

After stocks have been located, some manner of assessment follows. This involves determination of substocks, maximum sustainable yield of stocks, and understanding the interaction of stocks with the environment. Achievement of the latter leads to information needed for prediction of abundance and distribution of the fish stocks. It is here that oceanography may play its most important role.

According to Sette (1966) in a paper presented at the Second Annual Marine Technology Conference, one problem of the U. S. fishing industry is that, unlike most other U. S. industries, it does not easily lend itself to the American genius for applying technology and systems research and management.

He suggests that a large obstruction to applying a modern-system type of operation at the fishing level is the variation in abundance,

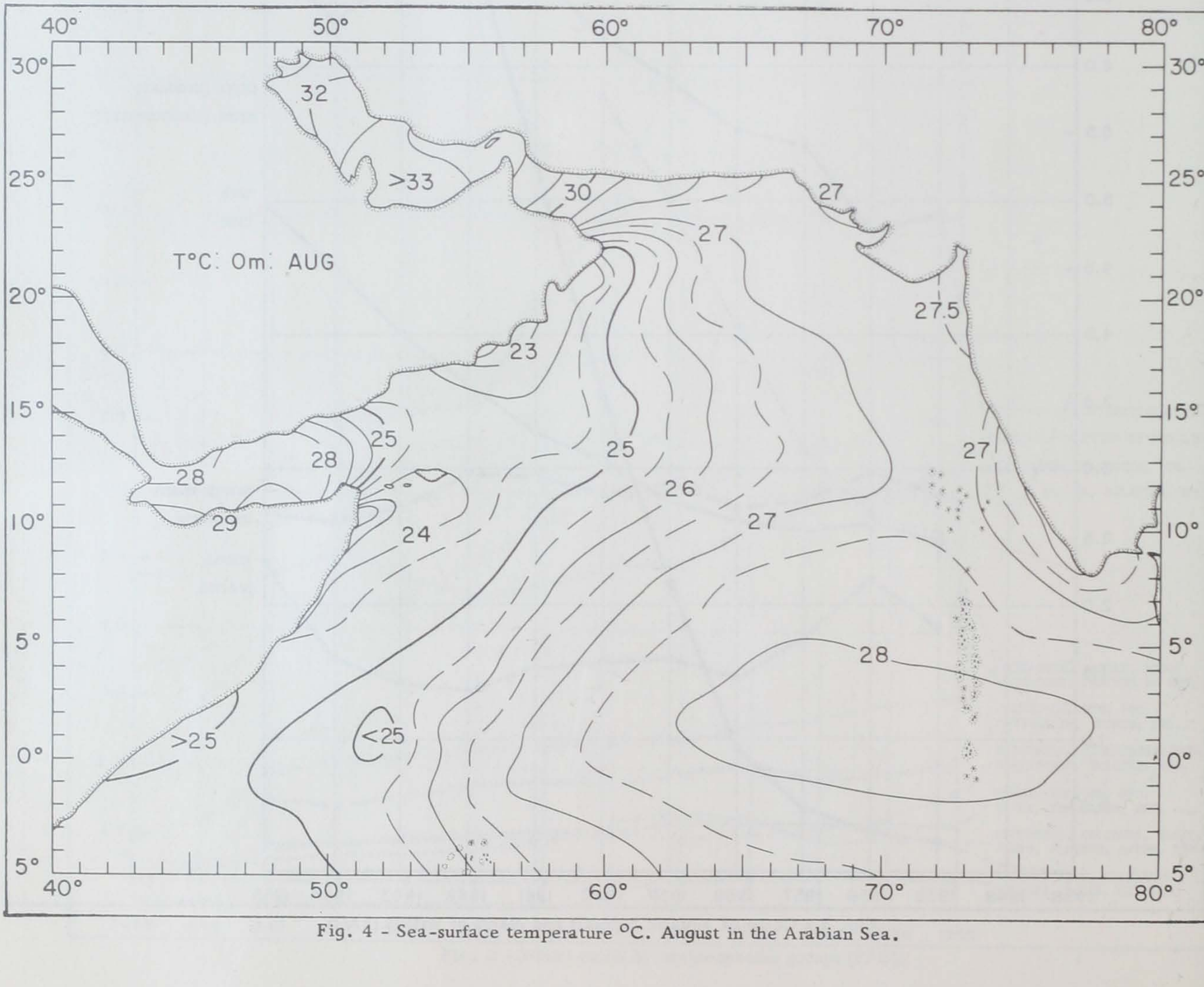

Fig. 4 - Sea-surface temperature °C. August in the Arabian Sea.

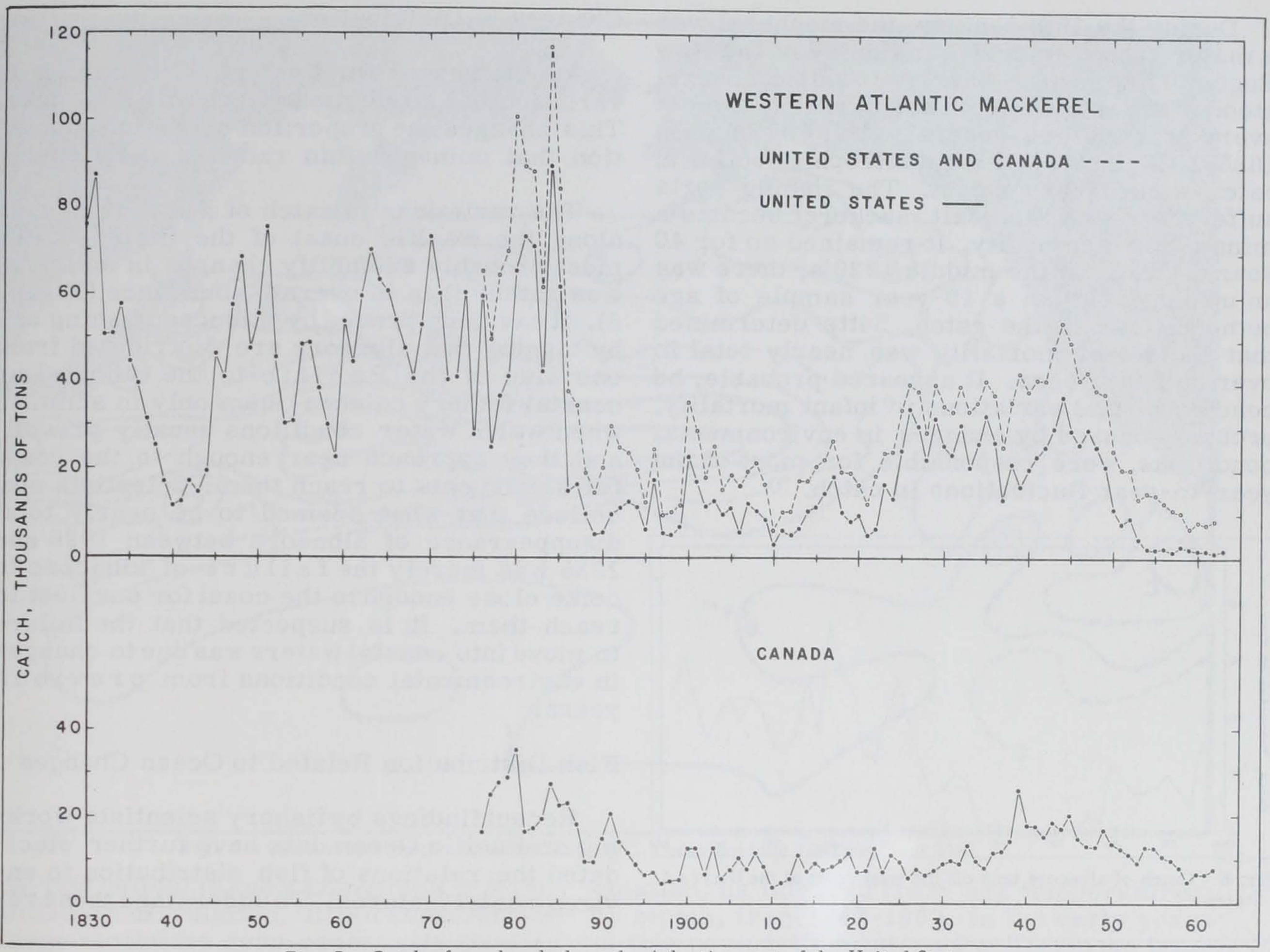

Fig. 5 - Catch of mackerel along the Atlantic coast of the United States.

location, and catchability of the fish. Too much time is spent hunting for fish; too little in catching them. On occasions, when a fleet comes upon good fishing, its landings glut the market and there is either a price reaction or, sometimes, a failure of the market to handle the fish. Often, the net effect on the fisherman is an income too little to keep his vessel and gear in repair; or, the income may be too little to keep him in the fishery. The effect on the processor or the wholesaler is a highly irregular supply of domestically caught fish. Since frozen fish have become a common international commodity, he can offset these irregularities by imports. No doubt this, as well as price advantage, has been a powerful factor in making this country a large net importer of fishery products.

Sette's thesis is that changes in the ocean environment cause major changes in fish distribution and abundance and thereby produce irregularities in fish catch. He points out substantial differences in the amplitude of fluctuations in the catch of various fishes. In general, the catch of bottom fishes like cod, haddock, and others fluctuates less than the catch of most other types. In contrast, the pelagic near-surface schooling fishes, such as tunas, mackerels, and herrings, fluctuate most widely in abundance and especially in distribution.

Factor of Infant Mortality

Variation in the overall abundance of a species may be caused by year-to-year variation in infant mortality. Regardless of the amount of spawning, it seems that in some years many young survive through larval and juvenile stages and grow to commercial size; in other years, very few survive. The record of the western Atlantic mackerel catch (Figure 5) shows variations which may be caused predominantly by such variations in infant survival.

During the 19th century, the mackerel was a major food item and a mainstay of the New England fishery. A barrel of salt mackerel stood along with the cracker barrel in almost every grocery and general store. Then, in 1885-1886, there was a catastrophic decline in catch of about 90 percent. The fishing ports suffered greatly, and salt mackerel became a minor food commodity. It remained so for 40 years. Then, in the middle 1920's, there was an upsurge. From a 10-year sample of age compositions in the catch, Sette determined that the infant mortality was nearly total in over half the years. It appeared probable, he concluded, that variations in infant mortality, probably caused by changes in environmental conditions, were responsible for most of the year-to-year fluctuations in catch.

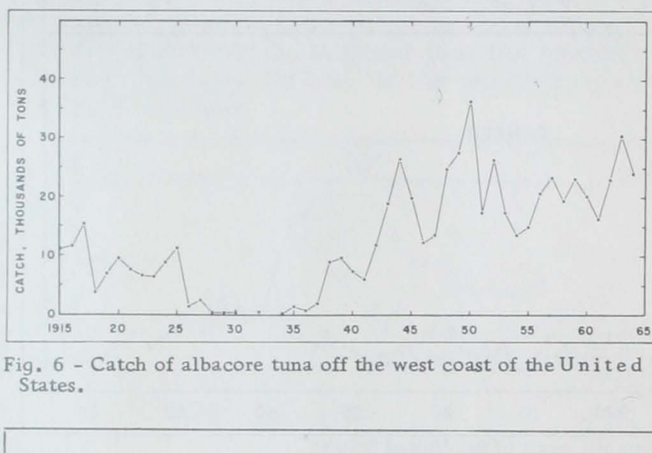

Fig. 6 - Catch of albacore tuna off the west coast of the United States.

Changes in Distribution

Another cause for fluctuation in catch is variation in distribution of fishable stocks. This changes the proportion of the fish population that comes within range of the fishery.

The variations in catch of albacore tuna along the Pacific coast of the United States most probably exemplify changes in distribution rather than in overall abundance (Figure 6). It has been proved by midocean fishing and by tagging that albacore are distributed from one side of the Pacific to the other. Our coastal fishery catches them only in summer when warm water conditions usually prevail, and they approach near enough to the coast for small boats to reach them. Scientists now believe that what seemed to be nearly total disappearance of albacore between 1926 and 1936 was merely the failure of albacore to come close enough to the coast for our fleet to reach them. It is suspected that the failure to move into coastal waters was due to changes in environmental conditions from previous years.

Fish Distribution Related to Ocean Changes

Recent findings by fishery scientists working on Pacific Ocean data have further elucidated the relations of fish distribution to environmental features. To understand these re-

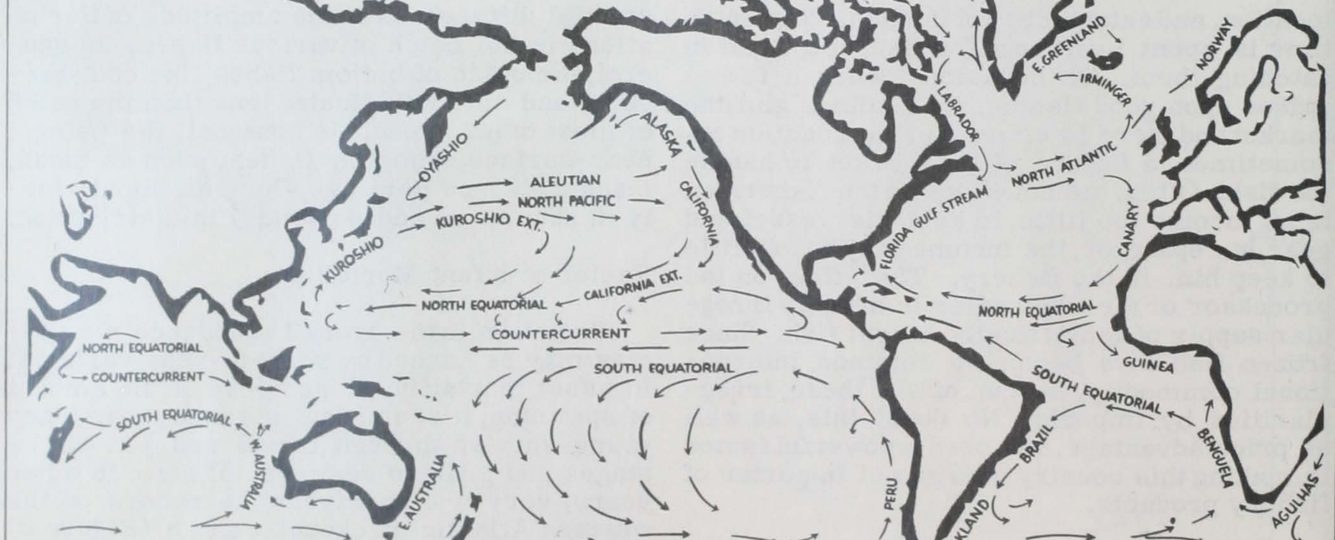

Fig. 7 - Pacific Ocean circulation.

Fig. 8 - Sea surface temperature difference (°C.) between June 1956 and June 1957.

lations, it is helpful to know something of North Pacific Ocean circulation. It is characterized by a large clockwise gyre, essentially similar to the atmospheric circulation (Figure 7). The North Pacific drift flowing easterly splits off the Oregon-Washington coast into a northward flowing current forming the Alaska gyre, and a south-eastward flowing cold California Current which turns westward off Baja California. The latter current flows past Hawaii as California Current Extension waters, becomes part of the North Equatorial Current, passes northward as the warm Kuroshio Current, and mixes with the cold southward flowing Oyashio to complete the clockwise pattern.

These currents and water masses can be identified by their temperature and salinity characteristics. For instance, the California Current, since it originates in northern latitudes, is a cold current. High rainfall and reduced evaporation in north latitudes also tend to keep its surface salinity relatively low.

The Bureau of Commercial Fisheries laboratory at Stanford University has been studying broad-scale changes in Pacific Ocean circulation, as inferred from sea temperatures, by month, from 1949-1962. In the early years of this period, the eastern Pacific Ocean temperatures were lower than average, but between 1956 and 1957 the eastern Pacific became much warmer and the western Pacific colder and remained so for several years (Figure 8).

The distribution of albacore in the North Pacific is seemingly affected by these broad-scale changes in the ocean climate. At some stage of their life history, the North Pacific albacore are sought by Japanese live-bait fishermen off Japan, Japanese longline fishermen in the west central North Pacific, and sport and commercial fishermen off the west coast of North America (Figure 9).

In May and June each year, the albacore move from central North Pacific into North American coastal waters. When spring warming occurs early in coastal waters, there is some evidence, though not conclusive, that albacore are available earlier to fishermen. If the coastal waters are warmer than usual, the fish appear farther north. The area of best

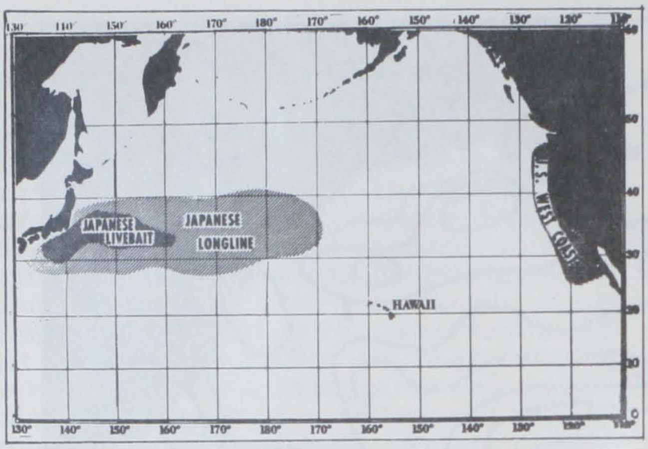

Fig. 9 - North Pacific albacore fisheries.

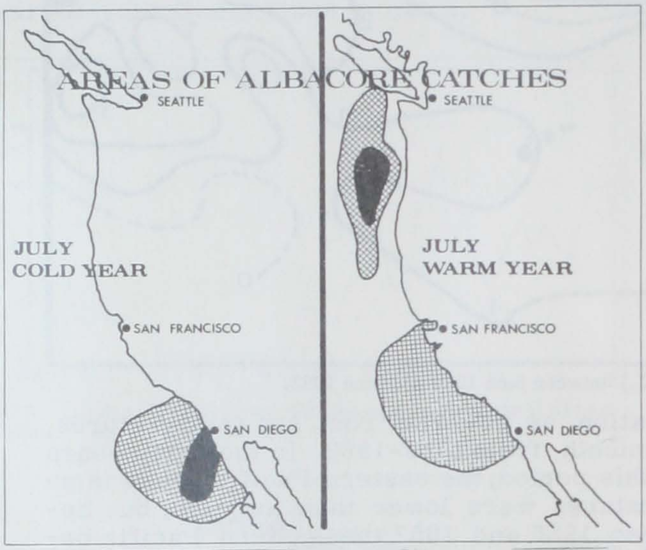

Fig. 10 - Areas of albacore catch during typical "cold ocean" years and "warm ocean" years.

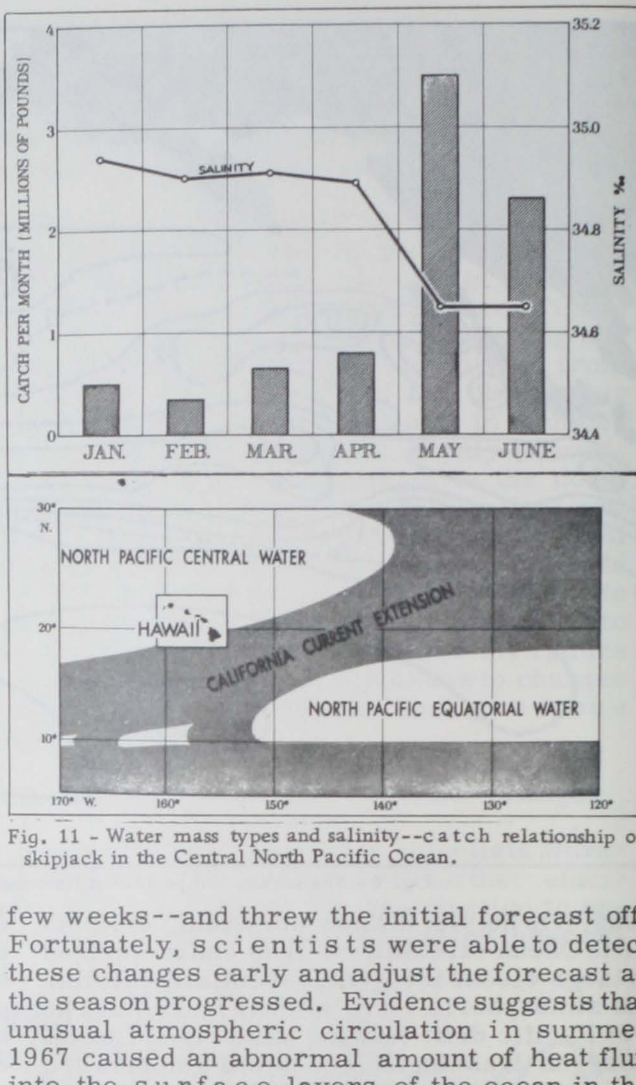

Fig. 11 - Water mass types and salinity--catch relationship of skipjack in the Central North Pacific Ocean.

catches during typical warm years is off California, Oregon, and Washington. In cold years, most of the fish remain to the south--off Baja California and California (Figure 10).

The temperature changes reflect changes in the California Current System. When large-scale changes occur, they usually persist for several months and sometimes for several years. This persistence over an extended period provides the basis for forecasting. In some years, however, preseason forecasts have been made but subsequently proved incorrect because of radical changes in ocean conditions between time of forecast and onset of fishing. The year 1967 is a case in point: The ocean temperature in the eastern Pacific changed radically from a cold temperature anomaly to a warm anomaly in a matter of a few weeks--and threw the initial forecast off. Fortunately, scientists were able to detect these changes early and adjust the forecast as the season progressed. Evidence suggests that unusual atmospheric circulation in summer 1967 caused an abnormal amount of heat flux into the surface layers of the ocean in the northeastern Pacific. This in turn caused seasonal warming of surface waters to proceed at an unusually high rate. Precision in forecasting will not improve until understanding of ocean and air-sea interaction processes causing these changes is further developed.

Downstream from the California Current, variations in the California Current Extension waters affect the Hawaiian skipjack fishery. Important to Hawaii are the North Pacific Central and North Pacific Equatorial water types and the transition zone between these, the California Current Extension (Figure 11). The boundary between the California Current Extension, with relatively low salinity, and the North Pacific Central water, with relatively high salinity, is well defined by a salinity gradient which usually lies just south of the islands during late autumn and early winter.

Normally, during February or March, the salinity gradient, and thus California Current Extension water, begins a northward movement. It passes the islands in spring and reaches its northern position just north of the islands in July or August. The movement of the boundary is monitored by analyses of salinity samples taken regularly at near Koko Head, Oahu. Scientists at BCF's Biological Laboratory in Honolulu have found that when the California Current Extension bathes the islands in summer, skipjack landings are generally high, but when North Pacific Central water prevails, landings are usually below average. From these findings, and additional information on the time that seasonal warming of surface waters occurs, predictions are being made on whether skipjack landings will be above or below average for the season.

At the western extreme of the large clockwise gyre of the North Pacific, Japanese scientists have also determined relationships between variations of the Kuroshio and success of the albacore and skipjack fisheries there.

Mentioned earlier was the eastward flow of North Pacific water diverging off the coast of Washington and Oregon. A part of this forms the counter-clockwise Alaska gyre and the Alaska stream flowing to the westward south of the Aleutians. Scientists at BCF's Biological Laboratory, Seattle, now believe that reduced flow of the Alaska stream in the spring of 1966 affected the migration routes of maturing Bristol Bay sockeye salmon, and thus affected the number of salmon available to the high-seas fishery.

Clearly, one can conclude from these few examples that variations in the ocean climate have major effects on the abundance and availability of fishery resources. An essential step toward increasing productivity of United States fisheries would be to proceed with oceanographic programs that would increase understanding of the processes causing changes in the "ocean climate." This would lead to more effective fishery predictions.

New Harvesting Techniques Needed

Development of new harvesting techniques is urgently needed in some segments of the fishing industry. In the broadest definition, these techniques can be classified as ocean engineering developments. Two examples show how development of new harvesting techniques greatly increased fleet efficiency.

The first example is development of the power block and nylon purse seine in the Pacific tuna fishery. Following World War II, the California tuna fleet experienced several very profitable years through live-bait fishing. By the early 1950's, however, a major change occurred: imports from the Japanese tuna fishery hit heavily and, for a time, it appeared that tuna fishing by the domestic fleet might disappear entirely.

In 1956, the first seeds of technological advances that were to revolutionize the fishery occurred with development of the nylon net and power block for improved hauling of seines. Lack of capital and natural reluctance on the part of fishermen to change their method of fishing delayed rapid conversion of bait boats to purse seiners. It soon became evident, however, that large purse seiners could operate much more efficiently than bait boats. Accordingly, even though the cost of converting to purse seiners ranged from \$50,000 to \$150,000, and cost of the all-nylon purse seine was approximately \$50,000, conversion increased gradually; in 1959 and 1960, it jumped to an unbelievable rate. Few events in the history of a major fishery have so completely revolutionized a fleet.

The second example of increasing harvesting efficiency is the development of the midwater trawl and telemetering device in the Pacific hake fishery. Hake resources are known to be abundant off Oregon and Washington, and the Soviets have been fishing them heavily. However, it was not until BCF ocean engineers developed a midwater trawl capable of fishing hake off the bottom did the United States reach the point where harvest could be attained efficiently with small vessels. The ability to position the trawl at certain depths was the clue to efficient harvesting. This was possible only through development of a depth telemetering device to accurately position the net. This is evidence that innovations do not have to be of major proportions to have a great impact on increasing harvesting effectiveness.

Summary

In summary, then, it is clear that the role of oceanography in the development of food resources will be large. Through oceanographic investigations to determine areas of high basic productivity, new resources will be located; oceanographic studies to determine the relation of fish stocks to the environment will lead to predictions of abundance and availability;

and ocean engineers will develop new harvesting techniques that will put the U. S. fleets again in a competitive position with foreign fleets. The development of new processing techniques and products, such as fish protein concentrate (FPC), and marketing programs also will play major roles in the growth of world and domestic fisheries.

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(Robert K. Brigham)