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PASTURES OF THE SEA*

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In view of the increasing human population on the face of the earth and its tremendous need for food, it may be of interest to consider a few points in reference to the food supply from the ocean.

Man is a land animal and by his make-up is closely associated with all land phenomena. He is part and parcel of the land fauna and flora and subject to all the environmental factors on the earth's surface. As man developed he gradually learned to grow things for food and to domesticate animals, mostly for food but also for work, travel, and mere pleasure. Gradually he became more proficient at agriculture, began to settle down in communities and his numbers increased. Those people who lived near the ocean learned to secure fish and shell-fish from the waters. In due time a scientific and industrial age developed and man's numbers increased at an accelerated pace. With population growth there was need for still more food and the production of food stuffs on land and from the sea has increased greatly.

The farmer may own a few or thousands of acres of land. His operations may be by hand with very primitive tools or they may be highly scientific and mechanized with all the latest implements, all power operated. He grows grain and raises stock of selected breeds which have been developed over the years by hybridization and selection. He knows the composition of the soil and supplements its make-up with any lacking elements. He can see his crops; can manipulate them much as he wishes and, except for adverse weather, harvest

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them when he desires. In all this, the farmer is surrounded by many plants and animals including weeds, insects, birds, mice, rats, squirrels, racoons, coyotes, and many others which are in direct competition with his own crops and herds.

The fisherman owns no part of the ocean although in some cases he may lease portions of the inter-tidal regions for the growing of oysters and clams. He knows that there are fish in the sea. His methods of capturing them may be very primitive and his operations close inshore, or they may be highly mechanized and capable of wide geographical range. He cannot sow or cultivate; he cannot fertilize the ocean to improve the quality of the flesh or the growth rate or the number in the stock; he cannot improve the stock by hybridization and selection because of the impossibility of isolation of the stock. He goes where he suspects or knows that fish occur and operates his gillnets, trawls, set-lines, purse seines, or traps as he chooses. He has to compete with fellow fishermen, sharks, fishes, seals, sealions, and whales for his catch. And he always has the weather to contend with.

Both the farmer and the fisherman depend upon the scientists for knowledge of the environmental factors and the biological processes which contribute to the production of living things on land or in the water. Similarly, they depend upon the applied scientist for improvements in gear and in the processing of their products.

A brief review of some of the features of the ocean may help in arriving at an understanding of the productivity of this field or pasture.

A very large part of the earth's surface is covered with water. If this water were removed, the ocean floor would appear somewhat like the land surface with plains, hills, mountains, mountain ranges, valleys, and canyons. Extending out from dry land is a relatively shallow area or bench from several hundred feet to many miles in width, known as the continental shelf. From the outer edge of the shelf, which is usually about 600 feet deep, the bottom slopes down rapidly to the ocean floor which averages about two miles in depth. The deepest part is a rift or trench in the sea floor off the Philippine Islands over 37,782 feet or more than 7 miles deep.

No part of the ocean is completely stagnant. A circulation has been set up determined by the rotation of the earth, the positions of the sun and moon, the winds and the configuration of the basins. There are movements caused by differences in density, by upwellings, and by inflows from rivers. Perhaps a brief description of some of the major movements of the water in the north Pacific ocean may illustrate these ideas.[1] The general circulation is shown in figure 1. The Oyashio, a cold southward moving current, is present along the eastern side of the Kurile Islands and off the northern Japanese Islands. The

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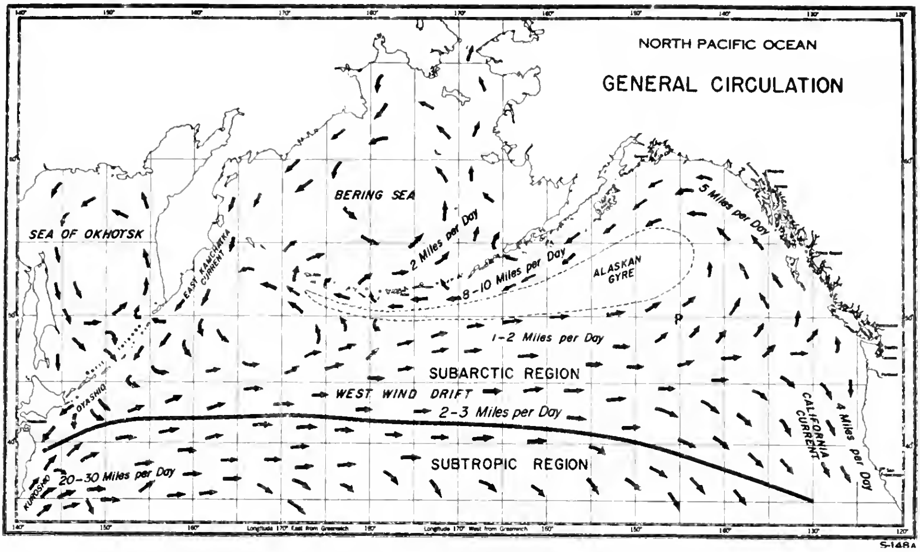

Figure 1. Ocean water currents in the North Pacific Ocean, as shown on "Base Map prepared by the Canadian Hydrographic Service, Surveys and Mapping Branch, S-148A".

Kuroshio, a warm-saline current moves northeast off the Japanese Islands to about latitude 40° N. At the confluence of the two currents some mixing occurs. The area is usually characterized by a wide system of eddies. The Kuroshio flow gradually turns southward, but the mixed water moves eastward as the trans-Pacific drift. The speed of this water is about two miles per day, and as far as is known the current extends almost to the bottom of the ocean.

The mixed waters of the trans-Pacific drift constitute a transitional zone separating subarctic waters from subtropic waters. On approaching the North American coast, a part of the mixed water is deflected northward to form the gyre in the Gulf of Alaska, and another part turns southward to form the California Current.

The upper waters of the Alaska gyre eventually enter the Bering Sea through the Aleutian passes, while the deeper waters flow through the deeper passages which lie farther to the west. The waters in the Bering Sea move in an anticlockwise circulation. Some of this water is dissipated through Bering Strait, while the remainder turns southward to form the East Kamchatka Current. In turn, part of the East Kamchatka Current moves into the Okhotsk Sea through passages in the north Kurile Island chain. The water circulates in the Okhotsk gyre and some flows through the middle of the Kurile passages to form part of the cold Oyashio current. The circulation in the subarctic Pacific is in part a closed system. It appears that about two years are necessary for the round trip.

Considerable variation occurs as to the point of division of the trans-Pacific drift on approaching the North American continent. In some seasons the sub-tropical part extends northward while in other seasons the division is considerably to the southward. Inflows of waters from the Columbia, Fraser, and other rivers create a coastal northwest movement of water which to some extent mixes with the water of the trans-Pacific drift among the line of contact, but mainly these waters join the northern portion in the Alaska gyre.

Early in the earth's history, the ocean must have been comprised of virtually freshwater, but during the course of billions of years the inflow of water off the land has added salts. In the course of the hydrologic cycle a very large amount of water is evaporated annually but the salts are left in the sea, so that the ocean has become increasingly salty because of the abundance of the common salt, sodium chloride. The surface water of the northern area, that is, subarctic water, is of low salinity usually less than 33 parts per thousand). In winter there may be almost uniform salinity from surface to 350 feet while in summer it is uniform for 30 to 100 feet. Below this there is a steady increase in salinity to about 34.66 parts per thousand). The surface water of the subarctic zone has a salinity of nearly 32 parts per thousand, while the upper water of the subtropical zone is about 35 parts per thousand. The salinity of the shoreward waters varies greatly, to almost freshwater off the mouths of rivers.

Other salts of importance, especially for plants, are phosphates, silicates, nitrates, carbonates, iodides, etc. As a matter of fact, the ocean is a reservoir for all elements; even gold is fairly abundant but cannot be extracted economically at the present time.

Oxygen, essential for practically all life, is reasonably abundant and may vary in amount from surface to bottom, from place to place and time to time.

The temperature of the water varies with latitude and, to some extent, with longitude, with the season, with depths, and with other factors. In the northern regions (subarctic) the surface waters vary from near 35° F. to 55° F., according to the season of the year, while in the southern regions (subtropical) the surface temperature is from 77° F. to 82° F. the year round. The bottom water is at 35° F. or less the year round, and throughout the ocean. The changes in temperature take place in the upper 400 to 500 feet approximately, leaving the great mass of water very cold.

Heat from the sun does not penetrate directly or deeply into the sea. Radiation to the extent of 62 per cent is absorbed in the first three or four feet. The heat absorbed by the uppermost layers is distributed downward chiefly by winds which mix and circulate the water.

Very little light reaches a depth of 3000 feet, and as far as known no light reaches 5,280 feet or one mile. Thus the great mass of the ocean bottom is in total and perpetual darkness. The ocean today consists of various environments comprised of innumerable combinations of chemical substances, temperatures, light, darkness, pressures, and currents as well as other factors. In the northern and southern regions there are seasonal and annual cycles of changes in physico-chemical conditions as well as very long term modifications. In this seeming complex of physico-chemical conditions life developed in great abundance.

Through the ages microscopic plant cells with chlorophyll developed in the upper lighted waters. They were able to catch the energy from the sun and in a complicated series of steps combined carbon dioxide and water to form carbohydrates in a process called photosynthesis. In their cell processes, nitrogen is built up into proteins. In due course, cells devoid of chlorophyll developed which were able to maintain themselves by feeding on the green cells. These were the animal cells. Thus the first step was established in a food chain.

On land, grass and other green things are eaten, digested, assimilated, and support animal life. In the ocean there is no grass, there are no fruits, no vegetables, no shrubs, and no trees. Instead there are small microscopic, green, one-celled plants of infinite variety and numbers, known as algae. Small animals and some fish feed on these. Among the small animals are many crustaceans such as ostracods, copepods, mysids, euphausids, amphipods, and shrimps. In shallow water the animal population is greatly augmented by immense numbers of the larvae of barnacles, crabs, worms, oysters, clams, and starfish. Fishes feed upon all these small plants and animals, and by doing so complete another link in the food chain.

The small plant and animal material is known as plankton, a name used by Müller in 1845. It may be collected by pulling a net of fine bolting silk or similar material through the water. In 1911, Lohmann pumped sea water into a

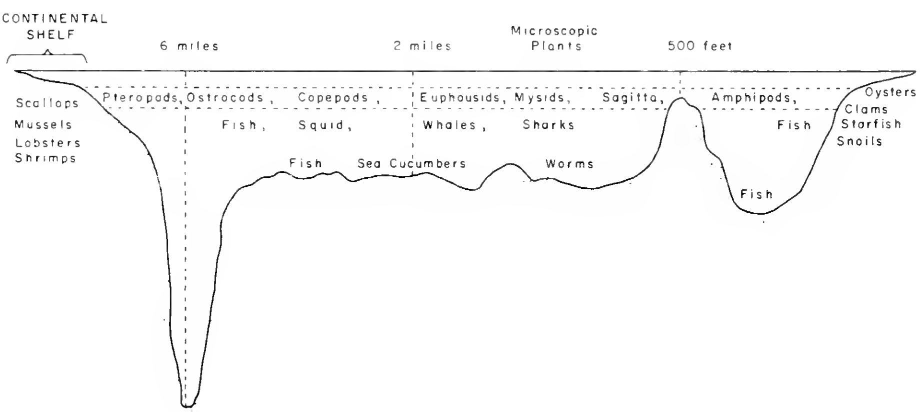

Figure 2. Ocean food cycles.

bucket and then centrifuged it. To his surprise he found a great quantity of minute plants and animals which ordinarily pass through the meshes of a net.

Nearly all fishes feed on the plankton at some stage during their life cycles. Especially important are the adults of herring, pilchards, shad, anchovies, smelts, sockeye and pink salmon. Then upon these fishes, feed many predators: seals, and some whales, as well as sharks and many other fishes, including spring and coho salmon, steelhead, tuna, cod, ling cod, and rockfishes.

Another food cycle results from the dead plankton settling on the bottom and forming the food of bottom-feeding creatures such as worms, shrimps, and clams and these in turn may be eaten by flounders, eelpouts, and blennies (figure 2).

The food cycles in the ocean are somewhat more involved than are those on land, but in both there is a continuous turnover of organic and inorganic matter. The turnover on land is simpler and, as far as man is concerned, more efficient. With each turnover there is a loss in energy-producing materials; for example, on land cattle and sheep are produced by feeding them on grass and then they are consumed by man. Cattle and sheep are not fed to tigers, lions, wolves, and mountain lions and then the latter animals eaten by human beings. It is said, very roughly, that ten pounds of food material eaten by the consumer, contributes only one pound to bodily weight. So in the case of the land chain: 1,000 pounds of grass contributes 100 pounds of weight to cattle and sheep, which in turn contributes 1 pound of weight to man.

In the sea the chain is longer and more complicated:

10,000 lbs.	1,000 lbs.	100 lbs.	10 lbs.	1 lb.
algae	crustaceans	fish (herring, pilchards, anchovies, smelts, sockeye, pink salmon)	man fish (chinook and coho salmon, tuna, cod, barracuda) seals, some whales	man

The above relationships may be expressed in the form of food pyramids (figure 3).

Theoretically, it would be more economical if man used herring and pilchards for food directly instead of turning the fish into oil and meal and thus inserting at least one more step in the food chain. If the human population continues to increase at its present rate, the time may soon come when these fishes will be used directly for food.

Plankton is not used as food by human beings as it is by herring and pilchards. There are several reasons for this. At the present time economic

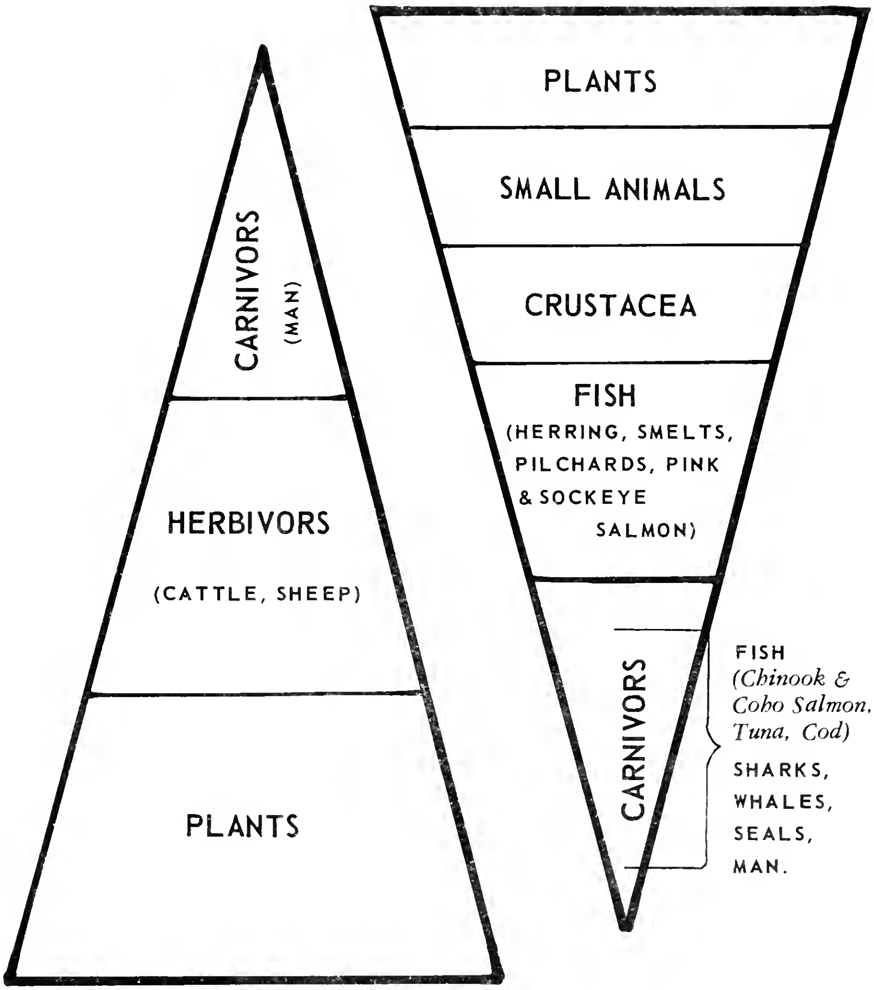

Figure 3. Food Pyramids.

methods for collecting the material have not been devised. Further, little information is available as to the regions of great abundance of plankton. Thirdly, the material contains so much silica and chitin that special processes may be needed to make it suitable for human food. Someday a suitable concentrated soup may be produced, but in the meantime it is better for herring and the pilchards to collect and assimilate the plankton, and for human beings to use these fish for food. Further, someday it may be possible to grow marine algae economically in tanks and ponds and thus add to the food supply.

Man has not exploited the sea to its fullest scientific extent. It is known that very large catches of fish may be obtained in some regions such as in the Indian Ocean; off the coast of Africa (the Union of South Africa has recently developed a large pilchard fishery); off the coast of South America; and in other regions and at greater depths. The possibility of "farming" the shallower waters of the ocean, for example, the continental shelf, is discussed from time to time. One is intrigued by the description of possible operations as given by Sir Alister Hardy in his book "The Open Sea: II Fish and Fisheries," where he envisions pressure-proof submarine tractors powered by atomic energy, manned by men in diving apparatus working in two-hour shifts from a mother ship.

Some idea of the present production of ocean fishes may be obtained from the following general figures:

Japan catches more fish and other sea products than any other country. Her production in 1961 was about 6,000,000 tons taken from practically all the oceans. Peru had a catch of 5,000,000 tons in 1961. The USSR is expanding its fisheries enormously and in 1961 took approximately 3,000,000 tons. In 1956, there were two USSR trawlers on the banks off Newfoundland; in 1960, there were 110 and several factory ships. China produces over 3,000,000 tons annually. Canada and Great Britain each take about 1,000,000 tons each year and the United States about 3,000,000 tons. The total world fish production in 1961 was about 40,000,000 tons.

To produce this amount of fish probably three to four billion tons of microscopic plants were consumed. When one remembers that this is only one food cycle involving only certain fishes, and that there are many other food cycles ranging from sponges and worms to crustaceans and molluscs and other fishes, some conception of the immensity of the productivity of life in the sea is realized.

In the light of present knowledge it is impossible to forecast the amount by which the fish catch of the world may be increased. With more boats, better gear, and improved technology, together with more human ingenuity and aggressiveness, it would appear that the catch might be doubled or even trebled. Such increases should be based upon sound scientific principles and upon fullest international cooperation. What is needed is more knowledge derived from investigations and fundamental researches in many fields such as biology, chemistry, physics, technology, and even in economics and sociology, and the spread of knowledge among all peoples.

Looking to the future one needs to visualize a world supporting a very much greater number of people than it does at present (1961), provided that the production of food stuffs may be increased. The ocean is undoubtedly an area which offers attractive possibilities for increased food production in the years to come.

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