FOOD from the SEA

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To feed the hungry mouths of a rapidly increasing population we may turn to the living resources of the sea around us to reap its substantial harvest of as yet untapped food reserves

MORE THAN 71% of the surface of the earth is covered by water, most of which is collected in the oceans. The oceans, populated with life which finds there better conditions for growth and reproduction than on land, are storehouses of food. But despite their impressive extent and their content of nutrient materials, the great bodies of water receive a disproportionate amount of attention as sources of food. This may not always have been true, as there are indications that human civilization originated along rivers and sea shores, where early man obtained his fare by gathering aquatic plants and animals before the advent of the hunting stage which preceded pastoral and agricultural pursuits.

Viewed from the atmosphere of our modern highly developed land cultivation, marine culture appears remarkably simple and seems almost to offer something for nothing—or at least for very little in comparison to the effort needed to gain food from the land. Terrestrial plants require aeration of the root system and a supply of water and nutrients. These growth conditions often require labor and expense for tilling, irrigation, and fertilization. Marine plants grow naturally and profusely in a complete nutrient solution containing not only all essential mineral elements, in concentrations varying geographically, but also large quantities of dissolved gases. Some estimates have placed the amount of carbon dioxide in the oceans up to a million times that of the content of the earth's atmosphere. This dissolved gas or soluble carbonate, the raw material for photosynthesis, is not being used as intensively in the sea, but the total amount of photosynthetic activity there has been estimated to be about 10 times that of all wild and cultivated plants on land (*4*). See Table I.

Furthermore, the land has been a source of mineral nutrients, some of which are physiologically essential trace elements, through the eroding and dissolving action of water. The minerals carried away have drained into the oceans, enriching their supply of nutrients.

The basic life cycle is the same on the ocean as on the land. Self-feeding organisms, especially plants, are aided by the sun's radiation in converting low energy substance into high energy substance. Subsequently, the self-feeding organisms are degraded by those, especially animals, which depend on others for their feed. The magnitude and intensity of biologic action often is greater in water than on land because the aquatic environment is more conducive to photosynthetic and metabolic processes.

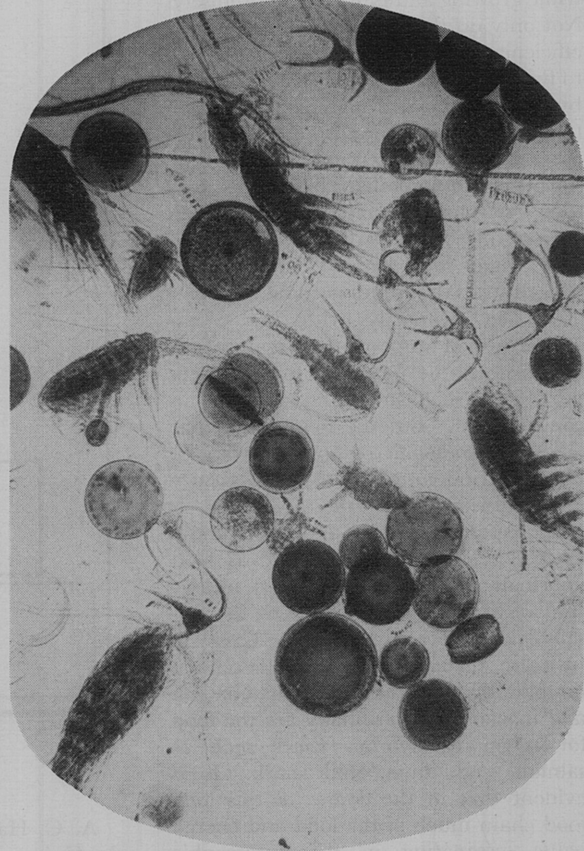
Seaweeds Are Natural Soil Conditioners

Probably, their high capacity for accumulating macro- and micronutrients have made the more conspicuous and readily accessible of the marine plants, namely the large seaweeds belonging to the brown, green, and red algae, so useful since time immemorial as manure for replenishing the soil. In addition to their nutrient value, seaweeds exert a beneficial influence upon the physical properties of soil. As early as 1911 it was discovered that algin of the weeds can consolidate and improve sandy soils (*16*), but this action remained unexplained until the advent of soil conditioners illuminated the function of polyelectrolytes. Actually seaweeds are natural soil conditioners. Their main organic constituent, which is a polymer of D-mannuronic acid, is very similar in both structure and function to the synthetic soil conditioners obtained by hydrolysis of polyacrylonitrile.

While the high nutrient content of soil manured with seaweed manifests itself in prolific plant growth, it is also observed that animals derive benefit from feeding on seaweeds or on plants grown in seaweed enriched soils. It is, therefore, not surprising that the use of seaweed as a feed for animals is a very old and widespread practice in areas where large amounts of seaweed are cast ashore or can be easily collected on the beaches. Although seaweed cannot be considered a complete animal food, it has attractive feeding efficiency as a feedstuff supplement and now is produced as such on the Pacific Coast.

As a human food algae are consumed in many coastal areas of the world. The

A sample of plankton from the southern region of the Grand Banks in the North Atlantic Ocean, off the coast of Labrador. Immature amphopods, shrimplike animals, dominate the sample (40-diameter magnification)



A representative group of plankton, collected from the North Atlantic in mid-winter, which includes diatoms as well as simple invertebrate animal forms (40-diameter magnification)

principal users are the people of Eastern Asia, especially the Chinese and Japanese, in whose diet these plants that are so rich in vitamin A and C (*24*) and in mineral nutrients play an important role. Occidentals eat to a limited extent certain red algae, such as *Gigartina stellata* and *Chondrus crispus*, also known as "Irish Moss"; larger brown algae such as *Macrocystis pyrifera* are of importance because of their content of phycocolloids, water-soluble polysaccharides of unique colloidal properties, which are used increasingly as stabilizers in food industries. Algin, for instance, has replaced gelatin to a considerable extent as a stabilizer in ice cream and chocolate milk.

While these constituents of the large algae, their chemical composition and physiological function are fairly well known, there are other aspects that are more challenging and intriguing. For instance, it has been known for a long time that the natives of certain Pacific islands cover freshly caught fish with the fronds of large seaweeds to protect them against rapid decomposition. The usual explanation for this practice was that fresh seaweeds shield the fish against bacterial contamination. The reason which had been a mystery may be explained by the recent discovery of antibiotic action of algal tissues. As the sea is populated by myriads of bacteria that readily decompose phycocolloids, we may assume that living algae contain powerful antibiotic substances that protect them against bacterial decomposition. This assumption is corroborated by the discovery of an antibiotic in the culture of *Cholorella pyrenoidosa* in vitro (*6*) and the recent finding by research workers at the University of California that numerous species of seaweeds collected on the Pacific Coast show antibiotic action (*20*). Thus, it is possible that antibiotic algae or their extracts may play a significant role in the preservation of fish and other food products, while their colloidal action sustains the texture and improves the taste and eye appeal of the canned product. Whether the presence of antibiotic substances in seaweeds used in cattle feed, rather than their high mineralization, is responsible for the high feeding efficiency is a matter deserving thorough examination.

While there are numerous applications of seaweed products in manufacturing textiles and plastics that are beyond the scope of this article, one deserves to be mentioned here because of its great potentialities in the food industry. Technologists in Germany have made from Norwegian seaweed a new type of sausage casing which, in contrast to the cellophane skin, has a kind of natural affinity for the sausage filling, is edible, and weighs only $^1/_{29}$th as much (*7*).

The larger marine algae or seaweeds, which are of greater immediate practical importance as foods, fertilizers, and feedstuffs, constitute only about 1% of the total marine vegetation. The great mass consists overwhelmingly of simple microscopic algae which, in spite of their precarious and short-lived existence, form the bases of the food pyramid of the sea (Figure 1). Through the buoyant force of tiny oil droplets they keep themselves suspended in the sur-

Table I. Photosynthetic Activity

Habitat	Area in Km.^{2}	Average Tons Carbon Fixed/Km.^{2}/Yr.	Tons C Fixed/Yr.
Oceans	361×10^6	375	13.5×10^{10}
Land	149×10^6	130	1.6×10^{10}

face waters and drift with the current while growing and multiplying profusely. Not only do they exhibit photosynthetic efficiency, but some species are also able to fix nitrogen, a fact recently established by cultures in vitro of blue-green algae (*27*). The most important classes of these floating plants that constitute the so-called phytoplankton are the diatoms and dinoflagellates which contain even in this low stage of development, all those major food groups—proteins, carbohydrates, fats, vitamins, mineral salts—associated primarily with the extraordinary food value of the organisms at the apex of the food pyramid, namely the fish and shellfish that serve for human consumption. But the food chain that leads from these microscopic plants to the large marine animals becomes greatly extended since the phytoplankton is grazed upon by protozoa and other minute animals. These animals serve as food for small crustaceans, the most important of which are the copepods that resemble miniature shrimps. They in turn are devoured by enormous schools of small fishes such as herring, menhaden, and mackerel which finally are the food for larger carnivorous fishes such as salmon, cod, tuna, and shark. It is evident that in the course of this long food chain much of the food and energy value originating in the autotrophic plants never reaches the ultimate consumer because of the catabolic activities of the individual links in the chain. It has been estimated that each "middleman" passes on only about one tenth of the substance and energy it receives (*23*). It follows that in the case of only four links between food production and food consumption, only one ten-thousandth part of the organic matter made by autotrophic plants comes to the ultimate consumer. As far as human food needs are concerned, nine tenths of the organisms participating in the food chain are unused, since they are not eaten by the carnivorous fish used for human food. It follows, as the greatly simplified chart (Figure 1) shows, that the production of one pound of food fish such as cod requires 100,000 pounds of vegetable plankton.

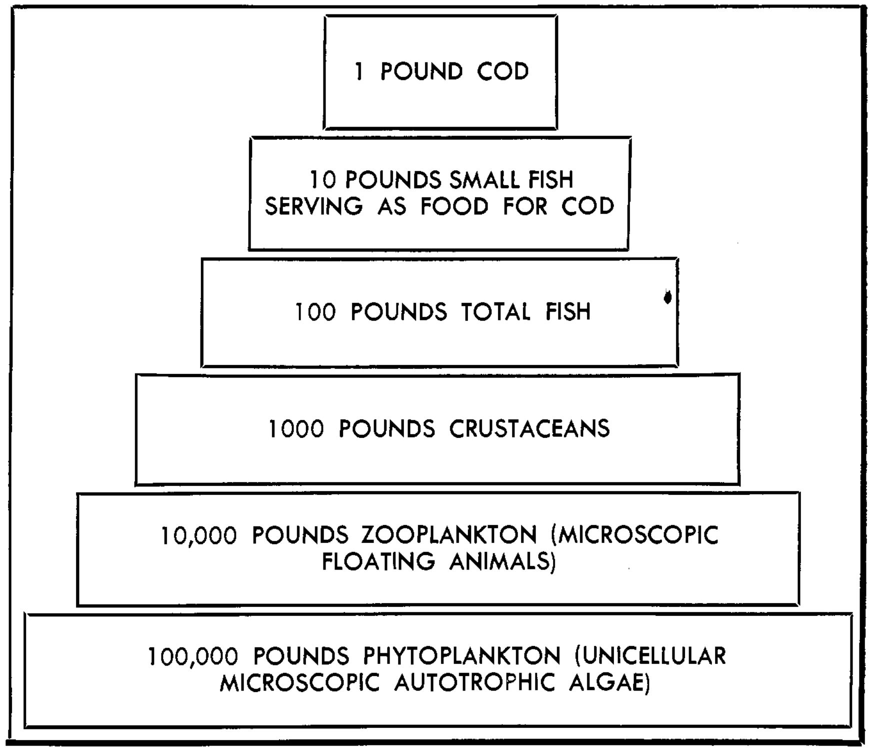


Figure 1. Food pyramid in the sea

Use Plankton Directly

This appalling waste and inefficiency in our present form of utilization of potential food resources of the sea should suggest that instead of depending on the long chain from plankton to fish, it would be more rational to use plankton directly as a food or feedstuff. In 1941, when the German U-boat campaign was at its height, Sir John Graham Kerr, member of the British Parliament, asked that a committee be appointed to investigate the practicability of large-scale collection of plankton by mechanical separators and its use as a food.

A. C. Hardy, professor of zoology at the University College in Hull, England, points to the very high food value of plankton for mammals demonstrated by the rapid growth of the blue and fin whales which feed on it. The average composition of the dry substance of zooplankton consisting mainly of copepods (microscopic crustaceans) is: 59% protein, 7% fat, 20% carbohydrates, 4.7% chitin, and 9.4% ash. It has a not unpleasant shrimp-like flavor and is perfectly suitable to sustain human life. The difficulty of commercial utilization of plankton lies, of course, in its relatively large dilution, but this difficulty is not insurmountable. There is no reason why man should not be able to achieve by suitable mechanical devices what the great whales do through their filter apparatus. In fact, Prof. Hardy points out that with suitably constructed nets two men could collect on the coast of Scotland 588 pounds of plankton per day, or enough to feed 357 people (*11*). It is true that some plankton organisms under circumstances not yet fully understood accumulate in their bodies poisonous metabolic products that would make them unfit for direct consumption. Development of extraction methods that would either destroy or separate harmful constituents from the edible portion of the plankton material, could be a solution to the problem. While we do not recommend plankton for human consumption, it is evident that it could be particularly well suited as feedstuff supplement for animals, if methods could be devised and if energy should become sufficiently cheap to make large automatic collecting plants economically feasible. Such installations would be especially valuable for people living on densely populated islands, such as the Japanese or Puerto Ricans, who have not available the large land resources necessary for animal production.

Crustaceans as Food Prospects

As the direct utilizaton of plankton at present is not of immediate practical importance, let us step up to the next floor of the food pyramid and ask whether the enormous quantities of crustaceans, because of their larger size and tendency to massive accumulation, offer better food prospects. We were unaware of the existence of such enormous masses of living matter in deeper layers of the ocean until the Second World War, when the U. S. Navy in cooperation with the Scripps Institution of Oceanography investigated the acuity of sounding devices such as were used to spot enemy submarines. In the course of this investigation a mysterious sound scattering layer was discovered at depth between 900 and 2700 feet. The most fascinating property of this layer is its diurnal migration. Between sunset and sunrise it approaches the surface, while during the day it recedes into the depth of the ocean. This excludes its causation by inaminate matter, but also rules out phytoplankton which does not migrate vertically. It also makes it unlikely that the uniform scattering is caused by large shoals of fish which are of a less continuous distribution. Moore concluded that such scattering probably is caused by euphausiacea, small crustacea which are extremely abundant and play an important part in marine life as food for whales and fishes. Their diurnal migrations coincide with the movement of the scattering layer and their geographical distribution is in good correlation with the intensity of the sound scattering (*13*, *17*). Euphausiacea are closely related to shrimps and would constitute a food of high nutrient value. The day may come in the future when large hoses are put down from ships to pump water containing these organisms to the surface where the organic matter can be strained out (*3*). Such collection of small marine animals from the depth of the ocean may be greatly facilitated by another very recent discovery, namely that animals, when exposed to an electric field, swim to the anode and are paralysed by sufficiently strong currents (*14*).

Having discussed this fascinating subject with many eminent oceanographers and marine biologists, I am now more optimistic about an eventual utilization of the material contained in the deep scattering layer of the oceans.

Relatively large amounts of organic matter are diverted from the food chain by the sponges which, from a physiological point of view, are simply large colonies of sedentary filter-feeding protozoa. Sponges constitute an entirely unexploited potential source of food, feedstuffs, and fertilizers, the magnitude of which has been recognized only very recently. Of the known 3000 species of this animal only 13 are commercially used in form of their fibrous skeletons which serve, due to their water-holding capacity, for bathing and mopping purposes. In order to obtain the natural bath sponge, the living sponge, which resembles a slimy beef liver, must be killed and its protoplasma allowed to decay. This so-called "gurry" weighs about three times as much as the skeleton and is rich in proteins, vitamins, and minerals. Considering an annual sponge production of 2 million pounds we can well imagine how much valuable organic matter is needlessly wasted. Yet that is only a small fraction of organic and mineral matter available from noncommercial sponges that are mainly of the calcareous and siliceous type. For instance the huge loggerhead sponge (Spheciospongia vesparia) which grows off the coast of Florida and in many other warm shallow waters attains a weight of more than 200 pounds and can be converted by a simple process into potent fertilizer and poultry feed supplement which is valuable because of its high organic iodine content (*18*).

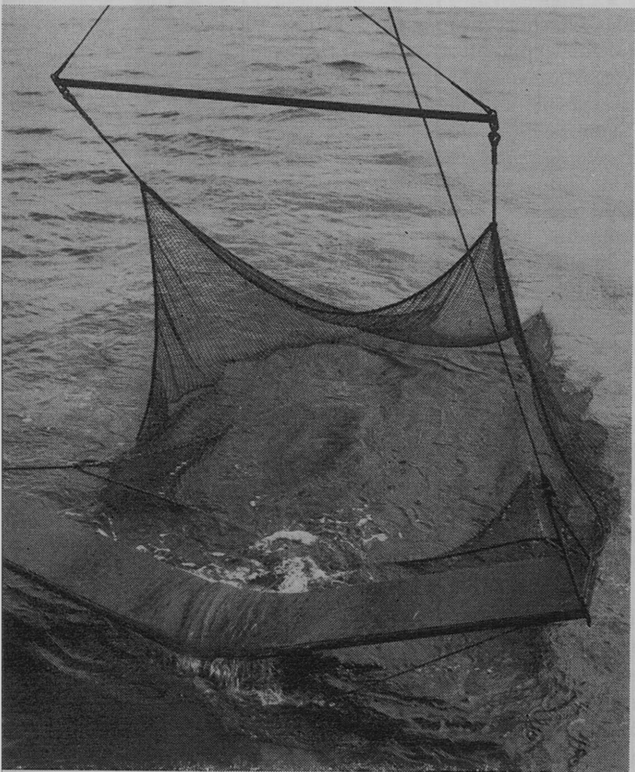
To meet present food requirements from marine sources it is not necessary to go down so deep into the ocean, as long as there are large unexploited fish and shellfish resources available closer to the surface. The discovery of lobster grounds and red crab deposits extending over hundreds of square miles about 100 miles off shore from Cape Cod, or the rapid development of a large crab industry along the Atlantic Coast are just two instances of immediate potentialities (*2*).

The large clam or ocean quahog (*Arctica islandica*) resembles the ordinary hard clam except that the former is about the size of a large hand. Buried in the muddy bottom of the sea about 100 feet deep, it came into prominence only after the second world war and is now scraped off the ocean floor in large quantities, dredged, shipped, cleaned, and converted, through highly mechanized processes, into tasty and nutritious foods such as clam broth, chowder, and minced clam. Nothing remains unutilized; even the shells are used for planting in oyster beds. What does not go into the can for human food is used as a valuable feedstuff supplement for farm animals.

Another valuable sea food that is very little known in this country, but offers enormous possibilities for the future is the sea mussel (*Mytilus edulis*) which forms large beds along the North Atlantic Coast; a closely related species, *Mytilus californianus*, occurs in great quantities on the Pacific Coast from Alaska to San Francisco (*24*). It can easily be harvested with present equipment and forms an excellent article of diet, either steamed, fried, chowdered, or otherwise prepared (*25*). Because mussels spoil rapidly, they must be preserved by very efficient methods such as quick freezing, canning, or pickling in vinegar. Mussels

A diver on the Scripps Institution's Capricorn expedition examines a giant clam on the surface of a submerged volcanic island in the tropical Pacific

Conrad Limbaugh (in diving gear), Scripps Institution of Oceanography at La Jolla, Calif., shows kelp recently harvested to William McNeely, Kelco Co.



A mid-water trawl, equipment developed by workers at Scripps to explore life in one of the last frontiers of biological exploration in the dark waters between the sunlit surface layers and the deep ocean floor

are consumed in large amounts in Europe particularly in France, Holland, and England. In fact, the European demand is so great that the natural supply is inadequate. For this reason mussels are cultivated artificially and thousands of "bouchots" or mussel hedges dot the French coast where mussel culture dates back to the 13th century (*25*). Acre for acre, a mussle farm produces 20 to 30 times as much food as the best pasture land. In a report of the French Ministry of Fisheries, a figure of 10,000 pounds of mussel meat per acre per year is given as compared to 190 pounds of beef obtainable from the finest pasture (*7*). The growing scarcity of meat during the second world war led Herrington and Scattergood to propose better utilization of our mussel resources as a source of attractive and very nutritious seafood (*12*) The Fish and Wildlife Service, in a series of investigations, studied the feasibility of large-scale mussle production in the United States and came to the conclusion that mussel production has great future potentialities if proper conservation measures and preservation methods are applied (*21*). However, a word of caution should be added. When mussels are grown in polluted water, they may accumulate germs that make them unfit or unsuitable for human consumption. It should be mentioned that mussels or parts of them that cannot be used for human consumption are a valuable poultry feed. According to a method developed in Denmark, mussels in the shell are dried at high temperature and ground. The meal produced has the following composition: 71.41 percent calcium salts, 13.21 carbohydrates, 11.64 protein, 1.68 fat, and 2.06 water. It is apparent that a feed of such composition should have a beneficial effect on egg production (*26*), although there is some problem of flavor.

Although well adjusted to their aquatic environment, marine plants and animals upon removal exhibit a high degree of perishability not encountered in terrestrial organisms. This is caused mainly by a very efficient enzymatic system which is checked in the living organisms by effective biological control. As soon as the organisms are taken out of the water the control mechanism ceases to function, while the enzymatic activity very greatly increases. If we want to derive optimum advantage from the harvest of the sea, we have to collect it at its optimum anabolic condition and either prevent catabolic degradation or, if this should not be feasible, lead it into controllable processes.

Marine Chemistry in Its Infancy

It is here that *marine chemistry* enters. After centuries of empirical application this science only recently attained a level of scientific exploration and technical application known in agricultural chemistry 100 years ago. The most perishable of all marine products are fresh fish. Almost the whole of the world's fish production of about 26 million metric tons per year is landed in a fresh condition. As a result the problem of fish utilization is essentially that of preventing or greatly retarding enzymatic or bacterial decomposition. The task of keeping fish in usable condition is made much more difficult by the seasonal and unseasonal, the predictable and unpredictable fluctuations in both supply and demand. Since very early times man has fought the destructive forces of enzymatic and bacterial decomposition by salting, smoking, curing, and drying; later by heating and freezing; and most recently by technically more advanced methods such as dehydration by forced rapid drying. Another way to prevent spoilage is, of course, the enclosure of the sterilized product in hermetically sealed containers as practiced in fish canning. Radiation sterilization now is being studied as a promising technique. Only to the extent that these preservation methods can be rationalized and technically improved will it be possible to make food from the sea available for the low-income groups and to make full use of the enormous fish resources of distant waters without overfishing the more accessible fishing grounds (*9*).

How far we have to go to achieve this goal is best illustrated by the fact that fishing, in spite of being man's oldest occupation, is also his least developed one. It is carried out mainly in the shallow waters around the edges of the continents, while vast areas of the oceans are unexplored as to their potential productivity. More than 90% of the entire fish catch is taken from the waters of the Northern Hemisphere, while the far greater expanse of the Southern Hemisphere is exploited only in a very limited way. Fish and shellfish contribute only about 2% to the total food consumption of the world, although fish, being essentially a protein food, could splendidly supplement the requirements of the great majority of the human race that subsists primarily on carbohydrate food.

Fish Wastes High in Food Value

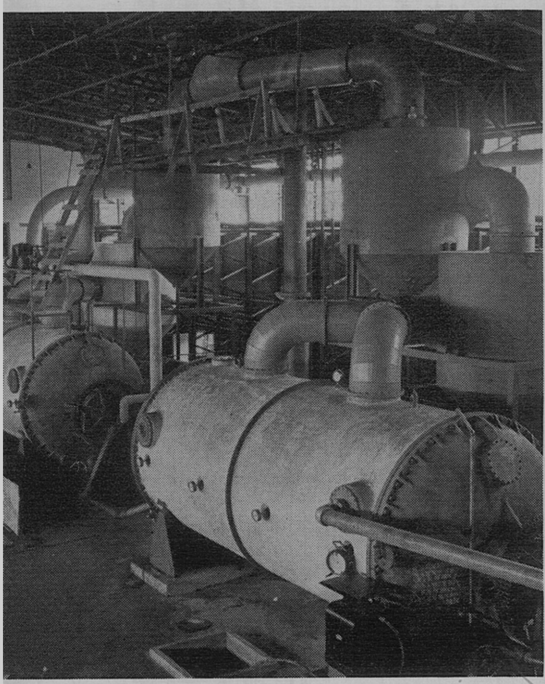
Only a part of the fresh fish goes into direct human consumption; the edible fraction of the different fish species varies widely between 30 and 50%. However, the "waste products" of the fishing industry contain nutrients such as proteins and vitamins that in some instances are of higher food value than the portions utilized. In the United States and a few other countries these products are recovered and used for fertilizers, feedstuff supplements, and fish oil, but in many parts of the world badly needed nutrients are unnecessarily wasted. The American fishing industry has not yet achieved a complete waste utilization; not all the water soluble substances obtained in the fish reduction plants are recovered. The nutritionally valuable salmon waste of Alaska and the equally valuable shrimp waste in the Gulf of Mexico are still thrown in the water.

While these are usable residues of fish primarily caught for human consumption, there is a large industry in this country engaged in the total reduction of fish unsuitable for human consumption, such as menhaden (*Brevoortia tyrannus*), which is highly appreciated as raw material for the production of fish oil and fish meal. While the total amount of fish waste in the United States in 1952 is estimated at 735 million pounds, fish meal production was 432 million pounds, and fish oil production 119 million pounds, about 50% of both being derived from menhaden. The now generally used wet-reduction process of treating fish waste or whole fish consists in steaming the material, separating the fish meal by pressing, and the fish oil by centrifuging. The watery fraction remaining after the removal of the solid and oily constituents is of highest nutritional value containing soluble proteins, amino acids, vitamins, minerals, and some undisclosed factors that in extremely small amounts exert a noticeable beneficial influence upon animal growth and reproduction. In spite of these remarkable nutritional qualities "stickwater" has been dumped into public waters; containing many growth substances it is an excellent medium for bacterial growth and putrefaction, giving off revolting odors.

It was not until the reducing plants were forced to do something against the public nuisance caused by dumping fish wastes that they adopted the Sharpless-Lassen Stickwater Process, developed by Sven Lassen for the elimination of water pollution and the recovery of valuable by-products (*22*). By slight acidification with sulfuric acid (from about pH 7.0 to 4.5) and subsequent evaporation to a 50% solid content, decomposition is halted and a semiliquid substance, "condensed fish solubles," is obtained; it contains a minimum of 32% protein, 4% fat, and 9% ash, as well as relatively large amounts of riboflavin, pantothenic acid, thiamin, nicotinic acid, pyridoxin, choline, and vitamin B_{12}. Addition of small amounts of fish solubles to fish meal enhances the feeding efficiency of poultry feed, and fish solubles now are used in increasing amounts as important components of "synthetic milk" in raising pigs away from the sow (*19*).

Considering the high nutrient value of fish products, the question must be raised why those fish or portions of fish that are not suitable for direct consumption or are far distant from potential markets could not be converted into a food supplement for humans. To a certain extent this has been done for centuries with fish-liver oils whose content of fat-soluble vitamins, especially vitamins A and D, makes them valuable to both animals and humans when the diet is lacking in these nutrients. However, no less significant is the deficiency of proteins among humans which in tropical and subtropical areas, causes one of the most widespread disorders, known generally as "kwashiorkor" or malignant malnutrition (*5*). This usually fatal disease is particularly rampant among the children of those African tribes whose main diet consists of manioc, a starchy plant product, while tribes living on the coast, who consume small amounts of fish, molluscs, and crustacea, are observed to be free from this disease. Following this lead it was suggested that the diet of the children in the stricken areas be supplemented with fish flour. The Food and Agricultural Organization of the United Nations, in cooperation with the United Nations International Childrens Emergency Fund, took up this suggestion and already has achieved remarkable results in preventing and curing kwashiorkor by dispensing relatively small amounts of fish flour. Such flour, now manufactured in Norway from whole fish and fish waste, is an odorless and tasteless free-flowing powder, high in proteins and vitamins, especially vitamin B_{12}, which can be used in biscuits, soups, gruel, and other nationally preferred dishes (*8*).

A large and completely modern herring- and fish-processing plant in Faxa Bay, southwestern Iceland



The manufacture of fish flour is only one way to use waste to meet human want. Recently there have been developed other ways of utilizing fish and fish waste that promise to have greater appeal to the Western world. At the end of World War II, it became known that a method of dehydrating fish had been developed by the Danish engineer, A. Gernow, in cooperation with the Atlas Food Equipment Mfg. Co., in Copenhagen. This method has the great advantage of producing whole fillets, thus meeting the most widespread objection against dehydrated fish, namely their comminuted nature. It is only natural that the Germans after invasion of Denmark avidly seized upon this method in order to relieve their great scarcity of protein foods.

After the war the British studied and improved the Danish method in their Experimental Food Factory in Aberdeen, Scotland, under the supervision of the Fish Section of the British Ministry of Foods (*10*). As now developed, this method consists in dipping the fresh fish fillets in a slightly alkaline solution, spreading them on trays, and dehydrating them at relatively low temperature in a high vacuum between heated plates. After reduction to a moisture content of 15%, the dried fish is sawed and compressed into rectangular blocks of six layers, completely dried, and packed in moisture- and vaporproof material. The British factory currently uses cod as raw material at a volume of about one ton per batch. The dehydrated fish easily can be reconstituted and then resembles fresh fillets. Flavor, odor, and appearance are said to be excellent. What makes this new method of fish preservation so attractive is the fact that it offers a most inexpensive way of making large amounts of fish available to markets far distant from the fishing grounds, where fish products preserved in the conventional manner are not economically attractive.

Enzymatic Digestion Acids Fight Against Perishability

It has been the aim of the fishing and fish processing industry to fight the extraordinary perishability of fish and fish products by all possible means, chemical, physical, and bacteriological. Therefore it may appear absurd to endeavor to reach the same object in exactly the opposite way, namely by making use of the powerful catabolic forces inherent in fish tissues. This idea is nothing new to the peoples of Eastern Asia who have been using enzymatic partial decomposition of whole fish for obtaining edible fish products that appeal to their palate, though certainly not to Western taste.

Fish pastes and fish sauces are very extensively used in Southeastern Asia, especially in connection with rice to which they form a nutritionally highly desirable supplementation. On the coast of Indochina and Thialand, the manufacture of fish paste ("pra-hoc") and fish sauce ("nuoc-mam") are active industries which consist essentially in preventing bacterial decomposition of uneviscerated fish by adding large amounts of salt in vats into which small fish have been pressed and at the same time promoting enzymatic digestion by the action of heat and the natural establishment of a favorable pH value (*28*, *29*).

The same principle of enzymatic digestion is now practiced on the West Coast of the U.S. to convert the viscera of tuna and other fish landed on a large scale into feedstuff supplements and fertilizer. The method is equally adaptable to fish muscle; the reason fish muscle is not used is simply that it lends itself to more economical utilization. The very strong proteolytic enzymes contained in the cecal mass of the tuna cause the viscera to liquefy in an hour or two under proper conditions. According to the experience of the Van Camp Sea Food Co. on Terminal Island, Calif., the best liquefaction is obtained if the viscera are ground with a hammermill and pumped into a tank provided with an agitator. At a pH of 3.5 to 4.0, obtained by adding sulfuric or phosphoric acid, and a temperature from 120° to 170° F., complete liquefaction is obtained in about two hours. Formol titration of the hydrolyzate indicates that a 50% liberation of amino acids is sufficient to bring about the effect described. Bones, scales, and connective tissues remain undigested and are separated from the liquid which is subsequently concentrated to a 50% solid content. This semisolid product has been well received by the feed manufacturers as a feedstuff supplement. Although it does not have as high a content of the B vitamins as condensed fish solubles, its content of vitamin B_{12} is larger and this makes it especially valuable for promoting growth of animals (*15*).

Recently, in an address before the Institute of Food Technologists, G. A. Reay emphasized the increase possible through improvement of techniques applied to the fishing industry as it exists today. He expressed the opinion that existing production might be quadrupled by the culturing of fresh and brackish water fish in natural waters and special ponds. Annual yields as high as 8000 pounds per acre have been achieved commercially. This compares very favorably with natural yields of 445 to 1780 pounds per acre per year. Another great source of food, according to Dr. Reay is whale meat. Only about 30,000 tons of the present catch of 1.3 million tons of whale meat is being used for food at present. Dr. Reay estimated that doubling of whale meat output for human consumption and development of fish farming could add 15 million tons a year to the world food supply.

There is no question that many more foodstuffs could be extracted from the vast expanses of the oceans to meet the steadily growing requirements for protein and other protective nutrients of an expanding world population. There is also no question that presently used raw materials of marine origin could be processed with less waste and better preservation of their nutrient value. And it is obvious that a greater utilization of fish and fish waste product for agricultural purposes, the improvement of the soil, and the growth of plants and animals will be of mutual benefit to farmers, fishermen, and consumers.

But the most pressing problem at the present time is that of distribution, which is greatly accentuated by the perishability of marine products. Only by way of nutritional education, by changing ingrained but inadequate food habits, by improving the purchasing power and living standard of backward nations, and by facilitating the free flow of commodities will it be possible to achieve a fuller and economically justifiable utilization of the large food resources of the oceans.

Francis Joseph Weiss, a native of Vienna, Austria, obtained his Ph.D. in chemistry in 1922 at Vienna University and subsequently got an Sc.D. in economics and statistics in 1928 from the same university. Combining his background in natural and social sciences, Dr. Weiss devoted most of his research work to the exploration of natural resources for the benefit of mankind. He worked for the National Planning Association, the Bureau of Agricultural Economics, the Office of Technical Information, and the Fish and Wildlife Service of the U. S. Department of the Interior, as well as for the Sugar Research Foundation. He is now a scientific consultant on food and nutrition.

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