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# RESOURCES OF THE SEA

(Beyond the continental shelf)

Report of the Secretary-General

## INTRODUCTION AND SUMMARY

* Reissued for technical reasons.

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# INTRODUCTION

1. This report is submitted to the Council, pursuant to its resolution 1112 (XL) of 7 March 1966, which, inter alia, requested the Secretary-General:

> "(a) To make a survey of the present state of knowledge of these resources of the sea, beyond the continental shelf and of the techniques for exploiting these resources ... ;
>
> "(b) As part of that survey, to attempt to identify those resources now considered to be capable of economic exploitation, especially for the benefit of developing countries;
>
> "(c) To identify any gaps in available knowledge which merit early attention by virtue of their importance to the development of ocean resources, and of the practicality of their early exploitation."

2. The Council will recall that, since the adoption of this resolution, two other resolutions dealing with related matters were adopted by the General Assembly. Resolution 2172 (XXI) on existing activities in marine science and technology inter alia, endorsed Economic and Social Council resolution 1112 (XL). The General Assembly adopted another resolution (2340 (XXII)) which is particularly relevant to the present report because, inter alia, it refers not only to the exploration and use of the sea bed and ocean floor as well as to development of the resources thereon in the interest of mankind, but also because it establishes an ad hoc committee to which the results of the studies being undertaken in pursuance of Economic and Social Council resolution 1112 (XL) have to be submitted.

3. The survey requested that the Secretariat pay due attention to these considerations. The present report on the resources of the sea beyond the continental shelf is presented in two parts, one dealing exclusively with mineral resources and the other concerning food resources excluding fish.

4. Part One of the report on marine mineral resources beyond the continental shelf reviews successively the present knowledge concerning marine mineral deposits and the techniques presently used or available for their exploration, evaluation and exploitation. This part has been prepared jointly by Frank Wang, Marine Geologist of the United States Geological Survey and the United Nations Secretariat.

5. The preparation of Part Two on food resources of the sea beyond the continental shelf, excluding fish was entrusted to C.B. Idyll, Chairman, Division

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of Fisheries Science, Institute of Marine Resources, University of Miami. It is based on an outline prepared by FAO in the course of its work on the Indicative World Plan for Agricultural Development (IWP), which will discuss fully the food potential of the sea. As the agency responsible, FAO has made available this and other draft background material from the fishery sector of IWP. C.B. Idyll's report deals with biological environment and a variety of problems arising when harvesting plankton, squids, whales, seals and the like. The possible limits of aquaculture are examined as well as the various types of research still needed for proper exploitation of the open sea.

6. The Secretary-General wishes to express his gratitude to Frank Wang and C.B. Idyll for their contribution to the work of the Secretariat.

7. The aim of the present report is to present the Economic and Social Council with a fairly comprehensive picture of the available knowledge on the subject. It is by no means exhaustive, but none the less it would provide a sound foundation on which more detailed and specific studies may be based and an adequate background against which they may be appreciated.

8. If the Council decides that the report should have a wider distribution, a number of figures would be added for illustration and a more comprehensive bibliography provided.

9. The following pages set out comprehensive summaries of both parts of the report.

## SUMMARY OF PART ONE

### Mineral resources of the sea beyond the continental shelf

1. There is no reason to doubt that substantial mineral deposits await development in the ocean environment beyond the continental shelf. They are becoming of increased interest and the Council may wish to be kept informed at regular intervals of associated developments in the scientific and technological fields as well as in closely related economic and legal domains.

2. Current technology, developing with great ingenuity, is already capable of locating and evaluating many of these deposits - though not always at an acceptable cost - but their economic exploitation is largely dependent on the development of greatly increased engineering capability. This in turn can only come about through our gaining a better and more precise understanding of the sea floor and its characteristics, the nature and origin of mineral deposits occurring on and below it and the marine environmental conditions which must be allowed for in the design and adaptation of the mechanical structures and other facilities required.

3. Because of the relatively high exploration costs and the vastly greater outlay on exploitation, operations in the ocean environment can only be contemplated by the very largest organizations in a few industrialized countries and will not be undertaken without reasonable expectation of economic development. They will only be justified if very large quantities of high valued products can be recovered at a cost which will permit competitive marketing.

4. Particularly in view of the large expenditure and inherent risks, it must be expected that would-be entrepreneurs will seek maximum safeguards for their investment, in the first instance by obtaining such exlucsive rights as may be necessary to offer the prospect of a fair return. At the same time, the legitimate interests of the world community as a whole must not be jeopardized by any undesirable activities.

5. All this presupposes the existence of some kind of administrative machinery with adequate authority to allocate exploration, exploitation and other rights over particular areas for specific lenghts of time and possibly for specific minerals; to determine the scale of fees and royalties and the proper use of their

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proceeds; to ensure systematic and orderly operations by the entrepreneur and afford such protection as he may reasonably expect. The establishment of such administrative machinery and its recognition by the international community appears to be a matter of some urgency.

6. Equally necessary, in the near future, is a decision at the international level on the outer limit of the continental shelf, which as presently defined is so imprecise as to leave virtually open the important question of where the exclusive rights of riparian countries cease to apply.

7. Among alternative concepts, which are examined in chapter V, for an appropriate administrative machinery exercising control over marine mineral development beyond the continental shelf, it may be noted that one body of opinion advocates a properly established international régime as being the most desirable to provide an orderly system by which the developed countries can develop the deep sea mineral resources on reasonable terms, at the same time ensuring that all countries - be they coastal or landlocked - will not be excluded from the benefits derived.

Marine mineral deposits

8. Mineral deposits occuring beyond the continental shelf, that is on the continental slope and the abyssal depths beyond, may be considered in three categories:

(a) Deposits associated with pre-existing geological formations of various ages now buried under the sea;

(b) Surficial deposits lying upon or immediately under the sea floor; particularly important are the chemical precipitates in process of formation in the ocean environment;

(c) Potential "deposits" in the form of unusual and mostly local concentrations of metals contained in solution in sea waters.

9. The first category may include any or all of those types of mineral deposits found in a similar geological setting on land - petroleum, gas, sulphur, salt and potash, coal, iron, as well as base, precious and rare metals, industrial minerals etc. There is however one important proviso - a majority of these are unique to the continental environment and are therefore not likely to occur in significant amounts in bedrock underlying the abyssal ocean floor, where only those metals associated with basic and ultrabasic igneous rocks, such as chrome, nickel, cobalt and platinum, are to be expected.

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10. In this category, the spectacular success of petroleum and gas development in many offshore areas throughout the world needs little elaboration; 16 per cent of the world's total oil production and 6 per cent of its natural gas come from offshore wells. With the list of new offshore petroleum discoveries growing yearly - United States of America, Mexico, Venezuela, Peru, Chile, Trinidad, Brazil, Nigeria, Gabon, Angola (Cabinda), United Arab Republic, Libya, Iran, Saudi Arabia, United Kingdom, Italy, Japan, Brunei, Australia are recent examples - continuous expansion is assured and possibly by 1980, 25 to 30 per cent of production may come from beneath the sea. Production to date has been mostly from nearshore areas of the inner continental shelf, which are still inadequately explored. Although the petroleum potential of the deeper water regions of the outer continental shelf and continental slope can only be evaluated tentatively, because of our meagre knowledge, there can be little question that they also contain substantial reserves of petroleum and related products which will come in for attention when technological development allows economic exploitation. It is theoretically conceivable that the continental rise - the apron of sediments sloping towards the abyss from the base of the continental slope - might also afford conditions for the generation and accumulation of petroleum but the almost complete lack of knowledge makes the question purely speculative at present.

11. The second category, surficial deposits, includes all the unconsolidated sediments lying on the ocean floor. Offshore placer deposits being exploited for tin, gold, diamonds, industrial minerals etc., in various parts of the world may conveniently be grouped in this category, but they are likely to be restricted to the continental shelf, with little importance in the slope and abyssal depths beyond.

12. Potentially the most important deposits in the group are the phosphorite being deposited on the shelf, slope and ocean floor and the manganese nodules found mostly on the abyssal sea floor; both these are being increasingly investigated by state organizations and commercial interests.

13. Phosphorite occurs on the sea floor in the form of blankets of nodules, flat slabs, pellets and rock-coatings, mostly confined to water depths of 20 to 200 fathoms in the outer continental shelf, upper continental slope and submarine

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banks. It has been recorded in dredged samples from many parts of the world and commonly forms in regions where deep cold waters rich in dissolved phosphate - from the decay of animal and plant remains, brought by rivers from land sources or from phosphatic sediments on the sea floor - are brought in large volumes to shallow depth by vigorous upswelling of ocean currents. As phosphate deposition also depends on a slow rate of offshore sedimentation, those areas of upwelling of desert coasts, with low rainfall and absence of large rivers, are particularly favourable, as for example along the Pacific coast of South America.

14. Of the known and potentially favourable areas - off southern California (United States of America) Baja California (Mexico) eastern United States of America, western South America, Australia, north-west Africa, Japan etc. - only the first three are being investigated in any systematic manner. It appears however, that the best submarine nodular phosphate, even after conventional processing, will only approximate to a low grade land product; further upgrading by chemical means may be necessary to produce a competitive product.

15. Manganese nodules have been reported from many locations on the ocean floor, generally at depths from 400 to 3,400 fathoms and therefore largely not subject to the exclusive rights of the riparian States. The nodules grow slowly on the abyssal ocean floor, the original sources of the manganese contained in the water probably being surface run-off in rivers from the continents and submarine volcanism. Chemical composition of nodules vary considerably with characteristic differences noted in Pacific, Atlantic and Indian Ocean occurrences. The maximum manganese content recorded, over 40 per cent in the Pacific, is still less than ferro-grade and battery-grade manganese ores from land sources. However, the significant quantities of other metals contained in the nodules - copper, cobalt, nickel etc., have resulted in their receiving considerable attention during recent years from the viewpoint of low-grade ores of copper, cobalt, nickel and manganese, rather than for manganese alone.

16. Although regional distribution is yet very imperfectly known, there is no doubt that the potential gross amounts of manganese and associated metals in ocean floor nodules are enormous. Numerous practical problems must however be solved before the vast economic potential can even be assessed, far less the nodules

commercially harvested and processed. For one, new extraction methods will be required to beneficiate the complex and metallurgically unfamiliar matrix of the nodules.

17. The third category of deposit, that contained in solution within sea waters, has come in for renewed attention by the recent discovery of hot spots in the Red Sea, where stagnant or semi-stagnant bottom waters show greatly abnormal concentrations of base metals and other mineral constituents. While the present exploitation from sea water of salt, bromine, magnesium and fresh water itself has no reason to extend far offshore, such unusual concentrations or higher valued metals in the sea - base, precious and rare metals - may one day warrant economic consideration beyond the shelf.

Exploration and evaluation

18. With due allowance for the additional problems to be faced when conducting surveys on and under the sea, mineral exploration and evaluation in the ocean environment involves a sequence of activities similar to that applied on land - geological review indicates regions favourable for broad exploration programmes, the results of which lead to more detailed prospecting and evaluation of deposits located.

19. Underwater mineral exploration has been pioneered by the petroleum industry which has successfully adapted land geophysical and drilling techniques for offshore work in many continental shelf areas of the world. These techniques, together with those developed from oceanographic and naval research and development programmes, have in fact produced a technology capable under most circumstances of locating and evaluating a deposit under the sea, not unexpectedly at a cost higher than on land.

20. The first major requirement is a suitable platform, usually a self-propelled surface vessel or perhaps a deep submersible, from which to conduct the various surveys. The critical need for accurately fixing the position of such vessels in prospecting for undersea minerals is met by many types of electronic navigation systems developed since the Second World War, while two well-tried procedures are commonly used to maintain the vessel's position relative to survey/sampling sites on the ocean floor - one is a mooring system using conventional anchors

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while the other, dynamic positioning, features auxiliary outboard propellers which control the ship's position.

21. The important task of charting the ocean floor has advanced with the use of sonic depth recorders whose echogram characteristics can provide much information on the nature of the sea bottom (sand, rock, mud) as well as its configuration. A further development, side-scan sonar, now enables man to see in the opaque oceanic waters up to a few hundred metres, and still further refinements are possible in sonic techniques.

22. As on land, an adequate understanding of the geological controlling factors is fundamental in the search for mineral deposits under the sea. In many cases, particularly that of petroleum, attractive prospecting targets are to be found in the seaward extension to the outer shelf and slope, of productive geological structures known on the coast or the inner shelf. In prospecting the surficial chemical precipitates, principally phosphate and manganese nodules, further studies of the factors controlling their origin and distribution would indicate potentially favourable areas and thus reduce unnecessary effort in random sampling.

23. Surficial deposits may be sampled by many types of bottom sampling device - grab samplers, dredge samplers, free-fall corers and mechanically-driven corers, all of which are limited in some aspect or other, particularly as regard depth of penetration. For economic minerals associated with bedrock, core drilling is indispensable - it is also the most expensive and time-consuming phase of mineral investigation, particularly in deep water beyond the shelf. There has been considerable progress in adapting drilling technology for deep sea work, both in the form of rigs mounted on surface vessels and machines operated on the sea floor by remote control - but there remains a great need to develop more efficient and less expensive drilling techniques for this task. Bottom photography and television are proving of considerable assistance, as for example in providing a means of viewing concentration of nodules on the sea bottom and in monitoring mechanical operations such as undersea drilling.

24. Of all the supporting services available to the exploration geologist, geophysics has generally been the most readily adaptable to undersea investigations. Continuous seismic profiling using sonic devices has become one of the most useful exploration tools for surveying the sub-bottom configuration. Airborne magnetometer

surveys are used extensively in reconnaissance petroleum exploration to give an approximate thickness of sedimentary sequences while gravity techniques have been developed for work in the ocean environment.

25. Marine seismic surveys, using both refraction and reflection methods, have been used for many years, principally by the petroleum industry. Although they have not yet been utilized, electrical and radiometric methods and the measurement of heat flow could also find application.

Deep water petroleum exploitation

26. Oil and gas dominate the history of profitable marine mineral development and as such technology in this field has advanced much more rapidly than in other offshore ventures. Reaching out into increasingly deeper waters, the industry has shown great ingenuity in the design and adaptaion of platforms for exploratory and production drilling, progressing from simple fixed platforms carrying normal land-type drilling rigs through floating pontoons for immersing in very shallow water to the development of sea mounted drilling platforms, self-elevating platforms, submersible barges and finally drilling ships and barges. Over 9,000 offshore wells have now been drilled with production established as far as 70 miles offshore, in water as deep as 285 feet. The accident rate incurred, despite maximum safeguards and highest quality of drilling crews, amply demonstrates the many hazards to be faced by drilling operations in the exposed and hostile environment of the open sea.

27. Mobile drilling rigs can today handle routine test drilling in 300 metres of water and may even be capable up to 1,000 metres; experimental drilling has been carried out at the far greater depth of 3,568 metres. This capacity far outstrips that of the more complex oil and gas well completion and production techniques. Whether installed above water or on the sea floor, producing facilities must be designed to withstand the elements during the twenty to fifty-year life of the producing field. Great advances have also taken place in this field with the development of large self-contained multi-well and multi-deck production platforms, directional drilling techniques, improved oil-well servicing and other systems for more efficient and economic exploitation. Divers using conventional equipment, deep diving techniques and submersibles, and more recently underwater robots, are all being utilized in the many underwater operational aspects of the industry.

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28. Deep water production techniques therefore, rather than drilling problems, limit oil exploitation in the ocean environment. Completion of production wells at depths beyond the continental shelf still requires technological advances but economic justification for them must come eventually, if not in the immediate future.

Ocean mining methods

29. Ocean mining operations today are limited to nearshore areas, mostly in protected calm waters and almost entirely for placer or other surficial deposits. As in the petroleum industry, exploitation capability will largely develop by progressing seaward from shallow waters to the outer shelf, slope and beyond, as economic justification allows. While awaiting technological advances and break-throughs in ocean engineering, being pursued by some government agencies, the mining corporations have been interested but not notably active in deep sea mineral development. The picture could however quickly change by interlock of ocean mining technology, offshore petroleum technology, and other branches of ocean engineering.

30. Of the water dredging systems now operating offshore - "clamshell", bucket-ladder and hydraulic - only the last, especially in its suction form, appears to have considerable adaptation potential for deep water operations, as for example in the mining of manganese nodules on the ocean floor.

31. Design studies are being carried out by a number of governmental and industrial organizations to devise systems in accordance with the rather limited knowledge of the characteristics of marine mineral deposits and marine environmental elements, and the capability of the various components from existing technology. Possible systems take in several concepts - dredge vehicles towed along the ocean floor, self-propelled bottom crawlers or wheeled vehicles and submersible hydraulic dredge vehicles with submersible ore hoppers to transport ore to the surface, to mention but a few.

## SUMMARY OF PART TWO

### Food resources of the sea beyond the continental shelf excluding fish

1. There are substantial non-fish food resources in the open sea beyond the continental shelf. Although an evaluation of their potential is made difficult by lack of reliable information, and their full harvest is beyond our present capacity, some living populations promise to yield significant quantities of food when one has learned to move with more confidence in the aquatic medium, and has discovered more about the ocean environment.

2. Much more intensive research is required on problems associated with the sea, and especially the open sea. The inability to make more efficient use of oceanic resources is largely a consequence of the lack of knowledge concerning marine animals and the ocean environment.

3. Man has little control over most of the factors that determine the survival of marine animals, but a better understanding of the complex interacting natural controlling factors would be very useful in increasing the efficiency of harvesting. One needs to know more about influence of the number of eggs produced, the amount of food, the numbers of predators and competitors, the temperature, and other physical factors of the environment.

4. One area which has been seriously neglected concerns diseases of marine animals and plants. Some of the unexplained large fluctuations in marine populations may be caused by epidemics. Disease organisms include fungi, protozoans, and bacteria. Their control is very difficult because we know so little about them, and we have almost no ability to manipulate the useful populations of fishes and other exploitable creatures in a manner that would permit treatment.

5. The greatest berrier to better use of high seas resources is the inefficiency of fishing operations. A great deal of time is spent in search and detection of concentrations of animals. Many populations which cannot now be exploited would become economically available if search and capture costs were reduced.

6. The necessary research includes more information on the nature of the water masses, the character of the living populations, and the development of

instrumentation. One must, for example, learn more about the normal situation in the sea, and the effects of variations from this norm. This will lead to prediction of effects of changes in the environment on the size and distribution of exploitable populations. Studies of the behaviour of animals will lead to better prediction of their distribution, and to the design of more efficient harvesting gear.

7. Many fishery regulations are falsely based, too many of them being unnecessarily restrictive. Most populations of marine creatures are still underfished, and could stand heavier exploitation. Except for mammals, the concept that reproducing animals always need protection has been a false one.

8. The full use of resources, to allow harvesting of the maximum sustainable yield, is the basis of modern conservation practices in the sea. But the establishment of rational regulations according to this basis requires painstaking and long research, and for many populations this has not yet been carried out. Measurement of the rates of growth and mortality, of recruitment and exploitation, of population size, must be made for thousands of different organisms.

9. The establishment of regulations for international fisheries beyond the continental shelf is especially difficult. Where several countries compete for the same stocks, conflict is inevitable unless there is mutual agreement for the sharing of the resources, and for their conservation. Biological research must be accompanied by economic and sociological investigations, and international co-operation is nowhere more necessary than in the area of exploitation of the resources of the open sea beyond the continental shelf.

Biological environment

10. In many fundamental respects the biological principles which apply on land are equally valid in the sea; but there are also important differences which render the two environments so unlike that new concepts must be developed and new principles of exploitation and management devised for ocean populations. The lack of awareness of the necessity for such a new rationale has delayed the progress in realizing the potential of the sea.

11. Among the similarities between oceanic and terrestrial ecology, the most fundamental and significant is that all life depends upon the capture

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of the energy of the sun by green plants. On land, most of the plants are large and obvious; many provide human food directly, and by far the greatest bulk of human food from the land consists of plant products. The next largest proportion of terrestrial food consists of plant-eating animals, the cattle, swine and other large herbivores. The whole immense complex of sea animals (whose variety and abundance are far greater than for land animals) is likewise based on the ability of plants to manufacture carbohydrates, fats and proteins from simple substances, using the energy of the sun and the catalyst, chlorophyl.

12. But the vast majority of marine plants are so different from typical land plants, and so small as usually not to be seen that their importance is missed by most observers. Discounting the relatively insignificant seaweeds of shallow shorelines, the oceanic plants are small, mostly microscopic in size. In turn, their grazers must be small in order to collect and eat them, so the equivalent of the cattle and swine of the land are crustaceans and other invertebrates, typically a few millimetres to a few centimetres in length.

13. The ocean environment includes many highly variable climates, differing in their patterns of temperature, salinity, light and pressure. Of these, temperature has the most profound effect on the abundance and distribution of marine plants and animals. In addition, the ability of light to penetrate the surface layers of the water determines to a great extent the productivity of a particular oceanic region, since the amount of light is proportional to the rate of photosynthesis or production of living material.

14. Another factor limiting the production of matter is the availability of nutrient materials. These are the same as those necessary for land plants, water, carbon atoms and such fertilizers as nitrates and phosphates. Water and carbon dioxide are always in abundant supply in the sea, but the fertilizers are often scarce, and their lack produces the deserts of the sea. These deserts are commonly in the open ocean.

15. Deserts are formed because the nutrients tend gradually to drift deeper into the water column, carried down in the bodies of dead animals and in their shells and waste products. In shallow water the bottom checks the downward drift of these minerals, and various processes stir them up and return them to the lighted water column where they can be used and re-used by the plants. In many parts of

the open sea, however, especially in mid-latitudes, the minerals continue to drift downward, and may be permanently lost to the plants.

16. The productive areas of the ocean are those where some mechanical process returns the nutrients to the surface. Seasonal temperature changes, which serve to lower the density of surface waters and cause them to sink and force deep water to the surface, constitute one of these processes. Others are upwelling due to coastal waters being swept away by prevailing winds, river outwash, and oceanic currents moving upward under the influence of islands and other obstructions.

17. The total amount of life in the sea, and therefore, the total amount of food man can harvest there, depends finally on the amount of primary production of plant substance. When plant material has been created it forms the broad base of the food pyramid in the sea (or the first link in the food chain). The other levels in the pyramid are the herbivore animals that consume the plankton, the first level carnivores that eat the herbivores, and the second and subsequent level carnivores that eat these.

18. Estimates made of the total productivity of the sea have varied considerably, the variation being largely due to our ignorance of the rates of production of material by plants and the losses between trophic levels. Estimates have tended to become smaller as the amount of information increases. One made by the United States National Academy of Sciences-National Research Council places the total annual productivity of the ocean at $19 \times 10^9$ tons of carbon.

19. Starting with such an estimate of total primary productivity, and calculating losses through each step of the food chain, estimates can be made of the total potential amount of potentially usable material from the sea. Widely differing totals have been arrived at by various experts. For "level 5 production", where much of the world's harvest takes place, values range all the way from 13 million tons to 1,050 million tons of organic substance. These do not represent the total amounts available to man since not all are useful as food, nor can all the useful components be harvested. The realizable totals are much larger than the present harvest, however, and this is especially true of the seas beyond the continental shelf. The amount of increase that can be achieved depends to a considerable extent on a better understanding of ocean ecology.

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Plankton

20. The small oceanic plants and herbivores drift together in the upper layers of the water, and are collectively called plankton. If one could learn to harvest and prepare plankton as food one would be able to tap the greatest food resources in existence. Unfortunately, the outlook for this is poor.

21. In the case of the plankton plants there is little hope that any use will be made of them for human food. In addition to their small size many of them have glassy, cellulose or calcareous exoskeletons which render them inedible. Some kinds are poisonous. They are expensive to collect.

22. The prospect of harvesting animal plankton is almost as gloomy, although there are possibilities for certain of the larger kinds. The animal plankton consists of an enormous variety of creatures, the most important of which are many kinds of crustaceans. Copepods are the principal zooplankters, with euphausids also being numerous and important.

23. While plant plankton is largely inedible, there is enough experience with the human consumption of some forms of animal plankton to suggest that it can be made palatable for many people.

24. In recent years Japan and especially the Soviet Union have investigated the possibility of harvesting one of the most abundant and the most densely swarming kinds of zooplankton, the Antarctic krill. While there is some chance that it can be made directly into human food (and the Japanese are investigating this) the most likely large use of the krill would be for the manufacture of meal, to be fed to domestic animals.[1/]

Squids

25. The squids represent a vast potential food source for man from the open sea, but its capacity is barely being scratched.

26. The squids are members of the *Mollusca*, which also includes popular seafoods such as the clams, oysters and mussels. They are distributed widely over the ocean, and are characteristically animals of the open sea. Some species which are already of economic importance, or which could be harvested, occur over very wide areas of the ocean.

1/ FAO is promoting work on scientific and technological aspects of the use of unconventional resources such as krill.

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27. Squids are used for food in Japan, southern Europe and in some other areas; they are used for bait and are made into meals for feeding poultry in some regions.

28. The lack of popularity of squids as food is related to their appearance and the toughness their flesh sometimes exhibits. But their flavour is somewhat similar to clams and oysters. If squids are properly prepared, the toughness can be overcome. The nutritional value of squid meat is high. It contains most of the same essential amino acids as fish flesh, which is notably high in these important elements of human nutrition. Squids contain larger amounts of some animo acids than fish; in other (histidine, lycine, methionine) the content is lower than that of fish flesh. Since squid flesh provides high quality human food, it is also suitable as fodder for domestic animals, and the meal made from squids can be of high quality.

29. Reasonable estimates of the quantities of squids available for exploitation cannot be made in view of the lack of information about them. But what data are available indicate that the stocks are extremely large. These animals will undoubtedly support large commercial fisheries in the future in many parts of the world. Among the most promising areas are the Gulf of Guinea and the waters off Chile and Peru.

## Whales[2/]

30. About twelve species of whales have been hunted commercially. The sperm whale is the only species of the toothed whales which is of high commercial value, the others all being representatives of the baleen whales.

31. The fishery and conservation of whales are greatly influenced by their biology. Since they are air-breathing mammals they must come to the surface to breathe and this, with their comparatively slow swimming speed, makes them highly vulnerable to fast vessels and explosive harpoons. Because they produce only very small numbers of young, whales are unable to withstand heavy exploitation, and stocks once depleted by overfishing are very slow in recovering.

32. Although oil was the major product from whales in the early days of the fishery, other sources have made this of less relative value. The flesh is eaten by the Japanese and other peoples, and this could be of great importance

2/ A number of problems mentioned in this and following sections of this summary (paras. 30-40), particularly on antarctic whale resources and the scientific appraisal of seal stocks, are already receiving close attention by specialized international bodies with the active participation of FAO.

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now that refrigeration allows the meat to be returned to port in good condition. Much of the carcass can be made into meal and animal food.

33. Since the invention of the harpoon gun in 1864 the efficiency of whale catching has improved steadily. Now very large factory ships accompany catcher boats to the fishing grounds, and the location, pursuit and capture of whales is rapid and efficient. Until very recent times the major fishing grounds were the Antarctic, but as southern stocks have declined, the emphasis has shifted to the North Pacific.

34. The trends of landings of whales have been sharply down for many years. Some species are critically low. The catch of the blue whale was nearly 30,000 in 1930/31, but only 372 were caught in 1963/64.

35. The international whaling Commission has attempted to check the serious status of whale stocks by suggesting regulations on the fishery. These regulations have included closed seasons, and quotas of catch. But the sharp competition among various countries for the dwindling harvest has caused those engaged in the fishery to ignore the regulations for the most part.

36. Whales still represent a large and important high seas resource of food and other useful materials, but unless greater wisdom is used than in the past by those engaged in the industry, this resource will be permanently lost.

## Other marine mammals

37. Like the whales, other marine mammals have been exploited for several centuries. Seals, sea lions and walruses comprise a relatively small group of marine mammals of economic use to man. They have been hunted largely for hides and oil; to a lesser extent their flesh and other products have been used. As a group these animals are few in number and they do not constitute a major resource.

38. Being mammals, the seals and their relatives must breathe air, and they depend on the land as a place for reproduction. These characteristics make them more vulnerable to capture than oceanic fishes, and reduce their capacity to withstand heavy exploitation since the low rate of reproduction rebuilds depleted stocks very slowly.

39. Only about twenty species have been exploited. The southern sea lion, the Pribilov fur searl, the South American fur seal, the walrus, the harp seal, the banded seal and the hooded seal are among the most important of these. Their commercial value is much less than formerly, since over-exploitation has reduced some stocks to remnants.

40. The amount of food and other valuable materials available to man from these mammals is never likely to be large. But the hides, and, to some extent, the oil and meat, make it worth while to engage in international co-operation for the restoration and maintenance of these stocks. This management should probably be based on the successful model of the Pribilov fur seals, undertaken by the United States of America, Canada, the Union of Soviet Socialist Republics and Japan. Here, herds which had been reduced to an estimated 150,000 animals have been restored to about 1 1/2 million, and catches of 62,000 skins a year is apparently close to the maximum sustained yield.

Aquaculture

41. Only 2 to 3 per cent of man's food comes from the sea, and one of the principal reasons is that one is obliged to obtain all other seafood by catching wild stocks. If one could learn to control the production of sea animals and plants in marine farms a great step forward would be taken.

42. There is considerable misconception with regard to aquaculture. It will not be feasible to cultivate marine plants, except on a small-scale comparable to the Japanese seaweed culture. This is because most marine plants are small, free-floating and unsuitable for food. The large seaweeds are relatively unutritious and would not be acceptable to most people. Further, the areas suitable for their culture are restricted to unpolluted, shallow water.

43. The most common mistaken idea about aquaculture is that extensive areas of the open sea may somehow be enclosed and useful animals protected, fed and bred there. Most of the valuable marine organisms of the open sea are large, swift-swimming active animals, requiring such large areas of open ocean and large amounts of food and oxygen that their herding would be impractical.

44. The existing aquatic farms are at the edge of the sea. Marshes and estuaries, commonly regarded as waste lands, are instead very productive. Such regions can produce more protein food per acre than the richest of land farms.

Shallow water culture has been practised for centuries, especially in Asia, but only in very recent years has scientific control been applied to any such ventures. There is great promise in this field for the increased production of molluscs, crustaceans and certain kinds of fishes, especially herbivores. Eventually the full control of the life cycle must be attained, brood animals being produced so that selective breeding can be carried out. But it should be noted again that this kind of control of the aquatic environment and animals will probably be restricted to the edge of the sea. The seas beyond the continental shelf will not be farmed in the foreseeable future.

Artificial overturn of deep water

45. There is, however, another kind of environmental control which may be possible in the deep sea. This is the artificial overturn of deep water to bring mineral nutrients to the surface.

These nutrients are trapped below the thermocline, the layer of rapid reduction in temperature which prevents the natural return of deep water to the surface. The nutrients are only useful to the plants in the upper lighted zone of the ocean where photosynthesis can take place. In regions of the ocean where natural overturns do not take place, the productivity of the ocean might be greatly enhanced by forcing the deep water to the top. But preliminary theoretical calculations of the technical and economic feasibility of this procedure suggest that our technology must advance before it can be considered seriously.

46. Power for this purpose might be supplied by either pumping or warming the deep waters to cause artificial upwelling. If a 64 kilometre square area is to be overturned a vertical distance of 50 metres, $7 \times 10^9$ kW. of power would be needed. This would require the output of hundreds of our present nuclear reactors, at a cost of $200 million. Other methods also show extremely high costs.

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