OLOGY AND ENVIRONMENTAL PROTECTION IN THE PACIFIC REGION

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Papers and abstracts included in this collection embrace a wide range of ecological and environmental problems which have been discussed at the XIV Pacific Science Congress. The collection is of interest for scientists and specialists engaged in these problems.

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FOREWORD

The XIV Pacific Science Congress which was held in Khabarovsk, USSR, in August-September 1979 has been attended by some 2000 scientists from 46 countries deeply interested in the solution of the present-day problems of human society and in its future.

The main theme of the Congress, Natural Resources of the Pacific Ocean for the Benefit of Mankind, demonstrates an enormous interest in the Pacific region which is in many respects vitally important for mankind. This theme, closely related to the goals of the Pacific Science Association - to develop and encourage the cooperation in the solutions of scientific problems of the Pacific region, especially those which influence the prosperity and welfare of the Pacific peoples - is very broad and diversiform. At the sessions of 14 Scientific Committees of the Congress and its 93 Symposia, more than 1500 reports concerning various problems of natural sciences, development of natural resources of the Pacific, medicine and health service, nutrition, scientific relations and education, social and humanitarian sciences, have bee presented. Considerable attention has been paid to the problems of the conservation of the ecological equilibrium in the ocean and of the protection of the environment on islands and in coastal areas.

There is no necessity to emphasize that in search of the solution of the problems concerning the society development, due regard for environment conditions is of decisive importance. It applies not only to the control of the level and varieties of environmental pollution, but also to the preservation and increase of the most important renewable natural resources. The Executive Director of the UNO Program on the Environment (UNEP) which advocates the economically grounded development, the development without disturbances of the environment, Dr. M.Tolba has emphasized that the optimum development process should be aimed principally at the satisfaction of main vital requirements of the present and future generations, without trespassing the limits beyond which the man's activities cause disturbances of the biosphere.

Taking into consideration that the very important place in the program of the XIV Pacific Science Congress has been assigned to the environmental protection, the Academy of Sciences of the USSR has invited the representatives of UNEP to take part in the work of the Congress. The contribution of UNEP, including the financial one, has made it possible for 42 scientists from 14 developing countries of the Pacific and Indian Ocean regions to take part in the Congress work. This has shown that interests of this organization in the protection and conservation of the environment are far from being narrow.

Half of the population of our planet live in the Pacific region. The Pacific is the largest and deepest ocean with a half of all water of the World Ocean. This factor determines the significance of the Pacific basin in natural processes of our planet and in the mankind's life. These processes regulate life conditions on the whole Earth. Waters of the ocean form the climate, control the weather, and represent a source of humidity and an accumulator of heat for a considerable part of our planet. Geological phenomena in the oceanic crust of the Pacific influence geological processes on continents; without studying the geology of the ocean it is impossible to reveal the whole geological history of our planet, to understand the regularities of the Earth's crust formation and the distribution of mineral resources in it. Hence, primary attention is attached to the study of the ocean, and of all the diversity of natural resources in it and around it, which is a leading scientific problem of our time.

The study of the World Ocean in the USSR is considered to be a state problem. The Secretary-General of the Central Committee of the CPSU L.I.Brezhnev said at the 25th CPSU Congress: "Global problems such as primary materials and energy, the eradication of the most dangerous and widespread diseases, environmental protection, space exploration, and the utilization of the resources of the World Ocean are already sufficiently important and urgent. In the future, they will exercise an increasingly perceptible influence on the life of each nation and on the entire system of international relations. The Soviet Union, like other socialist countries, cannot hold aloof from the solution of these problems which affect the interests of all mankind."

The USSR with its outlet to the Pacific stretching over several thousand kilometers has been carrying out a comprehensive study of the Pacific basin for several centuries.

The first substantial geographical contribution was made by Russian navigators of the Great Northern Expedition already in the 17th century. V.Bering and A.Chirikov discovered the Aleutian Islands, the Bering Straits, and the western coast of North America. In the 19th century Russian expeditions of I.F.Krusenstern and Y.F.Lisiansky (1804-1806), and of O.Kotzebue (1823-1826) carried out specialized oceanographic observations to study the physical properties of water, deep-sea phenomena, etc. These investigations were successfully continued and expanded by S.O.Makarov on the vessel Vityaz (1886-1889). He was the first to formulate the regional characteristics of the Pacific Ocean and elaborate some fundamentals of oceanology.

The Soviet Union highly appreciates contributions of other countries to the study of the Pacific Ocean. In this connection it is necessary to mention the excellent expeditions of an Englishman James Cook (1968-1779), of Frenchmen Bougenville (1768) and La Perouse (1785-1788), and of the English expedition on board the famous vessel Challenger (1872-1876).

The study of the Pacific Ocean assumed especially wide scope in the last three decades.

The 65 voyages of the research vessel Vityaz resulted in a complex study of the ocean that was summed up in a monograph The Pacific Ocean. In these years the whole scientific fleet of the USSR Academy of Sciences was built, including such famous vessels as Akademik Kurchatov, Dmitry Mendeleyev, Akademik Vernadsky, and many others.

The range of oceanic investigation carried out by USSR is very wide. Involved in it are tens of institutes of the USSR Academy of Sciences, the USSR State Committee for Hydrometeorology and Environmental Control, the Ministry of Fisheries, the Ministry of Marine Fleet, etc. The creation of the Far Eastern Scientific Center of the USSR Academy of Sciences, the advanced post of science in the Far East, resulted in a wider range of scientific investigation in the Pacific basin. This is a long-term, planned work which is carried out according to a wide-scale program. The materials prepared by the Far Eastern Scientific Center, the Institute of Oceanology of the USSR Academy of Sciences, and other institutions specially for the Congress, give a full idea of its scale, range, and complexity.

The Soviet Union has built a powerful scientific and technical base studying the World Ocean, including the Pacific, and it is prepared for close international scientific cooperation.

The Pacific region is an extensive depository of natural riches, a source of biological, mineral, and energy resources. To study this depository and to make it serve mankind is the task deserving special attention of the world science. The future of mankind is connected, to a considerable extent, with the exploitation of ocean rescurces. At present the Pacific Ocean is of great importance in providing food stuffs, as it gives more than 60% of world fish catches and holds first place in the output of seaweeds, shellfish, and other sea products. In view of this, the XIV Pacific Science Congress has attached a great attention to biological productivity of the ocean, the sea industry, and to the laws of life evolution in the ocean.

Biological investigations are very important for the fishery and collection of sea products. They are carried out by many oceanologic and fish industry institutes. For instance, a mathematic model of tropical plankton assemblages of oceans has made it possible to predict their main way of evolution as well as the productivity of various groups of plankton. Investigations in southern parts of the ocean helped to evaluate krill reserves and to specify recommendations for the level of catches. Specialists have elaborated scientific methods for evaluation of potential productivity of bioresources in the littoral oceanic zone.

Investigation of the fauna of deep-sea trenches in the Pacific Ocean has revealed unknown earlier species, genera, and families that inhabit the ultra-deep-sea zone. For the first time deep-sea fish species were studied. Scientists have refuted the notion of the so-called "cosmopolitanism" of ichthyofauna; different ocean regions are inhabited by different species of fish. This regularity is used when searching for new promising zones of fishery. In the near future mankind will apparently be engaged not only in catching in seas but will prefer to create sea farms for breeding sea products. The problem of the aquaculture development - a sea equivalent of the agriculture on land - is one of the promising themes.

In spite of the fact that geological investigations of the Pacific floor have been carried out only during the recent 20-30 years, even now we can speak of its immense mineral resources. Offshore zones of many islands and continents are known as the prominent suppliers of non-ferrous metals.

Geological investigation of the Far East, North East, Kamchatka, and Sakhalin won general recognition. Scientists determined the regularities of geological structure, formation and distribution of mineral deposits that are of great importance for the whole northern part of the Pacific Ocean and its continental framing not only of Asia but of America as well.

With scientific data received on continents, we have the opportunity to know better the wast space of the ocean floor, its structure, geological history, and raw material prospects. Scientists study in detail the submarine topography. They discovered and investigated many submarine ridges, spurs, and trenches, elevations and mountains. On the map appeared the Vityaz Trench, the USSR Academy of Sciences and Shatsky Elevations, and the Sysoyev Mountain. The maximum depth of the World Ocean, 11,022 m, was discovered in the Mariana Trench.

There are notable successes in studying the geology of the ocean floor. Until recently scientists had a vague idea about it. Bathymetric, tectonic, lithological, and mineralogical maps of the ocean showing a great geological complexity of the ocean were compiled. These investigations are already of great practical importance. Large accumulations of iron-manganese concretions containing nickel, cobalt, and some other elements, were discovered. These can be exploited. The ocean floor is full of surprises. Quite recently thick accumulations of metal-bearing silt containing polymetals were found at a large depth in some rift zones. Being very insufficiently studied now, in the future these can be exploited too.

The significance of the Pacific shelf as a source of liquid and gaseous hydrocarbons is already quite indisputable. In the near future the Pacific shelf will be one of the main suppliers of oil and gas. Scientists have proved commercial oil and gas productivity of shelves in Southeast Asia, the Arafura, and Tasman Seas. We gain additional information of prospects for searching oil and natural hydrocarbons not only in shallow-water areas but at larger depths than shelf, which extends the prospects of our planet for oil and gas.

Geological and geophysical investigations of the structure of deep layers of the ocean floor, which are accompanied in some regions by deep-sea drilling carried out in close international cooperation, have opened a new stage of the comprehensive study of the floor of the World Ocean and the Pacific as its part. Successes in this field help to understand better the regularities of our planet's evolution, causes of tectonic movements and submarine volcanicity, seismic activity and the origin of disastrous waves of tsunami. Having studied the ocean floor we begin to understand better the geological structure of continents. It is also necessary for the more complete understanding of the mineral potential of the planet as the whole, including the World Ocean.

Water is the main natural resource of the ocean, and its study allows to determine navigation conditions, heat and mass exchange between hydrosphere and atmosphere, and finally, the weather and climate of our planet. Soviet geophysicists, hydrodynamists, meteorologists concentrate on these problems. For the whole Pacific Ocean they studied the micro-scale distribution of temperature, salinity, and density of water and determined the scheme of water circulation. The system of equatorial sea currents, the Kuroshio and Oyashio currents, the Peruvian upwelling zone were studied in detail. Determination of some regularities in the formation and development of meanders (circular currents) and synoptical vortexes (so-called "rings") in the Kuroshio area that notably influence the climatic processes in adjoining regions is of great importance. Data on the dynamics of the Kuroshio current are necessary for weather forecasting.

It is very essential to penetrate deeper into the mechanism of interaction between the ocean and the atmosphere. Soviet and American scientists proved that intensive heat exchange between the water and air covers blockades the zonal transportation of air masses and leads to radical changes in the atmosphere, which is of great importance for a long-term weather forecast. For this purpose " hydrogeological sections" are carried out in the Pacific Ocean to determine the influence of heat storage of water on weather and atmospheric processes and to study the origin, evolution, and movement of typhoons in the Pacific Ocean and its "reaction" on them. Thus, the interdisciplinary expeditions "Typhoon-75" and "Typhoon-78" revealed characteristic features of the typhoon origin in the process of large-scale interaction between the ocean and the atmosphere.

The protection of the Pacific Ocean against pollution is an urgent problem of our day. The society armed with modern techniques interferes in all natural environments, including the World Ocean. The latter is no longer boundless and bottomless as it seemed earlier. Its natural resources are not so inexhaustible, and waters are not so immense that an unlimited amount of industrial and domestic wastes could be thrown therein. The violation of the ecological balance may lead to fatal consequences.

The participation of the UNEP representatives in the work of the XIV Pacific Science Congress is an evidence of such an enormous attention which should be paid to the protection of the oceanic environment.

Taking into account the necessity of a careful study of the South Pacific environment for working out the program of the environment management, at the XIII Pacific Science Congress in Vancouver, UNEP had called to joint efforts in the study of the environment of this region. During the past years, together with the South Pacific Commission, South Pacific Bureau on Economical Cooperation, and ESCAP, UNEP has carried out a thorough preparatory work on the South Pacific Regional Environmental Program which includes the estimation of the environment conditions in the South Pacific countries. Results of this work represent the basis for the decisions on regional environmental problems, especially those concerning coastal fish resources, determinations of joint actions, and main trends of the development which does not damage the environment.

In other regions of the Pacific, UNEP also has worked in close contact with other UNO institutions, intergovernmental organizations, and governments on the realization of the program on the environment. In the East Pacific, together with the Permanent Commission on the South Pacific, UNEP realizes the program of the protection of coastal waters and adjacent lands from Panama to Chile. In cooperation with the Association of Southeast Asian Nations and ESCAP, UNEP is preparing the plan to protect coasts and coastal waters of the South China and East China Seas, and of countries of Indonesian Archipelago and North Australia. A number of other programs for the Pacific region was also approved by UNEP.

I have touched only several problems arising in connection with the study and exploitation of natural resources of the Pacific Ocean. As scientists penetrate ever deeper into the secrets of the Pacific Ocean, they realize that only the mutual efforts of scientists from different countries can help to understand, study, and make the ocean resources and nature serve mankind. Only synchronous observations can help in solving all problems of the natural evolution of the Pacific Ocean. The study of all processes occurring in the ocean is of global character. The Chairman of the Presidium of the Supreme Soviet of the USSR L.I.Brezhnev said recently: "In recent years international scientific cooperation has acquired such a scope which never existed in the past."

The global scale of the natural processes occuring in the ocean demands simultaneous observations over a vast territory. Only international cooperation makes it possible to concentrate in a certain region of the ocean the necessary amount of research vessels and measuring equipment. Examples of high efficiency which is given by the combined efforts of scientists from different countries are the cooperation between oceanologists of the USSR and USA; the wide international cooperation in the study of the geology of the ocean with the help of deep-sea drilling by the US vessel Glomar Challenger; the international programs of the study of the Pacific Ocean that are carried out under the aegis of the Intergovernmental Oceanographic Commission (IOC) of UNESCO; the cooperation between Soviet and Japanese scientists in marine geological and geophysical investigation of the northwestern part of the Pacific Ocean in the framework of the International Project on the Upper Mantle of the Earth. The experience of the international cooperation shows that it is possible to use more fully the scientific data on the Pacific Ocean.

The principle of a peaceful coexistence of countries is a guarantee of the successful development of economic and technical cooperation between countries in the Pacific Ocean basin. It is a reliable basis for successful joint investigations of the Pacific and for cultural relations between peoples living on the coasts and islands of the Great Ocean.

The XIV Pacific Science Congress has given scientists from different countries an opportunity to get together in order to discuss common problems and latest achievements, to suggest new ideas and compile the plan of further joint works.

The participation of UNEP in the work of the XIV Pacific Science Congress has made it possible to prepare this collection of papers and abstracts submitted to the Congress by scientists from various countries and elucidating problems of ecology and environmental protection in the Pacific region.

A.V.Sidorenko

Vice-President of the Academy of Sciences of the USSR
President of the XIV Pacific Science Congress

C O N T E N T S

PROBLEMS OF SCIENTIFIC INVESTIGATIONS CONCERNING THE ENVIRONMENTAL CONTROL AND RATIONAL USE OF NATURAL RESOURCES IN THE PACIFIC BASIN

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Conditions in the Pacific basin are favorable for the solution of many fundamental and applied problems of natural and social sciences. Some problems of the natural history were solved just here. Recently, the Pacific region has been playing a very important role in the solution of economic, demographic,and social problems of the planet. Therefore, the investigations carried out by the Pacific Science Association are becoming extremely important for the world science and whole mankind. One of the major problems is environmental conservation and rational use of natural resources.

To distinguish the basic problems and to make reserarch less expensive it is necessary to coordinate the national and the international investigations and to correlate the numerous projects and programs.

The International Geological Correlation Program consists of several projects successfully carried out in a number of countries. The project on the correlation of granitic magmatism in the Pacific zone, which is headed by Prof. P.Bateman (USA) proved to be one of the most fruitful undertakings. The studies deal with fundamental problems of magmatic geology and supply information on the relationship between mineral deposits and Mesozoic granitoids. Geologists, particularly from Malaysia, Thailand, and Indonesia, advocate that tin mineralization is associated with the Mesozoic intrusive magmatism. Many Soviet scientists also support this concept and regard Pacific granitoids as an example of specialized magmas. The gold mineralization which coincides in time with the formation of the Mesozoic granitoids and the origin of many other mineral deposits are thought to be connected with the same magmatism. However, thorough investigations suggest that the Mesozoic granitoid magmatism was only a background for the various mineralization processes, having no genetical connections with them.

The Geological Correlation Program includes some other projects carried out in the Pacific region and concerning, in particular, the studies of Neogene deposits and ultramafic magmatism.

Another Soviet-American agreement is based on The Geodynamic Project which has been worked on for several years by a number of Far East scientific institutions including the Institute of Oceanology (Vladivostok), the North-East (Magadan) and Sakhalin (Yuzhno-Sakhalinsk) Interdisciplinary Scientific Research Institutes, the Institute of Volcanology (Kamchatka), the Institute of Tectonics and Geophysics (Khabarovsk), etc.

The Geodynamic Project gives certain hopes for more insight into the basic problems of geology.

The heart of the matter is that the fundamental geology of today undergoes something like a crisis of concepts which arose from the controversy between two trends, those of the so-called fixists and mobilists. Indeed, the role of the very common in the Pacific basin island arcs and volcanic belts in the structures of the Earth's crust is still fairly obscure. For instance, essential differences between the arcs and the belts are still underestimated. These differences, however, are so profound that unless the origin and development of volcanic belts and the island arcs of active volcanism is clearly understood, it is hardly possible even to compare the former with the latter.

Two other international projects are the Geological Map of the Pacific and Deep-Sea Drilling.

The agreement on composing the geological map of the Pacific, which was signed in Honolulu, envisages the participation of several countries of the Pacific basin in this work. It will be the first joint work of scientists of various countries on such a vast region of the palnet. The analysis of the geological data involved will permit us to elucidate a number of regularities in evolution of global structures of the Earth.

The deep-sea drilling, too, will supply information on the problems exceeding the limits of regional ones. For instance,the results of drilling in the Pacific region have led to the revision of many concepts concerning the evolution of the Earth's crust, the composition and age of rocks of the ocean floor, etc. Both projects are extremely important for the formation of ideas about the mineral resources of the region.

The working groups of the International Union of Geodesy and Geophysics and the International Union of Geological Sciences have prepared the project of an international program The Lithosphere: Frontier for the 80's, whose section The Special Problem of the Continent-Ocean Transition appears especially interesting for the scientists of the Pacific region. In fact, it is in our region where with the help of the unique data obtained by Soviet,Japanese, American , Australian, and other scientists a lot of controversial issues may be resolved in such fields as intrusive and extrusive magmatism, the dynamics of evolution of the oceanic crust, and mineral formation (including minerals of rare metals) in both the oceanic environment and the continent-to-ocean transition zones.

The next group of investigations united by various international programs and projects concerns the water masses of the Pacific Ocean and its seas and their relationship with atmospheric processes. The studies have for an object not only Pacific problems, but also global ones which are of interest for countries of Asia,Europe, South and North Americas, Africa, and Australia. Such programs include the projects Geodynamics, Cooperative Investigations on Kuroshio (CIK), studies on Western Pacific (WESTPAC), the interdisciplinary investigation of the Southern Ocean, investigation of global atmospheric processes (PIGAP).

The study of the dynamics of water masses has to reveal the macro- and the microstructure of currents, the structure, generation, and development of geophysical fields. These problems were discussed at the symposium CIK-IV and at the First session of the WESTPAC working group in Toko within the framework of the Intergovernmental Oceanographic Commission (IOC). It was suggested to promote investigations on the structure of frontal systems, the processes of vertical exchange in the divergence zones and island systems, the formation of meanders and vortexes in powerful currents of the Kuroshio type, and the influence of these processes on the general circulation in the Western Pacific. Another field to be developed is the physical oceanography of the offshore seas and the continental shelf of the Western Pacific.

Investigations of the dynamics of the Kuroshio current involved over 270 ship expeditions carried out by the USSR, Japan, the USA, Thailand, and other countries. The expeditions revealed annual and seasonal variability of the current, the position of Kuroshio in the ocean, the basic mechanisms of its formation and major anomalies. The fluctuations of the ocean level under the effect of Kuroshio were established. Finally, the interrelation was found between oceanographic conditions and atmospheric processes in the Kuroshio zone, as well as the dependence of certain dynamic parameters of Kuroshio on the topography of the sea floor south of Japan.

Among the properly oceanological investigations of the Pacific, the works on the Soviet-American project Investigations of the Southern Ocean approved in 1975 are of great importance. The final session in Cambridge (1978) demonstrated that the project had revealed unique features of this oceanic area, where the Antarctic circumpolar current with its hydrological fronts developed on the complex topography of the floor gives rise to powerful vortex formations. The correlation of these phenomena with atmospheric processes can result in the creation of a model for the climate formation.

Soviet scientists have discovered the so-called synoptical vortexes in the open ocean. The vortexes play an important role in the transfer and transformation of mass and energy in oceans: in central parts of cyclonic vortexes cold water rises from the depths, while in axial parts of anticyclonic ones warm water descends into the depths. It would be interesting to look for the similarity between these phenomena and cyclonic and anticyclonic atmospheric processes. Mathematical and physical modeling of energy exchange channels in both cases could help to relate climatic processes to hydrodynamic phenomena in the World Ocean.

A major problem concerning the cyclonic and anticyclonic oceanic vortexes is their influence on biological processes in connection with the heat and mass exchange.

In view of the seismic activity in the Pacific region the investigations of tsunamis are becoming extremely significant. An agreement between the USSR and the USA implies the development of methods for tsunami forecasting and warning the population. The USSR, USA, and other Pacific countries have created a special tsunami service.

As no other water area on Earth, the Pacific Ocean possesses such unique objects as island ecosystems almost untouched by technogenic processes. Certain islands in the Pacific are of a great ecological, geographical,biological, and geological interest as relatively closed natural systems, where the laws of autochthonous evolution of certain components and groups of components may be revealed. Due to the relative isolation of the islands in time and space they may be regarded as meeting the criteria of similarity to mainland ecosystems.

The development of the ocean and the continental shelf is becoming more intense, and island ecosystems inevitably suffer from a greater anthropogenic impact. Thus their importance for science increases. During the last five years Soviet scientists achieved an appreciable success in the studies of insular biotas. Conceptual models of the complex spatial and constitutional evolution of the ecosystems and their components were created on the basis of these data. Theoretical concepts resulted from the study of island ecosystems make it possible to assess the position of certain continental ecosystems in the mainstream of evolution, thus contributing to the designing of an optimum scheme of the use of natural resources on the continents.

The study of island ecosystems is also a basis of a general eco-geographic concept of the migration of mass and energy between aqueous, subaqueous, and aerial ecosystems. At present such problems as, for instance, the resistance of island ecosystems to various anthropogenic influences or the economic, social, and demographic aspects of the orgin of population on islands are not studied profoundly enough. All these problems form a vast field of future joint investigations within the program Man and Biosphere. According to this program, the Far East scientific institutions of the Soviet Union are carrying out studies on the project Ecology and Rational Use of Island Ecosystems. The 1978 Conference on the porject summed up the results and advanced the plan for future research.

Thus, the pooled efforts of the Pacific countries have resulted in an appreciable body of information in various fields which permits us to outline the plans of future investigations. Their general aim is the monitoring of anthropogenic impact on nature, conservation, and rational use of natural resources of the ocean for the benefit of mankind.

Unfortunately, the research projects of the Pacific countries on biological resources seem to lack international coordination. Of course, there is a number of elaborate national projects. Thus, Japan carries out complex investigations in the Northwest Pacific, as does the Soviet Union in the seas of Japan and of Okhotsk, Bering Sea and the open ocean. New Caledonia and Papua New Guinea works on tuna are worth serious attention. Indonesia, India, Vietnam, and other countries are working both on the problems of bioresources in general and on commercial sea species in various areas.

Nevertheless, all these projects do lack coordination, general concepts, and common methods of productivity assessment. Determination and prediction of biological productivity thus becomes less efficient and solving the problem of rational use of bioresources is impeded.

Over a half of the Earth's 4.2 billion population is connected with the Pacific Ocean. In this region such problems as nutrition and environment conservation are especially acute. Calculations show that mankind could annually obtain from 80 to 90 million tons of fish and seafood, and with regard for krill this figure reaches 100 to 130 million tons. These products could largely be supplied by the seas and the open areas of the Pacific Ocean.

The growing demand for protein can hardly be met at the expense of natural reproduction. An artificial reproduction of biological resources is successfully studied in many countries, including the USSR, USA, Japan, and others. For instance, Dr. Bardach (USA) suggests that the annual productivity of mussels is up to 300 t/ha, of oysters up to 20 and shrimps to 6 t/ha. Salmon ranching gives from 200 to 300 t/ha, just a little less than mussels. It means that not only fish, but also mussel, oyster, and other sea species farming offers exciting opportunities.

The efficient use of bioresources requires the existing natural regimes in the Pacific seas and in the ocean as a whole to remain intact. From this standpoint, it is necessary to investigate the technogenic influence on seas and the ocean, since above a certain threshold the biocenoses deviate from the existing equilibria and the natural reproduction of sea species may decrease dramatically. Especial caution should be exercised with technogenic interference in natural ecosystems aimed at the directed acceleration of bioreproduction.

Recent years have seen the growing interest of ecologists in coral reefs, around which the bioproductivity of waters is by one or two orders of magnitude higher than in the similar reefless regions. At the same time, reefs are extremely sensitive to water pollution and may be the first systems to feel the danger of global disbalance between mankind and environment.

Comparative studies of modern and ancient reefs appear to be especially important since the results may be used for geological prospecting in the ancient reef formations where, in particular, oil and gas deposits may be found. Using the information on the coral reefs of Oceania,Soviet scientists have suggested to built in the Northwest Pacific offshore zone artificial constructions modeling relations between organisms inhabiting coral reefs. Such constructions could be used in the works on the rehabilitation of reserves of herring, other commercial fishes, invertebrates, and seaweeds in the region.

A correct approach to the biological wealth of the open Pacific ocean and its peripheral seas can make it a major source of raw protein for most industrial and developing countries of the region. However, this requires pooled efforts of all the countries.

The Pacific region is an integral part of the world economic mechanism. The use of its mineral and energy resources, which was first discussed at the International congress in Honolulu in 1975, depends more than ever on the solution of international problems. Investigations of this problem are envisaged, in particular, in the project on the International Geological Map of the Pacific Ocean.

Along with traditional minerals extracted from the Earth's depth or from sea and ocean water, the manganese concretions containing various metals are widely distributed on the floor of the Pacific Ocean. The studies of the concretions, which have yielded notable scientific and practical results, could have been more efficient if they were coordinated by an international program.

More attention should be paid to the energy resources of the Pacific Ocean. Its wast shelves, which have hardly been investigated in detail, were flooded at late stages of geological evolution and may conceivably be oil- and gas-bearing.

The use of non-traditional energy sources such as the energy of tides, winds, and the sun is also worth mentioning.

A number of environment conservation programs has been recently realized in the Pacific region. They include the COMECON plan of the research and development cooperation on the program Global System of Environment Monitoring, the UNESCO program Man and Biosphere in its project concerning the environmental pollution and its influence on biosphere, a bilateral Soviet-American agreement concerning the Conservation of Northern Ecosystems project and others.

Environmental conservation studies are gaining scope and intensity and have already given first satisfactory results. Every country of the world is now concerned with the steady tendency for environmental pollution. The consequences of violating the equilibrium in individual ecosystems are so far rather obscure. There is certain evidence, however, that essential shifts in the global climate are quite possible. These shifts might be detrimental to the biosphere and to the human society. Particularly dangerous is the effect of certain chemical compounds which are supplied to the environment in vast quantities and bring about mutations, i.e. changes in the genetic information of cells. The dynamics of mutation processes in animal, plant, and human populations is being studied in the USSR. The global process of mutagenic pollution has its pronounced regional features. It might be therefore reasonable to create special regional genetic departments in charge of two problems - the assessment of detrimental mutations and, on the other hand, the revealing of beneficial adaptive tendencies of organisms.

Considering the utmost importance of environment conservation, the Soviet Union adopted several laws according to which administrative bodies are entitled to demand protective measures, limiting or eliminating environmental pollution and may sue or even close the enteprises for inadequate response.

Many nations of the Pacific region are concerned with the fact that in solving environmental conservation problems some states disregard the interests of all the countries of the region. Of these problems the most important is perhaps the burial of radioactive by-products.

The Pacific countries are also interested in ethnographic problems which are closely connected with the demographic processes rooted in the initial epochs of the mankind formation. At present the modeling of man's migration processes advanced by the famous Thor Heyerdahl is subjected to a well-grounded criticism, since it is incorrect to equate his experimental trips with paleomigration processes. To understand the history of formation and spreading of human society in the Pacific basin and to make demographic plans and predictions, it is necessary to carry out comprehensive interdisciplinary investigations by major scientific institutions of all the Pacific countries.

Archaeological investigations performed by the Vladivostok Institute of History, Archaeology, and Ethnography reveal an interesting page of history of tribal settlements in Eastern Asia in the 10-12th centuries and later on, when the area was populated by Chourchens, Tunguses, Nivkhs, and other nations. Similar investigations on the coasts of South America could supply exciting evidence on the still more ancient processes of human migration. Under the auspices of the Pacific Science Association, with the UNESCO financial assistance, such studies on a coordinated program could be organized in every country of the Pacific.

Modern demographic processes in the Pacific region are also of considerable interest. They bear direct relevance to the problems of employment, formation and dynamics of labour force, distribution of consumer products, the use of natural resources, especially land resources, providing population with food, infant mortality, etc.

Soviet researchers think that joint projects on social sciences are extremely significant. The Pacific basin is a region where civilizations in Asia, America, Australia, and Oceania have been in progress from antiquity to our days. The social, economic, and political processes occurring here are of fundamental importance.

Russian, American, Japanese, and Norwegian researchers as well as scientists from several other countries have performed large-scale investigations which shed light on the history of ancient civilizations in Asia, Oceania, America, and Australia. However, many problems are yet to be solved by archaeologists from the USSR, USA, Canada, Japan, and states of Asia and Latin America. On the eve of the 21th century mankind is particularly interested in the initial migration of man to Asia, Pacific islands, America, Australia, and New Zealand.

The history of geographic discoveries of Middle Ages, new and recent times should be studied with the use of past achievements. Mankind will never forget the heroism of Marco Polo and Christopher Columbus, Vasily Poyarkov and Yerofey Khabarov, Semyon Dezhnev and James Cook, Nikolay Miklukho-Maklay and Gennady Nevelskoy, Chester Chard and Thor Heyerdahl, Vladimir Komarov and Masao Oka.

Social scientists in the Pacific countries maintain different viewpoints on the periodization of history. We think that these viewpoints might be a basis for the special scientific discussions in this field.

The Soviet concept of historical periods is based on the recognition of the existing general regularities in the origin, evolution, and replacement of socio-economic formations. Therefore, we attach great importance to studies of the history of primordial society, the history of slavery in Asia and Africa, of feudal societies, and, finally, the history of capitalist formations and the socialist formation.

The nations of the Pacific basin have experienced an extremely complex social, economic, and political development from the primordial epoch to our days. It is in this region where one can organize wide-scale studies on the origin of races, nations, and national minorities and investigate, in particular, their interaction in the course of historical development, their culture, languages, dialects, and the arts.

The legal aspects of the use of natural resources of the World Ocean are crucial to the development of the world, as is the struggle for peace and security in the Pacific zone, in Far East, and Southeast Asia. Very promising in this respect is the SALT-2 treaty signed in 1979 in Vienna by the Secretary General of the CPSU, the Chairman of the Presidium of the Supreme Soviet of the USSR L.I.Brezhnev and the President of the USA J. Carter.

As the Chairman of the Soviet National Committee of the Pacific Science Association I would like to express my gratitude to foreign scientists and guests taking part in the XIV Pacific Science Congress.

The Pacific Science Association includes 15 special committees. Many of the questions mentioned in my report will undoubtfully be discussed at the special sessions of the Congress. I am sure that useful decisions will be passed to promote the solution of vital problems implied by our motto "Natural resources - to the benefit of mankind!"

BIOLOGICAL RESOURCES OF THE PACIFIC OCEAN

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Half of our planet's population lives in the countries of the Pacific Basin. Inhabitants of the Japanese and the Philippine Islands, Korean Peninsula, Malaysia, Singapore, Micronesia and Polynesia, coastal regions of the USSR, Canada, the USA, and Peru enjoy rich harvests from "water fields", while population of many other countries, including the newlyborn states, strives to improve the food balance, sometimes quite unsatisfactory, by developing fisheries and cultivating aquatic organisms. According to the UN statistics, nearly half of mankind fails to get a necessary amount of animal protein in their food ration, and several hundred million people actually starve.

As was often stressed, the Pacific Ocean encompasses nearly half (49,8%) of the World Ocean area, but within it the shelf and continental slope are less developed than in the Atlantic. At the same time, the pelagic area is twice as extensive in the Pacific as in the Atlantic. The summary areas of the most productive depths (up to 1,000 m) in the Pacific exceed those in the Atlantic and constitute 15.5 million square kilometers.

There are relatively shallow marginal seas around the Northwest Pacific (Bering Sea, Seas of Okhotsk and Japan, East China and South China Seas)with their total area exceeding the area of all other marginal seas of the World Ocean. For example, the area of the Bering Sea shelf alone is about the same size as the Barents Sea and the North Sea shelves taken together. The Sea of Okhotsk shelf is a slightly smaller. At present, the most effective fishery takes place just here, within these marginal seas.

The narrow and steep continental slope constitutes a considerable part of submarine margins of North and South Americas, Japan, and peripheral island ridges in the west and northwest of the ocean.

Characteristic of the topography of the floor of the Pacific basin are not only a predominance of great depths (over 3,000 m) and a relatively underdeveloped shelf, but also many islands, extensive submarine ridges, plateaus, and elevations. There is a great number of seamounts in the Pacific several thousands of which have summits at the depth less than 2,000 m. Such elevations enhance the mixing of deeper, rich in biogenic elements water with surface water masses, forming areas of higher biological productivity around them. Concentrations of fish are formed around and above many seamounts.

The current systems and general large-scale circulation patterns determine the zonal distribution of water masses and productive regions in the Pacific Ocean. The interaction between the dynamic factors and topographic features at the periphery of the ocean determines the formation of the productive upwelling zones rich in nutrients of intermediate waters. Biological productivity is clearly related to the pattern of the convergence and divergence zones, frontal zones, their complex and variable space and time structure. The frontal zones have spatial and temporal variations, responding to the variations of principal driving forces, the surface winds. Local vortexes, typical of the frontal zones, are important, as they are favorable for the development of pelagic spawns and larvae of many water organisms.

There are some upwellings in the centers of cyclonic vortexes in the northern hemisphere, which result in enriching the surface water layers with nutrients of intermediate waters, thus enhancing their biological productivity. Convergences have downwellings in their centers. Such processes prevent different dispersions of fish spawns and larvae and contribute to the zooplankton concentration, i.e., to the formation of zones of increased productivity.

Meso-scale water circulation, the presence of meanders, vortexes, and areas of stable upwellings result not only in the delivery of biogenic elements into the photic layer. They also influence the migrations of fishery objects and their life cycle. Frontal zones of currents can constitute boundaries of the distribution of some species and may guide migrations of many pelagic species, such as the salmon, squid, and tuna.

It's necessary to emphasize the critical influence of relatively minor circular currents (meanders, vortexes, and rings), which complete their cycle in ten to twenty days in the shelf, neritic and epipelagic zones, on the reproduction and thus on the abundance of fishery objects with pelagic spawns and larvae (anchovy, sardine, saury, mackerel, pollock, flatfish, shellfish, and others).

The contemporary concept of location of various water masses and of volume of primary production allow us to evaluate various regions of the Pacific Ocean in terms of their biological productivity. It has been established that the high productive coastal, neritic, divergence, upwelling, and vortex regions constitute about 30% of the ocean area, but encompass 70% of the whole primary production. Futhermore, 56% of all zooplankton occur in the 17% of the most productive areas. The average organic productivity in the Pacific (46.4 g/m^2 per year) is lower than the corresponding figure for the Atlantic (69.4 g/m^2 per year).

However, there are some very productive areas in the Pacific Ocean, for example, marginal seas, upwelling zones, Kuroshio, the Humboldt Current, Antarctic waters, etc. In the eastern Bering Sea the primary production is 150 g/m^2 per year, reaching within some limited areas 300 g/m^2 per year. Most of this production sinks to the bottom, providing food for the benthos.

The biomass of the benthos on the shelves of the North Pacific ranges from 100 to 500 g/m^2 and more, which is as dense as in the richest areas of the North Atlantic, and the general benthos production is sufficiently high.

It can be considered that the greater fish productivity of the marginal seas is the result of the following factors:

1. An abundant benthic fauna inhabits surface layers of sediments, obtaining its food from detritus (mainly, dead phyto- and zooplankton, sinking to the bottom), which in deep parts of the ocean would decompose in lower water layers. The highly productive benthos serves as a food source for numerous demersal fish.

2. The autumn and winter vertical circulation of water brings the nutrients to the surface layers, thus creating the necessary conditions for the high productivity in spring.

3. Characteristic of the shallow areas are minor circular currents; there is a necessary substratum there for sheltering spawns and providing the favorable conditions for the growth and vital activity of younger and adult specimens of many bottom species (flatfish, ocean perch, lingcod, herring, shellfish, etc.).

All these features essentially influence the formation of local ecosystems, bioproductive processes, and distribution of bioproductive zones.

About 6,000 or 7,000 million tons of zooplankton are produced annually in the surface(0 to 500 m) layer of the Pacific Ocean supporting the versatile fauna of fish and large invertebrates capable of providing the annual catch of up to 50 million tons, which is by far greater than the contemporary level.

The greatest increase in catches can be obtained through the development of the fishery of small pelagic species in the neritic zones, primarily saury, lantern fish, sardine, small tuna, and, especially, squid.

It should be noted that the sperm whale population in the North Pacific is 150,000, and they consume 51 million tons of squid and 9 million tons of fish annually, which equals the world's total annual catch of marine animals. If we take into consideration that the adult squid feeds mainly on pelagic fish and that the abundant marine pinnipeds, especially fur-seals of the Aleutian Islands and Bering Sea region consume more fish than the total commercial catch from these areas,it will become clear that the volume of biological resources in the North Pacific is quite impressive.

Investigations carried out by the Soviet, Japanese, and American scientists suggest preliminary and rather conventional estimates for the potential possibilities of the development of the fishery of the abovesaid pelagic species in the Pacific Ocean. They could be, according to these estimates, over 10 million tons and taking into account the development of the Antarctic krill fisheries could even reach more than 30 million tons.

At the same time, the relatively limited amount of the traditional fishery resources in the Pacific Ocean, the present intensive exploitation of most of these resources, and indications that some populations are already overfished demonstrate an urgent necessity to organize the study and utilization of the resources of new commercial objects as well as elaborate the technique of the management of biological processes in the ocean in order to raise its fish productivity.

Besides krill, the numerous mesopelagic Myctophidae (lantern fishes) and squids represent, perhaps, the most considerable and at the same time the least prospected among the exploited resources. The biological resources associated with numerous low-latitude islands are not fully evaluated, to say nothing of being investigated.

An experience of intensely exploited seas, such as the North Sea, indicates that such an explotation can cause a decrease in abundance of some species and increase in abundance of others, i.e., such shifts in marine ecosystems which can be predicted by means of the creation and utilization of large-scale models of these ecosystems.

It is imperative to develop such a modeling further in cooperative efforts in order to master both the optimum use of resources and the management of biological processes for increasing the volume of useful fish production.

The efforts to establish and develop aquaculture farms, to carry out directed biological melioration, to acclimatize and transplant hydrobionts, and to raise the biological productivity of the most valued commercial species, have become of special significance for the Pacific Ocean.

We should remember, that aquaculture farms were originated and highly developed in the Pacific Ocean region. The Hawaiians in the 15th century, long before Captain Cook's ships came to their shores, had cultivated and bred sea fishes, constructing for this purpose many effective pools.

The very fact that the Pacific Science Association Headquarters are situated in Honolulu imposes a special responsibility upon the Association for organizing research work directed at the scientifically based aquaculture development in the Pacific region. Besides, about 80% of the world total aquaculture production is raised just here, within its limits.

Japan, the Philippines, and many other countries have accumulated a great experience in raising aquaculture objects, and our task is to spread that experience.

In this connection, we would like to note the essential successes of the Soviet-Japanese symposium on raising bioproductivity of the Pacific Ocean, which, after eight years of activity with participation of scientists from the USA, Canada, and other countries, essentially promoted the cooperation in this field.

It is also appropriate to underline the enormous prospects for common efforts of the countries in whose rivers the Pacific salmon spawns to increase the artificial and natural reproduction of salmon. We have all the reasons to affirm that such kind of joint and coordinated efforts could provide in the nearest future for a substantial increase in the quantity of this valuable fish and in the growth of summary catches from 350,000 - 400,000 t up to 800,000 - 900,000 t. It may be recommended that Japan, Canada, the USA, and the USSR should reach an agreement on this problem. The total volume of the Pacific Ocean aquaculture production might constitute, in prospect, not less than 15 million tons.

Thus, we can believe that the efforts realized in agreement between the countries of the Pacific Ocean region, may provide in the nearest future for an additional production estimated tentatively as 50 million tons, which will at least double the present catch. To reach these aims, it is very important to evaluate the feed productivity of various regions of the Pacific, to assess the effects of predators, first of all marine mammals, to elaborate an effective biotechnique of aquaculture farms.

We would like to mention some problems pertinent to assessment of the living marine resources of the Pacific Ocean which are of particular interest for countries of the region.

Table

Generalized estimations of reserves and maximum annual catches of fin-fishes in ocean basins with different types of regimes

Type of basin	Total fish biomass[1], t/km^2	Exploited biomass, t/km^2	Maximum annual catch, t/km^2
1. Open continental shelves with the "upwelling" type of circulation			
Tropics	25 to 45	8 to 14	2 to 5
Medium latitudes	40 to 60	13 to 22	4 to 7
High latitudes[2]	30 to 40	11 to 17	3 to 5
2. Open continental shelves without the circulation of the "upwelling" type			
Tropics	15 to 30	4 to 10	1 to 3
Medium latitudes	25 to 45	9 to 18	2.5 to 4
High latitudes	20 to 35	8 to 14	2 to 3
3. Extensive marginal seas (medium latitudes) - (North Sea)	25 to 45	9 to 20	5 to 7.5
4. Semi-closed seas (Mediterranean type of circulation)	12 to 20	4 to 8	1.2 to 2.0
5. Semi-closed seas (Baltic type of circulation)	17 to 25	5 to 9	2.2 to 3.5
6. Open ocean			
Low latitudes	3 to 6	0.5 to 1.2	(0.3)?[3]
High latitudes	5 to 12	1.5 to 3	(0.6)?[3]

1) In items 1 to 5 the biomass and catch refer to areas shallower than 500 m.

2) Assuming that no great quantities of marine mammals are present.

3) Such catches can be obtained only in areas of gatherings.

1. Determination of the feed productivity of different regions and of the factors limiting this productivity and/or affecting the survival of young or adult animals.

2. Natural long-term fluctuations(changes) in different marine ecosystems and the replacement of one species by another in these systems, caused by an intense exploitation or by environmental anomalies.

3. Degree of utilization of the plankton and benthos for production of useful to man resources.

4. Areas of concentrations of pelagic resources, causes (mechanism) of these concentrations, and their spatial and temporal changes.

5. Short- and long-term variations in surface currents and frontal zones and their influence on marine resources.

6. The distribution, abundance, and behavior of squids and Myctophidae and the possibility of the utilization of these resources.

7. The nature, stability, and abundance of animals in tropical island ecosystems.

8. The effects of marine mammals on the productivity and utilization of other living marine resources.

9. Biological resources of Antarctic waters.

The fulfilment of this program can only be achieved by coordinated and consolidated efforts of all countries concerned in the study of biological resources of this region and in the elaboration of effective methods of their increase and rational use. For this purpose it is advisable to establish an intergovernmental international organization.

It seems necessary to support the initiative of the scientists from Canada, the USSR, Japan, and the USA to create the International Council for the Study of Biological Resources of the North Pacific. As it is known, an institution of the similar type, the International Council for the Sea Exploration, operates in the North Atlantic from the beginning of our century and is duly respected by all the countries of this region.

The Irving typhoon which has swept over the West Pacific, including Khabarovsk, shortly before the opening of the Congress, was a kind of severe confirmation of a necessity to extend a cooperation among the scientists of all the Pacific countries in the elaboration of forecast methods for both the destructive (like tsunami) and constructive natural processes, which are of essential or even decisive importance for the people of the Pacific region.

That is why the realization of the projects of the study of the Northern and Western Pacific and the Kuroshio current, the results of which have facilitated the forecast of large-scale variations in the abundance of salmon, herring, ivasi, i.e., objects determining to a considerable extent the results of the fishery of many countries, has been extremely important. We all remember the catastrophic reduction of Far-Eastern ivasi resources in the thirties, when the level of catches of that fish by the Soviet, Japanese, and Korean fishermen went down from 3.5 million tons practically to zero. It took over 30 years to restore these resources. At least about 80 million tons of fish worth of 50 billion dollars were lost.

It would be desirable to start, under the auspices and with the help of the Pacific Science Association, coordinated investigations of the perfidious El Niño current, which despite its tender and peaceful name ("The Child") can actually reduce to zero a Peruvian anchovy catch which only recently has reached 14 million tons or 25% of the world catch and now is reduced to less than 1 million tons. During five last years the people here were deprived of about 40 million tons of catches. Couldn't such natural catastrophes be really compared with disastrous destructions by typhoons and tsunami? It is also important to continue research in the Kuroshio pulsation and its effect upon biological resources in the Northwest Pacific.

Self-reproducing biological resources of the Pacific Ocean have tremendous potential possibilities. Provided rational utilizations and conservation, they could supply every inhabitant of the region with 30 kg of water objects, i.e., considerably more than now.

The consolodation of efforts by all scientists in this field will contribute to the realization of the motto of our Congress - Natural Resources of the Pacific for the Benefit of Mankind.

GEOGRAPHICAL PROBLEMS OF THE PACIFIC REGION

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The whole range of the geographical problems of the Pacific region requiring scientific research on the basis of modern approaches and recently developed techniques is as vast as the area of the Pacific Ocean and the adjoining coastal parts of the four continents: Eurasia, North and South Americas, and Australia. As it is known, the area of the Pacific Ocean alone accounts for over one-third of the globe and equals half of the area of the World Ocean.

If only coastal parts of the above-named continents are included into the limits of the Pacific region, even then the area of this region surpasses half of the globe, and the population of its countries is about 2,000 million, i.e., also exceeds a half of the world population.

Hence, the range of geographical problems of the Pacific has a worldwide or global character. It is characterized by a great diversity, resulting from the variability of nature and the composition of natural resources of the region, different levels of economic development and social peculiarities of its countries and nations. However, it is necessary to identify within the whole range of geographical problems of the Pacific region some certain groups of them, that are the most important in the scientific aspect and the most urgent from the point of view of the requirements of the modern life.

First of all, a large group of geographical problems of the region emerges from the deficiencies in the scientific studies of nature, resources, traditional forms of economy and socio-ethnographical characteristics of the population in different parts of the region. It is well known that the geographical studies of the Pacific region have always been closely linked to the studies of the ocean itself. The Europeans came to know this ocean only in 1513, when the Spanish conquistador Vasco Núñez Balbao for the first time crossed the Panama Isthmus and discovered that only Europe and North America are washed by the waters of the Atlantic Ocean in the northern hemisphere. The Portuguese F.Magellan called the new ocean separating America from Asia the Pacific, and the sea voyages by famous British, Russian, and other navigators resulted by the beginning of the 18th century in determination of its boundaries (except southern), discovery of a great number of islands, and a general description of its shores.

In the 19th century, various geographical studies were carried out on the expanses of the Pacific that envolved gigantic collective work by geographers of nearly all countries. By the beginning of the 20th century the major characteristics of nature, the essential components of terrestrial natural resources, and the characteristics of peoples, their economic and social structures were generally outlined.

The end of the 19th century and the first half of the 20th century were marked by the organization and realization of large-scale oceanological scientific research expeditions, along with thematical geographical studies and surveys in the coastal regions and islands. This period, however, was only a "prelude" to the great gain in the scope of national and international scientific investigations on the Pacific after the Second World War. It is well known what revolutionary changes in the scientific knowledge of geography and all related sciences have resulted from it.

Still, many things here remain unknown and scientifically unexplained. That is why, besides developing further the studies of the physical, and biological properties of the vast water body of the Pacific Ocean, it has become urgently necessary to further more detailed and comprehensive geomorphological, geophysical, geochemical, and gelogical studies of the structure of the floor of the Pacific Ocean, integrated geographical studies of the nature of its numerous islands and archipelagoes.

Unadequately studied in the light of the modern requirements to science are also the geographical problems of the vast continental parts of the Pacific region, especially of its Arctic sectors in Northeast Asia and the northwestern part of North America and of tropical regions in Southeast Asia, Central and South America.

In all these parts of the region, and, first of all, on the floor of the Pacific, its shelf, islands and submarine islands, important geographical discoveries are undoubtedly awaiting us.

My forecast is rested on my own experience. In 1977 I participated, for the first time, in an oceanological geological-geophysical expedition on board the scientific ship Akademik Kurchatov. Having crossed the Atlantic Ocean we came through the Panama Canal to the eastern part of the Pacific, did some work in the Hess basin near the Galapagos Islands and then moved to the southeastern part of the Pacific, to the region of the deep-sea Eltanin faults. Sensational geological discoveries were made there; from the depth of over 5000 m limestone of Cretaceous age and huge blocks of amphibolitic shist, i.e., ancient metamorphic (and not magmatic) rock, were brought to the surface.

On the way back, the expedition discovered a new large fault over 200 km in length and having maximum depth 6600 m on the floor of the Pacific, crossing the western slope of the East-Pacific mid-oceanic ridge. The first discoverers suggested that the fault should be named Akademik Kurchatov (Y.P.Neprochnov, 1978).

At the end of 1978 I again took part in the oceanological geological-geophysical expedition on board the Dmitry Mendeleyev. Moving from Hawaii to New Guinea and having a special apparatus for deep diving, we looked, for a long time, in the Marshall and Caroline archipelagoes for a suitable flat-topped seamount - a guyot which could be used to "land" our apparatus. In the process of searching we discovered and explored a nameless submarine elevation, rather large in size, that was completely erroneously described in the existing sailing directions. Having thoroughly studied this seamount or, to be more precise, having discovered it anew, we suggested that it should be given the name of Dmitry Mendeleyev.

Surely, these two examples of the geographical discoveries in the Pacific are rather modest. In no case can they be compared with the great discovery of the submarine Lomonosov Ridge in the Arctic Ocean made in 1948 by my late friend, Y.Y.Gakkel, and also with the splendid geographical achievements of the American, Soviet, and other oceanological expeditions that discovered the global system of mid-oceanic ridges, transform faults, etc. Still, it is significant, that despite a large scale of modern oceanological studies and perfect research technique, the Pacific Ocean and its continental framing did not completely lose their old romantic halo.

However, it is quite possible, that many reports to the congress will shake this opinion.

The second group of major geographical problems are especially topical in the light of socio-economic disparities in the levels of development of the countries of the region. Among them especially important are geographical problems connected with an effective development of the natural resources and modernization of traditional forms of economy required for the independent economic advancement of many developing countries that have gained political independence. Moreover, the presence of a number of common features in the geological structure and nature of the Pacific countries, for instance, such an immense structure as the Pacific ore belt with its enormous mineral resources, the presence of natural geographical structures and centers in the inner regions of new economic development in the USSR, Australia, Canada, and Alaska, which have become important and perspective producers of raw materials and energy in the group of industrially developed countries, makes especially urgent a comprehensive international exchange of national experience in this sphere.

A special group of the geographical problems of the Pacific concerns directly the sphere of socio-economic studies, dealing with versatile economic relations between the Pacific countries that possess different natural potentials and have different levels of development. Nevertheless, the primary role among these problems belongs to studying the geographical aspects of the international cooperation in the development of this or that type of natural resources as well as to comprehensive scientific and technological assistance in sharing the experience of the developed countries with the developing ones. In particular, this concerns an assistance to developing states in their industrial development and in the elaboration and realization of the projects to develop natural resources, including those in the areas with extreme natural conditions in the arid and tropical zones.

Regarding this, we may, for instance, mention the UNEP projects concerning the elaboration of methods for the use of natural resources of arid territories and measures against the growth of deserts by way of industrialization and agricultural (including agro-industrial) development.

Geographical aspects of such problems are inseparably linked to social and political aspects; these problems are integrated in the broadest sense of this term, although the leading role in their analysis should evidently belong to a socio-humanitarian approach.

The other group of the geographical problems of the region is related to nature protection, conservation, and the improvement of the qualities of environment on all its territory and in its individual parts. Among the problems of this group of special importance are, undoubtedly, the studies aimed at eliminating the negative aftereffects of industrialization and urbanization in the highly developed countries of the region; preventing such phenomena in the developing countries and realizing diversified measures for the nature protection in various parts of the Pacific region. Special attention in this respect should be paid to the natural ecosystems of the oceanic islands and the Arctic regions. Their nature is expecially sensitive to the anthropogenic influence and most vulnerable, i.e., subject to irreversible changes and devastation.

A special and very important group of problems deals with an international cooperation in the sphere of geographical investigations in the Pacific region. All the above-said makes it clear that such a cooperation is quite necessary for working out measures for using natural resources rationally (for instance, biological resources of the ocean) and for environment conservation. It always considerably increases the effectiveness of scientific investigations in solving all the problems. The close international cooperation in the sphere of scientific investigations is an important basis for our mutual struggle for general peace, for the peaceful coexistence and progressive socio-economic advancement of all countries and nations in the Pacific region.

REGIONAL SEAS: AN EMERGING MARINE POLICY APPROACH

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In accordance with resolution 2997 (XXVII) of the General Assembly, UNEP was established "as a focal point for environmental action and coordination within the United Nations system." The Governing Council of UNEP defined this environmental action as encompassing a comprehensive, transectoral approach to environmental problems which should deal not only with the consequences, but also with the causes of environmental degradation.

In the area of "Oceans", which the Governing Council identified as one of UNEP's priority areas, UNEP is attempting to fulfil its catalytic role and deal with the complexity of the problem in an integrated way, as demonstrated by UNEP's Regional Seas Program.

Although the environmental problems of the ocean are of a global nature, it seemed realistic to adopt a regional approach, since in this way UNEP could focus on specific problems of the highest interest to the states of a given region and, therefore, could more readily respond to the needs of the governments and mobilize fully their own resources. By including activities of common concern to most coastal states, in due time this regional approach should yield a mechanism that would deal effectively with the environmental problems of the oceans as a whole.

Two elements are fundamental to the regional seas program:

1. Cooperation with the governments of the regions

Since any specific regional program is aimed at benefiting the states of that region, UNEP tries to involve the governments in the program from the very beginning through their participation in the program's formulation and approval. The actual implementation of an adopted program is carried out through national institutions selected by their governments. UNEP's financial support always rests on the assumption that the governments of the region will themselves progressively cover the operating costs of the program as UNEP's initial catalytic role is fulfilled.

2. Coordination of the technical work provided through the United Nations' system

Although the regional programs are implemented predominantly by the national institutions designated by the governments of the region with UNEP acting as an overall coordinator (in some cases UNEP's role is limited to the initial phase of the activities), a large number of the United Nations' specialized organizations provide assistance to the national institutions, thus contributing to the program the support and experience of the whole United Nations' system.

The substantive aspect of any regional program is outlined in an "action plan" which is formally adopted by the governments before the program enters an operational phase. All action plans are structured in a similar way, although the specific program for any region will be dependent upon the needs and priorities of that region. A typical action plan includes the following components:

1. Legal component

In most cases a legally binding regional convention, elaborated by specific technical protocols, provides the legal framework for cooperative action. The legal commitment of governments clearly expresses their political will to deal individually and jointly with their common environmental problems.

2. Assessment component

All programs include a large number of activities aimed at assessing and evaluating the causes, magnitude, and consequences of the environmental problems. This assessment is not restricted solely to marine pollution, but also covers the assessment of the coastal and marine activities and socio-economic factors that may influence, or may be influenced by environmental degradation.

3. Management component

The assessment of the environmental situation is undertaken merely as a tool to assist national policy-makers to manage their resources in a more effective and sustainable manner. Therefore, each regional program includes a wide range of activities in the field of environmental management. Such activities may include cooperative regional projects on rational exploitation of marine living resources, utilization of renewable sources of energy, management of fresh-water resources, protection of soil from erosion and desertification, development of tourism without ecological harm, mitigation of environmental damage associated with human settlements, etc.

4. Institutional component

The program is implemented primarily through designated national institutions. Assistance and training are provided where necessary to allow national institutions to participate fully in the program. Existing global or regional mechanisms are normally used for the effective coordination of the program. However, specific regional mechanisms may be created if governments feel it is necessary.

5. Financial component

As a program develops, the governments of the region assume a progressively increasing financial responsibility. Government financing may be channelled through a special regional trust fund or provided directly to the national institutions participating in the program.

At present there are eight regions where regional action plans are operative or are under development: the Mediterranean (adopted in 1975), the Red Sea (adopted in 1976), the Kuwait Action Plan Region (adopted in 1978), the West African Region (under development, expected to be adopted in 1980), the East Asian Seas (under development, expected to be adopted in 1980), the Southeast Pacific (under development, expected to be adopted in 1980), the Southwest Pacific (under development, expected to be adopted in 1981), and the Wider Caribbean Region (under development, expected to be adopted in 1980).

It is extremely difficult to summarize the variety of activities which have been undertaken in the various regions, either as parts of the preparatory activities for the intergovernmental meetings called to give final approval for the action plans or as parts of the adopted action plans. Examples, selected very subjectively, highlighting our successes and failures, difficulties and pleasant surprises, could be presented as follows.

States, representing people with a different historical background, political system, level of economic development, religion, language, race, and social goals, were willing to join their efforts to save the seas which they considered their shared heritage.

None of the meetings, either on the level of marine scientists, economic experts, planners, or plenipotentiaries, have ever raised politics above business to protect the environment. States at war were ready to sit together and forget, at least for a moment, their political differences.

Two regional conventions for the protection of the marine environment have been signed (Barcelona, 1966; Kuwait, 1978) and entered into force after they had been ratified with speed unprecedented in the history of international treaties.

Specific protocols, attached to these conventions, have been negotiated, signed, and ratified, regulating dumping from ships and aircraft (Mediterranean) and cooperation in cases of pollution emergencies (Mediterranean and the Persian/Arabian Gulf).

Additional protocols are being negotiated, although the enforcement of some of them (control of pollutants from land-based sources in the Mediterranean) might cost the states concerned up to US $ 10 billion.

A regional oil combating center has been established in Malta (1976) and the establishment of an emergency mutual aid center in Bahrein will soon be negotiated. Similar arrangements are envisaged for other regions too (Southeast Asia, West Africa).

The marine environmental problems of many regions have been analyzed through a series of international workshops attended by scientists from the region: Monaco (1974), Trinidad (1976), Penang (1976), Abidjan (1978), Santiago de Chile (1978).

A network of 83 national institutions was established in the Mediterranean (1975) to cooperate on seven pollution monitoring and research projects using commonly agreed methodology. Similar networks will soon start operating in other regions, all using methodology yielding results comparable on a global scale.

A large training program is under way to improve the quality of data generated by the institutions participating in the cooperative programs. A considerable number of sophisticated equipment (atomic absorption spectrophotometers, gas chromatographs, etc.) was donated to institutions in developing countries. A common maintenance service is organized for this equipment. Quality control of data is ensured by a mandatory intercalibration exercise.

The facilities of the Geneva-based United Nations' International Computing Center were selected as the central data repository and processing facility. Data are collected, handled, and disseminated according to existing standard practices, making full use of the existing mechanisms for data exchange.

Regionally applicable environmental quality criteria are under development (Mediterranean bathing waters and seafood) and will be used for harmonizing national legislations.

The land-based sources of pollutants are systematically analyzed and the amounts of pollutants reaching each region are estimated.

In a variety of fields related directly, or indirectly, to the protection of the marine environment (aquaculture, wetlands, marine parks, soil protection, soft energy, tourism, human settlements) intercountry programs have been initiated.

Attempts to get the governments' agreements for studies on the riverborne load of pollutants, on input of pollutants from the atmosphere, or for large-scale modeling, have failed so far.

All these activities are based on the very close cooperation of 14 specialized organizations of the United Nations system, coordinated centrally by UNEP.

Having reviewed the general approach of the Regional Seas Program and demonstrated various ways of its implementation, it seems appropriate to summarize the state of affairs in the Wider Pacific Region. As mentioned earlier, three regional action plans are under development: (1) the Southeast Pacific, (2) Southwest Pacific, and (3) the East Asian Seas.

In the Southeast Pacific, a survey of sources and levels of marine pollution was carried out in 1975 by the Permanent Commission for the South Pacific (CPPS). Subsequently, an international workshop on marine pollution was convened in Santiago in November 1978, which reviewed the major environmental problems related to marine pollution in the region, including polices as well as domestic and international legislation. Major achievements of this workshop comprise: (1) a plan of short-term action on marine pollution; (2) guidelines for a convention on protection of the marine environment against pollution; (3) a draft agreement on regional cooperation for emergency measures against pollution of the Southeast Pacific by hydrocarbons and other harmful substances; and (4) recommendations to establish a special fund for research centers collaborating in the study and prevention of marine pollution.

Geographical coverage includes the coastlines of Colombia, Chile, Ecuador, Panama, and Peru, and the CPPS is now initiating a large-scale marine pollution monitoring program. UNEP is ready to assist in relevant efforts such as: (1) formulation of a long-term program for the assessment of the sources, levels, and effects of pollutants affecting coastal waters; (2) recommendation of analytical methods, including the intercalibration of analytical techniques and data handling; (3) formulation of a training program; and (4) preparation of a directory of marine research centers.

Work in the field of environmental assessment will gradually be broadened to include other aspects of marine pollution and, based upon the principles identified at the Santiago workshop, lead to the adoption of an action plan, possibly in 1980.

In the Southwest Pacific, a regional environmental program is about to commence. The aim of this program is to encourage and support an integrated approach to the environmentally sound planning in the countries of the Southwest Pacific in order to achieve maximum social, economic, and environmental benefits on a sustainable basis. The program is being cosponsored by four international bodies: the South Pacific Commission (SPC), the South Pacific Bureau for Economic Cooperation (SPEC), ESCAP, and UNEP. Its geographical coverage includes, provisionally, the coastal waters and the adjacent coast of states and territories of the SPC and the SPEC.

During the first phase of the program, national reports will be prepared highlighting the environmental and developmental problems of each country. The cosponsors of the program are ready to assist the countries in the preparation of these reports, which will be used to prepare a synthetic report on the state of environment in the Southwest Pacific, linking the issue of development and environment.

This report, together with a draft declaration of principles on the management and improvement of the environment and with a draft regional action plan on the development and environmental protection, will be the basic documents for a regional conference on the human environment in the South Pacific. The cosponsors of the program hope to convene this conference during 1980 and use it for the formulation of specific projects to be implemented at the international, regional, national, and local levels during the second phase of the program.

The role of marine pollution problems within the regional environmental action plan will be clarified through the fact-finding reports and the recommendations expected from the regional conference. Coastal area development, coastal water pollution, and fishing resources may be of general concern throughout the region, while specific problems such as coral reef destruction may also deserve attention in the program.

In the East Asian waters, the complexity of marine pollution problems and their impact on the coastal environment was first recognized at the international workshop on marine pollution in East Asian waters, held at Penang, Malaysia, in April 1976. This regional scientists' meeting established a comprehensive list of priority issues and, in addition, identified common needs such as: (1) more baseline studies of the marine environment with emphasis on marine ecosystems (e.g., coral reefs and mangroves), including the determination of present levels and distribution of pollutants in the various media, water, sediments, organisms; (2) greater understanding of the physical processes in the coastal waters, particularly water circulation, as mechanisms for the distribution of pollutants; (3) research on problems such as toxic effects, pollutant degradation, transfer of pollutants, and ecological effects; (4) standardization of analytical methods, including suitable intercalibration exercises; (5) intensive training of scientists and technicians in all aspects of marine pollution research and monitoring; (6) mechanism for the exchange of data, information, specimens, and samples on a regional basis; and (7) efforts to increase public awareness of environmental pollution and its significance.

The Penang workshop proposed several regional projects and, recognizing the large geographical extension of the region, prepared individual projects for six subregions, namely the Bay of Bengal, the Straits of Malacca, the Gulf of Thailand, the South China Sea, the Sea of Japan, Yellow Sea and East China Sea, and the seas of the Eastern Archipelago. The subregional approach was also endorsed by UNEP's Governing Council which decided in 1977 that steps were urgently needed to formulate and establish a scientific program involving research, prevention, and control of marine pollution and monitoring for the waters of Indonesia, Malaysia, the Philippines, Singapore, and Thailand.

Substantive proposals contributing to the formulation of a first subregional action plan for East Asian Seas were received through regional meetings such as: (1) Third Session of the Indo-Pacific Fisheries Council (IPFC) Working Party on Aquaculture and Environment, Bangkok, August/September 1976; (2) ESCAP/UNEP Intergovernmental Meeting on Environmental Protection Legislation, Bangkok, July 1978; (3) UNESCO Regional Seminar on Human Uses of the Mangrove Environment and Management Implications, Dacca, December 1978; (4) ASEAN Expert Meeting on the Environment, Jakarta, December 1978; and (5) UNESCO/IOC Workshop on the Western Pacific (WESTPAC), Tokyo, February 1979.

In anticipation of regional action plans in Asia and the Pacific, the Indian National Institute of Oceanography, Goa, prepared in 1978 a directory of Indian Ocean marine research centers. An intensive training program was launched by UNEP's and United Nations' agencies to support the national institutions interested in the regional program, including: (1) national seminars on the protection of the marine environment and related ecosystems; (2) an international workshop on the prevention, abatement, and combating of pollution from ships; (3) a regional workshop on coastal area development and management; and (4) a regional seminar on environmental impact assessment.

In addition, several pilot projects are now commencing in collaboration with ASEAN countries, covering subjects such as regional oil spill contingency planning, toxicity of oil dispersants, land-based pollution sources, river pollution transport, impact of pollution on mangrove ecosystems and of oil pollution on living aquatic resources, and environmental problems of offshore exploration and exploitation. Legal instruments for marine pollution control are also under consideration and preparation. Hopefully, these efforts will allow the subregional draft action plan for Southeast Asian seas to be prepared and adopted by the end of 1980.

To summarize: all three regional programs on marine pollution control in the Pacific are in their initial stages with preparatory work largely accomplished and are now heading towards their formal establishment as regional action plans. Thus, by the end of 1980 or in 1981, all three should be in operation. UNEP, together with the specialized organizations of the United Nations' system, will provide any support required to achieve this goal. However, UNEP's role in the development and financial support of the regional programs rests on the assumption that they will gradually become selfsupporting and that the major responsibility (financial and substantive) will be transferred to the governments in the region. In the regions where the regional conventions, providing the legal framework for the regional action plans, have been ratified, this is actually happening: the weight of the governments in deciding on the program of work is increasing and the financial burden is being taken over by regional trust funds controlled by the governments contributing to them. UNEP's catalytic role in these regions is fulfilled and UNEP's future involvement in these regions will be mainly restricted to safeguarding the comparability of data, thus facilitating the assessment of the causes, sources, levels, effects, and trends of marine pollution on a global scale.

ECONOMIC ENERGY USE IN FISH PRODUCTION

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Introduction

At present, the waters of the world furnish about 18% of humanity's intake of animal protein in the form of 73.5 million tons, wet weight, of aquatic animals, mainly fish. The nations of the Pacific Basin with their prominent fish eating traditions both contribute to and consume a large share of that tonnage. It is of special note here not only that Japan has remained in that year, as in several previous ones, the world's foremost fishing nation with landings of 10.7 million tons and that the Soviet Union came second, but also that China and Southeast Asia have most of the world's aquaculture production.

Some declining fishstocks of importance notwithstanding, further production increases for capture fisheries are deemed possible in tropical seas with the South China Sea apparently having underused demersal stocks and, with the Tropical Pacific, also underutilized pelagic fish populations. The growth in fresh water fisheries between 1967 and 1976 was 4.6% per year with the major increase having occurred in Asian aquaculture. In fact, in a century or so, fisheries and aquaculture combined may, under a sound management policy, yield perhaps even double the global tonnage they furnish today.

Fisheries now require substantial inputs of fuel and raw materials (steel, wood, synthetic yarns, etc.) as well as labor. Some of these raw materials, especially liquid and gaseous fossil hydrocarbon fuels, are being used at a rapid pace and their prices cannot but increase substantially. One would anticipate fuel inputs for future fish production to be largely of synthetic provenience, derived in part from coal liquification, and comparable processes and/or to be based on advanced renewable energy technologies. In any case, the cost of a unit of power to drive mobile or stationary machinery destined for food production of any kind will far exceed that of today. Thus, the energy cost of fishing and aquaculture technologies will assume increasing importance and choices in production modes may hinge on the possibilities of saving the direct and/or indirect energy inputs in one or another fishing or fish-rearing technology. Materials will also rise in price and in the case of aquaculture, the needs for land and water are likely to enter prominently into food policy planning.

Energy accounting or net energy analysis aims to compare, in invariant units such as calories or joules, the energy content in the end product of a process with the energy consumed directly, and, sometimes, also in the materials used, in the respective process. Such compilations permit predictions of relative economic advantages of certain production processes in a world where energy prices are likely to rise much more rapidly than other costs.

Labor is usually accounted for separately or in a concurrent economic analysis, though attempts have been made to express it in energy units along with other services, such as solar energy inputs, tidal energy, and the like. Other input accountings list separately fuels, materials, labor, etc., and also tends to comprise externalities (the resilience of environment to a certain amount of pollution, health hazards, etc.). In this paper, labor, land, and water needs in aquaculture will be mentioned separately if they are of relevance, and natural energy inputs that have ecologic and physiologic benefits (photosynthesis, acceleration of growth rates due to warming of water, etc.) will be disregarded. Data will exclude preliminary processing wherever possible and the output will be fish or shellfish as landed or at the pondside.

While inputs and outputs in the production of staple cereals are conveniently given in energy units, the nutritional value of aquatic proteins lies not so much in the calories they produce when they are metabolized as in the fact that an intake of balanced protein rations is necessary for the growth and maintenance of all animals in addition to their having caloric values. Thus, the output of fisheries or aquaculture - and by the same token, of animal husbandry - is best appraised in weight of flesh or in weight of protein in a unit weight of flesh.

With this said, we will now proceed to a comparison, in the terms just stated, of a number of fishing methods. Next we will describe the energy costs of aquaculture for various species under various conditions, including polyculture and proceed to compare further fisheries with aquaculture and both with animal husbandry. A caveat is in order here, however. Boundaries of various energy analyses tend to differ as do, for instance, the energy costs of certain inputs under different socio-economic conditions. These boundaries and other assumptions of different energy analyses must be known and considered before relatively detailed comparisons of different systems and processes can be made (Smith, 1979).

FACTORS INFLUENCING COSTS OF FISHING

Distance and gear

While examining the role of distance and fishing method or gear in energy or monetary cost-benefit analyses, one must stress strongly, almost obvious though this be, that the price of seafood varies enormously depending on cultural taste, end use (e.g., fish meal versus sashimi), local or regional abundance and scarcity,etc. This range will be considered to the extent that existing treatment of such data permits, as will be sizes and types of vessels.

Nomura (1979) compared for the year 1975 the catch relative to fuel consumption of several Japanese fisheries, combining in the comparison distance, fishing method, and vessel sizes within the range of ca. 50 to 400 gross tons. In this comparison, there emerge several clusters of values of kilogram of fish landed per kiloliter of fuel used - also possible to be expressed as kilocalories expended per gram of protein in unprocessed fish. These clusters of values represent greater or lesser distances traveled and gear or fishing methods predicated on fish behavior and habits such as schooling and seasonal whereabouts (Table 1).

Distant and offshore tuna long line catches are most demanding of fuel - between 127.8 and 77.2 kcal of fuel value in diesel oil per gram of protein. Another set, roughly between 95.0 and 64.0 kcal/g of protein, comprises schooling sea life such as skipjack, salmon, and squid as well as a demersal trawl operation (species not mentioned) in the East China Sea. One should note here that despite sometimes considerable distances to reach the fishing grounds, the quarry can be located with moderate search and schools permit relatively quick filling of the holds.

If total energy and not only fuel energy were taken as inputs here, the energy cost/gram would no doubt rise. Edwardson (1976) indicated that this rise would hardly exceed 25% (see below and also Column 3, Table 1); thus by including properly amortized energy costs of such gears as the nets made of synthetic yarn,most seafoods would still be energetically cheaper animal protein than beef or even chicken as they are produced in comparable economies (Table 1, Column 5).

Pelagic purse seining for individual fish and set nets in coastal waters are the most efficient fishing methods as far as fuel inputs are concerned with the stationary gear being four times as effective as the seine and yielding a gram of protein for the input of only 3.4 kcal (Table 1). The species caught in the net are not named but the return for the fish, given as 200 yen/kg appear to show them to be moderately priced table fish, rather than industrial fish. The seine-caught lot at 60 yen/kg was definitely destined for fishmeal production.

Set net fisheries in the United States are similarly effective with regard to energy expenditure per unit weight of protein produced; according to Rawitscher and Mayer (1977), "Maine herring are caught close to shore, sometimes in weirs, as was done by the Indians in colonial times." Their harvest exacts less than 7 kcal/g of protein, even less than is expended for the growing of the protein in staple cereals which is, of course, lacking in some essential amino acids. The same authors also establish that the American tuna fishery uses 81.3 kcal/g of tuna protein. Comparing this to the earlier cited highest value from Nomura for the Japanese tuna fishery we should note that Rawitscher and Mayer's 1977 and 1979 values are derived from energy accounting while Nomura's values are based on fuel use only. The American tuna fishery is presumably carried on by purse seining while the Japanese values are based on extensive voyages in long lining for bluefin and yellowfin tuna. The somewhat lower values for skipjack tuna come from a pole and line fishery where running times are less than in long lining; labor is not considered in any of these calculations.

Anticipating Nomura but treating the spatially more limited British fishery, Edwardson established that seining and surface or pelagic (especially pair) trawling was more efficient in terms of energy used per ton of fish landed than bottom or demersal trawling; these energy accounting data permit one to make a distinction in the amounts of total energy versus fuel energy used; depending on vessel size, direct fuel use may make up from just over 80% (smaller vessels) to 90% in the larger ships.

In another study about trawling, Wiviott and Mathews (1975) demonstrated clearly that energy efficiency of bottom trawling was strongly dependent on distance of the fishing grounds from home ports, and hence, on fuel inputs. They compared the State of Washington-based and Japan-based otter trawl fisheries on slightly overlapping, adjacent, and therefore, comparable grounds in the North Pacific during the 1971-72 fishing seasons. The vessels of the U.S. fleet (sample size 11) averaged 86 t and stayed on the fishing grounds from between one to 14 days, only separating and icing the catch prior to landing it. The vessels of the Japanese fleet (sample size 32) averaged near 2000 gross tons with engines nine times as powerful, on the average, as the smaller Washington trawlers. They were mothership-based and operated on the grounds for several months at a time. Yet both fleets had the same total amount of days away from port, during a season, 205 in all. The Washington fleet was calculated to have expended 171 kcal per pound of round weight landed while the Japanese fleet used 231 kcal. Fuel represented "the principal item of total energy requirements for both fleets," with the Washington fleet landing 36.55 pounds of fish per gallon (4.4 kg/L) of fuel and the Japanese fleet only landing 6.65 pounds per gallon (0.8 kg/L) of fuel. Measured by comparing overall output/input efficiences, the short-trip Washington fleet was doing four times as well as the Japanese fleet which operated far from its home ports.

We have no data for various fishing methods in tropical shallow seas, especially reefs and lagoons, substantial and important though they be both in terms of tonnages landed and in terms of valuable high grade food they provide. From the writings of Nomura and from personal experience, I would surmise that their efficiencies compare favorably with those of set-netting and seining. Investigations that could provide quantitative assessments are strongly recommended for they would facilitate planning of development policies both in nutritional and energy domains.

Reef fisheries are not usually highly selective in an absolute sense though artisanal fishermen may seize on temporal aggregations of one or another species. Other fisheries in relatively shallow water such as trapping for lobsters may appear moderately demanding of energy expenditures but appearances are deceiving here; lobsters are a luxury product wherever they are caught and fishery practices for them appear to be among the most energy-expensive so far recorded; 769 kcal of total energy expenditure go into the production of one gram of unprocessed Maine lobster protein according to Rawitscher and Mayer.

Fuel versus other costs

When wood is available for building fishing vessels, as it is in many developing countries, the total energy used in their construction is, of course, less than if they were made of steel, but the life span of metal hulls is longer. Also, as might be expected, there is an economy of scale in total energy costs with increasing ship size: large, 80 to 120 foot (24.4 - 38 m) trawlers have relatively less of their gross energy requirement or GER[1] tied up in the gear than smaller ones. The gear used also makes a difference in the energy input category: sweeping the sea bottom for fish,

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[1] GER is defined by Edwardson (1976) in gigajoules per ton of product.

necessitating relatively more metal than seining or pelagic trawling, makes otter trawling the most energy expensive method of industrial fishing. Purse seining, however, demands relatively larger inputs of synthetic fibers.

Truly long distance vessels such as freezing trawlers or factory ships with catcher flotillas cannot properly be entered in these comparisons because of the fuel requirements for freezing and other processing. Still, the largest freezing trawler analyzed by Edwardson, a 210 ft. (68 m) vessel, only spent slightly over 3% of its GER on freezing the catch, less perhaps than one might expect when one reads in Rawitscher and Mayer that processing of seafood takes considerable amounts of energy, in a few cases (canning) more than, and in others, a good percentage of that expended in catching the fish. It appears then that sea-based pre-processing is relatively energy efficient, a notion that is also supported, though not with numbers, in the initial attempts at harvesting krill. Fuel costs have increased, however, since then, and in the case of krill, the fuel demands of running the vessels may well not permit to produce it as cheap animal protein fare for the populous regions of the world, north of the equator. Massive oil developments in Antarctica or recourse to geothermal energy for onshore processing may conceivably invalidate this assessment.

AQUACULTURE

The husbandry of aquatic animals, the main component of aquaculture, which also includes the cultivation of certain aquatic plants (not treated here), whether performed in fresh, brackish, or sea water, is to fishing as the rearing of domesticated birds and mammals is to hunting for food. Thus, control over the animals' environment to varying, often pronounced, degrees is attempted and mastery over seed production - enabling improvement of breed - is generally sought though, to date, achieved only with some species. Also, aquafarmers tend to feed their stock directly or by means of fertilizing their ponds and they aim to exercise control over diseases and parasites that are perhaps more difficult to control in the aquatic than in the terrestrial environment.

In some variants of aquaculture some of these operations are either omitted as part of the management plan (e.g., rearing of oysters and other mollusks and salmon ranching), or not yet possible to be performed (e.g., the collection of milkfish fry from the wild instead of producing them in hatcheries). Thus the terms full- and semi-culture have been coined. In any case, economic and energy inputs into aquaculture are more numerous and varied than those into fisheries and they generally resemble those of agriculture.

Several assessments have been made of the economics and of energy demands of aquaculture. Their results can be summarized as follows:

1. Feed, fertilizer, and fuel for the pumping of water are the major recurrent inputs into fairly intensive to very intensive aquaculture operations.

If carnivores are reared in enclosures in larger bodies of water or in the sea (e.g., groupers, Singapore, Hong Kong; yellowtail, Japan), expenses for feed alone dwarf all others. If several compatible species are reared together with a balance of plant, plankton, and bottom feeders, the intensity of the operation, i.e., stocking densities, water flow or need for aeration, will determine which of the above-mentioned inputs predominate. Together they often account for well over 90% of the energy as well as the monetary inputs.

High pumping costs underscore the advantages to aquaculture of copious supplies of uncontaminated high quality water. Fertilizer needs together with the advantages of full use of the water body and ecological resilience due to having several species in polyculture instead of a monoculture indicate that recycling of organic wastes in fresh or brackish water ponds can save the aquaculturist at least a quarter of his inputs regardless of whether these are expressed in fuel or monetary units. Even while noting that market exigencies and culture-determined taste must be considered, a point can be made also for establishing joint aquaculture and animal husbandry installations, e.g., pigsties over fishponds, duck cum fish culture and use of biogas residues in aquaculture.

2. In aquaculture, as in other agro-industries, energy and labor inputs complement one another.

Edwardson arranges aquaculture systems by resource requirements, contrasting energy and labor inputs. Fresh and brackish water ponds in tropical regions may use about ten times the amount of labor per ton of fish produced that is expended on growing the same amount of fish flesh in roughly similarly sized fish ponds in higher technology countries. In the latter regions, however, one expends far more fuel energy per unit weight of flesh, even up to a hundred fold that which is lavished on a ton of fish grown in tropical developing nations.

These comparisons can be misleading, however, if one did not also mention that yields due to total inputs from comparable areas or volumes of water need not as strongly reflect these tradeoffs between labor and energy. This is especially true if the aquaculture installations are planned with due consideration of ecological advantages and include the use of externalities in the management techniques. Cases in point are several variants of sewage-assisted cage cultures for carp in Indonesia and elsewhere as well as milkfish culture in a run-off enriched lake in the Philippines compared to milkfish pond culture in Taiwan (Table 1). In the sea, these ecologically advantageous aquacultures are salmon ranching and the culture of sea-going trouts or certain oyster rearing operations where the main task of feeding the animals devolves upon nature. It is to be noted that man's alteration of or interference with the environment, especially poorly planned and badly managed industrial effluents, may reduce these opportunities for the production of considerable amounts of high quality animal protein at reasonable, if not low, costs.

3. Restrictions on the availability of land and water as well as gains in production capacity due to energy inputs have led, in some countries, to experimentation with highly controlled closed systems that recycle their water (e.g., capr, Japan; trout, United Kingdom; yellow perch, USA).

The main recurrent energy expenditure here is pumping, another is feed. If the former need could be satisfied with renewable energy sources, e.g., wind, or solar pumps, both with adequate storage facilities for water, and as such renewable energy sources become cheaper than they are now, in relation to fossil fuels, some future, might be foreseen for such schemes to provide anything but delicacies for the affluent. Yet one should also note that one gram of shrimp and one gram of lobster caught in the wild require inputs of 598 and 769 kcal of energy respectively while the value for growing yellow perch in experimental silos in Wisconsin is 535 kcal/g.

In contrast, pond-reared U.S. catfish require 139 kcal/g while a mixture of two carp species, tilapia and mullet in polyculture ponds in Israel can be produced for energy expenditure of 65 kcal/g of fish at roughly comparable levels of technology. Recycling of organic wastes, which was not used in the 80 fish farms from which the above average figure was derived, would have made the operation more energy efficient still. In fact, my rough calculations for very productive fully sewage-fed Indonesia carp culture in shallow fast flowages with a silt bottom, which enables copious growth of invertebrates and bacteria, indicate that under these rather special conditions a gram of table fish protein may be had for the expenditure of less than 10 kcal. Incidentally, absence of industrial wastes in the water, supersaturation with oxygen due to stream flow on the one hand, and cooking and eating habits that do not favor the eating of raw fish, on the other hand, made for a low level of danger of parasitic infection here.

DISCUSSION AND CONCLUSIONS

Emphasis in the treatment here has been on comparisons of energy requirements and hence, indirectly, on costs of certain management practices and/or operations in aquaculture and fisheries as those pursuits satisfy human nutritional requirements. Especially in certain countries of the Pacific, the relation of annual fish catch or production figures to the numbers in a country's population reveal that fish and other aquatic organisms furnish a substantial, if not major, portion of the per capita intakes of animal protein (e.g., Japan, China, Indonesia) aside from providing the livelihood of millions of people.

From these examples, it appears that food and energy policy planners, whether they work together as they should or separately as they often do, would seem to have a number of options to promote the direct saving of fuel in fisheries or of fuel demanding inputs, such as fertilizer in aquaculture. For instance, fertilizer costs may be reduced through the use of recycled organic wastes in aquaculture; tax benefits where applicable and/or credit subsidies would be employed to encourage recycling. It will be important, at the same time, to spread the skills necessary for the establishment of such practices. Conjoining of aquaculture, animal husbandry, and market garden agriculture, for instance, is energy saving and has economic and nutritional benefits. Also, it would be desirable to promote regional research into the way in which mixes of species could be altered to optimize management responses to local market and other socio-economic conditions.

In fisheries, the implications of the connection between fuel use and distances traveled lend new urgency to conservation measures, especially pollution abatement in inshore waters such as Edwardson advocates when he says: "The much lower (energy) intensity of inshore and near-water fishing emphasizes that this is the sector of the industry which should be protected." If nearshore waters are polluted and become devoid of sea life, the market price of fish will rise, in large measure due to the greater fuel costs in fishing offshore. Thus establishing quantitative relations of fuel consumption to distances traveled in fishing can contribute to the evaluation of conservation measures in monetary terms. At the same time, the relations of fuel use to fishing distance have clear implications on national policies for 200 miles (320 km) extended economic or fishery zones.

Wherever possible, fishery management advisory bodies should promote the use of stationary instead of moving gear. Among the latter, encircling instead of dragging nets are recommended. It is recognized, of course, that the behavior and the distribution of certain species leave the fisherman no alternative but to use bottom trawls, but gear specialists will find encouragement from their sponsors if they combine as their goals the conjoint improvement in catching capacity and energy efficiency, perhaps through innovative vessel design and partial use of sails; to date the former goal appeared to have been paramount.

The success of floating structures such as artificial rafts and stationary emplacements such as oil platforms in aggregating pelagic fishes, even without them having been designed with fish in mind, suggests that possible economic and energy use related advantages may be gained through experimentation with large floating nets; these might even be fitted with electronic and telemetering fish monitors signaling the presence of fish and thereby saving the vessels considerable searching time and hence fuel; chemical attractants might also be considered.

When evaluating tradeoff options among support needs for fisheries, aquaculture, land animal husbandry, and even cereal production, it should be remembered that some fish protein can be produced through capture fisheries more cheaply than through the rearing of avian or mammalian stock. Under the conditions that prevail in high-technology agriculture, cereal proteins, in addition to being deficient in essential amino acids when compared to fish protein, demand more energy inputs than necessary to secure certain schooling fishes (Table 1).

Aquaculture need not be as expensive as it is usually considered as a mode of supplying high-grade animal protein. In fact, if polyculture and organic waste recycling are employed, the protein produced is cheaper in terms of energy requirements than the rearing of pigs or chickens (Table 1). Obviously, this statement holds true for comparisons of these practices at the same or similar levels of intensity such as backyard pig-rearing and the feeding with household scraps of Asian catfish kept in cages by river dwellers on the one hand and modern chicken "factories" versus high-intensity polyculture fishponds on the other.

Energy and economic analyses of fisheries and aquaculture have established that economies of scale exist in both aquaculture and fisheries. These most strongly express themselves in the labor component of both pursuits and in the use of certain facilities and equipment. Nets and other harvesting gear in aquaculture and boat and small-engine repair facilities and ice supplies for nearshore fisheries are cases in point. In certain economies and under certain social conditions, it may not be possible for one entrepreneur to take advantage of such economies of scale, even though they can already find expression in moderately sized operations. Capital may be lacking or the small size of land holdings or the character of the water supply (rights, access) may prevent it. Pooling of resources through cooperatives or other communal enterprises is clearly indicated here. What is further indicated is that energy analysis, assessment of labor, resources, and material inputs can help to establish optimal sizes for fisheries and aquaculture establishments. To repeat, a suitable or optimal size here need not be very large and establishing it will take into account local ecologic and social conditions as well as purely technical and management considerations.

Setting a time frame to the close of this discussion one ought to remember that the world population by the year 2000 - just twenty years from now - will be about 6.5 billion, that its aggregate food demand will be at least double that of today and that coal and probably nuclear power will be the suppliers of baseloads in the energy field. Portable fuels will be made to some extent from coal and also from biomass. Solar energy technologies, for instance for pumping, will be a good deal more fully developed than they are today. The unit of power will however cost more than now, in absolute and relative terms. Implications of these predictions are obvious and ominous for fisheries and aquaculture among other pursuits, especially in tropical Asia where an expansion of fisheries is possible and where aquaculture is a tradition.

Energy concerns while they exist in agriculture and rural development today seem to be directed equally if not more so towards the supply of power for industrial development and to the satisfaction of the energy exigencies of the burgeoning cities. The expected doubling of food demands, just mentioned, suggests that increasing attention be given to energy relations in food production, centering in our purview on aquaculture and fisheries. As tropical Asia has less spare land per capita for agriculture than any other major portion of the globe, it will be especially important to direct attention to what food can be derived from its waters. Concomitantly, urgency will arise for devising methods of energy saving in food production and with it the need for documentation of the quantities of inputs involved; it is advocated here that investigations towards that end with internationally agreed-upon conventions and methods be strongly encouraged, especially in South and Southeast Asia and the Pacific.

Table

Summary comparison of energy expenditure for certain (selected) foods from fisheries, aquaculture, animal husbandry, and agriculture[1] (kilocalories/gram of protein in unprocessed products)

Product	Homura, 1979; Japanese fishery; fuel only	Edwardson, 1976; British fishery and international aqua - culture	Rawitscher and Mayer, 1977, 1979; U.S. fishery	Bardach, 1979; U.S. and certain countries; aquaculture	Pimentel et al., 1975; U.S.
1	2	3	4	5	6
Rice					40
Wheat					13.7
Corn (Maize)					
Pork					186
Beef					685
Chicken					149
Catfish		165	83 (330, edible portions)		139
Carp, mullet, tilapia (Israel)				65	
Tilapia (subsistence)		3.4			
Carp, sewagefed (Indonesia)				6 - 10	
Carp, cages and ponds (Japan and Germany)		31-130[2]			
Milkfish (Philippines and Taiwan)		3.5-12			
Flatfishes (trawls)			92-95		
Ocean perch			17		
Alaska pollock	9				

1	2	3	4	5	6
Flatfish and groundfish (trawls)		26-96			
Small surface-seine	12.3	5-17			
Schooling fish (set net)	3.4		7		
Salmon	70-141		30-159		
Large tuna	77-128		81-150		
Skipjack tuna,salmon, squid	64-90				
Lobster			769 (1300-1500, edible portions)		
Shrimp			598		
Malaysian prawn (Hawaii)				215	
Yellow perch (silo, U.S.)				535	
Carp (Japan, recirculating system)		531			

1) The values are extracted from the sources listed above the columns.

2) Ranges of values for a species indicate that various degrees of energy intensity may be used to produce the same or comparably priced species, as explained in this paper.

PROBLEMS OF BIOGEOCHEMISTRY OF WORLD OCEAN

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The typical feature of the present period is the growing interest toward the World Ocean, which is largely connected with the desire to reclaim its potential wealth in a more complete and rational way. The comprehensive investigation of the ocean and putting its wealth to use are expected to bring about a better satisfaction of the mankind's growing needs for feed, raw materials, and energy. Human productive activity on the seas as well as the dumping of domestic, industrial, and agricultural refuge into their waters (directly and through the rivers or the atmosphere) have made the pollution-protection problems to become very acute.

An important contribution to the solution of these problems is to be made by the third-generation sciences having the objective of the system analysis of phenomena as parts of the indivisible Nature. These include, among others, the biogeochemistry of the ocean, a complex synthetic science whose purpose is a system investigation of biogeochemical functions of the hydrosphere and the analysis of interrelations of biological, geological, and chemical processes occuring in it. Its scope is defined by geological manifestations of life. As well as in the chemistry, the objects of investigation of the biogeochemistry of the ocean may include all the bodies of the hydrosphere. In contrast to biology, it deals usually with an integral form of life manifestations. The biogeochemistry of the ocean may be regarded as a part of the teaching of the biosphere created by V.I.Vernadsky, a great Russian naturalist, or as a part of the geochemistry of the ocean, or, lastly, as an important part of oceanology - a complex science integrating some divisions from the physics, chemistry, geology, biology, and geography of the ocean. V.I.Vernadsky used to separate biogeochemistry from geochemistry and treat it as a separate discipline.

A retrospective view of the history of the formation and development of biogeochemistry enables us to distinguish three major stages. The initial stage was connected with the description of individual phenomena and with revealing the significant role of living organisms in giving rise to natural processes and in affecting their course. Biogeochemistry did not yet exist as a special discipline. It was still evolving in the deep interior of the medieval natural philosophy, and, later, within the framework of such disciplines as geography, biology, geology, and pedology.

The second stage is the birth of biogeochemistry as a discipline. Just as Lavoisier was one of the founders of modern chemistry, and his work The Circulation of Elements on the Globe Surface marked the birth of ecology, the Russian scientist V.I.Vernadsky created in the 1920's a new science of biogeochemistry at the junction of several disciplines and was the first to give such a clear and comprehensive quantitative estimation of the role of the totality of organisms - the living matter - on our planet.

The third stage in the development of biogeochemistry commenced in the mid-sixties. Characteristic of it is a gradual evolvement of biogeochemistry as an interdisciplinary science, whose methodology is the system analysis and the treatment of phenomena in their probability expression.

The biogeochemistry of the ocean is based on three fundamental concepts, firstly, of a prominent role of living and dead organic matter in the present and past oceans, secondly, of the presence of active zones and boundaries with considerably increased rates of chemical reactions in the ocean, and thirdly, of a circulation of matter within the ocean and between the Earth geospheres. These concepts underlie the main theoretical problems faced by the biogeochemistry of the ocean; they determine, also to a great extent, the ways and means of their solution. Let us consider these concepts in more detail.

THE BIOGEOCHEMICAL ROLE OF ORGANIC MATTER

One of the specific features of the Earth as a planetary body, which distinguishes it from other planets of the Solar system, is the constant presence of the hydrosphere. The contemporary ocean is a final product of the differentiation of the Earth matter, the reflection of the planet's tectonic history.

The emergence and evolution of life on the Earth, the appearance of simplest eobiont systems capable of heterotrophic feeding and reproduction in the hydrosphere ($\sim$ 4.25 billion years ago), the evolution of bacteria and cyanophytes, the development of protobionts capable of the photosynthesis of organic matter and oxigen ($\sim$ 3.7 to 3.5 billion years ago), the appearance of eukaryotes and the pass over to oxygen respiration, the appearance of the first metaphytes, pelagic and benthic metazoans (1.0 to 0.9 billion years ago), the extensive penetration of multicellular organisms into the depth of the ocean and to its bottom at the Riphean/Vendian boundary, the emergence of plants and vertebrates onto the ground and their widespread settling there, and, finally, the appearance of man whose cultural and productive activity has by now embraced all the upper shell of the Earth, had brought about the development firstly of the hydrobiosphere, and then of the biosphere as a whole, and had provided the distribution of life in all its parts.

The most important consequence of the appearance of non-living organic matter and living organisms in the hydrosphere, effecting the exchange of matter and energy with the environment, was a gradual replacement of purely chemical reactions by more complicated biogeochemical ones corresponding to the totality of different forms of matter organization, including the most complex among them, which are characteristic of the living matter. Such complex biogeochemical reactions comprise, for example, the skeletal function of the organisms; the disappearance of hydrogen sulphide in the ancient ocean and the development of hydrogen sulphide zones in the present-day ocean; the formation of carbonate, siliceous, and phosphate sediments; migrations of most of the elements; the change of the existing forms and time of presence of the elements and their compounds in the hydrosphere; accumulation of organic matter initial for the formation of oil and gas; and, finally, the change of the properties of water itself under the influence of living organisms and their excretions.

Thus, the processes of dissolving, sedimentation, sorption, biological absorption and liberation, chemical change of composition and existing forms of the elements, are essentially biogeochemical. According to V.I.Vernadsky, water and living substance are genetically connected parts of the organized Earth matter, whereas the World Ocean exhibits biogenous chemical properties peculiar to the living substance.

Jean Baptiste Lamarck wrote at the turn of the 19th century in his Hydrogeology that there is a powerful and unrelenting force in nature, and that this force is represented by organisms which act as a prominent geological factor.

A hundred years later, a renowned geochemist and the founder of biogeochemistry V.I.Vernadsky wrote that the living substance embraces by its influence all the chemistry of the Earth crust and directs in it the geochemical history of almost all elements. In the ocean, the leading role in the biochemical processes also belongs to the organisms and non-living organic matter interacting with inert matter. It is highly characteristic that it is totally penetrated by living substance which, directly or indirectly,wholly determines all the chemical properties of the ocean. In the global structure this is the most powerful manifestation of the living matter.

Let us dwell at some length on the concentration function of living matter, namely on the calcium function characteristic of numerous organisms. The lower boundary of the Phanerozoic was really a greatest turning point in the Earth history. That time (~ 570 ± 10 mln. years ago) was marked by the mass advent of skeletal fauna. The population explosion was, undoubtedly, of biogeochemical nature. At the same time, the concentration function of living matter with respect to calcium is a much more ancient phenomenon. It was peculiar to Proterozoic and Archeozoic algae living more than 2.5 billion years ago. During all the Riphean, the stromatolites, formed by blue-green algae, evidently,together with bacteria, had achieved a fantastic degree of development and diversity. Their carbonate formations occur in Aphebian deposits (~ 2.6 billion years).

Thus, the calcium and the silicon functions of living matter as well as other biogeochemical concentration functions of organisms - especially, the accumulation of biogenous carbon - are, as has been repeatedly emphasized, much more ancient phenomena on the Earth than was commonly believed recently.

At the present, the calcium function is no less a specific property of the organisms than it was in the past. The investigations of carbonate and silica accumulation as well as of accumulation of organic substance, made it possible to compile maps showing the distribution of percentage concentrations and absolute masses of $CaCO_3$, $SiO_{2\ amorph}$, and C_{org} in the present-day and Quaternary ocean sediments.

Living organisms concentrate within their bodies numerous chemical elements which they utilize as constructive and/or energy material. The optimum synthesis of biologically active compounds and the normal course of living processes do not take place below a certain level of concentration of microelements in the organisms. Here lies the substance of biogeochemical mechanisms linking the organisms and the environment. Owing to investigation by a number of researchers, the science now disposes of some information on the concentrations of elements in marine organisms. However, reliable data concerning concentration coefficients for some metals are not available for many living genera and species. Such kind of knowledge may be of practical interest.

The problem of extraction of elements from sea water by means of the combined use of selective sorbents and some strains of microorganisms deserves consideration and development. The concentration function is inherent not only in the living, but also in the dead organic matter. It is best examplified by the concentration of uranium and germanium in coals, or that of phosphorus in shallow-sea sediments of upwelling areas, where phosphorites are being formed. Here, the mechanism of concentration is undoubtedly of biogeochemical nature, and it requires a thorough investigation.

At present, owing to research by biochemists and biogeochemists (V.Kado, K.Wada, N.Watable, A.Williams, E.T.Degens, et al.), we have considerably enhanced our knowledge of the extrapallial mechanism of the origin of skeletal formations (however, as regards marine organisms, this is true mainly in connection with mollusks). Nevertheless, the biogeochemical mechanism of selective concentration, due to which some elements and substances are concentrated by the factor of millions, whereas others are enhanced only several times to the background level, is still poorly known. The hypotheses of epitaxy, biomineralization from the initially non-structured gel, highly ordered layered alternation of the mineral and the organic components, are self-contradictory and not especially elucidating. The examination of these problems is one of the tasks of biogeochemistry.

We should now discuss some other aspects of the biogeochemistry of organic matter and the circulation of carbon, which has been playing a leading role in geochemical processes over the entire Earth history.

On the base of experience gained during many years of research in the field of geochemistry of organic matter, A.P.Vinogradov had justly remarked that "it is difficult to divorce the geochemical role of living matter from that of organic substances formed after the destruction of the organisms." At the present time, as in the course of the largest part of the Earth history, the activity of photosynthesizing organisms, their interactions among themselves and with microorganisms, protozoans, and more highly organized animals as well as with the non-living nature, is the principal mechanism of fixation and redestribution of cosmic energy. It would seem, that the incompletely locked biotic circuit of organic matter - the incompleteness being different at various geological stages - has always been the main means for the transfer of solar energy into the interior of the Earth.[1)]

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1) An alternative mechanism could consist in the transformation of feldspars into argillaceous minerals, which increases the distance between Al and O atoms.

An analysis of recent results in the field of biogeochemistry of organic carbon permits to arrive at some conclusions. The highest C_{org} concentrations occur on the submarine continental margin and encircle the land as a continious belt. Here, on the shelf, but mostly on the continental slope and rise, more than 90% from the total mass of organic matter become deposited.

The organic matter fossilization coefficients, or, in other words, the percentage of buried organic matter from the combined amount of its reproduction in the ocean and inflow from the land, make up ~ 0.4% for the ocean as a whole (in Holocene), ~ 0.7% for continental margins, and ~ 0.1% for the ocean floor.

The analysis of the data obtained has indicated that, within the ocean, from 92 to 97% of the (gross) production of photosynthesis and of the amount of organic matter arriving from the land, disintegrates to mineral compounds. Between 1 and 3 billion tons of C_{org} reach bottom as suspended matter; this accounts for 3-8% of the (gross) primary production plus the supply of organic matter from the land (when considering only the primary production the percentage would increase to 5-15%). On the surface of the floor and in the uppermost sedimentary layer, some 92-97% of suspended organic matter that reach the floor burn up in biogeochemical reactions, become partially dissolved, and pass into the deep organic matter reserve. Thus, in spite of the fact that the absolute masses of organic matter mineralized in the water (mainly, within the photic layer) and in the upper sedimentary layer differ by an order of magnitude, the overall degree of balancing of the two major systems of decomposition of organic matter in the present ocean remains roughly the same.

THE CONCEPT OF ACTIVE SURFACES IN THE OCEAN

The interfaces in the ocean, coinciding with inter-science boundaries, are zones of biogeochemical interactions of highest intensity. In the vicinity of everyone of such surfaces there exists a field of increased chemical activity and physical anomalies. In mathematical models, boundary zones are frequently singled out as surfaces of discontinuity of various properties. On active surfaces of the interfaces maximum transformation of energy is occurring and high chemical affinity potential and the greatest variety of chemical compounds are being observed.

The most active ocean interfaces are: ocean - atmosphere, ocean - land, water - suspended matter, water - living substance, water - floor sediments, as well as hydrological boundaries, in particular, the liquid frontier stretching along the Equator and dividing

Defant's warm Super-ocean into the northern and the southern parts. Other liquid boundaries are the hydrological fronts and the thermocline, dividing waters of different properties and modeled as a discontinuity surface. Numerous interacting elements are treated as a local system whose possible states are characterized by the presence or absence of each conceivable link between the elements, the complexity of the system being greatly increased with the growth of the number n of elements forming interfaces in this particular local system: $N = 2^{n(n-1)}$, $R = lg_2 N = n(n-1)$, where N is the possible number of states for a system, and R is the variety degree similar to that introduced by R. Hartley. The systems exhibit maximum variety of conditions and, consequently, the greatest activity, in such areas where interfaces approach each other or intersect. The most complex interface in the ocean is the one between ocean and land. Here are brought close and supercede each other interfaces of different nature: water - air, water - land, water - sediment, water - suspended matter, water - living substance, and, sometimes, water - ice.

Especially active and complicated (multicomponent) nature is characteristic of the biogeochemical processes in the coastal zone, in and off river estuaries, in upwelling zones and other offshore areas where there is a supply of various material, where many new interfaces (suspended matter, living organisms, gas bubbles, etc.) are recently formed, and where the migration conditions as well as the existing forms of substances undergo a drastic change.

According to rough estimates, the ocean layer, open for interchange through interfaces with the remaining mass of the ocean and adjacent geospheres and comprising all, or nearly all, active interfaces, makes up about 2% of the total ocean volume. The internal inert, low-gradient part of the ocean, poor in life and with slowly going biogeochemical processes, accounts for some 75% of the volume, the balance corresponding to transition zones.

Thus, we can make some conclusions following from the second biogeochemical concept.

1. The processes in active areas largely determine the structure of the ocean and its mode of function, including the self-cleaning capacity.

2. The overall dimensions of the ocean are not indicative of its role as a source of natural reserves as well as of its capacity to accomodate, without apparent harm, human refuge through the means of self-cleaning. Moreover, the immense size of the ocean may well prove deceptive in this respect.

3. The most active parts of the ocean, whose volume is comparable to that of land, are subjected to the worst pollution. Some interfaces, e.g., water - living substance, river - sea, are being assiduously studied at present. Other highly interesting interfaces, as, for instance, the contact areas of interior matter with sea water in rift zones, or the water-ice boundary, are still poorly studied biogeochemically. Their exploration is, undoubtedly, one of the important problems in the biogeochemistry of the ocean.

Thus, the theoretical problems of biogeochemistry and the practical tasks of pollution control require the development of the concept of ocean interfaces and the conduct of extensive system research. Underestimating their role in the transformation of natural substances in the ocean cannot be justified.

CIRCULATION OF SUBSTANCES IN THE OCEAN

The repeating processes of transformation and migration of substances were in existence during all of the Earth geologic history; however, they did not remain invariable. After the formation of the Earth paleobiosphere (not less than 3.5 billion years ago), their evolution was governed by the common effect of geological, physico-chemical and biological factors, and was confined to the system: ocean - atmosphere - living matter - soil, sediments, surficial rocks - deep-seated rocks.

The classification of circulation of substances in the ocean and on the land has not been yet evolved. One of the fundamental ideas in geology is the concept of the major geological circulation of substances, on the basis of which, according to W.R.Williams, develops the minor, or biological, circulation. The major geological circulation of substances (the geochemical cycle) as well as the minor biotic circulation are not closed. The circulation of organic matter forms the backbone of the biotic cycle. Microorganisms play an immensely important part in the synthesis-destruction system of organic matter and, thereby, in the self-regulation and evolution of the hydrobiosphere. All the water of the hydrosphere is decomposed and reduced by organisms every 2 million years, and its volume equivalent of that of the World Ocean water (1.37×10^9 km^3) is filtered by organisms in half a year. The basis of the major geological circulation are tectonic movements - the rising of some parts of the Earth crust together with the sinking of the others, the spreading of ocean floor from mid-ocean ridges coupled with the subduction of sediments, basaltic layers, and mantle matter under continental plates.

The importance of studying circulation of substances in the ocean in terms of the concepts of the major and minor cycles has become deeply rooted in the minds of scientists. This seems to be the most sound way to attempt to trace the biogeochemical evolution of complex natural systems.

In view of the complexity, diversity and scale difference of biogeochemical phenomena taking place in the biosphere, the possibilities of analyzing natural processes on the basis of the concepts of the major and minor circulations of substances have not as yet been put into effect. It is conceivable that important generalizations and major discoveries may be realized in this direction. This is particularly true with respect to such elements as H, C, N, O, P, S, which constitute the bulk of biogenous and, at the same time technogenous compounds playing prominent role in the nature and human life. Due to an extremely high reactivity of these compounds, most of the problems presently faced by humanity (all, or nearly all, environmental problems) are connected with the six listed elements of the periodic table. Therefore, the development of biogeochemical models of global circulation of these elements and their compounds as well as of other technogenous substances is of great importance from the viewpoint of theory and practical application. It would enable us to predict the behavior of numerous natural and technogenous compounds in the ocean, to reconstruct its geochemical history,and to forecast further evolution of the biosphere.

Tables 1-2 comprise data concerning the content and masses of carbon on the Earth and global constants of the organic carbon circulation in the megabiosphere. Their analysis allows to arrive at some conclusions. The first noteworthy feature is an increasing equilibrium of synthesis-destruction processes of organic matter within the system: autotrophic cycle, heterotrophic cycle - land sediments - ocean sediments. This is reflected by the ratio of the amount of buried C_{org} in the stratisphere to the mobile C_{org} reserve on the Earth as a whole, in the ocean, and on the land. For the Earth as a whole $\varkappa/\rho$ relation is about 3,500, that is there is 3,500 times more C_{org} buried in the Earth sedimentary cover (together with extrusive rocks) than constituting the mobile reserve. The corresponding figure for the land is greater ($\sim$ 4,200) and for the ocean lesser ($\sim$ 2,500).

The second fact is that the mass of C_{org} formed in the Earth biosphere over a period of 3.5 billion years (i.e. in the megabiosphere or in its greater part) is rougly 3 times as big as the mass of the Earth crust and approximately 7 times as big as the mass of the megabiosphere. These values are likely to be underes-

Table 1

The content and mass of carbon on the Earth

Geosystems, biogeosystems	Content, weight percentage		Mass, 10^{15} g		Source
	$C_{CO_3^{-2}}$, HCO_3^-, CO_2	C_{org}	$C_{CO_3^{-2}}$, HCO_3^-, CO_2	C_{org}	
1	2	3	4	5	6
Atmosphere					
Atmosphere	0.009	0.0001	192	4[1)]	The global carbon cycle, 1979
Ocean					
Plants	-	27-37[2)]	-	0.1-0.2[3)] / 20-70	Bogorov, 1971, 1974; Koblenz-Mieschke, Romankevich, 1977
Animals	-	19-45[2)]	-	2-3[3)] / 5	Ibidem
Dissolved matter	$2x10^{-3}$	$1.5x10^{-4}$	38.4	$2x10^3$	Skopintsev, 1979; Horne, 1972
Suspended matter	1.1[2)]	5-40(10)[2,4)]	3.2-4.8	30-45	Romankevich, 1977
Floor sediments for the last 1000 years	4.3	0.6	$1.08x10^3$	85-220	Gershanovich et al., 1974; Romankevich, 1977
Petroleum	-	82-87	-	$1.5x10^3$	Vassoyevich et al., 1977
Hydrocarbon gases	-	65-80	-	$>1x10^3$	Ibidem

Table 1 (continued)

1	2	3	4	5	6
Oceanic stratisphere[5)]	4.3	0.1–0.5	-	5×10^6	Geodekian et al., 1978; Vassoyevich et al., 1977
		Land			
Plants	-	45[2)]	-	$\frac{450–770(523)^{3,4)}}{53.8}$	The global carbon cycle, 1979
Animals	-	45[2)]	-	2	Ibidem
Rivers, lakes (dissolved and suspended matter)	-	10×10^{-4}	-	2.2	Romankevich, 1977
Polar ice, glaciers	-	$(0.5–1) \times 10^{-4}$	-	14–28	Ibidem
Underground waters	-	27×10^{-4}	-	2.5×10^3	Shvets, 1973
Soils	-	-	-	2.07×10^3	The global carbon cycle, 1979
Peat	-	-	-	110–1.123[4)] (300)	Vassoyevich et al., 1977; The global carbon cycle, 1979
Coal	-	-	-	3×10^4	Vassoyevich et al., 1977
Pyroschist, domanikite, bazhenovite	-	4–40	-	2.1×10^5	Ibidem

Petroleum (in oil fields)	-	82-87	-	$2.5x10^3$	Ibidem
Hydrocarbon gas (in gas fields)	-	65-80	-	$2x10^3$	Ibidem
Continental stratisphere[5)]	2.61	0.5	$14.7x10^6$	$10x10^6$	Ronov, Yaroshevsky, 1976; Vassoyevich et al., 1977
			Earth crust		
Sedimentary cover with extrusive rocks	2.92	0.53	$80.5x10^6$	$14.7x10^6$	Ronov, Yaroshevsky, 1976
Oceanic crust	0.4	0.05	$82x10^6$	$3.4x10^6$	Ibidem
Subcontinental crust	0.37	0.07	$16.1x10^6$	$3.2x10^6$	Ibidem
Continental crust	0.40	0.08	$72.9x10^6$	$14.6x10^6$	Ibidem
Earth crust as a whole	0.39	0.07	$111.4x10^6$	$21.2x10^6$	Ibidem

[1)] At atmospheric mass $5.14x10^{21}$ g and air molecular mass 29; C_{org} only as CH_4.

[2)] Calculated for dry weight.

[3)] Upper line - biomass, lower line - annual production.

[4)] Numbers in parentheses denote the most likely average content.

[5)] Sedimentary cover with extrusive rocks.

Table 2

Planetary indicators of the C_{org} circulation

Amount of buried C_{org} in the stratisphere ($\varkappa$) - 15 x 10^{21} g
including: in the oceanic crust $\varkappa_0$ = 5 x 10^{21} g
in the continental crust $\varkappa_t$ = 10 x 10^{21} g.

Mobile reserve of C_{org} on the Earth (ρ) = 4900 x 10^{15} g
including: in the atmosphere ρ_a = 4 x 10^{15} g
in the ocean ρ_0 = 2200 x 10^{15} g
on the land ρ_t = 2700 x 10^{15} g.

Annual removal of C_{org} from biotic circulation:
autotrophic cycle K_h = 30-40%
heterotrophic cycle K_c = 0.8%
ocean[1)] K_o = 0.4%
land[2)] K_t = 1-10%

Ratio of the amount buried in the stratisphere to the mobile reserve:

$$\varkappa/\rho = 3061; \quad \varkappa_0/\rho_0 = 2273; \quad \varkappa_t/\rho_t = 3704.$$

Ratio of C_{org} mass formed in the biosphere over the time of its existence ($M_{C_{org}}$) to the mass of the Earth crust (M_{ec}) and the mass of the megabiosphere (M_{mbs}):

$$M_{C_{org}}/M_{ec} = 3.5^{3)}$$

$$M_{C_{org}}/M_{mbc} = 9^{3)}$$

Mean fossilization coefficient of C_{org} in the stratisphere

$$(15 \cdot 10^{21}\ g/10^{26}\ g) \approx 0.01-0.02\%.$$

1) Fossilization coefficient of C_{org} in oceanic sediments.

2) Fossilization coefficient of C_{org} in terrestrial hydrofacies.

3) It has been assumed in computation that primary production over 3.5 billion years under the condition of its increase from zero up to the present level ≈ 1 x 10^{26} g; mass of the Earth crust = 2.85 x 10^{25}; mass of the megabiosphere ≈ 1.1 x 10^{25} g

timated, since it has been assumed in calculation that the primary production of living matter in the history of the Earth has been steadily growing from zero (3.5 billion years ago) up to the present level.

The third remarkable feature is the organic carbon fossilization coefficient which ranges from 0.05 to 0.01% for the megabiosphere, and is on the average around 0.03%. This value is indicative of a high degree of balancing of production and destruction processes and of a tightly closed pattern of the organic carbon circulation on the Earth.

It should be pointed out that many values listed in Tables 1 and 2 have been calculated with insufficient accuracy; such highly important indicators as C_{org} annual production on the land and in the present ocean, according to the figures by various authors, differ by a factor of 2 or 3. At the same time, these values are principal indicators of the state of the biosphere. The knowledge of masses of C, N, P, O, S being actively cycled or constituting exchange and reserve funds is essential for balance calculations, for the computations of time of presence of numerous elements, and for the investigation of their geochemical behavior. Therefore, a major task in biogeochemistry is the obtaining of reliable and accurate estimates of biomass and production of different forms of organic matter in the ocean and on the land and more precise establishment of global constants of the carbon circulation on the Earth.

It is also imperative to avail ourselves of more reliable quantitative data on the budget of various dispersed forms of non-living organic matter (dissolved, colloidal, suspended), on their content and distribution in the seas, in the ocean and on the land. An important point is the elucidation of the role of organic matter in migrations of elements, in the formation of hydrogen sulphide zones and areas poor in oxigen.

The development of human society, especially over the last 50 years, has enhanced the part of anthropogenous factor up to a level comparable to the natural biogeochemical factors of circulation of substances in the biosphere as regards the scale of the processes, and exceeding them tens or hundreds of times as regards their rates. The most dangerous sequences of changes in a balanced carbon system, as well as in other cyclic elements, are related to the distrubances introduced by man, who have now involved all of the planet in his industrial activity. At present, about 10 million tons of organic and inorganic matter are brought annually into the ocean, the surface oil film is becoming progressively widespread. Human impact on the ocean and the entire biosphere results in increasing the one-sided horizontal transport of matter, in speeding up the circulations, in lowering their stability, and in enhancing the interdependence of biogeochemical systems remote from one another both in time and space.

The situation with the carbon circulation, which has now taken shape, has demonstrated that we are unable to manage the global equilibria in nature. At the same time, one can hardly agree with the conclusion of some scientists that we should better leave it in a state close to natural - that is, in a way it had been prior to the industrial revolution.

Much effort has been expended over the last decade in order to establish the level of pollution of the oceans, to develope the analyzing techniques, measures against oil spills, and, to a lesser degree, to determine the effect of various technogenous refuge on physical, chemical, and biological processes in the ocean. In the course of this research it became clear that it is impossible to obtain an accurate assessment of concentrations of any pollutant - to say nothing of the degree of its impact on various natural systems - basing solely on studying the anthropogenous compounds.

It is now evident that the problem of predicting the consequences of environmental pollution is seriously aggravated by the fact that various technogenous compounds react with a wide range of natural substances, with the result that their behavior and the effect on the biosphere may undergo a change. In view of this, an important current problem is the development of methods for separate quantitative determination, in the same object, of substances of anthropogenous and natural origin. The influx into ocean, as a result of human activity, of almost all elements of the periodic system in other proportions than previously (frequently many hundreds of times more than in the course of natural processes) has shown that the problems of the geochemistry of the ocean and the whole biosphere can no longer be treated without considering the anthropogenous influence.

The paradox of the situation consists in the fact that the huge volume of available information on the biogeochemistry of natural compounds in the oceans on one hand, and on marine pollution on the other, has not been discussed and generalized from the uniform viewpoint of the circulation of elements and their compounds in the biosphere. This work is just commencing.

Therefore, a problem of great priority in the biogeochemistry of the ocean is the study of biogeochemical cycles of natural and anthropogenous substances, their transformations as a result of human activity, and their influence on the physical, chemical and biological processes taking place in the ocean and the entire biosphere. The solution of this problem should rest on the following principles: first, on a system investigation of all forms, chemical composition, and migration patterns of natural and principal technogenous elements in the ocean (C, N, P, O, S, etc.) and their main compounds, which would be based on the teaching of the biosphere as a dynamically balanced system with certain self-regulation mechanisms developed in the course of evolution and at present disturbed by men; second, on evolving models representing circulations of elements and substances in the oceans as parts of the general circulation and exchange of matter between Earth geospheres; and, third, on conducting complex biogeochemical observations and experiments in the ocean on the base of uniform methodology, separate quantitative determination of natural and anthropogenous substances, and the use of intercalibrated measurement techniques.

MODELING AND THE BIOGEOCHEMICAL ASPECT OF THE POLLUTION PROBLEM

Until recently, while dispersed domestic effluents with easily biodegraded organics were the main source of hydrosphere pollution, the computations in connection with the pollution problem could be reduced to estimating the dilution of effluents, or be based on integral indicators of water quality and on very simple schemes, ideas, and models. However, at present the problem has been cardinally changed in connection with a sharp increase in the scale and variety of pollution. A problem of reliably estimating and predicting biogeochemical conditions on extensive ocean areas for various economical needs is on the current agenda.

The forecast of biogeochemical conditions is now first of all a mathematical modeling problem. Indeed, direct measurements of matter transformation rates in the ocean are usually impossible, and data of in situ observations on concentration fields of substances also cannot be successfully utilized to this purpose (especially for evaluating specific rates) on account of non-uniqueness of solution of reverse problems and unstability of such solutions relative to observation errors.

It would seem that laboratory modeling could have a final say in this question. Experiments with such models are becoming widespread all over the world. However, in the course of this work, the questions of the similarity of the model and the natural original usually escape notice. Meanwhile, hydrodynamical and chemical criteria of similarity (i.e. Reynolds and Damkeller criteria, respectively) are frequently incompatible, whereas ecological similarity criteria are not yet established. Since the distribution and transformation of pollutants are related to the combined effect of hydrophysical and hydrochemical processes and the functioning of ecological systems, the laboratory modeling, to a considerable degree, turns out to be a self-deception. The way out of this vicious circle lies in the mathematical modeling, which should be complemented by experimentation for estimating parameters of the model and, generally, for its identifying and, together with in situ observations, for assessing the adequacy limits of mathematical models.

The main difficulties in the mathematical modeling of biogeochemical conditions and cycles of elements stem from the complexity of the modeled system and the necessity of strictly coordinated participation of different scientists: mathematicians, hydrodynamicists, chemists, biologists, geologists, geographers. Some experience in conducting multi-aspect complex investigations is already available in oceanological research. However, this experience as well as the knowledge gained in solving corresponding direct and reverse problems in mathematical physics, happen to be insufficient. Of considerable importance is the methodology of system approach and, particularly, of system analysis - a systematic consideration of all aspects of major complex problems and alternatives. We can note that present pollution research to a great extent repeats typical methodological errors that have been revealed and even classified earlier in conducting system analysis of other large complex problems. The most essential of these are: (1) inadequately truncated formulation of a problem, of the objectives and purposes, and functional misuse of models; (2) a lack of care regards the establishment of proper limits of model adequacy; and (3) identification of system analysis with modeling involving the use of detailed mathematical models (especially, simulation models) realized on electronic computers, as well as the tendency towards developing universal models capable of answering any question concerning the system. In reality, this is in contradiction to methodologies of both the classical physical approach and the system analysis.

All this may bring about the discreditation of the system analysis and mathematical modeling. Meanwhile, only through those means lies the way toward the solution of the present-day theoretical and applied problems in the biogeochemistry of the ocean.

SOME CLIMATOLOGICAL ASPECTS OF OCEAN RESOURCE MANAGEMENT IN THE PACIFIC BASIN: A PRELIMINARY ASSESSMENT

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This paper is based on the assumption that the assessment of climatic environmental limitations to all types of marine resource exploitation is essential in order that the marine environment might be optimally used by commercial activities and still be preserved for use by future generations. Such activities include deep sea mining, fisheries, outer continental shelf energy resource exploitation, offshore drilling, the transportation of energy resources, various types of ocean-related energy exploitation such as wave power , thermal power, and tidal power, among others.

Two totally different case studies have been chosen for brief discussion: the Peruvian anchoveta fishery and Ocean Thermal Energy Conversion (OTEC). The former represents a living resource for which environmental and climatic limitations have been known probably for as long as the resource has been exploited on a sustained commercial basis. The latter (OTEC) represents a potential solar energy resource about which environmental and climatic impacts can at best be hypothesized, as there is no operational OTEC power plant at this time (although prototypes are being constructed for experimental purposes).

PERUVIAN FISHERIES AND EL NIÑO

By the late 1960's Peru had become one of the leading commercial fishing nations in the world with respect to tonnage of fish landings. The Peruvian fishing industry had undergone a meteoric rise since 1952 in fish landings as well as entrepreneurial investments in all aspects of the fishmeal industry. However, by 1978 Peru's ranking had dropped below fifteenth with anchovy catches that year registering about 5% of what they had been in 1970. What had happened to the anchovy fishery which at one time had supplied Peru with about one-third of its foreign exchange?

What happened has been referred to as the collapse of the anchovy fishery resource. That collapse has been blamed - not quite correctly - on an oceanographic-meteorological phenomenon known as El Niño, defined as the invasion of warm water from time to time in the eastern Equatorial Pacific upwelling. This invasion adversely affects the natural upwelling processes and therefore the food chain, beginning with the phytoplankton and technically ending with the Peruvian fishermen.

The population dynamics of the anchovy is highly variable from year to year, a variability which, at least in theory, is recognized. Thus, the concept (somewhat controversial) of maximum sustained yield (MSY) has been established to indicate an amount of fish that can be taken without adversely affecting the ability of the fishery to sustain itself through natural recruitment processes. If fish population had been the only variable, and if fishermen had strictly adhered to the MSY, there might have been no problem with the preservation of this Peruvian natural resource. However, there were other intervening variables which must also be considered.

In the late 1950's a number of guano-producing birds off the coast of Peru was estimated to be about 28 million. These birds (pelicans, cormorants, and gannets) had been the basis of Peru's guano (fertilizer) industry. For decades the Peruvian Guano Administration had enough political power to thwart attempts by entrepreneurs to develop on a commercial basis a fishing industry based on the anchoveta. Their argument was based on the need of Peruvian agriculture for guano and on the fact that the main food source of these birds was the anchoveta. However, in the early 1950's a political decision was made to develop the fishing industry in Peruvian coastal waters (at that time Peru was one of the few countries to claim a 200-mile territorial limit). Thus there were two predators, fishermen and guano birds, competing for the same resource. At that point in time there was little concern for calculating the MSY and placing restriction on the anchoveta exploitation, as the resource seemed to have been there for centuries and seemed to be in infinite supply.

Yet another, sometimes overlooked variable, the periodic occurrence of El Niño, precipitated a crisis with respect to the impact of the rapidly increasing exploitation on the anchoveta fishery. El Niño events occur mostly at Christmas time and last for a few months. However, occasionally they last for more than a year, adversely affecting primary productivity in the eastern Equatorial Pacific. El Niño affects anchoveta fishing at least in the following way: on the one hand, the fishery will be greatly thinned out, while on the other, the surviving fish will be clustered along the coast and at other points where the cold, nutrient-rich deep upwelled water can break through the warm, nutrient-poor water that has invaded the region, giving the illusion of an abundance of fish population in the regions where they have concentrated. Thus the fish become easy prey for the fishermen who catch them in great numbers in a short time, with little regard for MSY, or year class. The fish population structure is impaired as the young fish are taken along with the adults, thereby reducing the ability of the fishery to replenish itself.

This is essentially what happened in 1972-73. The demand for and the price of fishmeal were high. The incentive to catch anchoveta was there. Few restrictions were placed on the fishing effort and those restrictions that were levied were often bypassed (for example, when ships were allowed only a few sorties per unit of time, the fishermen simply increased the hold capacity so that they could increase their catches on any given sortie). The end result was a combination of excessive biological, oceanographic, meteorological, and managerial pressures on the fishery, leading to a collapse of that resource base, not to mention near-total devastation of the guano bird population. The social, political, and economic impact of the collapse was a major setback to Peru's political and economic development plans. In addition, the 1972-73 event led to the nationalization of the fishing industry. The standing stock of anchoveta has not returned to previous levels and remains at a critical level with respect to its future viability as a resource.

A significant point about the history of the anchoveta fishery is that there was environmental information available about the fragility and therefore vulnerability of the anchoveta as an exploitable resource, yet the messages were apparently not heeded by political decision-makers. For example, in 1954, R.C.Murphy wrote extensively on the potential problems that would develop if the interests of the birds (that is, the guano industry) were not taken into account in any scheme to exploit the Peruvian anchoveta fishery in a major commercial way. He noted that if care was not taken, the two resources would collapse together... and they did in the early 1970's.

Another example of existing environmental information was supplied by a 1969 report of Peru's Marine Institute (IMARPE) Panel of Experts. That report asserted that the fishery was in trouble from overexploitation and that it could conceivably collapse from economic pressures alone. The report did not even mention the complication of El Niño's impact on the fishery. In 1970 Paulik warned that the combined effects of the fishermen, the market, and a major El Niño on the fishery would be the collapse. Within two years his scenario became a reality.

Thus it can be argued that there was a considerable amount of information about the limitations of the resource from a biological as well as climatic standpoint, but that information was apparently not given any value in the decision-making process or was superseded by more immediate economic and political pressures.

OCEAN THERMAL ENERGY CONVERSION (OTEC)

The ocean serves as a collector of solar energy. There have been many attempts in history to tap that resource. One of the most recent ones is the ocean thermal energy conversion scheme, designed to utilize the thermal gradient that exists between the warm surface waters and the colder deep water. The gradient is used to operate a turbine to generate electricity to be used either directly or for producing a synthetic fuel, liquid hydrogen. The OTEC system has a low conversion efficiency but requires no fuel. Furthermore, although the efficiency is low, the thermal gradient is practically a perpetual source of energy. However, those regions where the thermal gradient is the largest and which would therefore be the ideal locations of OTEC plants (between 20°N and 20°S latitude), are farthest from the regions where the energy could most easily or most effectively be used.

OTEC is not a new concept, but has been discussed and occassionally attempted throughout the past century with limited success at best. However, it has received a new impetus as a result of the energy shortages of the mid-1970's. Federally funded research and development has increased several fold in recent years, with more than $ 60 million being requested for 1979, an increase of about $ 26 million over 1978. It is considered to be a viable alternative source of energy in lieu of increased dependence on fossil fuels.

The 1970's witnessed not only an increased interest in OTEC, but also a sharp increase in concern for the environmental impacts of new technologies. Perusal of the various OTEC conference proceedings suggests a strong awareness and concern about OTEC's impact on the environment (ocean, atmosphere, and biota). This concern, of course, is not solely motivated by a desire to protect the environment, but also by the need to assure that environmental fluctuations (i.e., winds, currents, seasonal effects, mixing, severe storms, etc.) will be incorporated into the OTEC engineering design. In addition, such concern is meant to ensure that the OTEC power plant will be able to maintain its commercial value during a relatively long period of time. Thus it seems that, at least in theory, many of the potential environmental impacts of OTEC are being made explicit. However, the real impacts of OTEC plants can only be evaluated when plants are built and are operational on a significant scale. It is nevertheless encouraging that many environmental implications are being made explicit, and the methods to assess them being developed simultaneously with the technology. What are some of these implications?

As has been pointed out, the interactions between OTEC and the environment are symbiotic. That is, OTEC can have an effect on its environment and the environment can have an effect on the OTEC operations. For example, with respect to the former, OTEC can bring about artificial upwelling and therefore a redistribution of nutrients; it can lower sea surface temperatures (SST) thus affecting global evaporation patterns; it can modify ocean temperatures through mixing; it can potentially alter the paths of ocean currents; it can lead to increased CO_2 emissions into the atmosphere; it can cause biostimulation of marine life; it can alter salinity and/or mixed layer depths; it can introduce (through leakage) biocides and working fluids into the marine environment. These effects, among others, can become significant as the size and the number of OTEC power plants are increased in a given locality. Most of these effects have the potential to alter the climate in some way, as the following discussion suggests.

It has been suggested that the major effect of an OTEC operation on climate would be related to SST changes that would result from OTEC-induced artificial upwelling. Artificial upwelling might be expected to produce similar conditions to those created by natural upwelling processes: local climate anomalies and enhanced fish populations (as a result of increased primary productivity). However, with just one OTEC plant the effect on the microclimate would most likely be negligible, whereas clusters of such plants would affect SST on a much broader scale and could therefore have a significant effect on atmospheric as well as oceanic processes.

It has also been suggested that the physical presence of OTEC plants could have an effect on ocean currents and their associated eddies which could affect oceanic poleward heat transport. It is clear that interference with this northward transport of energy by the oceans could have large-scale climatic effects.

Another aspect of artificial upwelling is that it would lead to an increase in primary productivity resulting in phytoplankton blooms which could in turn change the albedo (reflectivity) of the ocean surface. This could result in a heat loss of the ocean water and of the atmosphere and a change in the microclimate.

There has been much concern expressed in the scientific community about the constant increase in CO_2 content in the atmosphere because of the increased burning of fossil fuels. It has been suggested by some observers that the continued rate of increase of

CO_2 loading of the atmosphere could lead to a rise in global temperature averages on the order of 2 to 4°C, given a doubling of CO_2 by the mid-21st century. This could have a major impact on precipitation, temperature, and SST patterns in various (yet undetermined) regions around the world. This brings us to the second potential effect of OTEC operations on the climate. As the cold deep water artificially wells to the surface and warms, it will give up CO_2 to the atmosphere. It has been estimated that an OTEC plant would release one-third as much CO_2 to the atmosphere as does a fossil fueled plant of equivalent energy production.

There are also many effects that the climate can have on OTEC operations. All these impacts merit continual observation, redefinition, and, reassessment. As OTEC becomes more feasible as an alternative source of energy, these investigations will become increasingly more urgent.

Conclusion

The Peruvian case raises some important considerations about the use of existing environmental impact assessments. As it has been suggested, there existed much information about the limitations of exploitation of the Peruvian anchoveta, yet for one political or economic reason or another, that information was apparently not used in the decision-making processes related to various aspects of the fishmeal industry. The end result was the impairment, if not destruction (it may be too soon to tell), of a living marine resource.

This raises, by analogy, important concerns about those environmental impact assessments that are being done (even on an experimental basis) for OTEC. Will these assessments be used in such a way as to ensure that OTEC plants will either operate in harmony with their environments or operate not at all? What would happen to those assessments (and those environmental limitations) if another energy crisis were to occur? Would OTEC-related environmental standards be set aside?

Finally, while considerations about the impact of a new technology on the environment are made in most countries, the quality of national legislation related to such matters is at the least uneven.Yet it is very likely that OTEC plants will be deployed in international waters. In order to avoid uncontrollable low grade insults (abuses) to the international marine and atmospheric environments, one must begin now to develop international regulations for the operation of OTEC plants in international waters, while the technological capability is being developed.

ENERGY CONSUMPTION, CLIMATE, AND NATIONAL PARKS AND RESERVATIONS

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This paper is intended to be of interest to everyone who is concerned about the preservation of the flora and fauna on Spaceship Earth as well as those with specific national park and reservation interests. It should be emphasized that this paper is concerned with the development of science policy concerning the possible implication of inadvertent anthropogenic climate change and not with the acquisition of the scientific evidence necessary to justify these policy decisions. This paper suggests that the concept of prudence can play a useful role in the development of global science policy. The object of this paper is to show the possible climatic and other impacts of the release of carbon dioxide into the atmosphere and of thermal energy into the earth, water, and atmosphere due to present and projected human activity and to suggest possible courses of action.

It is useful to recall that it is about 230 years since Captain Cook, amongst others, initiated what Alan Moorehead (1968) has called "that fateful moment when a social capsule is broken" in describing the impact of western culture and technology on the peoples of the Pacific basin. Today, this same technology is threatening to burst another capsule that may produce a much more serious shock for all humankind than did these earlier impacts since we are embarked on an inadvertent experiment. Revelle and Suess (1957) first clearly articulated the nature of this experiment, when they stated: "Human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor repeated in the future. Within a few centuries, we are returning to the atmosphere and oceans the concentrated carbon stored in the sedimentary rocks over hundreds of millions of years. This experiment, if adequately documented, may yield a far-reaching insight into the processes determining weather and climate." Unfortunately, as it is hoped this paper will demonstrate, the probable global implications of this inadvertent experiment are too serious to justify its continuation. However, it is rather surprising and disturbing that few lay people and particularly politicians other than a rather limited group of climatologists are aware that it is being performed and the risks involved. It is hoped that this paper will help to redress this situation.

It appears that the earliest parks may have existed in ancient Persia about 4000 years ago. The contemporary concept of national parks and reservations appears to have arisen in the latter half of the 19th century as a response to return to nature movement popularized by Thoreau, Muir, and Wordsworth amongst others. This movement was, in part, a reaction against the impact of industrialization on man and his environment. National parks and reservations have become an accepted part of western culture, and the concept has been disseminated to other cultures where it has been absorbed and altered. It is, perhaps, useful to give the following description of an encounter with a person for whom the parks concept was alien."What is a park?" asked a puzzled Inuit (Canadian Eskimo) elder of an eager civil servant during recent hearings into five proposed northern parks. Scratching his head, the civil servant could only come up with an approximation, the Eskimo word, "minnguirsirvik," but it pleased the elder. The word translates as a resting place. In Canada, the general purpose of national parks is determined by the governmental National Parks Act (1974): "The National Parks of Canada are hereby dedicated to the people of Canada for their benefit, education and enjoyment, subject to this Act and the regulations, and the National Parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations." It will be argued that a mandate such as this requires park managers and policy makers to take account of the possible outcomes of the abovementioned inadvertent experiment.

Today, western technology and culture is responsible for a wide spectrum of social, medical, and environmental impacts throughout the world. National parks and reservations are not exempt from these impacts particularly in developed countries. Mishan (1969) has observed: "As for the rapid destruction by mass tourism of the world's dwindling resources of natural beauty, a small contribution towards preservation could be made by the prohibition of motorized vehicles within selected areas and by the discontinuing of air services to such areas. Once the public becomes aware of the spread of devastation, international agreement on more radical measures mav be forthcoming - if by then there is anything worth preserving." Ten years later, little of this prescription has been implemented (Yosemite is an exception), and the rate of devastation continues to increase exponentially both inside and outside our "resting places."

Tourist and recreation residues are a measure of this devastation since industrial residues are those unwanted by-products of industrial activity including not only chemical, thermal, and atmospheric pollutants, but also undesirable social, medical, and other impacts. Such residues are called diseconomies by economists. "Unimpairment for future generations" can be realized only if these residues are minimized or eliminated by imaginative park management policies.

The concept of economic growth has become, as Wagar (1970) has suggested, "elevated to the same sacrosanct level in western society as rain dancing has been in other societies." In this paper, it is sufficient to note that there exists an empirical one-to-one relationship between the traditional indicator of economic activity, the gross national product (GNP) per capita and the energy consumption per capita. The developed countries are characterized by the largest GNP and hence energy consumption, emerging areas such as Latin America have smaller GNP, and the less developed areas of the world have the smallest GNP. Today, a growing number of economists are questioning the validity of the GNP as an indicator of quality of life once the basic requisites of life, food, shelter, and clothing are provided, since industrial activity frequently becomes directed to the provision of "non-essential" goods that are made to appear as essential. It is now believed that other quality of life indices should replace GNP. One nation, New Zealand, continues to set a precedent by not using this index when compiling economic and social data for the OECD. GNP is a measure of consumption and an increasing GNP encourages the wasteful use of finite non-renewable resources including fossil fuels.

The paper demonstrates that two physical limits to growth of the consumption of energy exist and hence to GNP on a global basis. It will also predict that we will reach these limits within the next half century if the present trends continue. These limits are determined by the intimate relationship that exists between energy consumption, the release of thermal energy, and climate change.

It is useful to start by examining global climate. We know from various geological indicators that there have been many periods during the history of the Earth when the mean temperature of the land masses was 1-2°C cooler than at present and that these periods were characterized by the extent to which the land masses were covered by glaciation. The basic explanation for the advance and retreat of this glaciation was given by Milankovich although refinements have been necessary. We also know that the climate was much warmer (1-5°C) and moister during the various periods when the lush vegetation developed that is responsible for the fossil fuels found in the Paleozoic and Mesozoic sediments. The coral composition of many limestones of these ages also implies that the atmospheric carbon dioxide concentration - $C(CO_2)$ - was much larger (600 - 1200 ppm) than at present (330 ppm). However, we should remember that the species Homo sapiens did not exist under these conditions.

It is estimated that since the last ice age the mean land mass temperature has fluctuated by ± 0.5°C, although some climatologists believe that there was a period between about 4000 to 8000 years ago when the temperature was 1°C warmer and there was more rainfall due to increased evaporation. It it instructive to consider where this increased rainfall occurred during this Altithermal or Hypsithermal period. Subtropical desert regions such as the Sahara, northwest India, southwestern North America, and parts of Australia received appreciably more rainfall and there was more rainfall in western Europe, but less rainfall in Scandinavia, central midwest United States, and Siberia. The important lesson is that even moderate climate changes can produce significant regional changes that would have important geopolitical ramifications. It is also estimated that the $C(CO_2)$ remained near the preindustrial (1850) value of 290 ± 10 ppm. The mean temperature during the last 4000 years has fluctuated by ± 0.5°C about its present value. The lower limit was attained during the Little Ice Age that occurred in Europe from 1300 till 1800 A.D. and the upper limit in about 1950 after which a cooling trend commenced.

The inadvertent climatic experiment is most likely to be caused by the "greenhouse effect" due to an increasing value of $C(CO_2)$ caused by the accelerating rate at which humankind is consuming fossil fuels. The greenhouse effects occurs because most of the solar energy incident at the Earth's surface is at visible wavelengths because the sum approximates to a black body with a temperature of about 5800°K, whereas the Earth reradiates at infrared wavelengths because its temperature is about 280°K. Atmospheric carbon dioxide has strong absorption bands at these infrared wavelengths so most of this radiation is reradiated back to the Earth. The 1957-58 International Geophysical Year initiated the first reliable and continuous $C(CO_2)$ measurements in both the northern and southern hemispheres. These measurements show that the concentration has been increasing by 1.0 ± 0.5 ppm between 1958 and 1973. During the same interval, the burning of fossil fuels has generated 1.10 ppm (1958) to 2.26 ppm (1973) so that the airborne fraction has remained at about 50%. Not all the remainder can be accounted for by existing models, but the oceans are the major storage reservoir. Photosynthesis plays an important role as can be seen from the annual fluctuation in $C(CO_2)$ which attains a minimum in August and a maximum in February in the northern hemisphere. The fact that the maximum and minimum are reversed in the southern hemisphere verified this explanation. Deforestation and land clearing, particularly in the tropical rain forests of the Amazon and Congo, may play an important role in increasing the percentage of carbon dioxide which enters the atmosphere. It is estimated that the preindustrial concentration of 290 ppm will double by 2025 A.D. if the rate of fossil fuel consumption increases exponentially as it has increased during the past thirty years, or by 2075 A.D. if it increases by 6% per annum. The best climatic models available at present indicate that the mean land mass temperature will increase by 1^oC by 2000 A.D. when $C(CO_2)$ is 400 ppm if the present consumption trends continue and will increase by $5^o \pm 3^oC$ when $C(CO_2)$ is 600 ppm (double the preindustrial value). There are uncertainties in the estimated temperature rise, but there is no about whether it will rise.

The models upon which these predictions have been based have been discussed by Keeling and Bacastow (1977) and Siegenthaler and Oeschger (1978) amongst others. These models also indicate that the mean temperature rise will be minimal in the equatorial regions and maximum in the polar regions where it will be two or three times larger than at midlatitudes. This latter effect will be responsible for the ultimate destruction through melting of the Greenland and Antarctic Ice Caps. The time scale for this effect will be longer than a hundred years and less than a thousand years. It is estimated that the level of the oceans will rise by 80 ± 20 m as a consequence of this effect. All the major seaports would become submerged and much fertile river estuary farm land would be lost. The geopolitical implications are most significant. Most of Denmark, The Netherlands, other parts of the European Continent would disappear as would a significant portion of England, Scotland, and Wales. The same scenario will occur throughout the world.

Our ability to predict the climate that will result from such temperature increases is imprecise, but the climate that occurred during the Altithermal period mentioned previously gives some indication. We can be certain that there will be significant shifts in the agriculturally productive areas. The "bread-baskets" in the United States and the USSR will probably be affected adversely. It is obvious that failure to adapt agricultural practices to the changing climatic conditions may lead to serious food shortages.

The rise in the mean global temperature can also be caused by another anthropogenic activity closely related to the consumption of fossil fuels. At present, the sun provides energy to the Earth at the net rate of 1.7 x 10^{18}W (~ 5 x 10^{24} J/yr). The Stefan Boltzmann law enables us to estimate that a 1% change in this rate will lead to a 0.25% change in the mean temperature of the Earth, or about 0.7°C. At present, the inhabitants of Spaceship Earth are consuming energy at the rate of about 10^{13}W. Not all this energy is converted to heat or thermal energy but more than a third and possible one half is converted directly or indirectly. Recently, this rate has been increasing at 6-7% annually, and this rate of increase has been increasing. At 7%, the rate doubles every ten years. If it remains at 7%, then in one hundred years it will increase by 2^{10} or 1024 to about 10^{16} W which exceeds the 1% limit of 1.7 x 10^{15} W necessary to produce a temperature rise which may be sufficient to melt the polar ice caps. The one of two possible models for future energy consumption assumes that the increase remains at 6% while the other model assumes that the present trend of increase continues into the future. The important point is that the 1% limit will be achieved by either 2025 or 2075 depending on the model. These are essentially the same dates as predicted by these models for the increasing atmospheric concentration of carbon dioxide. It may not be a coincidence that these two physical limits, which are defined as the total amount of either thermal energy or carbon dioxide that will produce a temperature rise sufficient to melt the polar ice caps, are similar, since fossil fuels produce 85% of the global energy. The error in these limits may be a factor of two, but this results in only an error of ten years in the time required to attain the limit.

At present, the uncertainty or noise in the estimates of mean hemispheric temperature due to natural sources masks the anthropogenic effects due to the release of carbon dioxide and thermal energy. However it is expected that these effects will become dominant in the near future. The natural sources are tidal energy (3 x 10^{12} W), geothermal and seismic energy (32 x 10^{12} W) and tornadoes and hurricanes (2 x 10^{12} W). It is difficult to estimate what fraction of this energy is thermal but it probably exceeds 10^{12} W. It is possible that other energetic mechanisms contribute to the short-term natural climatic fluctuations. The current cooling trend masks the present anthropogenic heating effects.

Kellogg and Schneider (1978) have suggested that there are three possible responses to the experimental data available at present and the predictions based upon theoretical climatic models. These responses are: (1) world decision makers can agree that the possible outcome of this inadvertent experiment is too serious to allow it to continue and act to avert the climatic change,

(2) they can wait for more experimental and theoretical research on climate systems to see if the present predictions are verified, or (3) they can do nothing and ignore the existence of the problem. It is evident that the latter decision would be foolhardy but it appears to be the one that we are taking out of ignorance. The ramifications of this decision are horrendous if we take the predictions outlined in this paper seriously. It is very tempting to sit on the fence and await the outcome of further research. Unfortunately, it will probably take another ten years to improve the reliability of our predictions, but, at present trends, by this time we will double our consumption of fossil fuels and hence increase the atmospheric $C(CO_2)$ by about 15-20 ppm. If we assume that our predictions are verified after ten years, then it will take several further decades before we can decrease our fossil fuel consumption to levels which will not produce climatic change because of the sluggishness with which economic and societal systems respond to major changes. Unfortunately, by the time the corrections have been effected it will be too late and the predicted irreversible changes will have begun to occur. Consequently, we are left with only one prudent option and that is to effect major changes in the energy consumption policies of the developed countries but, in particular, the United States and Canada. These latter two countries are specifically identified since they consume 40% of the world's annual energy with only 5% of the world's population. West Germany and Sweden provide a comparable quality of life for their citizens as in the United States and Canada but consume 50% and 60% respectively as much energy on a per capita basis. It is also worthy of note that West Germany has one of the lowest rates of inflation in the world at the present time.

The question really is: "How much proof is necessary?" It is not the quality of the proof but the consequences of the risk that must be evaluated. Humankind is accustomed to making many decisions as individuals based on the concept of prudence. It is necessary for governments to act in the same manner. The need for immediate action is obvious since four of the leading American scientists with expertise on inadvertent climate change, Keeling, MacDonald, Revelle, and Woodwell have presented in 1979 a statement to President Carter's Council on Environmental Quality, warning that the top priority energy policy decision must concern the possible disastrous warming of the atmosphere from the release of carbon dioxide associated with the combustion of fossil fuels, rather than the search for alternative fossil fuel sources. It is interesting to note that in 1978 MacDonald had provided a rather unconcerned, dispassionate assessment of the problem. One must conclude that his views have altered in the last year, and this is probably an important indicator of the growing confidence of climatologists in the validity of their models. It is evident that major revisions in the energy policies of all developed countries should receive top priority if humankind is to act prudently and provide responsible stewardship for all the life on Spaceship Earth.

It is interesting that the managers and policy makers for national parks have not become concerned about the implications of inadvertent anthropogenic climate change. Most national park systems involve a mandate either implicitly or explicitly as in the case of Canada to preserve them for future generations. It should be clear from the discussion in this paper that the issue of climate change cannot be ignored. The implications are particularly disturbing for those parks that are located near polar latitudes. For example, the Canadian Auyuittug (The Land That Never Melts) National Park is located on Baffin Island and is essentially covered with snow and ice the year around. It would be destroyed when the polar ice caps melt. Other Canadian National parks such as Banff, Jasper, Waterton, and Glacier would lose much of their attraction since it is the dramatic combination of ice and snow and the rocky spires that characterizes their landscape. Similar effects will occur in Alaska, Scandinavia, the USSR, Argentina, and Chile, for example.

The preservation of our "resting places" requires that national park and reservation managers and policy makers play a leading role in the education of both the public and the politicians. It is a sad fact that this has not occurred to the best of my knowledge. Spaceship Earth is a park since it is "the resting place" as well as "the working place" for all of humankind.

This paper would not have been written if I had not received the encouragement of my wife, Margaret, and critical discussions with my friends and colleagues. In particular, Dr. J.G.Nelson, now Dean of Environmental Science at the University of Waterloo, is responsible for challenging me to examine the implications of energy consumption patterns on national parks and for stimulating me to think about innumerable other environmental problems. I am indebted to the National Research Council of Canada for making it possible for me to attend the XIV Congress of the Pacific Science Association in Khabarovsk, USSR, where an abridged version of this paper was presented.

PRODUCTIVITY AND ELEMENTS OF ENERGETICS AND BIOGEOCHEMISTRY OF LAND ECOSYSTEMS IN THE CIRCUM-PACIFIC BELT

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The circum-Pacific belt extends for more than 50,000 km, embracing all thermal belts of the Earth. Three main factors determining the productivity, energetics, and biogeochemistry of land plant formations can be distinguished there.

1. Oceanic climate which is transformed by oceanic and air currents and by morphostructure and morphosculpture of a continental framing. A climatic asymmetry of the circum-Pacific belt can be traced. Thus, more uniform moistening is characteristic of the full length of its western half. There is a number of climatic anomalies such as powerful steady cyclonic areas at the northwestern coast of North America and in the southwest of South America. In addition to high precipitation (1000 to 1200 mm in North America and more than 5000 mm in South America), fogs raise the moistening by 120 to 140 mm.

2. Coincidence of the circum-Pacific belt with an area of active modern volcanism with recurrent ash falls bringing elements of mineral alimentation. Typical of these areas is an andesite-basalt composition of volcanic material which contributes to favorable hydrophysical properties (low volume weight and good filtration) of soils formed here as well as to their abundance in bases and other alimentation elements.

3. Direct influence of oceanic waters (salt impulverization, enrichment of precipitation with salts) which, on the one hand, serves as an additional source of mineral alimentation and, on the other hand, in arid and subarid areas, against the background of insufficient leaching, results in an accumulation of excessive quantities of Cl, Na, sometimes Mg in plants and in an appearance of stunted forms.

On the whole, these factors have caused higher productivity of land ecosystems of the circum-Pacific belt in comparison to intracontinental areas.

PRODUCTIVITY OF ECOSYSTEMS

The estimation of the productivity of ecosystems is based on the quantity of a phytomass of living plants and their annual production. As the available data on these parameters are frequently incomplete (there is no information on the underground realm of phytocenoses, sometimes on green assimilating organs), non-standard (are given in different volume and weight units per different area units), and, therefore, incomparable, it has been necessary to put them in a single system. For the estimation of missing parameters, data on similar ecosystems have been used. Conversion of volumetric data into the weight ones has been made through volume weights.

Literary data on the productivity of land ecosystems of individual areas of the circum-Pacific belt are uneven and unequivalent.

Polar belt

Information on the productivity of land ecosystems in the polar belt is rather scanty. The total phytomass of plant communities ranges from 15 to 60 t/ha (tons per hectare); the shares of overground and underground phytomasses are approximately equal in the communities with a predominance of lichens and mosses; the underground phytomass amounts to 70% in the communities with a predominance of shrubs and undershrubs (Dryas octopetala, Vaccinium vitis-idaea, V.uliginosum, Ledum decumbens, Pinus pumila, etc.). Data on the phytomass reserves listed in Table 1 are similar to those cited by many authors for tundras of other regions. Extreme values are higher for tundras of the circum-Pacific belt (up to 60 t/ha) than for mountain tundras of the Arctic Ocean.

Values of annual production (0.6 to 2 t/ha) lie within the same limits as those of similar ecosystems in other regions (Northern Norway, Sweden, Kola Peninsula). An exception within the circum-Pacific belt is represented by more productive mountain tundra of Subantarctic islands (Chorisodontium ariphyllum, Politrichum alpestre, Deschampsia antarctica, etc.) with the annual production of 8 to 9 t/ha, including herbaceous communities (up to 4 t/ha taking into account both overground and underground organs).

Phytomass reserves in light forests and forest-tundras (Pinus pumila, Larix dahurica, etc.) increase up to 90 to 125 t/ha. Here underground organs frequently make up 50% of a phytomass in connection with a low bonitet of stands. The part of a green phytomass is rather important which is caused by relatively large quantities of needles on low trees and a development of mosses and undershrubs. On the whole these values are higher than in forest-tundras of the Arctic Ocean coast.

A primary production of light forests and forest-tundras within the circum-Pacific belt is 1.5 to 2.5 t/ha annually, and only in alpine regions of lower latitudes (subnival belt, Japan) with a predominance of Abies veitchii, Tsuga diversifolia, Pinus pumila, etc., it may reach 4 t/ha annually.

Table 1

Values of the biological productivity and biogeochemical cycles of nitrogen and mineral elements in ecosystems of the polar and boreal belts

Thermal belts and plant formations	Latitude, longitude	Phytomass, t/ha	Annual production t/ha	Contents of nitrogen and mineral elements (Ca, K, Mg, Fe, Al, Mn, Si, P, S, Cl), kg/ha			
				in phytomass		in annual production	
				nitrogen	mineral elements	nitrogen	mineral elements
Polar Belt							
Subantarctic, tundras	60°S, 45°W	n.d.	4-9	n.d.	n.d.	n.d.	n.d.
Asia, mountain tundras	61°N, 150°E	15-60	0.6-1.3	75-200	114-140	3-9	6-15
Asia, forest-tundras	60°N, 150°E	72-105	1.5-4	480-540	up to 640	16-22	28-38
North America, forest-tundras	60-65°N, 150°W	up to 125	2	n.d.	n.d.	n.d.	n.d.
Boreal belt							
Asia mountain and valley forests: coniferous	40-55°N, 135-160°E	80-160 and up to more than 300	6-10	340-727	776-2270	up to 40	up to 100
small-leaved	45-55°N, 145-160°E	80-160	up to 10	up to 430	up to 710	up to 60	120-190
North America, mountain coniferous forests	47-51°N, 123-127°W	470-650 and up to 1760	12-18	310-560	1275-1700	n.d.	n.d.
Asia, meadows	46-52°N, 143-157°E	26-125	11-93	990-3000	4300-12000	400-2200	1400-8600
Australia, meadows	54°S, 158°E	12-26	10-56	n.d.	n.d.	n.d.	n.d.

Boreal belt

The phytomass reserves and production of boreal forests are considerably greater. In connection with a complex mountain-valley topography, noticeable variations in these parameters can be observed here. As a rule, the higher productivity is characteristic of valley forests.

In the vast region of boreal forests within Asian part of the USSR direct determinations of productivity values have not been carried out, and presented materials are based mainly on calculations. Considerably more data have been collected in Japan, both on natural and artificial forests. Natural forests, especially in lower latitudes, are composed of many species.

Phytomass reserves in coniferous forests (Larix kurilensis, L. dahurica, Picea ajanensis, P.koraiensis, Abies nephrolepis, A. sachalinensis, A.mayriana, A.veitchii, Pinus silvestris, P. koraiensis, etc.) average 80 to 160 t/ha. Sometimes these reach 200 to 300 t/ha and even 350 t/ha in valley forests and 50 t/ha in forests of Picea koraiensis. These characteristics vary considerably depending on latitudes, heights above sea level, slope exposition, and distances from the coast.

An annual production of coniferous forests is 6 to 10 t/ha including 2 to 2.5 t of green assimilating organs. It increases in southern regions (Japan) up to 18 and even 24 t/ha. On the whole, the annual production of a green mass is 4 to 4.5 t/ha.

Stands of Betula ermanii, as a rule, have a low bonitet and a low productivity. Their phytomass reserves average 80 to 160 t/ha, their production being somewhat increased (up to 10 t/ha) at the expense of a rich herbaceous cover with an overground phytomass reaching 5 t/ha.

Characteristic of boreal forests is an increase of phytomass reserves and an annual production within coastal areas usually better moistened and on islands where precipitation may reach 1000 mm per year as well as in valleys looking oceanwards and in some southern areas.

The unique feature of insular boreal forests is a participation of bamboo (Sasa kurilensis, S.nipponica, etc.) in the plant cover. The bamboo phytomass may amount to more than 25 t/ha, including 5 to 12 t of an overground one, and the annual production is 6 to 7 t/ha.

Thus, the productivity of natural boreal forests of the Asian part of the circum-Pacific belt is almost the same as in similar forests of intracontinental regions (phytomass reserves in the taiga of the USSR are 100 to 200, less frequently 300 to 350 t/ha).

The annual production of forests in coastal areas and island ecosystems is higher than in intracontinental areas (5 to 8 t/ha annually) and reaches 10 to 18 t/ha annually.

Artificial plantings of conifers, occupying relatively large areas in Japan, are considerably more productive than similar natural forests. An annual production of these plantings ranges from 16 to 20 t/ha, reaching in some places 27 t/ha.

Boreal mountain forests of North America are composed exclusively of conifers: Pinus langenoda, Abies amabilis, A.plicata, A.procera, Tsuga myriana, Pseudotsuga menziesii, etc. These forests are 300 to 500 years old; they are of an exceptional aesthetic and recreational importance. Their productivity is very high, the phytomass reserves reaching 500 t/ha in Canada and 1500 to 1760 t/ha in lower latitudes (USA). The annual production estimated on artificial planting is 12 to 16 t/ha. These values are considerably higher than in coniferous forests of intracontinental regions where the phytomass reserves are only 200 to 340 t/ha.

A very characteristic feature of the Pacific region within the boreal belt is a wide distribution of herbaceous communities. On the Asian coast and adjacent island systems these are composed of gigantic forms of herbs (Filipendula kamtschatica, Polygonum sachalinense, P. weyrichi, Angelica ursina, Calamagrostis langsdorfii, etc.) which differ from meadow forms of intracontinental areas in a very high biological productivity. Phytomass reserves in northern areas (Kamchatka) reach 20 to 30 t/ha, an annual production is 10 to 20 t/ha. Southwards (Sakhalin), the both values increase, reaching 30 to 70 and 15 to 25, and even 93 t/ha, respectively.

Similar data are cited by S.F.Jenkin for the meadows of Poa foliosa, Stilbocarpa palaris, and Juncus scheuchzerioides on Macquarie Island.

In contrast to intracontinental herbaceous communities, characteristic of oceanic boreal meadows is a narrow ratio of the mass of underground organs to that of overground ones, ranging usually from 1.5 to 2.5. Sometimes, overground phytomass reserves may exceed underground ones which virtually never can be observed in herbaceous communities of a boreal belt within intracontinental regions.

Subboreal belt

Within the subboreal belt of the Asian part of the circum-Pacific belt, where coniferous-broad-leaved and broad-leaved forests are widely distributed, a further increase in the productivity values may be observed. This is caused not only by a longer vegetative period, but also by a more favorable thermal regime and an increased precipitation (up to 1000 mm/year in coastal areas and to 2000 mm/year and more on islands). Forests here are notable for a great species diversity and a considerable participation of herbs. The forests are composed of Quercus mongolica, Tilia amurensis, Acer mandschuricum, Fraxinus mandschurica; in lower latitudes of Quercus crispula, Acer mono var. mormoratum, Fagus crenata; conifers are represented by Pinus koraiensis, Abies nephrolepis, A. sachalinensis, Picea ajanensis.

Phytomass reserves range, depending on altitude and slope exposition, from 125 to 300 t/ha, reaching occasionally 400 and even 500 t/ha (Table 2).

A phytomass structure (interrelation of trunks, roots, etc.) in subboreal forests is somewhat other than in forests of the boreal belt. In connection with a considerable participation of deciduous species, the share of green assimilating organs decreases to 4 or 5%, being particularly low in broad-leaved forests where the mass of leaves makes up 2 to 3% or even 1%. Perennial wooden organs account for 75 to 80% of the phytomass, and roots make up 17 to 20%.

In accordance with the phytomass reserves, the annual production increases, too, and makes up 11 to 16 t/ha and in beech forests 20 to 25 t/ha. The mass of annual green assimilating organs is greater than in boreal forests (3.5 to 4 t/ha in an arboreal story). A herbaceous cover here plays a considerable part in the annual production (3.6 to 4 t/ha of an overground mass only) in contrast to subboreal forests of intracontinental areas where the annual production of overground organs of herbs commonly does not exceed 0.5 t/ha.

The biological productivity (and particularly the phytomass reserves) of the forests of a coastal zone of North American mountains is very high. Stands of old age (300 to 500 years old) composed of Pseudotsuga menziesii, Abies amabilis, A. procera, Tsuga heterophylla, Picea sitchensis rise up the slopes of the Cascade Range to the altitude of 1500 m. The phytomass reserves of these unique stands are very large, 600 to 2000 t/ha and, according to some estimations, up to 2900 t/ha. Perennial wooden organs account for 70 to 80%, roots for 15 to 17%, and needles for up to 2% of the phytomass. The annual production of younger (around 100 years old) stands is 9 to 15 t/ha, including 3 to 4 t of needles.

Table 2

Values of the biological productivity and biogeochemical cycles of nitrogen and mineral elements in ecosystems of the subboreal and subtropical belts

Thermal belts and plant formations	Latitude, longitude	Phytomass, t/ha	Annual production, t/ha	Contents of nitrogen and mineral elements (Ca, K, Mg, Fe, Al, Mn, Si, P, S, Cl), kg/ha			
				in phytomass		in annual production	
				nitrogen	mineral elements	nitrogen	mineral elements
1	2	3	4	5	6	7	8
Subboreal belt							
Asia, mountain and valley forests:							
coniferous-broad-leaved	43-45°N, 135-145°E	125-430	11-16	n.d.	n.d.	n.d.	n.d.
broad-leaved	35-45°N, 135-145°E	150-500	15-25	900-960	2600-2750	65-120	170-350
North America, mountain coniferous forests	45°N, 123°W	600-2000	9-15	725	2500	18	165
South America, mountain broad-leaved forests	40-52°S, 72°W	up to 450	n.d.	n.d.	n.d.	n.d.	n.d.
New Zealand, mountain broad-leaved forests	42°S, 72°E	325-500	14-20	up to 400	up to 3000	up to 100	up to 400
Asia, meadows	38°N, 140°E	18-37	9-20	up to 64	up to 840	up to 75	up to 620

Table 2 (continued)

1	2	3	4	5	6	7	8
Subtropical belt							
Asia, mountain forests: coniferous	35-45°N, 135-140°E	215-480 and up to 1700	16-23	300	700	30	140
broad-leaved	33-45°N, 130-140°E	140-480	20-23	300-900	1000-2750	120-200	370-600
North America, mountain coniferous forests	36-42°N, 123°W	500-1700 and up to 4280	15-27	n.d.	n.d.	n.d.	n.d.
South America, mountain broad-leaved forests	25-42°S, 71°W	450-500	n.d.	n.d.	n.d.	n.d.	n.d.
New Zealand, broad-leaved forests:							
mountain	40°S, 72°E	320-465	18-26	up to 420	up to 3200	up to 120	up to 450
lowland	40°S, 72°E	830-960	n.d.	n.d.	n.d.	n.d.	n.d.
Australia, mountain broad-leaved forests	27-37°S, 145°E	180-380	10-25	460 and more	1000 and more	80 and more	150 and more
Asia, bamboo stands	33-45°N, 130-140°E	up to 660	up to 125	n.d.	n.d.	n.d.	n.d.

The phytomass reserves of subboreal forests within intracontinental areas are considerably lower, averaging 250 to 300 t/ha and only in some cases reaching 500 t/ha.

The broad-leaved forests of a subboreal belt of South America (Nothofagus betuloides, N. pumilio) and New Zealand (Nothofagus truncata), despite favorable moistening conditions, are similar to the forests of the Asian coast of the Pacific by productivity values. Their phytomass reserves are 300 to 350 t/ha, less frequently up to 500 t/ha, and the annual production ranges from 14 to 20 t/ha. The share of roots in the phytomass of the southern beech forests decreases to 10%, and that of perennial overground organs increases up to 90%.

In the subboreal belt, as in the boreal, highly productive meadow communities are widely distributed. These are composed here of Miscanthus sinensis, M.sachariflorus, Arundinaria hirte, Polygonum sachalinense and have the phytomass reserves of 18 to 37 t/ha including 5.5 to 10 t of the overground phytomass. The ratio of the underground phytomass to the overground one does not exceed 1.5 or 2. The meadow production ranges from 9 to 28 t/ha, being somewhat lower than in the meadows of the boreal belt. At the same time, the subboreal meadows of the Pacific region are more productive than other herbaceous communities of the temperate zone.

Thus, the review of the data on the biological productivity of ecosystems of the subboreal belt also testifies to its higher characteristics within the circum-Pacific belt in comparison to the productivity of ecosystems of intracontinental areas.

Subtropical belt

An analysis of available data suggests that the values of a biological productivity continue to increase from the subboreal belt to the subtropical one. At present for the Asian continent there are data on island ecosystems only, mainly in Japan. The phytomass reserves of natural coniferous (Cryptomeria japonica, Chamaecyparis obtusa, Abies, Pinus, etc.) and broad-leaved (Distillum racemosum, Shia sieboldii, Quercus glauca, Machilus thunbergii, Ilex pedunculata, Clethra arvinensis, Camelia japonica, etc.) forests of Japan are 240 to 480 t/ha, reaching 1000 t/ha in some localities.

Until recently, these values have been considered the highest among those which are known in ecosystems of the Earth. However, it turned out that these conclusions should be reconsidered.

In Japan, alongside with the highly productive forests, there are forests of low productivity, with phytomass reserves not exceeding 130 to 140 t/ha.

The phytomass structure in the forests of the subtropical belt is of the same nature as in the forests of higher latitudes. Their annual production ranges from 16 to 20 t/ha and for the stands of a higher bonitet to 23 t/ha, the mass of annual green assimilating organs increasing up to 6 or 7 t/ha and in some localities to 10 t/ha. The annual production of artificial plantings is higher than in natural forests, reaching 17 to 25 and even to 30 t/ha.

The bioproductivity of the ecosystems of the Pacific coast of North America within the subtropical belt is the highest among all other ecosystems of the Earth. The mountain sequoia forests (Sequoia sempervirens, Sequoiadendron giganteum, Pinus muricata, etc.) stretch as a narrow stripe along the Pacific coast, reaching an altitude of 1000 m and growing predominantly on valley floors and low terraces with alluvial soils, within aggradational landscapes provided with an influx of mineral alimentation elements.

The phytomass reserves in the seqoia forests average 1300 to 1700 t/ha, reaching frequently 4250 t/ha. The height of trees in the stands which are a thousand years old exceeds 100 m, the trunk diameters are 3 to 5 m and sometimes up to 11 m. The phytomass structure in these forests is generally of the same nature as in other coniferous forests. Only a relative increase in the share of perennial overground organs (mainly trunks), accounting almost for 90% of the phytomass, and a decrease in the share of roots to 10% can be observed. An annual production, according to estimations for younger (47 years old) plantings, is very high, up to 27 t/ha, and phytomass reserves there reach 1600 t/ha.

Subtropical beech forests of South America are intermediate in the bioproductivity between the forests of island ecosystems of Asia and the forests of the North American coast. Their phytomass reserves are estimated as 450 to 500 t/ha.

The mature eucalyptus forests of Australia, in connection with a lower moistening, accumulate the phytomass only within the limits of 180 to 300 t/ha. Characteristic of the phytomass structure (mainly in low-productive stands) is a greater share of roots (sometimes up to 40%). The mass of leaves here, as in other regions of the subtropical belt, increases in comparison to subboreal forest and makes up 4 to 7 t/ha. The annual production of the eucalyptus forests may reach 10 and even 25 t/ha.

On the islands of New Zealand the values of productivity of forests are higher than in Australia, and the phytomass reserves in river flood plains make up 800 to 960 t/ha. Some forests, for example, those of Podocarpus, have the somewhat lower phytomass reserves (320 to 460 t/ha). The annual production of these forests has not been determined. There are data only on the annual production of leaves (up to 7 t/ha). The annual production of artificial plantings with Pinus radiata and P.muricata may reach relatively high values of 24 to 45 t/ha. Eucalyptus trees 25 years old have already heights of 30 to 40 m with trunk diameters of 60-75 cm.

Herbaceous communities of the subtropical belt of the Pacific region are studied insufficiently. According to M.Watanabe and K. Ueda (1976), the phytomass reserves of bamboo (Phyllostachys bambusoides) on Honshu Island, Japan, may reach 660 t/ha. The data on the phytomass structure of bamboo stands suggest that their annual production may reach 125 t/ha, including 80% of green assimilating organs. The values are half as high again as those of meadows of the boreal belt.

In conclusion, it should be noted once more that the phytomass reserves of the forests of the Pacific coast of North America are the greatest of all the known at present in terrestrial ecosystems of the Earth.

Tropical belt

The phytomass reserves of tropical forests are not greater than those of subtropical forests and are even considerably smaller than the phytomass reserves of North American subtropical forests. This results, evidently, from the great expenses on respiration typical of tropical forests. These expenses, according to E.Golley (1975) may account for 60 to 90% of gross production.

The phytomass reserves in lowland and mountain rain forests of the Asian coast and islands (Acacia confusa, Taiwania cryptomeriodes, Mangifera, etc.) average 450 to 550 t/ha, increasing to 750 t/ha in flood-plain gallery forests (Table 3). The phytomass reserves of the dryer monsoon forests composed of Lagerstoemia, Croton argiratis, Calicalata, Hopea, Shorea, etc., are 250 to 450 t/ha.

The annual production of tropical forests can be estimated less definitely, since the studies here are hampered by some circumstances, including the absence of annual rings, short series of observations, etc. On the average it is 20 to 24 t/ha, the production of green assimilating organs being 8 to 11 t/ha.

Mountain and lowland equatorial rain forests of the Sunda Islands composed of Padbrugea pubescens, Dipterocarpus, Celtis luzitanica, Ficus, Shorea leprosola, Sh. uliginosa, Dryobalanops, Agathis forsis, Altingia excelsa, Magnolia blumei, Podocarpus archboldii, Tectona grandis, Eucalyptus urophylla, E. alba,

Table 3

Values of the biological productivity and biogeochemical cycles of nitrogen and mineral elements in ecosystems of the tropical and equatorial belts

Thermal belts and plant formations	Latitude, longitude	Phytomass, t/ha	Annual production, t/ha	Contents of nitrogen and mineral elements (Ca, K, Mg, Fe, Al, Mn, Si, P, S, Cl), kg/ha			
				in phytomass		in annual production	
				nitrogen	mineral elements	nitrogen	mineral elements
Tropical belt							
Asia, rain forests:							
mountain	17°N, 122°E	460–550	20–24	up to 1550	up to 7200	n.d.	n.d.
lowland	17°N, 100°E	500–750	23–25	up to 1600	up to 7500	n.d.	n.d.
monsoon mountain forests	14°N, 102°E	250–450	n.d.	n.d.	n.d.	n.d.	n.d.
mangrove forests	10°N, 104°E	160–250	23–31	up to 950	up to 2600	up to 100	up to 350
savanna-forests and mountain and lowland savannas	17°N, 100°E	80–160	n.d.	n.d.	n.d.	n.d.	n.d.
Equatorial belt							
Asia, rain forests:							
mountain	7°N-7°S, 99-144°E	280–690	28–32	n.d.	n.d.	n.d.	n.d.
lowland	7°N-7°S, 100–144°E	250–530	20–30 and up to 40	n.d.	n.d.	n.d.	n.d.
America, rain forests:							
mountain	9°N, 82°W	250–610	n.d.	n.d.	n.d.	n.d.	n.d.
lowland	9°N, 82°W	280–380	23–50 and up to 1200				
mangrove forests	9°N, 82°W	250–470	n.d.	950 and more	2600 and more	100 and more	300 and more
lowland savannas	9°N, 82°W	26	66	415	1590	570	2580

Dacrycarpus cinctus, Araucaria, etc., accumulate 250 to 690 t/ha of phytomass. The annual production of these forests ranges from 20 to 35, less frequently to 40 t/ha.

The productivity of mountain and lowland equatorial forests of America is of the same order as in equatorial forests of Asian islands: the phytomass reserves are 250 to 610 and to 1200 t/ha in gallery forests; the annual production is 23 to 50 t/ha.

Characteristic of the phytomass structure in tropical forests is a very great share (up to 90%) of perennial overground organs with a share of roots of only 8 to 10%. The mass of green assimilating organs is greater than in subtropical forests, averaging 10 t/ha and occasionally reaching 20 t/ha.

Mangrove tropical forests of Rhizophora apiculata and R. brevistyla are not inferior to tropical forests of land ecosystems in productivity values. Their phytomass reserves may make up 250 to 450 t/ha and more. The phytomass structure in these forests is notable for some characteristic features. Perennial overground organs accounts for only 45 to 50% of the phytomass, while the share of roots increases to 40% and, with pneumatophore roots taken into account, may reach 50 to 55%. The annual production of mangrove forests, especially younger ones, is similar to that of land tropical forests, reaching 23 to 30 t/ha.

All these data demonstrate that the productivity parameters of tropical and equatorial forests within the circum-Pacific belt don't differ considerably from the same parameters of tropical forests of intracontinental regions. This is caused, evidently, by favorable moistening conditions existing through all areas of distribution of tropical forests. At the same time, we should not forget a powerful influence of the ocean upon the land ecosystems of adjacent areas (typhoons, tsunamis, wave abrasion, etc.) resulting in the permanent rejuvenation of these ecosystems.

Herbaceous communities or communities transitional from forest to herbaceous ones (savannas, forest-savannas) have considerably smaller phytomass reserves (25 to 160 t/ha) which vary depending on the participation of tree species. This participation determines also the phytomass structure. With a predomination of herbaceous forms the share of green assimilating organs reach 75 to 80% of the phytomass. The annual production of savannas (of forest-savannas) varies widely, depending on the structure of communities. Herbaceous savannas yield annually around 65 t/ha which is a rather high production. Green parts of plants predominate in the production in contrast to herbaceous communities of a temperate belt where underground organs of plants play the main part.

An analysis of the geographical distribution of phytomass reserves within the circum-Pacific belt demonstrates the asymmetry of this distribution. Characteristic of the eastern half of the belt is a very contrasting distribution of phytomass reserves with an alternation of areas where these reserves considerably exceed 1000 t/ha (in humid zones of boreal, subboreal, and subtropic belts) and areas where the reserves don't reach 2.5 t/ha (in arid zones). In the western half of the circum-Pacific belt the range of variations in the phytomass reserves is essentially narrower, arid areas with a low productivity are absent. The maximum phytomass reserves are peculiar to the forests of a subtropical belt.

ELEMENTS OF ENERGETICS IN LAND ECOSYSTEMS

An estimation of the efficiency of the utilization of a solar energy by plant communities is an important part of the study of the biological productivity.

On the basis of data on the weighted mean heat capacity of land plant formations of the Earth, approximate values of the energy accumulated in the phytomass and annual production of land ecosystems of the circum-Pacific belt have been calculated. According to C.F.Jordan, the heat capacity of a plant organic matter is 4.1 kcal/g in the tropics, 4.8 kcal/g in the boreal forests, and 4.5 kcal/g in the tundra. In herbaceous communities this characteristic reaches only 4 kcal/g.

The calculations have shown that, despite the peculiarities of a heat capacity of a plant organic matter in various thermal belts, a regular increase of accumulated energy both in a phytomass and in an annual production of ecosystems can be observed from the higher latitudes to the lower. This is connected with the fact that the changes of the parameters of a biological productivity depending on energetical resources of an environment are subject to considerably greater variations than the accumulation of energy in a plant organic matter.

The greatest reserves of the energy accumulated in a phytomass (8×10^9 to 20×10^9 kcal/ha) are characteristic of subtropical forests both on the Asian and North American coasts of the Pacific. The second place in mobilization of the energy is taken by boreal and subboreal forests of North America accumulating more than 9×10^9 kcal/ha. Tropical forests take only the third place accumulating up to 3×10^9 kcal/ha. Herbaceous communities in this respect take virtually one of the last places.

Geographical distribution regularities of the efficiency of a photosynthetically active radiation (PAR) are not related to the distribution of energetical resources, being of another nature in principle. Thus, the highest PAR efficiency is characteristic of herbaceous ecosystems in all the thermal belts without exception, reaching its maximum value (around 9%) in herbaceous meadows on the islands of the Asian coast. The PAR efficiency is 1 to 2% in meadows of the subboreal belts, around 2% in subtropical meadows, and 3.5% in savannas.

The utilization of a PAR influx with the higher efficiency of 1.5 to 2% is observed in subboreal and subtropical forests. The PAR efficiency is appreciably higher (1.7 to 3.4%) in the forests of New Zealand. The efficiency of the energy utilization reaches only 1.1 to 1.7% in tropical forests, increasing up to 2.8% in gallery forests. Boreal forests utilize the PAR energy even less efficiently (1.2 to 1.3%). But the lowest PAR efficiency (0.1 to 0.3%) is characteristic of forest-tundras and tundras.

These regularities reflect the characteristics of the utilization of energy resources by the plant cover depending not only on climatic conditions, but also on biological peculiarities of plant species composing phytocenoses and their life forms.

It seems to be interesting to compare the PAR efficiency in various plant formations of the circum-Pacific belt with the mean PAR efficiency calculated for the whole globe. This calculation has been made on the basis of the data on the biological productivity and energy flow in the biosphere. The production of the land of the Earth makes up 172.5×10^9 t/year and the energy mobilization is 732×10^{18} cal/year; the World Ocean production amounts to 60×10^9 t/year and the energy accumulation is 294×10^{18} cal/year. Considering that the Earth receives 610×10^{21} cal/year of the solar radiation, the mean efficiency of its utilization is 0.17% and the PAR efficiency is 0.34%.[1)]

Thus, the utilization of the solar energy by the plant cover is either lower than the mean values for the land of the Earth or similar to these values only in the polar zone of the circum-Pacific belt. For a number of plant formation of the Pacific region, for instance, for meadows of islands within the Asian boreal belt, the efficiency of the solar energy mobilization approaches to the theoretically possible maximum values.

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1) PAR approximates 50% of the whole radiation because plants utilize in the course of photosyntesis only a part of coming solar energy, viz. that of the radiation with 0.38 to 0.71 μ wavelengths.

Values of biological productivity and parameters of a rotation of alimentation elements in ecosystems are very closely connected. It should be noted that the data on biogeochemical cycles in the Pacific region are rather incomplete. In order to compare the available data, those have been put in a single system. The missing parameters have been calculated with the use of the works of many authors.

The analysis of the data has shown that the accumulation of chemical elements in a phytomass depends directly on the phytomass reserves, which has been noted earlier for other regions of the Earth. At the same time, the increase of accumulated chemical elements resulting from the increase of phytomass reserves occurs in coniferous forests at a considerably lower rate than in leaf-bearing forests (see Tables 1, 2, and 3).

The quantities of alimentation elements consumed for the formation of the annual production are within the same limits as in the similar ecosystems of other regions.

With the equal values of phytomass reserves and an annual production, herbaceous formations accumulate ten times more nitrogen and ash elements than forest formations. The newest data have demonstrated an enormous range of the accumulation of alimentation elements by herbaceous communities, up to 10 t/ha of ash elements and to 3 t/ha of nitrogen in the phytomass of boreal meadows. These values surpass considerably all the values which are so far known for the herbaceous communities of a temperate zone.

It should be noted that the recognized earlier biogeochemical regularities, common for plant communities of different thermal belts of the Earth, are valid for the analysis of the interrelation between various chemical elements taking part in biogeochemical cycles of land ecosystems of the circum-Pacific belt. In tundra communities nitrogen plays a dominant part and K and Ca are predominant among ash elements. Chemism of an annual production is of a steady calcium-nitrogen nature in coniferous boreal forests and of a nitrogen-calcium nature in broad-leaved subboreal forests. In leaf-bearing forests of the subtropical and especially tropical belts the first place is often taken by silicon and the content of Al and Fe is also high. Silicon is always a dominant element in grass formations, being second to nitrogen only in some phytocenoses. In herbaceous meadows the chief elements are Ca, K, and N.

In contrast to the plants of intracontinental regions, an overwhelming majority of plants within the circum-Pacific belt, especially herbs and leaf-bearing trees, are notable for a somewhat increased accumulation of Cl and Na (Table 4). This is related to the considerable influence of the ocean upon the formation of the chemical composition of the precipitation in the Pacific region (Table 5).

The total mineralization of the precipitation here is, as a rule, higher, with the concentration of Na usually 2 or 3, sometimes 5 times and even dozens of times higher than in the precipitation of intracontinental areas. The same may be said about the content of Cl. The calculations demonstrate that the total influx of Na and Cl with precipitation is rather great and appreciably exceeds the requirements of plant communities. This is manifested in a surplus accumulation of these elements in plant tissues, being conducive to the appearance of stunted plant forms, especially in droughty areas. Usually, however, against the background of the abundant precipitation and leaching regime of soils, a somewhat increased content of biohalogenic elements in the precipitation can serve as an additional source of a mineral alimentation of plants, as a one of the factors causing the higher productivity of land ecosystems.

Thus, summing up the consideration of the spatial variability of bioproductivity parameters, biogeochemical cycles, and a solar energy utilization in the enormous Pacific Coastal region, some characteristic features should be noted.

The increase in phytomass reserves and an annual production, including the production of the main photosynthesizing apparatus of plants, i.e. the production of green assimilating organs, can be distinctly traced from the polar belt to boreal, subboreal,and farther on, to subtropical and tropical belts. The increase in the quantities of the solar energy mobilized both by a phytomass and by an annual production and of mineral alimentation elements and nitrogen involved in biogeochemical cycles by plants, occurs simultaneously.

At the same time, the maximum accumulation of phytomass reserves is confined to the ecosystems of the humid bioclimatic areas of a subtropical belt rather than a tropical one. This is related to great expenses on respiration of tropical plant formations.

The parameters of a biological productivity (phytomass reserves and annual production) and accumulation of solar energy and chemical elements are appreciably higher in coastal and island ecosystems of the Pacific than in intracontinental ecosystems. This regularity can be observed throughout the circum-Pacific belt, but most strongly it is manifested in ecosystems of a subtropical belt. An exception is represented by a tropical belt,

Table 4

Contents of nitrogen and ash elements in some plants of ecosystems of the circum-Pacific belt; %% of dry matter

Plants and their parts	N	Si	Ca	K	Mg	P	Na	Cl	Authors, sites of sampling
1	2	3	4	5	6	7	8	9	10
Pinus pumila, needles	1.26	.23	.44	.92	.05	.13	.01	n.d.	Ignatenko, Pugachev, 1976; northern coasts of the Sea of Okhotsk
cones	3.91	.05	.60	1.11	.05	.07	.02	n.d.	
Betula ermanii, leaves	n.d.	.30	.63	1.20	.23	.15	.10	n.d.	Zonn et al., 1963; Kamchatka
									Ivlev, 1977; Sakhalin
Picea ajanensis, needles	n.d.	.15	.27	.68	.16	.09	.11	n.d.	
branches	n.d.	.08	.11	.20	.08	.02	.03	n.d.	
Shrubs, leaves	n.d.	.04	.48	1.54	.44	.20	.11	n.d.	
trunks	n.d.	.05	.47	.40	.13	.05	.07	n.d.	
Herbs, stems and leaves	n.d.	.47	.60	3.50	.40	.20	.15	n.d.	
roots	n.d.	.79	.48	2.50	.20	.09	.17	n.d.	
Mosses	n.d.	1.06	.33	.56	.44	.06	.13	n.d.	
Ground vegetation in the forests of									Turner et al., 1978; northwestern USA
Pseudotsuga menziesii:									
Pteridium aquilinum	.86	n.d.	1.25	.72	.30	.12	.05	n.d.	
Gaultheria shallon	.91	n.d.	.47	1.10	.24	.21	.07	n.d.	
Plagiothocium undulatum	.73	n.d.	.37	.77	.15	.19	.07	n.d.	

1	2	3	4	5	6	7	8	9	10
Hiba (*Thujopsis dolabrata*) forest, litter	n.d.	.04	1.39	.59	.22	.05	.30	n.d.	Koichi, 1962; Japan
Juniperus japonica, litter	n.d.	.01	.61	.79	.21	.08	.09	n.d.	
Pinus resinosa, litter	n.d.	traces	.17	.63	.13	.07	.09	n.d.	
Eucalyptus signata,									
leaves	.37	n.d.	.15	.35	.28	.52	.14	n.d.	Westman, 1978; Australia
branches	.05	n.d.	.10	.09	.03	.03	.05	n.d.	
trunk	.06	n.d.	.10	.03	.03	.03	.15	n.d.	
roots	.06	n.d.	.05	.02	.02	.05	.04	n.d.	
Nothofagus truncata,									
leaves	1.29	2.15	.77-	.49-	.15-	.09	.14-	.30-	Miller, 1963; New Zealand
Tropical forest, leaves (14 samples)	1.32	n.d.	1.19	.91	.29	.08	.16	n.d.	Edwards, 1973; Papua New Guinea and Australia

Chemical composition of the precipitation, mg/L

Table 5

Sites of sampling	Time of sampling	Distance from the ocean, km	HCO_3	Cl	SO_4	CA	Mg	Na	K	Total mineralization	Authors
Southeastern Sikhote Alin	Summer	0–2	2.7	13.4	3.8	1.8	0.3	2.5	0.7	27	Kachur, 1976
	Winter	0–2	7.3	9.3	2.7	1.7	0.6	3.7	0.4	33	
	Summer	5–30	1.5	6.7	1.4	0.7	0.3	0.4	1.0	20	
	Winter	5–30	10.0	3.6	4.5	4.3	0.2	0.7	0.2	30	
	Summer	30–65	1.4	6.9	1.9	0.5	0.2	0.2	0.6	20	
	Winter	30–65	7.3	2.5	2.6	1.9	0.4	0.6	1.2	25	
	Winter	0	6.1	7.2	3.7	1.7	0.6	2.0	0.7	20	Yelpatyevsky, 1976
	Winter	50	11.0	2.5	1.5	2.6	0.4	0.7	0.4	12	
An island in the Sea of Japan, USSR	Summer	coast	0.7	5.1	2.4	0.3	0.2	0.9	0.1	10	Yelpatyevsky, 1978
	Summer	inner part	0	3.8	4.2	0.3	traces	0.3	n.d.	9	
Australia	Spring	up to 50	n.d.	n.d.	n.d.	0.3	0.5	1.7	0.2	n.d.	Attwill, 1966
	Summer	up to 50	n.d.	n.d.	n.d.	0.5	0.6	2.4	0.3	n.d.	
	n.d.	coast	n.d.	4.3	1.4	0.7	0.3	1.7	0.2	n.d.	Probert, 1976
	n.d.	30–40	n.d.	2.5	0.7	0.4	0.2	0.9	0.1	n.d.	
New Zealand	n.d.	inner part	n.d.	n.d.	n.d.	0.1	0.2	1.1	0.2	n.d.	Neary et al., 1978
	n.d.	inner part	n.d.	7.8	2.1	0.8	0.8	4.2	0.3	n.d.	Miller, 1968
California, USA	n.d.	coast	n.d.	2.0	n.d.	0.2	0.2	2.0	0.1	n.d.	Clayton, 1972
	n.d.	inner part	n.d.	0.4	n.d.	0.1	0.1	0.5	0.1	n.d.	
Pacific Ocean (200 samples)	n.d.	above ocean	n.d.	14.4	3.5	1.4	1.2	6.5	0.4	n.d.	Selezneva, 1974
(6 samples)	n.d.	above ocean	0.4	4.0	1.6	0.4	0.3	2.2	0.1	n.d.	Savenko, 1976
(9 samples)	n.d.	above ocean	2.2	5.3	2.5	0.2	0.3	2.1	0.1	n.d.	Yelpatyevsky, 1980
Smolensk, European part of the USSR	n.d.	above continent	1.5	1.1	4.5	0.7	0.2	0.5	0.5	11	Alekin, 1970

where similar and very favorable hydrothermal conditions exist both in coastal and intracontinental humid areas.

The higher values of a biological productivity of coastal and island ecosystems of the Pacific region in comparison to intracontinental areas are caused not only by a more favorable combination of heat and moisture, but also by an intense modern volcanic activity within the circum-Pacific belt. This provides for a periodical influx of mineral alimentation elements with ash falls and satisfactory hydrophysical properties of soils.

The ocean itself plays an important part in the additional influx of chemical substances into coastal and island ecosystems (with wind, precipitation, spray, etc.).

The biological productivity characterized by phytomass and accumulated solar energy reserves reaches its maximum for the Earth values (more than 4000 t/ha and up to 20×10^{9} kcal/ha, respectively) in ecosystems of the Pacific subtropical belt of the northern hemisphere. The maximum for the boreal ecosystems of the Earth values of the biological productivity, PAR efficiency, and accumulation of nitrogen and ash elements has been also observed in the meadow formations of the boreal belt of this region.

Characteristic of the biogeochemical cycles of the ecosystems in the Pacific region is the constant participation of the increased concentration of biohalogenic elements, sodium and chlorine, which are brought by the precipitation, and the chemical composition of the precipitation is formed with a direct participation of the ocean.

The revealed characteristic features of the structure and functioning of the land ecosystems in the circum-Pacific belt make it possible to consider them as a special class of natural formations.

MONITORING ISLAND ECOSYSTEMS: AN APPROACH FOR CONSERVATION PURPOSES

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Introduction

Monitoring island ecosystems for conservation is herewith suggested as the new theme of the Committee on Conservation and Environmental Protection. The term monitoring means to periodically check or keep track of certain elements, events, or phenomena. In our understanding these elements or phenomena are broadly defined as the island ecosystems themselves and as the biological, environmental and/or socio-economic influences that effect these systems.

During the 13th Pacific Science Congress in Vancouver in 1975, the outgoing Chairman of the Committee on Conservation and Environmental Protection, Dr. Lee Talbot, suggested two alternative program directives for this Committee. One suggestion was to reorganize the Committee to include the conservation activities of other scientific committees, the other suggestion was to maintain the existing Committee, but to coordinate activities of other committees in the area of conservation.

We were then asked to be the new Chairman (D.Mueller-Dombois) and Vice-Chairman (A. L. Dahl). Since then, we have done some rethinking of these program directives. We have contacted a number of conservation-minded scientists from different areas in the Pacific and have formed a program, which I would like to present at this Congress for consideration.

BACKGROUND

A review of past Congress resolutions has shown that the thrust of the Pacific Science Association, apart from promoting scientific knowledge in the Pacific countries, has been in the area of conservation. Conservation and environmental protection has become a viable and ongoing theme with a tradition which began with the first congress in 1920 in Honolulu. As a result, almost all scientific committees in the Pacific Science Association have incorporated certain aspects of the conservation theme.

Therefore, it would hardly be possible nor desirable to reorganize this Committee to include such activities of the other committees. Instead, our Committee can only endorse the conservation activities of other committees and concentrate on coordinating such activities with a particular focus.

As a major focus we have chosen the island ecosystems of the Pacific. These ecosystems constitute a unique marine-terrestrial resource for the island nations in the Pacific and the world as a whole. They deserve particular attention in conservation management. Island ecosystems are characterized by their limited nature. Islands are generally small, the areas of each habitat are limited, and total population numbers of species present are generally not large. Island biogeographic theory states that species numbers are related to the size of the available area (among other things), and any reduction in that area will eventually lead to a reduction in species present. As a result, problems of conservation in island areas are particularly critical.

Changes in the conservation status of island floras and faunas can come very quickly with development. Rapid action may be required to prevent irreversible extinctions. Yet too little information exists for most island areas to evaluate their conservation status. A simple monitoring program could do much to identify critical conservation problems before it is too late.

The need to concentrate research efforts of high conservation value on the Pacific island ecosystems was particularly emphasized during the 10th Congress in Honolulu (1961), when Dr. F.R.Forberg had organized the first major symposium on island ecosystems. In spite of Forberg's appeal, advances in island ecosystems research with practical value in conservation management have only been very slow in coming.

During the International Biological Program (IBP), there was only one project, the Hawaii project of the U.S.IBP, which was specifically concerned with island ecosystems. Its focus was on the biological organization of selected island forest communities. During the 11th Congress in Tokyo in 1966 an island checklist was presented as another initial conservation effort sponsored by IBP. At the 13th Congress in Vancouver in 1975 Harold Brookfield organized a follow-up symposium to the 1961 island ecosystems symposium in Honolulu. Brookfield's symposium was under the sponsership of UNESCO s MAB project / Ecology and National Use of Island Ecosystems. The Vancouver Congress concluded by stressing five areas of concern for scientific activities in the Pacific Region: mineral resources, human resources, coastal zones, island ecosystems, and biosphere reserves. The latter three areas are encompassed in MAB projects 5, 7, and 8. Among these, the MAB project 7 on island ecosystems has so far received the least attention in funding in the United States.

However, the South Pacific Commission (SPC), in coordination with the International Union for the Conservation of Nature (IUCN) organized a conference in 1976 in Apia, Western Samoa. One of the authors, Dr. Mueller-Dombois, had the privilege to participate in this Conference as the representative of the Pacific Science Association. The theme of the Apia Conference was Conservation of Nature in the South Pacific. Major discussion topics were survey of regional ecosystems, ecologically based development, and conservation legislation. Among the 16 resolutions generated from this Conference, resolution 12 called for support of the UNESCO MAB projects 7 and 8 through the Pacific Island governments and the continental governments with major responsibilities in the Pacific region.

Thus, the 1976 SPC-IUCN Conference in Apia reemphasized and reendorsed nearly the same areas which had been proposed in the last Pacific Science Congress in Vancouver.

The new program of the Pacific Science Association Committee on Conservation and Environmental Protection is based on this background.

THE PROGRAM

The program is divided into four parts:

1. Analysis of spatial variation among island ecosystems.
2. Analysis of dynamic processes.
3. Methodology and approaches.
4. Application and conservation action.

These four areas are open-ended, but focused enough so as to yield progressive results and products, which will be of high conservation value. We will now briefly describe these four program elements.

1. Analysis of spatial variation among island ecosystems

By this we mean study of vegetation, animal communities, species, and habitats in the spatial or geographic sense. Methods involve inventory and mapping of vegetation, climates, topography, soils, and landforms. Special emphasis should be given to the distribution and habitat requirements of endemic species, particularly endangered species.

Since the appointment of one of the authors, Dr. Dahl in July 1974 as Regional Ecological Advisor to the South Pacific Commission, he has traveled to all major islands in the South Pacific, where he has collected a large amount of information on the major ecosystems of the South Pacific region. The information was compiled for 20 biotic provinces (named by island group, such as Bismarck Archipelago, Solomon Islands, etc.) and for 73 biome types (i.e. 12 forest biomes, 3 scrub biomes, 1 bog type, 5 grassland or savanna biomes, 3 march biomes, 2 desert biomes, 9 acquatic or semi-aquatic biomes, 3 specialized animal habitats, 2 coastal biomes, 12 reef habitats, including algal and seagrass beds, 6 lagoon types, and 15 marine habitats). A two-way overview table in his report allows for a quick spotting of the presence or absence of any of the biome types in each of the 20 biotic provinces. Four physical island types (continental, volcanic, elevated reef, and sealevel reef)were similarly identified (as present or absent) in each of the 20 biotic provinces. In his draft report, many of the biome types are further subdivided into major vegetation and habitat types and their status of protection is indicated. In addition, lists of rare and endemic species are compiled and information is given on existing reserve and conservation legislation for each island group (or biotic province).

A copy of Dr. Dahl's draft report is kept on file in the Pacific Science Association Office in Honolulu. The report is intended for publication.

2. Analysis of dynamic processes

This program area emphasizes three project elements, namely the impact and response to natural stresses and/or disasters, new stresses, and the study of long-term changes. Among new stresses we consider particularly the impact of exotic species and animals and the effects of pesticides in island ecosystems. Professor Wodzicki, a member of our Committee, is planning to work on a synthesis review of the impact of exotic animal species in the South Pacific island ecosystems. Dr. Marshall, an entomologist stationed in Western Samoa, has worked in the Tokelau Islands on the effect of DDT seepage onto coral reefs. His results have been documented on film, but a detailed report is still outstanding.

Dr. D.R. Stoddart (University of Cambridge) has a longstanding scientific interest in the effects and recurrence of natural disasters on Pacific island ecosystems. As a member of the tentative U.S. MAB project 7 he was to prepare a synthesis review on this topic. However, the project has not yet received any funding.

The longer-term dynamics in the Hawaiian rain forest will be the subject of another talk in this conference. Here, natural stresses produce symptoms of forest dieback which were initially thought to be the effects of a newly introduced disease or insect pest. Instead, the canopy dieback is associated with rejuvenation processes in this island rain forest ecosystem.

A study of stress factors and responses to natural stresses in island ecosystems will help to better understand the important question of fragility versus stability relationships in island ecosystems. It has become clear through the Hawaii IBP research and the study of the Hawaiian rain forest dieback that the fragility theory of island ecosystems will have to be reexamined. Such reexamination is of particular relevance to conservation management.

3. Methodology and approaches

This program area concentrates on three project elements,namely on the ecological significance of traditional cultural practices, on appropriate methods for monitoring island ecosystems and biotas, and on conservation education.

Traditional cultural practices were a major subject of discussion in the second SPC-IUCN Regional Symposium on Conservation of Nature in the South Pacific in Apia in June 1976. The focus was on using and revitalizing certain aspects of traditional cultural practices for ecologically based development (i.e. ecodevelopment) in the Pacific Island nations, wherever such practices offer a viable and ethically acceptable alternative to resource development based otherwise on a technology developed by the industrialized continental nations.

Dr. Lance Hill (University of Papua New Guinea) has indicated an interest to work on a synthesis review in this project area for achieving the conservation objectives of our Committee.

Monitoring island ecosystems should ideally be based on a thorough knowledge of their structures and functions. These should be a complete inventory of the fauna and flora, with their distribution, abundance, and roles in the ecosystem. The dynamics of the system over time should be clearly understood. Knowledge of the minimum size necessary for the ecosystem to function and of the minimum population number required for the survival of each species would then allow a precise definition of the requirements for conservation.

Unfortunately, this knowledge does not exist for any ecosystem, not even the most thoroughly studied. For island ecosystems where our ignorance is manifold, conservation decisions must be taken on other bases.

Human and material resources available seldom permit even a reasonably complete study of an ecosystem. The challenge of an appropriate monitoring program is to collect the minimum amount of information necessary to detect all significant changes in the system or its components. Fortunately, the interactions within an ecosystem are such that one factor can often serve as an indicator for many facets of the system. A judicious choice of indicators can provide a reasonably full coverage of the ecosystem.

The accuracy with which measurements are made is also important. Too often highly accurate measurements have no significance because of sampling error or natural variability. A larger number of gross changes may be more meaningful than a few very precise figures. The level of accuracy chosen should be a function of the kind of conclusions required for monitoring. Similarly, several diverse measurements will generally be more useful than one parameter studied in much greater detail.

Forest is the most common natural cover on islands and therefore is of the greatest interest for conservation. As natural forests tend to be reduced by development, the distribution of total forest cover is a simple way of measuring terrestrial conservation status. Forest cover and other land features of interest to conservation can quite easily be determined from aerial photographs. Such photographs taken at 5- to 10-year intervals will give a reasonable measure of longer-term changes in major terrestrial habitats. Reduction in forests and other natural habitats is one of the major causes of conservation problems.

At the more local level, specific monitoring sites can be permanently marked and regularly examined for parameters indicative of the state of the ecosystem. Techniques for doing this in coral reefs and lagoons are now being developed by the South Pacific Commission, using area coverage measures and counts of selected species and life forms. Simple definitions based on obvious features permit the method to be used even by non-specialists.

Each island has some critical habitats in need of special consideration for conservation. These may be important breeding areas, lakes, swamps, or other sites with small-size or distinctive biotas. Special monitoring methods may be required for these areas.

Such monitoring activity, which provides the basic information input for conservation management, can only have success, if the respective island people support and participate in the process. Support and participation by island people can only be expected, where conservation education is included as a major aspect of the program.

This was recognized early by the South Pacific Commission at its First Regional Symposium on Conservation of Nature, Reefs and

Lagoons, in Noumea, New Caledonia in August 1971. Further emphasis has been given to conservation education in Apia in 1976 at the Second Regional Symposium. Mrs. Margie Falanruw from Yap Island (Western Carolines) has been an IUCN consultant on environmental and conservation education to the South Pacific Commission. She is a member of our Committee and will cover this important aspect in our program as much as this is possible from her perspective.

Of cousre, conservation education should be an integral part of any conservation-oriented research, initially when a project is suggested by the researcher and the endorsed by the land administrator and particularly at the completion of the project where it is an important element on the information transfer phase.

4. Application and conservation action

Three activity areas are considered to be of particular value for the application of conservation measures: the preparation of field guides, appropriate suggestions for resource-use options and alternatives, and efforts directed for protecting critical habitats or to restore them where necessary.

The preparation of field guides includes such items as the description of island floras with keys and illustrations, the description of island vegetation and habitats with maps and profile diagrams, or the monographic treatment of important island animal groups. Emphasis is put on illustrative handbooks which are both scientifically sound but easy to understand and thus useful to the island people. Major progress in this direction has been made in recent years by the Wau Ecology Institute in Papua New Guinea under the directorship of J.L.Gressitt. A series of field guides has been completed on New Guinean frogs, beetles, upland birds, and other life forms.

Appropriate suggestions for resource-use alternatives should always be included as an important follow-up of such studies which deal with the description and mapping of vegetation habitat and land-use patterns. The point is that such biophysical land classifications yield information value on land capabilities, which, with minor additional effort, can be translated into appropriate suggestions for land-use options or alternatives by keeping an overall perspective for ecologically based development. The Environment and Polity Institute (EAPI) at the East-West Center in Honolulu under the directorship of W.H.Matthews is engaged in such activities. The EAPI is concerned about bringing the environmental impact assessment procedure into the resource-development projects in all tropical areas of the Pacific. Recently, the institute held a workshop conference on the forest land assessment for sustainable uses in which procedures for land classification and suitability ratings were reviewed, synthesized, and adapted for ecologically based development.

Efforts for conserving critical habitats are a continuing need particularly in tropical island ecosystems. Such efforts are best directed through an overall project of inventory and description of vegetation, habitat, and animal communities as was outlined under part 1 of this Committee's program. As mentioned before, the South Pacific Commission in conjunction with IUCN has taken initiatives in this direction. However, a major impediment to developing an adequate system of natural areas and ecological reserves consists in increasing and conflicting socio-economic demands of the natural resources. It is therefore important that a dialogue is established and continued between the land researcher or naturalist who makes the suggestions and the land administrator who makes the desicions. This project element is of vital concern for the realization of conservation efforts in the Pacific region, although it is certainly not the only one of concern.

Summary and conclusions

Conservation and environmental protection is such a broad area of concern in the Pacific Science Association that a committee working for this goal is in a certain danger of becoming diffused by too many tasks. It is therefore necessary to have a program with a certain focus, which is neither too narrow nor too broad.

The area of focus, as resulting from a traditional concern of the Pacific Science Association, are the island ecosystems of the Pacific. The program directives as outlined are in summary as follows:

1. Analysis of spatial variations among island ecosystems:

Ecological inventories.

Vegetation and habitat descriptions, land capability classifications, and mapping.

Habitat-requirement studies of endemic species (particularly endangered ones).

2. Analysis of dynamic processes:

Impact of natural disasters (such as tsunamis, droughts, floods, etc.).

Impact of new stresses (such as introduced animals and plants, use of pesticides and their effects, etc.).

Study of long-term changes (such as changes in land-use patterns or changes in natural communities).

3. Methodology and approaches:

Ecological significance of traditional cultural practices.

Appropriate methods of monitoring through remote sensing and field studies using biological indicators.

Conservation education and teaching of appropriate methods.

4. Application and conservation action:

Preparation of field guides to island organisms and ecosystems.

Appropriate suggestions for resource-use alternatives, based on land capability research.

Ecosystem protection and restoration.

This program is open-ended, and flexible, but it provides for a framework in which progress can be shown in certain increments. Such incremental progress is intended for presentation at the present and future congresses and inter-congresses of the Pacific Science Association.

An important ingredient of this program is an ecological orientation towards synthesis. Committee members are encouraged to participate in certain of the project elements. At the same time they come from different areas of the Pacific and thus bring together expert knowledge of different islands and island groups. They are encouraged to present in-depth analysis and synthesis review, which inform periodically of the overall progress in each of the four areas of the program.

THE LIVING MARINE RESOURCES OF THE SOUTH PACIFIC - PAST, PRESENT, AND FUTURE

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Introduction

The oceanic environment - high seas, coastal zone, and oceanic depths alike - cannot be studied apart from the atmosphere, the terrestrial biosphere, and the geology of the ocean floor. Both the living and inert elements of the ocean and its depths comprise elements related to those of the adjacent environments. In discussion of "resources" it is normal to draw a distinction between "renewable" and "non-renewable" resources. In the oceanic environment renewable resources include all forms of plant and animal life, while non-renewable resources arise from accumulation of the products of biological cycles (petroleum, coral limestone, and globigerinal ooze of the depths), from chemical reactions within the oceans (manganese nodules), or from elements of geochemical origin.

However, the term "resource" also implies the capacity for human use and exploitation. Elements of the oceanic environment which have never been used by man cannot be described as resources in the context of present or past technology. If confusion and misunderstanding are to be avoided, it is necessary to draw a firm line, and the criterion employed here is that "resources" are those elements which has been, are, or will be used by man on a collective scale. Thus, for example we might say that the fish caught in the lagoon of a small island are as much a resource as its production of copra and rice, while a small shell occasionally collected by children or women for domestic use does not belong to the same category. This distinction is important, and is sustained throughout the discussion of this paper.

At present, therefore, many elements of the marine environment are no "resources" because they have never been exploited. However, the range of exploited elements has not remained constant in the past, and is likely to enlarge in the future, so that ultimately all elements of the oceanic environment may come to be thought of as potential resources. Already it is possible to foresee the exploitation of polymetallic nodules and of pharmaco-dynamic substances extracted from marine organisms. It is not possible to foresee what will be regarded as resources 30, 50, or 100 years hence. 150 years ago pearl cultivation was unknown; only 30 years ago there was no conception that polymetallic nodules on the ocean floor might come to be exploited. The concept of resources is therefore both relative and dynamic, and is particularly dynamic at the present time in the marine domain.

On land, a high proportion of man's total harvest is produced by cultivation and breeding, but this is not true of the oceans. Marine products collected or otherwise obtained by man can be estimated at some 60 million tons annually (1976), and of this total harvested biomass approximately 95% is derived from fishing and collection, and only 5% from aquaculture. It would be appropriate to add some ten million tons obtained from inland waters to this total, but in this paper only the oceanic harvest is discussed.

There have been great changes in the pressure on marine resources in modern times. So long as only the harpoon and line were employed for fishing, and the canoe or small sailing vessel as vehicles, there was no threat to marine life. However, the technology of modern civilization has made possible the evolution of fishing systems which operate on a completely different scale from the earlier systems. The impact of these new systems on marine life is serious, for the harvest is taken from normal natural production, and it is easy to surpass the limits at which depletion of the cropped species becomes inevitable. On land, man has long ago moved from hunting and gathering to agriculture, but such a transition has scarcely begun on sea. The range of modern technology applied to what remains a hunting and gathering industry is alarming. It includes factory-ships to collect and preserve the harvest of the hunters; use of satellites to detect the presence of large shoals of fish; growth in the size of flotillas and of ships. The effect of these developments and of the growing food demands of a rising world population has already included serious depletion of tuna, anchovy, and whales and threatens the extinction of some whale species in particular.

MAJOR TRENDS IN THE WORLD FISHING INDUSTRY

The growth of activity. The tonnage of fish harvested has multiplied 30 times in 100 years and has doubled during the last 20 years. About 70% of the present harvest is composed of pelagic species and fish of the middle depths (anchovy, herring, mackerel, tuna, etc.), and most of the remainder consists of demersal species (cod, snapper, etc.). Less than 8% consists of invertebrates (mollusks, shellfish, etc.). Over 70% of the total annual catch is made up of only seven families, all of which have been fished for more than a century. But while 27% of the harvest is consumed fresh by man, 18% after freezing, 13% canned, and 11% salted, it must be noted that no less than 31% is now used to make fish flour. This latter is used only to feed animals, or as fertilizer, and the quantity used in this way has doubled during the past decade; we shall return to this question below. The fishing industry has now spread to every part of the oceans where fish are to be found, but the creation of 200-mile (370 km) "economic zones" will reduce the proportion of the planet's surface available for free fishing from about 70% to 50%. Almost all the continental shelves are included within the new "economic zones," and these areas provide 88% of the total catch.

Wolrd-wide fishing perspectives. Authorites place the maximum potential catch, consistent with maintenance of the total fish biomass without depletion, at between 55 and 100 million tons; the present annual catch is around 60 million tons. Pessimists maintain that over-exploitation is already a fact; even the optimists allow only a narrow margin. However, the concept of "resources" again becomes important. Man does not yet exploit the krill of Antarctic waters, but if these and other species come to be employed, the maximum potential catch might be raised as high as 235 million tons.

Aquaculture. In terms of the additional energy imputs supplied by the "cultivator," the term aquaculture covers a wide range of activities. At one end of the line is the breeding of oysters whose entire nutrition is derived from their natural environment; at the other is the cultivation of fish in closed ponds or tanks, where all food and fertilizer are supplied by man. Whereas the first system merely intercepts nutrients which might otherwise enter natural food webs, the other derives food at much greater cost from elsewhere in the whole planetary system. Whether measured in financial or in energy and nutrient terms, there is as much range in the "budgets" of aquaculture as of agriculture, and simple statements are not possible.

Ultimate limits to the marine food resource. Discussion of the nature of aquaculture serves to underline the ultimately limited nature of marine food resources, even though the limits may lie well beyond present estimates. Unless nutrients are imported from the land, and hence subtracted from the production of terrestrial ecosystems, they all derive ultimately from the process of photosynthesis, requiring light, nutrient minerals, and carbon dioxide. By far the major part of primary production in the marine system consists of phytoplankton, some 99% of the whole biomass. However, benthic algae (living on the sea bed) and symbiotic algae (living in symbiosis with animals) are significant out of proportion to their biomass because of their location and concentration. They are particularly important in the tropical seas, since they include algae in symbiosis with coral organisms and other species such as the coelenterates and some mollusks, including the giant clams (Tridacnidae). Directly or indirectly, these primary producers form the sustenance of all other animals in the ocean. The "law of tenths" applies throughout the system, so that 10,000 kg of phytoplankton are required to feed 1000 kg of zooplankton, and in turn 100 kg of plaice and 10 kg of man. Among the present marine harvest of some 60 million tons, the majority of species are secondary and tertiary consumers, and among important species only the anchovy feeds directly on the zooplankton.

THE RELATIONSHIP BETWEEN NATURAL FERTILITY AND THE ABUNDANCE OF MARINE RESOURCES

Much less is known about the ecosystem relationships of the tropical marine environment than about those of the temperate seas. A great deal more research is required. Much present research is misplaced because it is concerned with the natural fertility of coastal and marine environments and hence with the abundance of natural resources. This is misplaced for two reasons, one concerned with the food chain, and the other with the real nature of resources, which is also determined by human activity. It will be helpful to elaborate.

Primary productivity and trophic levels. It is not disputed that the best criterion of the biological fertility of any environment is its primary productivity, since all animal life depends ultimately upon productivity at this level. In the oceans, however, primary production is limited to the shallow euphotic zone within which light penetrates. Moreover, it depends not only on the depth of the euphotic zone but also on the presence of mineral nutrients, in particular nitrogen and phosphorus. These are abundant in the deep oceans, but sparse at the surface except in the limited areas of upwelling from the depths. Such upwelling is confined to only about 0.1% of the ocean surface, but these areas are responsible for 0.5% of primary production, and for 50% of the total tonnage of fish harvested.

It is here that the length of the food chain from these marine "prairies" to the fish caught by man becomes of major importance. Five trophic levels separate the phytoplankton from the tuna. In waters of the continental shelf there are generally three trophic levels between the primary food base and the herring. In the upwelling zones only two trophic levels separate the phytoplankton, via the zooplankton, and the anchovy.

The selective nature of man's harvest. Two areas of the ocean may thus have similar primary productivity and thus be similarly "fertile," but the resource exploited by man will be far greater if it is drawn from the second trophic level than from the fifth. Given the "law of tenths," the difference will have a magnitude of 1000. Everything, therefore, depends on the nature of man's levy on the marine resource, and this depends on taste, technology, and economic considerations. In the Antarctic, for example, man has exploited the whales at the third trophic level almost to extinction; technology now permits exploitation of the krill (second trophic level) on which the whales feed. In some instances, however, man has begun his exploitation at the other end of the chain, with the first level. We will examine this latter situation further in relation to the south Pacific, with the examples of the trepang, the mother-of-pearl shell, and other mollusks.

It follows that there is no simple correlation between the fertility of an oceanic environment and the abundance of its natural resources. In any environment, resources will be abundant if they are exploited at a low trophic level, but this is not often the case. Moreover, the volume of primary production determines an ultimate limit to the renewable resources of the oceans, and this is of the order of 550×10^9 tons per year; in practice nothing like this tonnage is available, since man's harvest is selective of higher trophic levels.

Aquaculture will not eliminate this limitation, for it entails a heavy input of food and fertilizer. The determining factor in the evolution of aquaculture will be the growth of demand, and hence the price that can economically be paid. If fish are to be bred with fish flour, the fish that are used will themselves be diverted from the natural food web and their ultimate productivity will remain subject to the law of tenths. There is no escape from this loss until or unless man himself is able and willing to employ only the primary production of the oceans.

THE MAIN ELEMENTS OF ENVIRONMENT IN THE SOUTH PACIFIC REGION

It will be convenient to define the south Pacific region by reference to the area of operation of the South Pacific Commission, including the archipelagoes of Polynesia, Micronesia and Melanesia:

French Polynesia, the Cook Islands, American Samoa, Niue, Tonga, Tokelau, the Gilbert Islands, Tuvalu, Guam, and the Trust Territory of Micronesia. Papua New Guinea is included only as the context requires, and the seas of Hawaii, New Zealand, and Australia are excluded. We are therefore dealing with the southwest and central-west regions of the Pacific, a region extending over some 100 degrees of longitude and lying almost wholly within the tropics. The region comprises some 30 million km^2 of which only 2% is land, with many thousands of islands and a total human population of some two millions excluding Papua New Guinea, or 4,700,000 including the latter.

The principal physical characteristics of this region have been described many times, and need only to be summarized. The distinction between the high volcanic islands and the low coral islands and atolls is fundamental. Most of the former are quite small; the largest island in the region is New Caledonia, which covers only 17,000 km^2. Viti Levu covers only 10,000 km^2 and is ten times the size of Tahiti, the largest island in the eastern part of the region. Among atolls in the south of the region, that of Kwajelin in the Marshalls is the largest, being 140 km in length, and most are far smaller. Lagoons generally reach a depth of 40 to 60 m, but the large number of closed atolls have much shallower lagoons. A fact of major importance throughout the whole region is the absence of any continental shelf; although the submerged slopes of the islands are important, they are small in area, and separated by the deep ocean.

The past human use of resources in this region has been confined mainly to the land, and to the immediate offshore waters. Sufficient supply of marine foods was available on the coast, in the lagoons, and around the reefs, and it was only rarely that islanders ventured onto the ocean in search of tuna and bonito. Historically, therefore, there was never any need to exploit the resources of the ocean itself, or to develop technology capable of such exploitation. Even in modern times, the whole region has depended overwhelmingly on its copra exports, and the only major extractive resources exploited for export have been minerals - nickel and phosphates. Only in Fiji has the commercial agricultural economy become significantly diversified, and while certain marine resources have been or have become important in commerce, their exploitation has in no time or place yet become central to the island economies.

Marine resources and their distribution. In this region there is no important zone of upwelling from the depths. The waters are oligotrophic systems, and there is no large input of nutrients from adjacent land masses which might favor primary productivity. Moreover, the thermocline - the level at which colder but richer waters are encountered - is everywhere at fair depth.

Although the oceans themselves are relatively barren, the coastal areas have great richness in corals. The coral communities which surround these islands are among the most productive ecosystems of the Earth. This extraordinary contrast demands explanation. The coral reef ecosystem is itself the most remarkable instance of symbiosis between animals (the madrepores and some other organisms) and algae, which inhabit their tissues. The whole food web of these isolated ecosystems depends on these algae trapped by animals, and analogous in other respects to the free algae which are the phytoplankton in the oceans. An important consequence of this symbiosis is that energy losses between trophic levels are reduced to a minimum. Moreover, the coral community has developed mechanisms with which to supply itself with indispensable nitrogen and to recycle acquired phosphorus, within a larger oceanic environment characterized by extreme poverty in these elements. In addition, the mucus and detritus created by these symbiotic algae are fundamental to all trophic interrelationships among the coral communities. The richness of this community is thus a remarkable natural adaptation to a quasi-desertic environment.

The contrast between oceanic poverty and coralline wealth prevails throughout the region. However, there is no uniformity. Going from west to east in the south Pacific, the number of species encountered diminishes steadily. For example, more than twice as many species of mollusks are encountered around New Caledonia than are found around Tahiti, and the same relationship prevails for all other zoological groups. In terms of species, the western Pacific arc from the Philippines, through Indonesia and Papua New Guinea, to New Caledonia, is the richest area of the whole Indo-Pacific region. However, the relative poverty of areas away from this arc presents a potential advantage to which we shall return later; there is the great range of possibilities offered by the introduction of selected species with economic potential.

It is now necessary to describe in greater detail the resources which have been discussed above in general terms. The living creatures which are gathered or caught by men and women in the area between the shore and the deep ocean can be classified in several ways. In this study a distinction is drawn between the resources of the lagoons and reefs on the one hand, and of the surrounding ocean on the other. The first group comprises a large number of genera: mollusks, algae, crustaceans, echinoderms, fish, turtles, and marine mammals. Only whales and fish represent the second group. Between these two groups are those fish which inhabit deeper waters on the outer slopes of islands; little interest has been taken in this latter group until quite recently, and for convenience they are discussed here together with the fish of the reefs and lagoons. Detailed discussion follows, beginning with primary and secondary resources that are of value to man.

INVERTEBRATE RESOURCES OF THE REEFS AND LAGOONS

Algae

Although each year about one million tons of marine plants are either gathered or cultivated in the world as a whole, in the south Pacific they are not a "resource" in the terms described in this paper. Their use by man is virtually confined to the temperate regions of the northern hemisphere. While some algae are consumed by islanders, and a few are even on sale in the markets, consumption is mainly at the domestic level. This is the case in Fiji with green algae (Caulerpa) which are consumed on Lakeba in Lau, and are sold in the Suva market. Recently, there has been an unsuccessful attempt to cultivate Eucheuma in Tahiti, though this species is cultivated commercially in the Philippines and exported as a jellifying agent for industrial use. The lack of success in the eastern Pacific was doubtless due in part to the want of nutrients and of nitrogen, which constituted limiting factors in the growth of this species.

Mollusks and shells

Pearl shells. Commercialization of pearl shells in the south Pacific extends over a period of 170 years and constitutes a classic case of over-exploitation of a limited resource. The market for these shells developed early in the 19th century for the manufacture of buttons and continued into modern times despite the advent of synthetic substitutes. Three principal species are involved, the mother-of-pearl, trochus, and burgau; they will be discussed separately.

Mother-of-pearl oyster. This black-lipped oyster, Pinctada margaritifera, can attain a size as great as 30 cm and the two valves may weight as much as 5 kg; the average, however, is between three and four specimens per 1 kg. Though it extends throughout the south Pacific, the only large banks are in the east, in French Polynesia and the Cook Islands. A highly prosperous trade to Sydney, Valparaiso, and later San Francisco began as early as 1802, and while Tahiti statistics show that 50,000 t have been exported since 1827, the total export was probably two or three times this figure. Many ships cleared directly from the smaller islands, and moreover, the heaviest pillage was already over before 1827. Production in French Polynesia has subsequently fluctuated between peaks of 643 t in 1833 and 1319 t in 1924, and troughs of 179 t in 1850 and 60 t in 1933.

From the outset of the business, diving for mother-of-pearl has been an important social and economic activity in eastern Polynesia. Several thousand persons, including divers, traders, and their families, moved to the atolls - there were 4000 at Hikueru in 1921. Marutea Sud and Takaroa were the most productive atolls. Mentions of depletion of the stocks emerged in official reports as early as 1863, and efforts began thereafter to regulate the harvest. These measures included a rotation of lagoons open for diving and their division into sectors, declaration of limited diving seasons, imposition of quotas and prohibition on taking small shells, but they had limited effect. Depletion of the stock and the use of polyester substitutes together led to a steep decline in production between 1969 and 1977 (183, 185, 72, 75, 19, 24, 5, 5, 4 t in succeeding years). In 1977 shell accounted for less than 0.4% of the total exports of French Polynesia. Some years ago a button factory was established in French Polynesia, but it was designed for a minimum annual supply of 200 t and quickly failed.

A similar story can be recounted about the Cook Islands. Twenty years ago, mother-of-pearl shell was still the principal export of the Cook Islands, but since that time there has been a rapid decline. In 1976, 94% of the remaining world production came from the Philippines, Fiji production was 10 t, and no other Pacific country produced more than a few tons.

This classic case of over-exploitation has reduced a renewable natural resource to an extremely low level. However, the mother-of-pearl oyster is indispensable for the new industry of pearl cultivation described below, and there is active research on ways of re-creating the resource. A complete halt to the small residual exploitation for a long period of years is one method. Laboratory cultivation from collected oyster embryos has successfully been carried out by the Fishery Service in French Polynesia in 1977. It opens up a real possibility of re-stocking the depleted lagoons.

However, the exploitation of natural stocks is no longer viable, and it is only through aquaculture methods that the industry can be reestablished.

Trochus shell. The *Trochus niloticus* is naturally widespread in the western Pacific from Fiji through the New Hebrides, New Caledonia, and the Solomon Islands to Palau. This thick conical shell has been collected for use in the button industry since the beginning of the 20th century, mainly around New Caledonia, and the annual level of exports still holds at around 1000 t; in 70 years more than 30,000 t have been exported. However, there have been increasing problems due to exhaustion of stocks, leading to a shift from low-tide collection to diving, and search over wider areas. Stocks already reduced before 1940 were re-constituted during World War II when there was little exploitation, but renewed over-exploitation led to an embargo on collection in 1956 and subsequently to a system of regulation similar to that applied to the mother-of-pearl oyster in French Polynesia. Regulations have been continually modified, and more recently conflict has emerged between the New Caledonian Melanesians and the Polynesian immigrants who have entered the business. Elsewhere in the region, in the Solomon Islands and Fiji, trochus has been exported intermittently since World War II, but harvests have never exceeded 300 t. Two button factories were established in Fiji some 30 years ago, but they lasted only a short time.

Though threatened, this resource is still in being, but it constitutes only a minor element in the economy and offers no secure base for higher levels of development. Some efforts have been made to transplant trochus into areas where it is not naturally present, in Micronesia and Polynesia. The Japanese succeeded at Truk and Ponape, but failed elsewhere. Fifty specimens were brought to French Polynesia from the New Hebrides in 1957, and were successfully established at Tahiti and Moorea, but the experiment failed at other islands, including all the atolls. Export production has varied greatly due to large price fluctuations, but has totaled 578 t since 1972. In addition, 150 to 200 t are used locally each year for the manufacture of bracelets and curios for sale to tourists. FAO statistics for 1976 show only Fiji and the Solomon Islands as exporters within the region (225 and 480 t, respectively), but 12 t from French Polynesia should properly be added.

Burgau. This large, globular gastropod (*Turbo marmoratus*) is widely distributed in the southeast Asian archipelagoes, and extends east as far as the New Hebrides. Around 30 years ago, some 50 t were exported each year from the New Hebrides, but the danger of over-exploitation led to an embargo in 1962. Since that time collection has resumed and has developed; exports of trochus and burgau together increased from 88 t in 1972 to 279 t in 1976. The only known experiment in transplantation was to Tahiti in 1967, and while this experiment was successful, the species is still protected in French Polynesia and has not yet given rise to any exploitation.

Pearl cultivation. Pearl cultivation was initiated in Japan, where it has become a major industry since early in the 20th century, using the Japanese pearl oyster (Pinctada fucata). However, the technology remained secret until after World War II, and even then development elsewhere proved difficult because the necessary conditions are rarely found in conjunction. In the Torres Strait area of Australia the cultivation of Pinctada maxima began in 1956, and the number of pearl farms increased to eight in 1962 and 15 in 1966. Pinctada maxima lives from New Guinea to New Caledonia, but occurs most abundantly in Torres Strait. Pinctada margaritifera, which is widespread in the Pacific, has also been used for pearl cultivation, this species producing the black pearls.

Within the region, this activity is confined to French Polynesia where, despite past depredations discussed above, Pinctada margaritifera remains more abundant than elsewhere. Japanese specialists, brought to French Polynesia by the Fishery Service, have taught several groups of islanders, especially in the Tuamotu group, the delicate technique of grafting to obtain round pearls. Cooperatives have been formed and four private groups have opened five farms in the Tuamotu and Gambier Islands. In 1976 the value of exported production approximated $ US 165,000, and though this represented only 3% of the Territory's exports, it ranked second after copra. The industry is growing in scale, but expansion is limited by the rarity of the oysters. This is why the experimental work discussed above is of such importance; breeding of the oyster from collections of the embryos or larvae makes possible a far more rapid rebuilding of stocks than by natural recovery.

At the beginning of 1978 the American Institute of Gemmology provided official authentication of the natural untreated status of Polynesian pearls, and it is possible that their value on the international market will rise in consequence. Pearls are a product of high value, and once the technical and marketing problems are solved, it seems likely that this industry can grow into a major and fairly secure export activity. This noteworthy development is of double interest from the present point of view. First, it relies on a natural, renewable resource successfully managed; second, it is an activity of the outer atolls, environments which elsewhere in the region offer extremely limited cash-earning possibilities to their inhabitants.

Decorative shells. Throughout the south Pacific a small, though far from negligible trade in decorative shells has gained significantly in importance from the spread of tourism through the region. A distinction needs to be drawn between the simple collection of shells, and the manufacture of selected species into necklaces and curios. Shell necklaces are made everywhere in the Pacific, especially in French Polynesia where they constitute customary parting gifts, complementing the floral leis given to visitors on arrival. Several tons of *Cardium fragum* and *Cypraea* are used for this purpose each year, without seeming to pose any risk of over-exploitation.

The sale of shells, both to undiscerning tourists and to more knowledgeable buyers, is an important element in petty commerce in all Pacific countries, both in the rural areas and more particularly in the towns, where market stallholders and street vendors engage in this trade in some numbers. In cases where valuable shells are endemic to particular areas, as is the case with varieties of Conidae, Cypraeidae, Mitridae, Strombidae, Muricidae, and some others, very high prices can be obtained, especially by middlemen and professional collectors. Some aspects of this business give cause for concern on ecological grounds. Both ordinary islanders and commercial collectors are responsible for some over-intensive and unselective search, which can include the overturning of coral blocks and even breaking up coral colonies with crowbars. The habitat of the mollusks may be damaged and even destroyed by this careless, or wantonly destructive, exploitation. A good deal of damage is also done by ignorant amateurs, especially in the main tourist areas. No restriction is applied to the sale and export of shells in any Pacific country, though such restrictions have been imposed on certain islands in the Indian Ocean. There is, however, no doubt that some measure of protection of this natural resource will soon be required in the more heavily impacted areas.

Mollusks as food. Mollusks are collected for food throughout the Pacific. Generally they are consumed by the collector and her or his family, but they are sometimes traded or bartered at the village or island level, and more rarely between islands; there is, however, almost no formal commercialization. This harvest is everywhere important, but is selective of different species between archipelagoes and even between islands within the same archipelago. The range of species consumed is very large, but the commonly used species in French Polynesia and eastern Fiji, for example, are less numerous, and belong to bivalves (Tridacnidae, Veneridae, Psammobiidae); cephalopods (small octopuses); and gastropods (Trochidae, Turbinidae, Strombidae, Vermetidae).

In the Tuamotu archipelago the consumption of mollusks has been estimated as 40 g/day for each inhabitant, but at certain seasons it may rise as high as 400 g/day; at these times the intake is composed entirely of giant clams (Tridacna maxima) which are very abundant in the lagoons. In several islands such preference for certain species has caused them to become rare, especially when the preferred species are of large size and grow only slowly; this is the case with the giant clam at Lakeba, in the Lau Islands of Fiji.

It is safe to conclude that the population of edible mollusks could not support commercial exploitation of any scale; all evidence suggests that it is already quite heavily taxed on the present subsistence basis. However, this situation might change were these species incorporated at some future date into a system of aquaculture.

Cultivation of oysters. Although the cultivation of oysters has been discussed above in the specific context of a high-value industry producing pearls and mother-of-pearl shell, there is also a wider aspect that should not be overlooked. The cultivation of edible mollusks is quite highly developed and widely practiced in temperate lands of both hemispheres, but is still almost unknown in the tropical Pacific. The edible oysters, of the genera Ostrea and Crassostrea, require a moderately saline environment for best development, conditions such as are found in estuaries and some lagoons.

While there is no cultivation, however, there is a large natural resource, and oysters have been collected for food throughout the south Pacific since time immemorial. Two main situations are encountered: natural banks of rock oysters, as for example in the Baie de Papeari at Tahiti, and mangrove oysters which live on the roots of Rhizophora in bays and estuaries of Fiji, the New Hebrides, the Solomon Islands, and New Caledonia. The Lau group is the eastern limit of mangroves in the Pacific, and these communities do not occur in Polynesia. Collection is at a family level, though there is a little trading to shops, restaurants, and hotels; however, harvesting is not on a scale to create any danger of over-exploitation.

The work on the breeding of Crassostrea cucullata, collecting the embryo on Tridacna shells close to a natural bank, is carried out by the Fishery Service of French Polynesia. This work was successful in producing commercially viable oysters, and it has since been possible to establish colonies in several of the Leeward Islands, where conditions are favorable. In 1974 there were a hundred oyster farmers at Raiatea, Tahaa and Huahine, though most of them also had other activities. A production of 3 t in 1971 increased to 15 t by 1974; meantime imports also increased, so there was no danger of market saturation. Attempts to introduce new species from Australia, New Caledonia, and America, between 1966 and 1972, were not successful, but none the less locally based oyster farming has become established in the group, even though its present output is far less than the 100 t collected each year in New Caledonia[1].

Crustaceans and echinoderms

Crustaceans. On a world scale, the annual catch of crustaceans totals some 2 million tons, more than half of it consisting of prawns. Very little of this comes from the south Pacific, where the only major enterprise is a prawn fishery in Papua New Guinea, producing 872 t in 1976, almost half of the whole regional production in this group. Mangrove crabs (Scylla serrata) are also of some importance in Papua New Guinea (450 t) and in Fiji (170 t), and the only other harvest of significance is represented by lobsters, a few tons of which are caught each year in Samoa and French Polynesia. These figures, based on FAO (1976), exclude the subsistence which is substantial in certain territories, but even so, it seems clear that exploitation of these resources is currently at a low level in this region.

Lobsters. Lobsters are found throughout the region, but the level of fishing is far below that of Australia and New Zealand, both of which countries export these crustaceans in quantity.Four to five species of the genus Palinurus are encountered in each of the archipelagoes of Melanesia, one to two in each Polynesian archipelago, but exploitation has remained at a small scale, and

[1] A complate inventory of the mollusks should also include the cephalopods of deeper waters, sometimes caught by the Japanese in the Coral and Tasman Seas, where a potential annual catch of several thousand tons might be possible. However, in the region discussed here resources are sparse and not exploitable at present.

attempts to organize marketing have had little success. However, there is an evidence, e.g. in Tonga, that heavier exploitation was soon followed by reduced catches and diminished size of the lobsters caught. While small-scale commercialization seems practical, it is probable that the stocks available in the coral environment, and the slow growth of lobsters, would rule out any significant expansion. Nor is there any immediate likelihood of lobster cultivation; the Japanese have not yet mastered the problems of breeding and raising this slow growing animal in more than 20 years of research.

Echinoderms. This last group of marine invertebrates ranks far behind the mollusks and crustaceans in terms of world-wide harvest - only 50,000 t against 3.3 million tons of mollusks and 2 million tons of crustaceans. In the tropical south Pacific, however, holothurians have a greater relative importance, and this is especially so in historical perspective, since the holothurian trepang, or beche-de-mer, was among the earliest products of the south Pacific to enter international commerce. Unlike the sea urchins, which enter only local commerce, they are still actively exploited to this day.

Trepang or beche-de-mer. The principal market for trepang has always lain in China and among Chinese overseas, and trepang has been exploited in both Indian and Pacific Oceans ever since Chinese traders and emigrants first entered these regions. Trepang is rich in protein (43%) and is believed to have aphrodisiac properties. Several species of holothurians of the genera Actinopyga, Thelenota and Holothuria are collected and sold dried after preparation which includes emptying of fluid, cleaning, and cooking. The trade in trepang flourished greatly during the 19th century and in the early 20th century; around 1900 the annual export from Truk in the Carolines was of the order of 500,000 t. The main centers of commerce were then Penang, Singapore, and Hong Kong, and today almost all the traffic between some 30 producing countries and 20 consuming countries is still channeled through the last two ports. Since World War II, however, there has been a very marked reduction.

The present annual trade in trepang is only about 500 t, not including about 13,000 t produced in Japan from Stichopus japonicus. Papua New Guinea, the American Trust Territory, the Solomon Islands, and Fiji are now the only exporters within the region. Present exports from Fiji amount to only 2 t a year, half the level of a decade ago, but serious efforts are currently being made to expand production; these efforts are part of a new drive for decentralized fish curing and drying, using simple and locally available technology. The only factory for preparation of trepang in the region is at Honiara in the Solomon Islands, but this enterprise has problems due to its need for rapid and continuous supply which is difficult to ensure, given the biology of the species, the problems of collection and storage. Some Pacific archipelagoes, such as the Tuamotu group, have very large populations of certain species, such as Halodeima atra, but no steps have yet been taken to exploit these resources commercially. There is no doubt that the exploitation of trepang is capable of considerable expansion, given a more effective system of production and marketing than prevails today.

VERTEBRATE RESOURCES OF THE REEFS AND LAGOONS

Fish of the reef-lagoon complex

Productivity and biomass. The coral reef ecosystem is among the most important on the surface of the planet in terms of its productivity. The ecosystem occupies approximately 0.12% of the Earth's surface and 0.17% of the oceans. Within this total, the area with depths between 0 and 30 m represents some 15%. The fish populations of these systems rest on a very rich base in primary productivity, yielding daily 4 to 10 g/m^2 of carbon, while the marine plants have a daily production of carbon as high as 12 g/m^2. These levels of productivity may be compared with cultivated fields on dry land, which produce on average only 4 g/m^2 of carbon daily. The biomass of fish living in the reef environment is of 40 to 200 g/m^2 or t/km^2 and values as high as 390 g/m^2 have been measured on the outer reefs of the Australian Great Barrier Reef. These biomass values are very much higher than those reported from large lakes and coastal zones in the temperate belt. It should also be noted that in artificial reef environments the concentration of the supported fish population can go as high as 1700 g/m^2. However, these very favorable indicators for exploitation are offset by a number of constraints.

Factors limiting the possibilities for large-scale exploitation. Great species diversity is a major characteristic of the reef-lagoon ecosystems, and the number of species is very large. A high proportion of these species is edible, in contrast to the situation in temperate zones, but in consequence the numbers of each individual edible species are far smaller than in the temperate seas. Moreover, many of the edible fishes are of small size, a fact which does not favor their commercial exploitation.

Many of the exploited species live in restricted areas even within the reef-lagoon ecosystems, so that it is only in the largest such systems that major exploitation is possible without risk of rapid reduction of stocks. This is the outstanding risk entailed in harvesting any small marine system to feed massive demands of concentrated urban populations. It is also necessary to note that fish toxicity is a serious constraint to commercial exploitation, especially as the problem of toxicity is more common and more serious among carnivorous fish that is generally realized. Finally, it must also be remarked that, quite apart from the dangers of over-exploitation, the fish are the first inhabitants of the reef-lagoon ecosystem to feel the effects of pollution and other consequences of man's activity. They occupy an environment of undoubted fragility, which is much more vulnerable to such damage than the marine environments of the temperate zone.

Methods and technology of fishing in the reef-lagoon system. The presence of numerous coral heads in the lagoon militates against the use of modern industrial methods of fishing. Given these constraints, ancient and individual methods have to remain the most appropriate. The former include the lance and spear, bow and arrow, harpoon, line, fish trap, hand-net, and the use of Barringtonia fruit as poison, together with the "fish drive" of Polynesia and parts of Melanesia. Among the latter the harpoon-gun is certainly modern, but requires individual operation. The use of some "modern" methods such as the killing or stunning of fish with explosives can be extremely damaging, and has already at least partly destroyed the food web in the lagoon at Truk. Use of the trawl, drogue, seine net, and other devices is possible only in those large and deep lagoons where coral heads are few.

A major potential resource. These constraints explain why the fish of the reef-lagoon ecosystems have continued to be exploited only on a small scale, by manual methods and mainly for subsistence purposes. However, some specialists have estimated that the total fishery potential of these ecosystems may be as great as six million tons, about 10% of the total harvested from the world's seas. Present exploitation is probably less than 5% of this potential, even if all subsistence production is included together with commercial production.

The number of species caught and consumed is very large. Most of them belong to basses, groupers (Serranidae); parrotfish (Scaridae); jackfish and trevally (Carangidae); emperors (Lethrinidae); rabbitfish (Siganidae); surgeonfish (Acanthuridae); goatfish (Mullidae); mullet (Mugilidae). In addition to this harvest for human consumption, an important new activity is developing now in association with the tuna and skipjack (bonito) fisheries in the surrounding ocean. This is the collection of fish for discharge into the seas close to the Thonidae shoals as living bait; the tuna and skipjack are thus drawn into the vicinity of the fishing lines. This live bait may be fished from the natural resource, but is more and more derived from aquaculture. Anchovies, sardines, immature mullet, apogon, and tilapia are among the fish used in this way.

Present exploitation of reef and lagoon fish. Fishing in the lagoons and on the reefs has alwys been the main source of animal protein for the island populations of the south Pacific. It is not possible even to estimate the quantity harvested for subsistence purposes, and it is only since World War II that the growth of towns in the islands has led to the development of formal and informal marketing channels. In the same period, Fishery Services have been created in several Pacific countries and territories, charged with the development of commerical fishing. The task faced by these Fishery Services is not easy. They have to deal with labour-intensive methods of fishing, the problem of storing and preserving the catch until it can be collected, the problems of inter-island shipping and the need to organize an appropriate marketing system. All this costly work has to be undertaken in the face of competition from imported frozen and canned fish drawn from foreign sources enjoying all the economies of scale.

The FAO statistics for 1976 show a total product of the reef-lagoon fisheries of the south Pacific countries (including Papua New Guinea) amounting to 26,300 t. For the same territories, the recorded catch of tuna and skipjack totaled 66,400 t (73% skipjack), without taking into account the larger quantity caught by foreign companies operating in the region. The grand total of 90,000 t, therefore, represents the FAO estimate of the commercialized local fishery, and only 29% of this is drawn from the reefs and lagoons. It is of some interest to list the country data for reef and lagoon fish in decreasing order of magnitude:

Papua New Guinea	15000 t
Fiji	3192 t
French Polynesia	2075 t
Solomon Islands	2000 t
Western Samoa	1100 t
Tonga	1019 t

New Caledonia	700 t
Cook Islands	400 t
U.S. Trust Territory	215 t
New Hebrides	200 t
Guam	122 t
American Samoa	60 t

Excluding Papua New Guinea, the total is only 11,300 t. However, this is only a part of the total, since the subsistence production has to be added. In French Polynesia, total production is estimated to be at least 4000 t, and some would regard this estimate as much too low; the present writer would place the total around 6000 t, and estimates as high as 8000 to 9000 t have been published. This writer would estimate that the total fish catch in the south Pacific lagoons and reefs is around 100,000 t/yr.

In a very interesting report, Clutter (1972) has discussed the underdeveloped state of exploitation of the coastal marine resources of the south Pacific countries. There is a long record of failures extending over a thirty years and affecting almost all territories. The two principal stumbling blocks have been the preservation of the catch awaiting transport, and the transport to the market itself. Fiji has had such an exprience with its costly Small Fisheries scheme. It may be helpful to review a more successful scheme, in which inshore and oceanic fisheries were combined in one enterprise. In Tahiti, the Societe de Commercialization et d'Exploitation du Poisson (SCEP) was founded in 1973 with the object of developing a fishing industry mainly in the Tuamotu group, from which more than half of its throughput is derived. Freezing units were installed at Raiatea and at Apataki in the Tuamotu, and a central freezing plant at Papeete (Tahiti) permitted fish to be held so that it could be supplied to the urban market, or exported, in accordance with demand. The supply ship also has a freezer space. Three fishing vessels are operated, and fish are also brought to Apataki from neighboring islands. A sufficient supply has been established to serve the Papeete market, to export skipjack in small quantities, and to embark on the manufacture of fish fillets, dried and salted fish, and fish flour for aquaculture.

Fishing on the outer reef slopes

Environment and fish population. In the absence of any continental shelf around the Pacific archipelagoes, the outer slope of islands commonly descends at angles as steep as 45° to depths of 3000 or 4000 m, sometimes more. Live coral extends only to 80 or 90 m below the surface, since light is essential for photosynthesis by the algae which are symbiotic with the coral. Beyond this depth are some corals without symbiotic life, but these species living beyond the range of light occur only as isolated colonies and do not construct reefs. Living corals cover the outer slope completely to depths of 30 to 50 m around high volcanic islands, and to greater depths around atolls where the seas are generally less turbid; at Takapoto in French Polynesia they have been observed as deep as 80 m. Below these depths there are no live coral or algae, and the surface is composed of dead, eroded corals of great age.

These depths are not, however, without marine life. Demersal fish, snappers and emperors (Lutianus, Aprion, Etilis, Lethrinus, Pristipomoides), have for long been caught by individual fishermen in canoes and small boats. The fish are strong and of good size. Some Serranidae are also found, including groupers and bass (Epinephelus). These fish live at depths of 80 to 350 m, and have been caught at 500 m in the Cook Islands. Fishermen using traditional methods cannot tap this resource, and strong lines with manual or electric rewinders are necessary to bring the catch rapidly to the surface. Fishing of this type is now practiced off New Caledonia and the New Hebrides.

Exploitation of resources. The fish stocks of this sub-system are very under-exploited, since few islanders possess the means with which to work at these depths. Even though there is insufficient knowledge of the constitution, abundance, and distribution of species, it seems none the less clear that a much heavier exploitation is possible. It is for this reason that the South Pacific Commission has undertaken a small experimental program in outer-reef fishing. This project, which was also concerned with skipjack and tuna fishing, employed three vessels which worked successively in the New Hebrides, Western Samoa, the Cook Islands, and the Solomon Islands. The project completed its work at the end of 1977, and results have not yet been published; however, it appears that stocks sufficient for exploitation without large capital investment have been established. In the New Hebrides the French Residency established a school of fishery on Malekula in 1975; in six months a total of 3.3 t was obtained, mostly at the depths between 120 and 180 m. The Japanese have also investigated the possibilities of demersal fishing in the inshore waters of Tonga. Technology seems to be the principal limitation to more intense exploitation of these resources. However, more knowledge is also necessary.

Turtles

In a region almost without terrestrial mammals, turtles have always been important as a source of animal protein other than fish. Turtles mate at sea and lay their eggs at the top of beaches in sites used for many generations; there is heavy infant mortality. The sea turtle is keenly sought after, not only for flesh, but also for the gelationous part of its stomach which is used to make soup, and for its leathery skin and shell. In addition,the fat is used as a cosmetic base, the eggs are gathered, and infant turtles are raised in captivity to be sold as souvenirs.

Before discussing the turtle as a resource in this region, however, it is necessary first to examine the world-wide position of the sea turtle; all seven species are in danger, and are included in the Red Data Book of the International Union for the Conservation of Nature (IUCN). There is widespread discussion of turtle breeding, but too little information about what this in fact means. It is important to distinguish between the protected breeding of youngsters which are collected wild (turtle ranching), and the controlled management of the whole life cycle (turtle farming). The turtle colonies maintained in some brackish lakes in eastern Fiji, for example, fall into the former category, and there is, in fact, only one example in the world of true turtle farming. This work, on the island of Grand Cayman in the Caribbean Sea, has not yet fully resolved the problems of adult behaviors, female fertility, and bacterial and fungal disease. On the basis of present knowledge, turtle raising can only begin with captured young specimens, or with eggs gathered from the natural cycle.

There is very little scientific information on turtles in the south Pacific. Few statistical data are available on the turtle catch, or about the size of island resources. Among five known species in the region, only two are relatively abundant. These are the green turtle (Chelonia mydas) and the hawksbill turtle (Eretmochelys imbricata). The world catch is listed by FAO as 7777 t in 1976, and half of this is drawn from the Pacific coast of Mexico. The only south Pacific country recorded is the U.S. Trust Territory, with a catch of 4 t. In 1974, the South Pacific Commission initiated a project on the sea turtle, with work in Fiji and Rarotonga. The purpose was to establish turtle ranching as an income source, but the projects did not prove viable and were abandoned in 1977 pending the outcome of national studies in French Polynesia and Western Samoa.

French Polynesia: regulation, breeding, and marking. In December 1971 the catch and sale of turtles were regulated by decree. A minimum legal size was established, a limited season declared, and quotas were set. Sale and the collection of eggs were prohibited. Since that time 200 turtles intended for sale have been seized, and released into the sea after marking. Many other turtles were also marked, and this work has led to accumulation of knowledge concerning the migration of turtles throughout the south Pacific. It is apparent that these migrations are very extensive, so that protection in one country is of little value if uncontrolled massacre of turtles continues elsewhere.

Western Samoa: establishment of hatcheries. The creation of hatcheries is strongly recommended. The mortality of young turtles which hatch in the sand is very high in the first hours and during the first days when they leave the beach, and cross the lagoon and reef to the open sea. A hatchery has been established in Western Samoa. Eggs gathered after laying are put to hatch - a two month period - and the young turtles are then nurtured for a few weeks before being released in small groups in the open sea.

Some recommendations. At present, the International Convention on trade in endangered species, which prohibits the import or export of turtles and their eggs, specifically excludes the green turtle. It is questionable whether this exclusion can long continue without disastrous diminution of the species. Stocks of all turtles in the south Pacific are seriously reduced. Not enough is known about them scientifically, and since full turtle farming is not yet feasible it would be as well for the Pacific countries to: (1) limit the development of private enterprise in turtle raising; (2) undertake more intense study of stocks, and establish statistical data; (3) protect certain of the egg-laying sites from depredation; (4) regulate collection (as is done in some areas) and forbid trade in turtles; (5) to regulate very carefully all trade in and manufacture of products derived from turtles.

It is only at the price of measures such as these that the species will be conserved until the time when a technology for turtle farming is perfected and makes possible the use of these animals to augment the diversity of island economies and provide a valuable source of income.

Marine mammals (dugong)

Among five original species of sirenians (sea-cows) one is extinct, three survivie in very small numbers in the Atlantic,and the fifth survives in parts of its original range of habitation, which extended from the Red Sea to the Pacific. This latter is the dugong (Dugong dugong) and it is now threatened with extinction through over-hunting, and through the destruction of its estuarine habitat by man.

Dugongs have always been hunted for their flesh, because, like the turtles, they constitute a useful source of animal protein. There remain a few colonies in Australia, in Somalia, in Indonesia, and Melanesia. Almost nothing is known of those surviving in the last named region. The dugong might in fact still survive in the Solomon Islands, the New Hebrides, perhaps the Caroline Islands, in New Caledonia, and certainly in Papua New Guinea. The IUCN and the World Wildlife Foundation have decided to institute a program of research, conservation, and rational exploitation in coastal areas of Papua New Guinea, where hunting is now severely regulated.

In former times, the hunting of dugong in these island regions was regulated by custom and tradition, but this protection has been lost. Only rigorous conservationist measures can now prevent the disappearance of these remarkable marine creatures which feature widely in fable and legend and have unusual significance in the evolutionary record.

RESOURCES OF THE HIGH SEAS

Whales

The whales of the world's oceans offer a striking example of a marine resource that has been so heavily exploited that the point of complete extinction has been reached for certain species. The main whaling areas of the world have been displaced successively; whaling on the coasts of Europe ceased in the 12th century, and about the same time in the waters around Spitzbergen; the Greenland waters continued to be worked until the 18th century, and since the beginning of the 19th century activity has progressively shifted to the last major source area, in the Antarctic. About 1.4 million whales have been taken in this region each year since the beginning of the exploitation.

During the early 19th century there was a period when the tropical Pacific was also an important source of whales. Two species were important. The humpback whale (Megaptera nodosa), which can reach a length of 15 m and a weight of 30 t, was caught in quite limited areas near Tonga and in the Coral Sea. More important, however, was the sperm whale (Physeter catodon), which was caught in a zone between 2° N and 5–10° S from New Guinea to the eastern limits of Polynesia. These two species were intercepted in the course of migrating for reproduction purposes, northward from the Antarctic. Between 10 and 20 whaling vessels were based at Tahiti each year from 1840 to 1860, but activity declined as the stock was reduced. Already in 1858 it was observed that the costs of whaling were beginning to exceed the returns, and all activity ceased before the end of the 19th century.

Thus it was that all commercial whaling became concentrated in Antarctic waters, but this too cannot last. The humpback whale is no longer hunted because of over-exploitation; the species has been protected since 1966, and probably fewer than a thousand individuals remain. The sperm whales now constitute about half the annual Antarctic catch. Some whales still frequent tropical waters, and a survey was made of stocks in Fijian waters in 1950; although an "appreciable" resource was reported, there has fortunately been no return of whaling activity to the central Pacific.

Tuna and bonito (skipjack)

The demand for tuna and related species has increased greatly since World War II, especially in the United States and Europe. Expansion of fishing fleets, modernization of technology, and extension into new fishing grounds have been the response. Between 1970 and 1976 the annual tonnage of tuna, bonito (skipjack), mackerel, and billfish taken by the world's fisheries has been between 1.6 and 2.2 million tons. In 1950, production was only 600,000 t. All three tropical oceans are now fished, and in the Pacific production extends north to the Japanese coast and south to New Zealand.

Resources of the intertropical south Pacific. Four principal species of commercial value live in these waters:

Thunnus alalunga, white tuna, average weight 25 kg, maximum 60 kg. This species lives below the thermocline migrating between latitude 10°S in the southren winter and 30°S in the southern summer. World catch: 194,000 t in 1966; 237,000 t in 1976.

Thunnus albacora, yellowfin, average weight 90 kg, maximum 250 kg. Large individuals are above and small individuals mainly below the thermocline, along the equatorial zone in all three oceans. World catch: 275,000 t in 1966; 527,000 t in 1976.

Thunnus obesus, bigeye, average weight 125 kg, maximum 300 kg. This species also lives both above and below the thermocline, but is of more restricted distribution than *T.albacora*, and is more strictly confined to the equatorial seas. World catch: 116,000 t in 1966; 186,000 t in 1976.

Katsuwonus pelamis, bonito or skipjack, average weight 14 kg, maximum 20 kg. This species lives mainly above the thermocline in the intertropical regions of all three oceans. World catch: 350,000 t in 1966; 643,000 t in 1976.

These four species account for 76% of the total world catch of tuna and related fish. There are also four others of lesser importance: Scomberomorus commerson, thazard; Euthynnus affinis, eastern tuna; Makaira spp., marlin; Xiphias, swordfish.

Technology and history of tuna fishing in the south Pacific. A range of methods is employed. Trolling, with a metallic or plastic lure, is common with white tuna. More important is rod-and-line fishing among shoals attracted by live bait thrown into the sea, and seine nets 80 to 100 m in size are sometimes used to collect fish which are brought together in the same way. The Japanese have developed the "long line" method, employing a horizontal bearer between floats some 250 m apart, carrying from 4 to 12 lines with hooks baited with dead fish; these lines may be several kilometers in length. Finally, fish traps are sometimes used in coastal waters. The rod-and-line method requires the least capital, and is thus best suited for adoption by island fishing enterprises.

Pre-industrial commercial fishing. Trolling from single or double canoes is the traditional method of tuna and skipjack fishing in the south Pacific, especially in Micronesia and Polynesia. Fishing of this type was more an incidental activity of voyages than a deliberate enterprise, for the abundant resources of the reefs and lagoons were sufficient for normal demands. However, at least in the French territories, Tonga, the Cook Islands, and the Gilbert Islands, a small commercial fishery developed using this method.

Industrial tuna fishing. The modern industrial fishery in the south Pacific began in 1952, when the peace treaty between Japan and the United States was signed under which Japanese fishing was freed from territorial restriction. Japanese fishing fleets accompanied by mother ships with freezer storage began to operate in the waters around Fiji and later in other parts of the tropical Pacific. The first shore-based cannery was established at Pago Pago in American Samoa in 1954, the cannery itself being American owned. In 1957 a second installation was established at Palekula, on Santo, New Hebrides, and while in this instance the shore installation was operated by a local company, the capital was mainly Japanese; freezing as well as canning was undertaken. The long-line vessels were crewed mainly by Koreans and Taiwanese;

labor ashore include both Japanese and islanders. In the ten years to 1964 more than 300,000 t were handled through these two operations, the area of fishery being steadily extended both east and west. Already by 1958 there was some evidence of over-fishing among the three species of tuna (Thunnus). However, two further shore installations were establsihed in the early 1960's in New Caledonia and at Levuka, in Fiji. The former lasted only a short time, but the latter has continued, and has formed the basis of a new and large joint Fijian-Japanese venture in 1976. Negotiations were also carried on in 1977 for a further shore base in the Gilbert Islands. Whereas local capital participation was initially only small, and the benefit to the islands consisted mainly of taxes and a small amount of employment, the local share in the newer ventures is larger, and includes local participation at all stages. This is particularly the case in Fiji, where it is hoped to supply the major part of the home market in canned fish, as well as to export. Meanwhile, however, purely local ventures without Japanese participation have not been successful in any Pacific country, though new attempts are being made in French Polynesia and New Caledonia.

The present state of tuna and skipjack fishery in the region. By 1975 the total catch of the long-line boats had risen to 80,000 t of which 50,000 t was handled at Pago Pago and 13,000 t at Levuka. However, it is clear that the tuna themselves are suffering from over-exploitation, so that much greater interest is now being taken in the smaller skipjack, caught with the aid of live bait. In the six south Pacific fishing zones as defined in the FAO statistics, the catch of skipjack has increased from 440,000 t in 1973 to 540,000 t in 1976. Combining the FAO data with the information provided by Baird (1975) and by Lewis and Smith (1977), it is possible to estimate the production of skipjack in the region in 1976 as follows:

Papua New Guinea	24000 t
Solomon Islands	15600 t
U.S. Trust Territory	5800 t
French Polynesia	2000 t
Fiji	570 t
Gilbert Islands	200 t

An under-exploited resource. There is no doubt that the skipjack is a major, and perhaps the major under-exploited marine resource of the south Pacific. There seems at present to be no threat to the natural stock. For this reason a conference on fisheries sponsored by the South Pacific Commission in 1975 set up an expert committee on skipjack fishing which, at its first meeting, established a program of statistical collection and, more importantly, initiated the marking about 100,000 fish in order to establish migratory patterns; like the tuna, the skipjack is migratory and it is possible to establish information only on a regional scale.

There remain serious technical problems to be overcome before skipjack fishing can become a major industry. The most appropriate method is relatively labor-intensive: fishing with rod and line among shoals attracted by living bait. Moreover, the provision of the bait itself call either for commercialization of the reef and lagoon fishery, with all the attendant difficulties discussed above, or else for aquaculture. The energetics and economics of such an industry are likely to impose serious problems.

Other species: swordfish

In conclusion it should be noted that interest is also being taken in other species, in particular the swordfish, which is mainly the domain of "game fishing" for sport. The commerical vessels quite frequently catch swordfish, but the catch goes unrecorded unless the proportion exceeds 50%. Lack of data makes it difficult either to propose any program for this species, or to undertake any measure of regulation which will prevent the ultimate disappearance of the species.

MAIN FACTORS OF THE FLORA AND VEGETATION FORMATION ON TROPICAL AND SUBTROPICAL ISLANDS

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According to Dansereau (1963), dispersal, ecesis, competition, and adaptation are the stages of naturalization of a species, i.e., an obtaining of the ability to perform a life cycle in the region where this species was earlier absent. All the stages, except the first one, can go on more or less simultaneously or, sometimes, successively.

Scientists estimate the role of different factors in the dispersal unequally. Now the two theories of dispersal existing earlier, the land and migration ones, each one with its adherents, have forfeited their unrestricted significance. Different types of islands are now examined, in terms of dispersal, separately. Of the present-day prominent botanists-geographers, only Van Steenis advocates the land dispersal, producing numerous proofs of the inapplicability of ideas about the dispersal for distances exceeding 500 km: an absence of correlations between the presence of the appliances for the distant dispersal by wind and with the help of birds and the range of dispersal of plants; an absence of correlation between the distance from the continent which is a source of insular flora and the abundance and diversity of this flora; etc. He believes that interrelations between various regions of a continental flora don't differ in principle from those between the floras of individual islands, and that all the islands have relict floras, and even atoll floras are remains of former, richer ones, of which only coastal species have survived. Often the views of this author contradict the present-day geological concepts. At the same time, Van Steenis admits a possibility of migrations for short distances.

Ways of the transfer of plant diaspores across the ocean include the transportations by animals (epi- and endozoochore), by winds, including hurricanes, and, finally, by sea currents, often with floating fragments or even "rafts," islets of vegetation. Man can substitute to some extent all the three ways of transfer: the aerial one by planes, the aqueous one by ships, and the transfer by animals by the transfer on clothes and inside a digestive tract. The transfer by man is by an order or several orders more intense than all existing earlier ways of transfer.

Dispersal by common winds is not undoubtedly, too intense; diaspores have not a good chance to hit a small piece of land in the middle of a boundles- ocean; hurricanes are of a consierably greater importance, and even an insignificant decrease of the velocity of their movement above an insular land may result in settling here plant sprouts or parts.

The transfer of diaspores by sea currents is strongly influenced by current velocities and an ability of seeds to preserve their germinating capacity in sea water. Charles Darwin has suggested, on the basis of numerous experiments on soaking seeds in sea water and of data on current velocities, that 10% of seeds of any flora may cross an oceanic expance for a distance of 900 miles without losing their germinating capacity. Since then, Darwin's experiments have been repeated many times on other objects and under other conditions, and we may affirm that seeds preserve their germinating capacity in water long enough to be transported for a considerable distance. However, this ability of plants should not be overestimated. For example, according to the data of R.G.Word (personal communication), coconuts cannot overcome the distance between Polynesia and western coast of tropical America without losing their germinating capacity.

It is possible that the traveling across an oceanic expanse on floating islets, tree trunks, etc. is more important for the plant dispersal than the direct transfer of diaspores by sea currents. Of four types of islands distinguished by Ignatyev (1979), continental, geosynclinal, volcanic, and biogenic, only the islands of the first type received a considerable part of their flora in the course of separation from the continent. The islands of other types are more or less strongly influenced, depending on the distance from the continent, by stepping stones which can be used by some species for moving from the continent to an island and from one island to another. In some way or other, plant diaspores come to an island either already occupied by plants or completely lacking them. Their ecesis on the island, i.e. an accomplishment of a complete cycle of growth including the seed generation and subsequent reproduction, may be hampered by a number of circumstances. Island environments at the place of the delivery of a diaspore may be unfavorable for the plant growth; places favorable for this species may be occupied by other plants delivered earlier or inherited by island (continental one) from the continent with which it was connected; in case of diclinous plants, the species of only one sex may be delivered to the island. Environments of coralline atolls, where primitive soils form a discontinous cover on limestones, are particularly monotonous. As a matter of fact, all the surface of low atolls is a coastal zone. A more considerable diversity of environments exists on islands of volcanic origin, where, alongside with ash and pumise surfaces, lava flows differing in chemical and physical properties are observed. Sharp differences in steepness and exposition of slopes resulting in differences in weathering and erosional processes are observed on high volcanic islands.

Life conditions of vegetation and, therefore, floras are even more diverse on geosynclinal islands with their diversity of underlying rocks, topography, and soil-formation factors.

Finally, a reserve of species on continental islands, which is gradually impoverished as these islands are moving away from the continent in the course of time, remains nevertheless richer than on any islands of other types under similar conditions.

At the same time, an influence of salts carried by winds from the ocean to islands is most powerful just on low atolls, where it envelops all the area of islands. It is considerably weaker on higher volcanic islands and even more weaker on geosynclinal islands where wind shadow covers many inner regions. On the islands of last two types, the strong influence of salts is observed only in coastal zones.

There are no data on the percentage of sprouts successfully passing the ecesis stage. In any case, rather few of organisms whose diaspores come to an island may be naturalized there. Unavailability of necessary resources just in time is one of a main causes of the incompleteness of ecesis. Thus, diaspores of light-requiring plants may get into a forest and diaspores of xerophytes into a swamp. As the delivery of seed sprouts goes gradually, sometimes with rather long time breaks, plants get into unequal conditions at a new place. Those which came earlier may have consolidated their hold there and put up resistance to newcomers. On the other hand, they may also create favorable conditions for new settlers, fertilizing the soil, shading its surface, etc.

The most favorable conditions for the dispersal and ecesis have coastal plants: their diaspores get into the sea more often than those of plants living far from the coast, and after being transported by sea currents they are under conditions close to those of the habitat of their parents.

Weeds often pass ecesis successfully, as they commonly have a wide ecologic range (which just has helped them to become weeds) and the main condition for their settling, an uncloseness of a vegetative cover, is often brought about on islands, particularly within their coastal parts.

Competition with other species, acquiring a certain significance still at the ecesis stage, also impedes an acclimatization of a species.

As a matter of fact, ecesis is a result of overcoming unfavorable abiotic influences, while competition deals with biotic influences. On islands, abiotic factors usually reduce the tension of competition, as life conditions on the coasts which are influenced by wind-transported salts, or on the lava flows where small quantities of a peculiar substratum accumulate only in cracks, or on loose ashes, are so specific, that the range of species, which can pass their cycle of growth here, is limited from the beginning. Probably, the intraspecies competition is pronounced here considerably sharper, especially after the completion of ecesis by the first settlers of a species.

Finally, the last stage of acclimatization of a species is an adaptation. In the course of adaptation, the species may change very considerably. On the one hand, the process of speciation on the island sharply accelerates under the influence of a genetic drift resulting from the small number of specimens of any species coming to the island and the lack of many genes characteristic of the species as a whole. Besides, the sets of genes in populations of the same species on different, even on neighboring, islands may be different, and speciation on different islands may go in different directions. On the other hand, the deficiency of flora results in the adaptive radiation of plants. A striking example of this process is a tree Metrosideros kermadecensis from Raoul Island, Kermadec Archipelago. The tree have several growth forms:

1. Pioneer shrubs on the ground free from vegetative cover.

2. Shrubs on the rocky coastal slopes often subject to the effect of winds; these differ from the previous forms in their branches which are prostrate on the ground; only uppermost branches rise into air.

3. High shrubs with an irregular branching,which we have observed on fertilized by birds soils of slopes on an islet adjacent to Raoul Island.

4. Single robust trees with upright trunks and broad crowns.

5. More or less straight-boled trees growing in a forest community; often with aerial adventitious roots going down into the soil.

6. Forms with large crooked trunks growing in upper parts of slopes of middle height.

7. Largest trees up to 30 m high having trunks of 10 m and more in diameter, with hollows which often are higher than man's height; their horizontal branches with prop-roots give rise to upright trunks.

8. Epiphytes on other tree species.

9. Trees-stranglers developing in an epiphyte form.

Epiphyte form may be also characteristic of other tree species of this island: Ascarina lucida var. lanceolata, Myrsine kermadecensis, Cyathea kermadecensis, C. milnei, Pseudopanax arboreus var. kermadecensis, Rhopalostylis baueri var. cheesemanii, Melicytus ramiflorus ramiflorus, and, possibly, other species. Melicytus generally possesses a considerable ecologic plasticity, although less than Metrosideros. The tree Myoporum obscurum in coastal environment makes up a shrub form.

These examples show an existence of adaptive radiation of many tree species on Raoul Island pronounced to a various degree. It is undoubtedly connected with the fact that owing to deficiency of the flora of the island many ecological niches are not filled.

Formation and complication of vegetation communities occur parallel to the naturalization of various plant species on islands and formation of insular floras. Vegetation communities of islands of a continental origin have veen formed when these islands were the parts of continents, therefore the change of communities here may be connected only with a falling out of some components, a change of a role of other components, an appearance of new components.

Ignatyev (1979) distinguishes six stages of evolution of landscape characteristics of islands, each of them having certain relationships between biogenic and abiogenic components of natural territorial assemblages.

The first stage is the formation of an abiogenic stage. An original surface is not uniform, its parts have a different salt and water regime, there are differences in micro-, meso-, and sometimes megalandforms. Later on, all this undoubtedly results in a diversity of a vegetative cover. The surface may exist without a vegetative cover tens of years. (I shall add from myself, that it concerns macrophytes; as for algae, first of all blue-green ones, as well as bacteria and sometimes fungi, they settle, as a rule, just after the environment becomes convenient for the life, e.g. after the cooling of lavas.)

The second stage is an assimilation of a lithogenic base by vegetation, the beginning of soil formation. The third stage is a complete assimilation of a surface by an original vegetation. The secondary differentiation of natural territorial assemblages occurs at the forth stage. Biotic assemblages come to conformity with a lithogenic base at the fifth stage. The sixth stage, according to Ignatyev, is brought about on a continental land and islands of a continental origin. At this stage biocenoses are transformed into relatively autonomous systems with internally balanced components.

Stages of the formation of phytocenoses correspond more or less to these stages. A certain consideration was given at the XIV Pacific Science Congress to the formation of microbocenoses on ash deposits of volcanoes. The phase of sterility of freshly extruded ashes, an uneven settling of microorganisms of various systematic position (blue-green and diatom algae, bacteria, etc.), and change of dominants in time have been observed there. Thus, the installation of macrophytes is preceded by at least two stages of evolution of a territory: the stage of sterility of a ground and the stage of development of microbocenoses (which can be, in its turn, subdivided into stages of a second order).

After the installation of macrophytes, the evolution of a vegetative cover usually enters the phase of a mixed pioneer aggregation. The pure aggregation evolves very seldom, as the condition of its existence is a delivery of diaspores of only one species. It can be accomplished only during the period of an initial populating of a whole island just emerging from under ocean water, when established plant communities are absent on the island and no arrival of seeds upon pioneer surfaces can be brought about. Single-species, pure aggregations can also arise in cases when the substratum is very specific: strongly acidic, strongly alcalic, containing toxic combinations, etc., i.e. possessing well pronounced limiting properties.

Communities of extensive lava flows, of areas of ash or pumice extrusions, of limestones emerging from under ocean waters may linger on stages of pioneer aggregations.

More often, following the stage of mixed pioneer aggregations, simple (pure or mixed) and complex aggregations evolve on islands. Characteristic of simple aggregations is an interaction between plants by their underground organs, even though their overground parts are not closed. The vegetative cover has a spotted structure, in mixed aggregations spots formed by plants of one species being separated by unpopulated areas from spots formed by plants of another species. There are thickenings and thinnings of plants in pure aggregations.

Stages of pioneer aggregations exist on islands considerably longer than on a continent, e.g. on floors of drying lakes, on overgrowing fallows, etc. The mastering of extreme environments on islands requires much more time. Many areas of a coastal vegetation of atolls, of vegetation of ash and pumice fields are at the stage of pioneer aggregations. All this areas correspond to the second stage of evolution of natural territorial assemblages, according to Ignatyev.

The third stage of evolution of a phytocenosis is represented by a complex aggregation with a not completely established composition and an unclosed community where new species can be easily introduced; components are distributed not diffusely, although accumulations of a one species may be penetrated by other species; species forming the community are represented by different life forms; stories may be pronounced. In island environments such communities are represented by palm associations of atolls with an undergrowth of a spotted structure and a herbaceous cover which is developed only here and there and is also of a group character, sometimes by a vegetation of coastal outcrops of limestone or old lava flows which includes, besides few species of herbaceous plants, the trees, for example, beefwood. Such communities correspond to the third stage of evolution of island ecosystems, according to Ignatyev.

Finally, the last stage is represented by established communities, which evolve on the basis of a differentiation of a complex aggregation into individual sections. It corresponds to the rest of the stages of evolution of ecosystems distinguished by Ignatyev. The evolution of established phytocenoses and change of one phytocenosis by another is characteristic of this stage.

The man's influence results in the destruction of the established phytocenoses which are usually replaced by complex aggregations (when cenoses existing earlier are not destroyed completely) and pioneer aggregations (when plant communities are destroyed completely).

The poverty of species composition of communties on islands with a broadening of an ecologic range of a number of species results in the appearance of various combinations of species composition, depending on variations in exposition, steepness of slopes, pecularities of soil cover, and other factors.

The floral abundancy of a community also influences the formation of its vertical structure. For instance, characteristic of the communities with a limited floral abundance (which may result from the youth of the island or from its isolation) is a simpler type of vertical stratification with one or two layers, while multilayered communities evolve where floral composition is richer. Only sometimes communities with a little species diversity can be of a more complex vertical structure owing to the plasticity of some species.

Formation of plant communities is also essentially influenced by hurricanes which result in falling out of largest emergent trees and in formation of a well-pronounced mosaic pattern of the forest with an alternation of individual high trees and areas of saplings of various age. Thus, a tropical or subtropical forest on an island cannot, as a rule, evolve to such a complexity which is characteristic of this type of community on continents. Such communities that virtually don't differ from those of continents exist only on large islands of a continental origin.

Thus, it can be suggested that the flora and vegetation of continental and oceanic (geosynclinal, volcanic, and biogenic) islands evolve along just opposite ways: on islands of the first type by means of their impoverishment, simplification of their structure, and decrease in a number of life forms; on oceanic islands by means of their enrichment, complication of their structure, increase in a number of life forms. For all that, islands of the two types are ever essentially different, the complexity of phytocenoses on oceanic islands never reaches the degree which is typical of phytocenoses on continental islands, even though their ecosystems tend to become similar.

The closing stage of the vegetation evolution on oceanic islands of different types is represented by different communities. On low and, probably, elevated atolls, such a climax community is represented by poor in species two- or three-layered aggregations which change predominantly with a transitions from one terrace to another. On volcanic islands, these are poor in species established communities with a similar composition of dominants, varying in species composition and dominants, depending on the exposition and steepness of slopes. On geosynclinal islands, these are richer in species established communities changing one another rather directly, depending on changes in environment.

GALAPAGOS NATIONAL PARK: ACCOMPLISHMENTS AND PROBLEMS

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After 20 years of existence of the Galápagos National Park, I feel profound satisfaction at having the opportunity to explain what the Ecuadorian Government has been doing to defend our Islands' heritage, as well as what it is trying to accomplish in the future.

The recent international recognition of Galápagos as a natural area of the World Heritage Trust Program firmly ratifies the decision of the Ecuadorian Government, made 20 years ago, to maintain the Archipelago of Colón (official name of the Galápagos Islands) as a National Park. Although 85% of the terrestrial area of the Galápagos was legally established as National Park in July of 1959, it was not until 1968 that the Galápagos National Park Service (SPNG) was created. This governmental institution is entrusted with the administration, management, and protection of the Park's resources.

The establishment of the Charles Darwin Biological Station in 1964 also constituted a decisive step towards the conservation and protection of the Islands' resources. With the creation of the Galápagos National Park Service the physical boundaries of the protected area were established, the colonized areas being excluded from the Park jurisdiction. While in 1968 the whole of the SPNG was represented by only two conservation officials, after 11 years of existence it is now composed of one superintendent, one assistant superintendent, one chief naturalist, one chief of protection,five conservation officials, and sixty park wardens. As a government institution it is a part of the Department of Administration of Natural Areas and Wildlife, which in turn forms a part of the Ecuadorian Forestry Service under the Ministry of Agriculture and Livestock.

One of the more important steps in the administration and development of this Park has been the elaboration of the Master Plan for the protection and use of the Galápagos National Park, in 1973. The foremost objective of this document is to provide the administration of the Park with certain norms and general policies which will assure its continuity of direction in its development, regardless of changes in personnel.

In order to fulfill its objectives, the SPNG operates four work programs, each one headed by a conservation official, directing a group of park wardens, who are in charge of the actual carrying out of the program.

The Park work programs are as follows:

Environmental education

The main responsibility of this program is the organization of courses of various types and purposes. With the collaboration of the Charles Darwin Station, the SPNG organizes two yearly courses for tourist guides (one for auxiliary guides and another for naturalist guides) and one yearly training course for park wardens. Also, together with the Darwin Station, courses or seminars in various fields are given to different segments of the local population. It is also important to point out that the SPNG and the Darwin Station have personnel who give lectures on ecology, general biology, and natural history of the Islands in the schools of Santa Cruz and San Cristóbal, these two islands holding 95% of the total human population of the Archipelago. The SPNG publishes leaflets and other informative materials, and maintains a permanent system of circulars that reach many local levels, as well as national and international ones. Also in preparation are several books covering the natural history of the Galápagos.

Tourism: control and management

1. Zoning. To facilitate the administration and management of the Park, its territory has been divided into five categories of areas, each with a different objective. In two of this zones normal tourism activities are permitted. The areas intended for extensive use are allowed to receive a maximum of 12 people at any one time, whereas those for intensive use have a maximum capacity of 90 people. The existence of these zones enables the Park to direct the visitors to its most outstanding and relevant features, and at the same time prevents the destruction of the natural resources.

2. Trail System. Unobtrusively marked trails are found in almost all of the visitor areas and lead the visitor to observe and enjoy the most remarkable features of each site. To leave a trail represents an infraction of the established rules. There are also a few sites that are designated as "open areas" where the visitor may move about freely within relatively ample boundaries.

3. Guides. Considering that it is not permitted for any person or group to visit the Park without the presence of a legally authorized guide, the preparation of such guides is of extreme importance for the proper handling of the visitors. The SPNG has established two categories of guides: auxiliaries and naturalists. The first, with a basic training in the rules, norms and laws of

the Park, act mostly as "tourism policemen"; whereas the naturalists, being persons with a minimum background of three years of university study in natural sciences, have a very important role in transmitting to the visitor as much as possible concerning the natural history of the Galápagos, the conservation problems, and the successes and failures of the Park's protection efforts. In addition to creating a type of educational tourism in this manner, this also makes it possible to maintain effective control over the visitors by making the guide responsible for the visitors' behavior.

4. Patrolling. All the above is complemented by an active patrolling system. The SPNG has several patrol boats that constantly observe and regulate the use and the state of the Park's resources. At the present time only three boats are in operation, while a minimum of seven would be necessary to obtain a fully effective control. It is worth mentioning that funds now exist to obtain two more boats, and their construction has already begun.

5. Limitation on the number of visitors. The Park Master Plan has established the need to fix a maximum limit of the number of yearly visitors to the Park that should not be exceeded. Although it is very difficult to actually establish such ceiling, it is obviously necessary to follow a definite policy in this respect in order to avoid irreparable damage to the fragile Galápagos environment. The Park Administration is deeply concerned in this problem, and it hopes that the definite norms will be obtained from the Ecuadorian Government so that a fixed policy may be established. This is specially important considering that the limit of 12,000 recommended in the Master Plan has already been exceeded.

Although the potential danger of the "over-visiting" of the Park does exist, it cannot be said that up to now any large conservation problems have been caused by the visitors. The coordinating system consisting of the park wardens, visiting zones, trails, guides, and patrol boats, all supporting the existing strict rules, has allowed the Park's resources to be maintained without significant deterioration.

Protection of the native fauna

1. Care, raising, and repatriation of giant tortoises. One of the native species of Galápagos which are in the greatest danger of extinction is the giant tortoise, also called galápago, from which the name of the Islands originates.

Several of the 15 subspecies of giant tortoises become extinct before anything could be done to save them. When the conservation programs began, the situation of most of their populations was very critical. At the present, after 10 years of carefully organized programs involving caring, raising, and repatriation, as well as captive breeding, it can be said that several of these populations have been truly saved from extinction. Noteworthy is the case of the subspecies from Española Island which had been reduced to such an extent that when the program has begun only 14 individuals could be found (12 females and two males). 86 young tortoises produced in the breeding center, have been returned to Española Island by June 1979, which means that the original population has increased sixfold. Although the successes that have been attained are remarkable, some difficult situations remain such as the one regerding the population of Pinta Island. Of this subspecies, only one male individual has been found, despite an intensive search.

2. Care and breeding of land iguanas. The land iguanas (Conolophus subcristatus) are part of the group of the endemic animals of the Galápagos Islands. The feral dogs introduced by man have brought about the imminent danger of extinction of the land iguanas. As the only effective protection measure, in 1976 the remainders of two populations (one from Cartago Bay on Isabela Island and another from Cerro Dragon on Santa Cruz Island) were transported to facilities on Santa Cruz Island. Being the result of an emergency situation, this was the beginning of a program for the captive breeding of these iguanas. In spite of severe funding limitations as well as the lack of knowledge regarding the ecology of the land iguanas, after several trials, in June 1978 we have succeded in producing the first young iguana hatched in captivity under controlled conditions. Even though this iguana did not survive beyond 6 months of age, we now have 46 individuals hatched between January and June 1979.

3. Study of Hawaiian petrel. This sea bird (Pterodroma phaeopygia), due to its habit of nesting in humid highlands of the interior of the islands, suffer severe predation from various introduced animals. The adults, eggs, and chicks are destroyed to such an extent that in certain areas the level of reproduction is zero. One of the scientist of the Darwin Station is in the process of studing these Hawaiian petrels, trying to obtain data that might help the SPNG to design some protection methods.

Even though some very serious problems threaten the survival of certain Galápagos animals, many others are in a fine state. Some populations, such as these of the fur-seal (Arctocephalus australis) have made a very remarkable comeback since measures were taken for their protection.

Eradication of introduced plants and animals

Perhaps 90% of the conservation problems that we must face in Galápagos are caused by introduced plants and animals, all of which are direct results of human activities.

Many of the plants that were taken to the Islands by the colonists have turned into dominant species in the wild and constitute now serious pests which are very hard to combat. Several pasture grasses such as pangola and elephant grass begin to invade areas adjacent to colonized zones. Tree species such as guayaba (*Psidium guaiava*) and cascarilla (*Cinchona* sp.) are spreading into areas belonging to native species such as miconia. With the few human resources available these plants have been eradicated from critical areas where they were threatening to invade Park areas. However, there is much as yet to be done in the field.

Even though efforts to eradicate introduced animals began already in 1961, they have been carried out on the fairly small scale and only on certain islands, and it was not until 1969-70 that systematic campaigns were undertaken, especially against goats and pigs. In 1971 goats were eliminated completely from the islands of Santa Fe and Rábida. An outstanding case in this program was the eradication of goats from Española Island. When the systematic campaign was undertaken there, nobody thought possible to ever eliminate the goats. After eight years of work, in October 1978, the last goats were killed on this island, leaving it totally free of any introduced animals. The problem of the introduced goats remains on several islands, particularly on Pinta, Marchena, and Santiago, the latter being particularly affected. With the experience obtained on Española we hope that soon it will be also possible to free Pinta and Marchena of the goats.

Not only goats are the problem. In different regions and islands, there are pigs, donkeys, horses, cattle, cats, mice, and even ants, all these animals one way or another, and to a greater or lesser degree, being a threat to native organisms and the greatest problem to us who are trying to maintain the Galápagos in a state as natural as possible.

The goals that have been attained by the SPNG, and the development of the Park itself demand that an evaluation of what has been accomplished be made.

There are many accomplishments in our work in Galápagos:

1. The due recognition by the Ecuadorian Government of the political, scientific, and cultural importance of Galápagos, which has reached the point of being regarded as an integral part of the country's life.

2. The very close relationships between the SPNG and the Darwin Station, which has permitted us to work together towards common goals.

3. The unconditional support of all conservation measures by the Ecuadorian Government which has enabled us to implement perhaps three quarters of the goals stressed in the Master Plan for the development and use of the Park.

4. The strong international support which allows us to accomplish the various work programs effectively.

There are several things that must be done to ensure the future of the Park:

1. To include in the Park area a fringe of the ocean of at least two nautical miles in width around each of the islands in order to preserve the island ecosystems as complete entities. The interdependence of terrestrial and marine environments requires this measure to be taken.

2. To define the exact policy to be followed regarding the ultimate number of yearly visitors. This is necessary in view of the fragility of these island habitats.

3. To bring the Master or Management Plan up to date in order to establish new goals and courses to be followed beyond what has been accomplished.

4. To ensure, in an adequate form, such financial resources which are necessary to carry on with the conservation programs.

Much is yet to be done in Galápagos, and many are the problems which are still unresolved, or which have not even begun to be considered. However, what has so far been accomplished allows us to be optimistic, with the realization that true conservation in the Galápagos is attainable and that we will be able to maintain the Islands for future generations in the same state as we know today, realizing the slogan: A Natural Heritage for All Humanity.

METHODICAL APPROACHES TO ECOSYSTEM INVESTIGATIONS OF PROTECTED TERRITORIES

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The present paper has been written under the influence of the ideas repeatedly put forward and successfully developed by P.P.Vtorov (1968-1978). Although the research program presented below is meant primarily for research teams of nature reservations, it could also be of interest to individual scientists. The inspection of Central Babatag could serves as an example of practical work carried out on a similar program by a small research team.

Investigation of the structure and performance of separate ecosystems and the biosphere as a whole is necessary for the long-term development of a system of rational use of natural resources. The establishment of a well-balanced net of biosphere reservations which represent a basis for the cenotic monitoring and of other types and classes of protected territories on standard biosphere plots to serve as a source of the most useful information needed to predict all possible effects of anthropogenic interference in ecosystems is most important for the development of such a system.

The quantity and quality of information on the structure and functioning of ecological systems depends on the investigation period, the number of specialists and their qualifications, the equipment and procedures used, that is, on all aspects of the general research program. The proposed ecosystem research program presents an attempt to optimize the problem conditions "at the entrance and exit" in order to obtain the maximum information under the certain time and resource restrictions. We believe that just such "minimum" programs would make it possible to gather comparable data on the ecosystem structure and functioning from large territories and from all main types of terrestrial biomes in a short time.

Making the vegetation and animal kingdom inventory of the reservations, representing standard biosphere plots, should provide a basis for long-term research programs. The intention is not only to make a flora and fauna inventory, but also to establish the set of predominant communities, determining the complementary quality parameters, both biotic and abiotic.

A flora and fauna inventory does not necessarily precede the cenotic one. This is proved, particularly, by the experience in making flora and geobotanic inventories which can be compiled in any order of succession or simultaneously. In any case they complement each other.

The present-day development of general ecology, biogeocenology, and synthetic biogeography makes it possible to compile inventories of key communities by relatively small teams. The aim of such inventories is to determine the composition and abundance of dominating groups of organisms, the participation of different biological groups and life forms in communities, to find out the type of geochemical and hygrothermal regime of ecosystems, etc. The data of such inventories will allow to plan more profound investigations along certain particular research lines more efficently. They also are of great independent value for the comparative geographical analysis and taxation of the standard biosphere plots. Besides, regulary repeated community inventories serve as a basis for the cenotic monitoring. This kind of observations over the state of natural ecosystems will certainly make a part of future global system of the biosphere monitoring. The sooner such inspections are introduced into practice, the greater the volume of relevant information both we and our descendants are to receive.

In choosing plots for investigations it is necessary to combine representative and unique, primary and secondary, typical and extreme variants. It is advisable to make choice of key plots using the method of ecological profiles embracing both extreme and typical conditions. In the mountains and, generally, in cases of extremely contrasting communities, it is convenient to distinguish profiles of different scales, from greatly generalized to detailed ones with a clearance limit up to one meter and more. It is necessary to use the principle of different scales, since various groups of organisms require different approaches to setting out elementary plots.

The investigation period should cover the peak of vegetation, since just at this time maximum output of information per unit of time and contributed resources can be obtained. This is also the most convenient period for comparative geographical investigations. In different regions the peak of vegetation varies greatly (from the end of April to the beginning of August). To obtain certain characteristics of structural and seasonal dynamics, in addition to the observations carried out during the basic period of vegetation peak, it is necessary to study individual components of communities in spring (usually in the period when buds of the trees in forest zones open) as well as in the summer-autumn period. The middle and the end of winter is a supplementary period to register many groups of warm-blooded animals. Thus, except the basic period for making cenotic inventories there are three supplementary periods, one of which, the winter one is usually relevant for birds and animals only. The duration of direct field work in the basic period should not exceed two or three weeks. The data so received provide a kind of a snapshot, a static model of the ecosystem. It is desirable that supplementary periods would be of the same duration, and a phenological characteristic of each period is necessary to provide for a comparability of data.

At the chosen ecological profile, the composition and abundance of the key groups of organisms have to be determined. The profile as a whole provides for the most physionomic parameters (topography and vegetation type) and the data on such groups of organisms which are associated in their active life with a more extensive territory (e.g., large mammals). The key plots are used to study the whole set of parameters. However, it is necessary to limit the levels of detailing and the number of variables. That is why the majority of groups are studied at the level of the large taxons only (orders, basic families) and only individual, so-called "probe groups" are studied in greater detail.

The main attention should be paid to the most universal and comparable indicators. In the first place it is the volume of biomass (dry and wet; for the animals, usually, the gross weight only) and also the quantity per unit of territory. Energy parameters both of the reserve (in kcal/m^2, kJ/m^2, etc.) and of the energy flow (e.g., kcal/m^2 per day) are also desirable. It is expedient to choose a certain dimensionality for the abundance indicators in order to make all obtained data comparable (e.g., g/m^2 or kcal/m^2 per day). This does not mean, however, that the data must by no means be expressed in some other dimensions. On the contrary, various groups usually require the use of different indices.

To provide rational planning of multiple investigations, ecosystems are subdivided into blocks. The largest are represented by abiotic components, an autotrophous level (mainly the photoautotrophous complex), and heterotrophous levels of ecosystems. Usually, the first two blocks are studied somewhat better then the third one. In any case, they are examined on a more uniform basis and, as a rule, many important general characteristics of them (heat and moisture regime, geochemical features, reserves and primary productivity, etc.) are known.

It is expedient to distinguish whithin each block mentioned above the blocks of the next order which are a basis for obtaining certain characteristics. The set of such blocks is represented by:

1. Abiotic components: hygrothermal conditions of the region (the climate diagram, sums of temperatures, restrictive factors); space variability of soil cover, characteristics of the key soil cross-sections, direct and indirect indices of geochemical conditions in the system"plant - ground litter - soil - water runoff " (the composition and the amount of ash elements and nitrogen, the direction and intensity of transference).

2. Photoautotrophic level: lower green plants (algae and lichens); mosses and liverworts; vascular plants (arboreal-shrubby level, ground level).

3. Heterotrophic levels: bacteria, actinomyces, micromices, protozoans, macromyces (saprophytes, parasites, mycorrhiza makers), soil nematodes (except mermithids), and similar dimensional groups (tardigrades, rotifers); collembols, oribatids and other soil ticks, other microarthropods (the whole assemblage of arthropods determined by the analysis in thermoeclectors); soil mesofauna, invertebrates of a ground surface and of herbaceous and arboreal-shrubby levels; amphibians and reptiles; birds; mammals.

In classifing various communities and choosing the characteristics, two basic, mutually complementary approaches, analogical and homological ones, are possible. The first approach reflects certain physico-chemical environmental conditions and associated biotic processes. The second one shows the ways of formation and evolution of communities and permits to reflect the relationship with other territories. By using the analogical approach one can compare different territories. The homological approach implies the use of various levels of estimation (those of a species, genus, family, etc.). While gathering and analyzing certain materials one should take into consideration the existing approaches.

The quantity and quality of information obtained at a given ecological profile will be greater if similar studies are conducted simultaneously or during the similar periods at other profiles. An ideal approach implies that it is necessary to carry on a program of parallel investigations at a large number of plots characterized by a maximum diversity of information and primary structure features. The protected standard biosphere plots composing the network of our country's nature reservations serve as the basis for such investigations.

RESERVATIONS OF THE SOVIET FAR EAST AND THEIR ROLE IN NATURE CONSERVATION

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The Far East of Asia is the region of special scientific significance. A gradual continuous transition from ecosystems of Arctic deserts to those of humid subtropical forests can be observed here. An absence of the continental glaciation in the past and of the considerable migrations of floracenotic assemblages connected with it made it possible for vegetation to evolve for a long time without any essential alteration. Multiple thermal springs at the continental margin, the result of constant volcanic activity, favored this, too. The Far East of Asia was a place where the core of a nemorose vegetation began to form earlier than in other regions of the planet and where this vegetation is continuously evolving up to the present days. Nemorose formations of the Far East show a rare combination of archaic floristic basis (floristic connections with humid subtropics can be clearly traced) with the advanced phytocenotic structure and the far-gone rhythmological differentiation. These specific features determine a high scientific significance of southern nemorose formations for further development of biogeocenology and a necessity of a special approach to their preservation.

There are eleven nature reservations in the Soviet Far East with the total area of 24,000 km^2. Of the total areas of the various districts of the region the reservations account for 3.2% in Primorye, 2% in Kamchatka, 0.6% in the Magadan District, 0.4% in the Amur District, and 0.1% in the Khabarovsk District; Sakhalin has no reservations. Totally, the preserved area makes up 0.7% of the area of the Far East.

The Arctic polar desert zone is represented by the Wrangell Island reservation (795,000 ha) established in 1976. The main purpose of the reservation is conservation and study of animal life of the main part of the Arctic. The main animal species are walrus, white polar bear, arctic fox, snow goose, thick-billed guillemot, kittiwake, Ross gull. Arctic falcon and peregrine occur sometimes. White polar bear, Ross gull, peregrine, and arctic falcon have been enlisted in the USSR Red Data Book. The Kronotsky reservation, the largest in the USSR (964,000 ha) is situated in the specific natural area of stone birch (Betula ermanii) forests and meadows of the Pacific coast in the Kamchatka Peninsula. It was established in 1967. Its main aim is conservation and investigation of the Pacific upland ecosystems in the middle part of Kamchatka, rare and valuable wildlife, present-day volcanic activity, geysers, and thermal springs. Kamchatka sable is the most valuable representative of animal life. For the sake of its protection, in the second half of the 19th century native people agreed to establish the Kronotsky sable preserve. In 1882 the Governer General issued an order legalizing the decision. Besides, brown bear, snow sheep (Ovis nivicola), and reindeer are common here. Sea beaver, Steller and white-tailed sea eagles, and peregrine, have been enlisted in the USSR Red Data Book as well as Kamchatka fir (Abies gracilis).

Middle taiga subzone of the Far East taiga zone is represented by the Zeya reservation (82,600 ha) established in 1963. The main direction of its work is conservation and study of ecosystems of the northwestern part of the Far East and forecast of their change under the influence of the largest in the Far East Zeya water reservoir. Forests of Dahurian larch prevail here, forests of Ayan spruce, thickets of Siberian dwarf pine (Pinus pumila), and mountain tundra occur, too. The northwestern boundary of the range of some nemorose plant species (Mongolian oak, Amur linden, two elm species, Ulmus propinqua and U.lacineata, Chinese shizandra, etc.) is situated here. Prokhorov birch is the endemic of the reservation. Two species of ladies' slipper (Cypripedium macranthon and C.calceolus) of plants and mandarin duck and dikusha (Falcipennis falcipennis) of animals have been enlisted in the USSR Red Data Book.

The Far East coniferous-broad-leaved forest zone is characterized by eight nature reservations aimed mainly at conservation and an interdisciplinary study of the ecosystems, rare and valuable plant and animal species. The Khingan and Komsomolsk reservations are situated in the north of the zone. They were organized in 1963 on the areas of 79,5000 and 32,200 ha, respectively. Japanese yew and two ladies' slipper species (Cypripedium calceolus and C.macranthon) of plants and Amur tiger, Steller and white-tailed sea eagles, peregrine, Japanese and white-naped cranes, white and black storks, mandarin duck, and dikusha of animals have been enlisted in the USSR Red Data Book. In the middle part of the zone there are the Bolshe-Khekhtsyr (established in 1963) and the Sikhote Alin (established in 1935) reservations. Their areas are 45,000 and 347,000 ha, respectively. A vertical vegetation zonality is characteristic of the Sikhote Alin mountain system: oak, coniferous-broad-leaved, fir-spruce, and stone-birch forests, dwarf-pine thickets, spots of the mountain tundra. Yew (Taxus cuspidata), Sichote and Fauri rhododendrons of plants and Amur tiger, ghoral, squamous merganser (Mergus squamatus), mandarin duck, and dikusha of animals have been enlisted in the USSR Red Data Book.

In the southern subzones of coniferous-broad-leaved forests there are Lazo (116,500 ha), Ussuri (40,400 ha), Kedrovaya Pad (17,900 ha) and Far East Maritime reservations. The oldest of them is Kedrovaya Pad, established in 1916 and the youngest (1978) the Far East Maritime reservation. Among the first three reservations liana-hornbeam, cedar-broad-leaved, and black-fir-broad-leaved forests are of considerable interest. Peculiar broad-leaved forests of Amur linden, Mongolian oak, Sakhalin and Maksimovich cherries, and Micromelas alnufolius with Japanese yew are characteristic of the Far East Maritime reservation. The Lazo reservation on the Petrov Island has the largest yew grove of the Far East; there are ghoral and the unique for the USSR aboriginal population of spotted Ussuri deer (Cervus nippon hortulorum) enlisted in the USSR Red Data Book in the reservation. Among the plants of the reservation, an endemic of the Far East, coniferous shrub Microbiota decussata is the most interesting. Rare animal species - Amur tiger, East Siberian leopard, mandarin duck, squamous merganser, black stork dwell in Lazo, Ussuri, and Kedrovaya Pad reservations. Rare plant species Panax ginseng and Oplopanax elatus represent the Araliaceae family. Besides, Schmidt birch and Schlippenbach rhododendron enlisted in the USSR Red Data Book are characteristic of the Kedrovaya Pad reservation.

The Far East flora and fauna contain many endemic and relict species. This feature is explained by the specific history of ecosystem formation in the region, by the mountainous topography of the greater part of its territory, and by the nearness of vast water areas of the Pacific Ocean. Ancient Araliaceae family is represented by perennial herb (Panax ginseng, Aralia cordata, A. continentalis), shrub (Eleutherococcus senticosus, Oplopanax elatus), and arboreal (Kalopanax septemlobus) life forms. Amur and Sakhalin cork tree (Phellodendron), hollies, Microbiota, Chosenia, Japanese yew, water shield, Komarov lotus, etc., are also very ancient. Lungless newt, Far East leathery newt, Far East soft-shelled turtle, relict Callipogon, relict cockroach are of considerable scientific interest. Numerous liana species (actinidias, grapes, shizandra, Coluteocarpus vesicaria, Aristolochia) are characteristic of the Far East nemorose coniferous-broad-leaved forests, giving a subtropical appearance to them.

Stone-birch forests with tall herbs, which are widely spread over Kamchatka, and dwarf-pine thickets occupying vast areas in the mountains and in the forest-tundra zone are of great interest due to their origin and floristic composition.

The present-day volcanic activity, essentially influencing the formation of landscapes and vegetation, is typical of the Kuril Islands and Kamchatka.

In the USSR, only in the Far East one can meet Amur tiger, East Siberian leopard, ghoral, aboriginal spotted Ussuri deer, Asiatic black bear, sea beaver, fur-seal, dollar bird (Euristomus orientalis), tiger shrike, painted snipe, mandarin duck, squamous merganser, and many other species.

The main tasks of nature reservations are conservation and the study of ecosystems, typical of certain regions of geographical zones,as well as preservation and the study of diversity of genofond and cenofond. Biosphere reservations, a wide network of which is being organized in the USSR, serve as the basis for ecological (biological, geophysical, and geochemical) monitoring. It will help to estimate the state of the nature environment and biogeosystems, to forecast their possible change under the influence of natural and anthropogenic factors, and to elaborate scientific recommendations on averting negative consequences of economic activities.

Reserves of a genofond and cenofond carry valuable potential information. The most rich biotically biogeocenoses are of the highest informative value. Impoverishment of a natural cenofond goes much faster than degradation of a genofond. Special attention of conservation institutions should be paid, first of all, to the conservation of cenofond.

Under conditions of intense economic development of new areas and a paramount use of natural biological resources, an important role of reservations consists in their being the storehouses of rare and valuable wildlife and primary plant associations (cenofond). For instance, liana-black-fir and cedar-broad-leaved forests as well as valley broad-leaved forests of Manchurian ash, valley elm (Ulmus propinqua), Amur cork tree (Phellodendron amurense), and Manchurian walnut are of great value. These polydominant formations in East Asia are well preserved only in the Soviet Far East and many relict and rare species of plants and animals are characteristic of them.

One of the primary measures necessary for successful nature conservation in the Far East is an organization of reservations in the areas of new development, where there is a real threat of essential change in nature biogeosystems, impoverishment of genofond and cenofond, and also in those physico-geographical provinces and zones where there are no reservations at present. First of all, in the vicinity of the Baikal-Amur Railway region, in the north of the Far East in the tundra and forest-tundra zones, and in the Eastern Oceanic province of coniferous and coniferous-broad-leaved forests (Sakhalin and South Kuril Islands).

Of large complex reservations with the area not less than 100,000 ha it is advisable to establish:

1. A reservation of a typical larch and fir-spruce taiga with the East Siberian and Okhotsk fauna on the Bajal mountain range.

2. The Omeldinsk reservation in the lower catchment area of the Amur River at the northern border of the Korean pine range.

3. The Chukotka reservation in the lower catchment area of the Amguema River, including the Chukchi Sea coastline, where lowland and mountain tundras are represented and there are wild reindeer, walrus, snow goose, and brent goose.

4. The Koryak reservation, Mount Ledianaya inclusive. There are here all vertical zones characteristic of the Pacific forest-tundra, and an isolated population of sable is preserved.

5. A reservation in the south of Kamchatka, Cape Lopatka, and a portion of the Paramushir Island with adjacent waters inclusive. Here one can find mountain tundra and forest-tundra with the Kamchatka fauna (wild reindeer, snow sheep, sable, brown bear, souslik, sea beaver).

6. The Dzhugdzhur reservation between Ayan and Okhotsk, including an elevation of Topko and its glaciers. Typical fir and spruce forests, dwarf-pine thickets, spots of mountain tundras and mountain cold deserts with East Siberian and Okhotsk fauna are well preserved here.

7. The Commander reservation including parts of Medny and Bering Islands, as well as two small islands Toporkov and Ariy Kamen with adjacent waters of the Bering Sea. Typical plant formations are tundras and meadows, animals are represented by sea beaver, some species of pinnipeds. There are unique colonies of birds here, the nesting ground of the redlegged kittiwake inclusive.

8. The Kunashir reservation, encompassing slopes of Tiatia and Golovin volcanoes. Peculiar rich vegetation of the South Kuril Islands with many rare and relict species (indented oak, silver magnolia, Swida controversa, poison sumac, Japanese yew, etc.), and vertical zonality are well represented here. Animal life consists of the Kuril-Japanese insular fauna species.

On Sakhalin it is advisable to establish two reservations in the middle and southern parts of the island in order to protect coniferous and coniferous-broad-leaved forests and insular fauna.

At present the work to establish a complex reservation occupying parts of the water area and the coast of the large freshwater Lake Khanka is coming to an end. Rare flora (lotus, Euryale) and fauna species (Far East soft-shelled turtle, white stork, Manchurian white crane, spoonbill) dwell here.

Besides the establishment of new reservations, it is expedient to enlarge the area of some present ones - Sikhote Alin, Lazo, Ussuri, and Zeya. First of all, it is connected with protection of individual areas of such big animals as tiger, leopard, brown and black bear, etc.

To protect the unique landscapes and genofond and cenofond diversity in the Far East it is necessary to organize, besides large complex reservations, numerous small ones with the area not more than 1000 ha (in the Moscow Region there is such an experience), sanctuaries and nature monuments. Such measures in combination with a rational use of nature and a system of conservation measures will make it possible to conserve peculiar biogeosystems, rich wildlife of the Soviet Far East.

MONITORING ISLAND ECOSYSTEMS: THE HAWAIIAN RAIN FOREST DIEBACK

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Introduction

A widespread and significant tree dieback was discovered a decade ago in the natural rain forest on the island of Hawaii. Subsequently, an aerial photo analysis was made of the dieback phenomenon using three successively prepared photographic sets, the first made in 1954, the second in 1965, and the third in 1972. It was concluded (Petteys, Burgan, and Nelson, 1975) that the native rain forest was rapidly declining. The decline was described as a "severe epidemic," and a prediction was made that the native rain forest would be eliminated in 15 to 25 years if the present rate of damage would continue. This prediction implied the assumption that the native rain forest was struck by a newly introduced disease.

Intensive disease research was begun in 1972 by the U.S. Forest Service. Several potential pathogens were isolated, among them Phytophthora cinnamomi, a soil and root fungus which causes large-scale native forest decline in West and Southeast Australia.

Consecutively, with the disease research, I began to study the dieback phenomenon with three graduate students in 1974 under the general hypothesis that the dieback may be a recurring natural phenomenon in primary succession. Three observations led me to assume that the dieback was a natural phenomenon.

During my initial observations in 1965 I noticed that the dieback occurred mostly on inundated or poorly drained sites. Searching with my students through the literature, we came upon the "Maui Forest Disease," an ohia rain forest dieback that had occurred in the early part of this century on the island of Maui. In spite of several years of intensive research, no pathogen could be detected for the Maui forest disease. No biotic agent was found to be involved (Lyon 1919). Thirdly, in spite of claims by some foresters that ohia trees and other tree species were dying in all age classes, I could never find any appreciable death or dying of the undergrowth. Only upper-story ohia trees were dead or dying in large quantities.

The following pages will give a short description of the area and a brief explanation of our field approach and current results. I will then summarize the major findings up-to-date and present a dieback theory and a new working hypothesis.

AREA

The air-photo analysis relates to an 80,000 ha territory (i.e. an area of about 16 x 50 km) on the east slopes of Mauna Kea and Mauna Loa, between 610 and 1830 m altitude. Throughout most of this territory, the natural forest is dominated by only one tall-growing tree species, the native Metrosideros collina subsp. polymorpha, locally called ohia lehua. A second tall-growing tree species, the native Acacia koa, occurs in a narrow band in the upper altitudinal fringe area of this territory and more localized also in the lower altitudinal fringe-area on the east slope of Mauna Kea. In addition to the monodominant ohia, there occur about 20 other woody plant species, usually lower-growing trees and arborescent shrubs. These are associated with the ohia in various porportions. A second dominant and widely distributed, ohia-associated, plant life form is represented by the tree ferns, particularly the species Cibotium glaucum. Typically, the tree ferns form a distinct second layer at about 2-3 m height with the ohia trees reaching above the heights of 10-20 m. Depending on the density and activity patterns of feral pigs the forest floor may be covered by a dense growth of native, herbaceous ferns or it may be very sparsely covered by plants.

Other introduced mammals include the roof rat (Rattus rattus) and the mongoose (Herpestes auropunctatus) and very rarely a feral cat or dog. The native fauna consists of a great number of species of arthropods and tree snails and of several species of forest birds, most of them belonging to the honeycreeper family (Drepanididae).

The climate of the area is continuously humid, with monthly rainfalls almost always in excess of 100 mm. The annual rainfall varies (geographically) from about 1.8 m in the south part of the study area on Mauna Loa to 7.5 m in the middle-area on Mauna Kea. The mean annual temperature at 610 m is about 20°C, at 1830 m it is about 15°C. Temperature is equable throughout the year, i.e. summer and winter temperatures differ by only a few degrees (about 4-6°C). Daily temperature ranges are often somewhat greater (8-10°C). Therefore, the forest fits into the concept of tropical montane rain forests on a worldwide scale.

The substrate is volcanic. On Mauna Kea it consists mostly of deeply weathered ash of heavy clay texture. Between the two mountains and on Mauna Loa, the substrate consists mostly of basaltic lava flows (pahoehoe and aa lavas). Depending largely on geologic age, location, and drainage, the lava flows are covered with a shallow layer (10-50 cm) of woody peat (histosols) or a mixture of ash and black muck.

METHODS

We began with a detailed belt-transect analysis in a severe dieback area. The transect was 6 m wide and extended to a length of 1.3 km. On the transect we enumerated all ohia trees in 3 x 5 m subplots by their sizes from small seedlings to mature trees and snags. In addition, we prepared species checklists and quantitative evaluations by the Braun-Blanquet method for every subplot along the transect. Soil pits were dug at every obvious change in substrate, profiles were described and soil samples taken for further analyses. Another long transect was done similarly in a "healthy" forest.

Following the transect analyses we prepared a large-scale vegetation map from the 1972 colored air photos, with intensive ground checking. Ground checking involved the establishment of relevés (vegetation samples) in many of the important air-photo patterns (with and without dieback) and in different geographic locations of the study area. So far, we established 40 relevés, each 400 m^2 in size.

In each relevé, a total floristic analysis was made using the Braun-Blanquet method. One or two soil pits were dug, described in detail, and samples taken. The soil surface of each relevé was analyzed for its drainage condition by the point-sampling method along predetermined transects and the topographic setting and the microtopography was described for each sample site. A full enumeration analyses of all ohia population members from seedling to snag were made in each relevé, similarly as along the transects.

In addition, further work was done by colleagues (Dr. W. Ko and a graduate student) on the biology of Phytophthora cinnamomi and its possible relationship to the dieback.

RESULTS

The soil profile and drainage analyses done in each relevé allowed us to prepare a preliminary habitat classification. Two habitat series were recognized, one with shallow soils (<50 cm fine soil or organic deposit over lava rock substrate), another with deep soils (> 50 cm). In addition, five drainage classes were recognized. These ranged from well-drained to poorly drained in the shallow soil series and from well-drained to permanently water-soaked in the deep soil series.

Surprisingly, ohia dieback stands were found in all moisture regimes and soil-depth ranges. Earlier, I had overlooked the dieback on well-drained sites. The occurrence of the dieback across so many soil variations gave some support to the disease hypothesis. However, the dieback patterns differed in relation to these site variations. Dieback over large areas, continuous over several hectares, was found only on poorly drained sites. On deep, boggy soils there was a pepper-and-salt pattern of dieback, i.e. healthy crowned trees and snags occurred intermixed. On shallow, poorly drained soils occurred a more continuous tree-to-tree dieback pattern. This was the more typical large-area dieback, which originally drew attention to the problem. On the better drained sites, dieback was much less area-extensive. But also two patterns were found, a tree-to-tree dieback and a salt-and-pepper dieback. The tree-to-tree dieback occurs on well-drained soils in pockets of up to one hectare, but it usually occupies still smaller areas. This pocket dieback was formerly recognized as "hotspots" or so-called "disease centers," but wherever investigated the results were negative for disease-causing organisms. The second dieback on the better drained sites, which also resembles a pepper-and-salt pattern was found locally only, but over a larger area of about 25 km^2, on moderately well-drained, deep ash soils, which are rather rich in nutrients.

Our vegetation map analysis has shown that general vegetation structure patterns such as closed versus open canopy forests are not well correlated with the physical habitat types. This means that both closed and open forests can be found on nearly all moisture-regime and soil-depth types. This in turn implies a dynamic nature to forest deneness instead of a site-indicator value.

Our population counts of ohia trees and seedlings in form of density/size class have brought out an almost direct relationship between openness of the canopy and ohia tree reproduction. In all relevés sampled so far in the tree-to-tree diebacks, on both well-drained and poorly drained sites, we found adequate ohia reproduction. We defined "adequate reproduction" as at least 3,500 seedlings and saplings from 0.1 to 5 m height per hectare. The only form of ohia dieback, under which ohia reproduction was not adequate (according to the above standard) is the salt-and-pepper dieback on the fertile ash soil. Here, the growth of tree ferns (<u>Cibotium</u> spp.) is so vigorous that the ground is almost totally shaded by them, and tree fern density is very high. The dieback seems to be resulting in a displacement of ohia and a development of almost pure tree fern forests. Our data on the salt-and-pepper dieback of the boggy deep-soil sites are insufficient, but our preliminary observations indicate a slow decline of ohia and a displacement of trees by shrubby forms of ohia.

SIGNIFICANT FINDINGS

Significant findings contributed to the ohia dieback problem by our study can be summarized as follows:

1. There is a site relationship with regard to the dieback pattern, i.e. small-area "tree-to-tree" dieback occurs in stands on well-drained sites, while large-area "tree-to-tree" dieback occurs on poorly drained sites. There are also "salt-and-pepper" dieback patterns on deep-soil habitats, particularly on moderately drained, fertile ash soils and on boggy soils. Thus, we can distinguish at least four site-related dieback patterns.

2. Regardless of soil-moisture regime, all tree-to-tree dieback sample stands examined (18) showed significant ohia reproduction (at least > 3,500 seedlings or saplings/ha). The salt-and-pepper dieback sample stands examined (4) showed inadequate ohia reproduction. All (9) closed-canopy or "healthy" stands examined showed only few small seedlings and lacked taller ones. This indicates clearly that the tree-to-tree dieback is resulting in rejuvenation of the forest and not, as originally suggested, in a forest decline.

According to the air-photo analysis done by the U.S. Forest Service in 1975, 120 ha were recognized as showing severe decline on the 1954 air-photo set, 16,000 ha on the 1965 set and 34,500 ha on the 1972 set. On this basis the conclusion was drawn that the remaining ohia forest in the 80,000 ha study area will succumb to the epidemic in another 15 to 25 years, if present conditions continue.

Clearly, the conditions did not continue, because by extrapolation, by 1978 there should only be approximately 5000 ha left, which are not classifiable as severe decline. Instead the area with "healthy" forest is still quite extensive. We are still working on a more detailed mapping analysis of the dieback pattern, but by estimation severe decline still has not spread over more than 50% of the area.

The initial air-photo interpretation was undoubtedly exaggerated. The air-photo analysis may have suffered under the failure to distinguish between the different dieback patterns. However, there is no doubt that the tree-to-tree dieback is a rapid and spatially significant phenomenon.

As to the causal mechanism of the dieback, three findings are of significance so far:

1. The soil and root study of <u>Phytophthora cinnamomi</u>, done within the framework of our project (Hwang, 1976) resulted in the findings that the fungus is more common at lower elevations and almost absent at higher elevations, further that it is a good sap-

rophyte and that it shows no relationship to the ohia dieback. In other words, healthy stands at lower elevations (around 610 m) showed the fungus in the soil and some roots, dieback stands at higher elevations (around 1120 m) lacked the fungus in soil and roots.

2. Insect and disease research done by the U.S. Forest Service has revealed that among several disease-causing candidates, such as Armellaria mellea, Pythium vexans and others, Phytophthora cinnamomi was considered the most likely cause of the ohia decline. The latest finding is that P. cinnamomi has a relationship to soil moisture. It occurs only in moist, but not in well-drained sites nor on sites which are very poorly drained. Dieback, however, occurs on all of these sites. It is currently suspected that the fungus may have a secondary or contributory role to dieback on moist sites.

Among insects, only the native host-specific wood borer Plagithymusus billineatus was suspected as a causative agent. Intensive research over the last several years has shown that it is not causative, but that it may have a "hastening effect" on the dieback, once the trees are physiologically weakened from another cause.

3. A few plots with dieback trees were treated with NPK fertilizer. The declining tree crowns recovered with foliage. This fertilizing experiment indicated that the ohia dieback was related to nutrient deficiency in the soil.

When originally discovered, this fertilizer response seemed puzzling. Nutrient starvation of forest stands in natural environments does not seem a commonly reported phenomenon.

Conclusions

However, the six important findings about the rain forest dieback problem in Hawaii can be fitted into a new dieback theory.

It is almost absolutely certain that we are not dealing with a newly introduced insect pest or disease-causing organism. This was initially suspected not only because of the large spatial extent of the dieback, but also because we are geared to think that island ecosystems are fragile. Even indigenous biotic agents are not involved as initiating causes of the dieback. The dieback then, is clearly a natural phenomenon in the dynamics of this rain forest, which is initiated by an abiotic environmental cause.

Our current working hypothesis is that the dieback is initiated by a climatic instability which becomes effective through the soil-moisture regime under certain conditions of forest stand maturity. As climatic instability we suspect excessive rainfall in certain years, which may flood and drown out the root systems of the taller growing trees on poorly drained sites. Dieback under these conditions may be associated with iron toxicity. On well-drained sites we expect the opposite climatic instability to initiate the dieback syndrome. A certain "lull" in the rainfall pattern may manifest itself as soil drought. Trees, which are already surviving under nutrient starvation, particularly when this is aggravated by intra- or inter-specific competition, may suddenly succumb and die.

We have found that the tree-to-tree diebacks on both well-drained and poorly drained soils are associated with rejuvenation of the same tree species. The dieback thus has become a successful mechanism to maintain an essentially shade-intolerant pioneer species as the structure-forming dominant in the course of primary succession.

ECOLOGICAL AND ECONOMICAL PROBLEMS OF THE INVESTIGATION AND DEVELOPMENT OF CONTINENTAL TERRITORIES IN THE NORTH OF THE PACIFIC REGION

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The northern continental territories of the Pacific region embrace Magadan and Kamchatka Districts in the USSR, Alaska in the USA and Northwest Territories in Canada. At present they are of great importance in the economy of these countries, and in prospect this importance will increase with the development of their natural resources. In this connection, it is necessary to organize an interdisciplinary examination of a number of scientific theoretical and methodical problems of the investigation and development of the North.

This paper deals with the problems of the development economics which are related to the characteristic features of the environment, to the geography of natural resources, i.e. to the whole complex of geographical factors of this zone.

At present it becomes more and more obvious that the most important problem of the populating and development of the North is a determination of the specific features of the environment and a due regard for them in an economic activity. For example, the high sensibility of natural Arctic and Subarctic ecosystems to any anthropogenic influences is well known. The biochemical capacities of water and air media is comparatively low, and the level of bioproductivity is not high. Therefore, the maximum permissible economic and populating loads per unit of area in northern territories are considerably lower than in temperate latitudes, the specific ecological capacity of northern territories is lesser.

Meanwhile, it is not always taken into consideration in practice of construction and exploitation of economic works at every stage of the development and populating of a territory. To a considerable extent it can be explained by the fact that scientists have not completely worked out the maximum permissible concentrations of wastes and pollutants and, consequently, the norms (standards) of the maximum permissible loads for various ecosystems and biogeocenoses of northern territories. Lately the scientific elaboration of standards of the environment quality, maximum permissible concentrations of wastes and pollutants, and norms of permissible economic loads for northern territories is given special consideration. However, this work is still far from completion.

We have to take into consideration that the ideas of an ecological capacity and ecological possibilities of a territory, widespread earlier, should be specified and sometimes revised in view of a scientific-technical revolution and new demands of an economic construction. Thus, due to the sharp increase of dynamic and thermal loads onto grounds on account of constructions of roads and airports with an intense traffic of a heavy machinery, of erections of many-storeyed residential and industrial bildings, etc., the measures necessary for the conservation of ground in a perennially frozen state should be substantiated anew and specified in accordance with a real environment.

The elaboration of ecological-economical norms is also hampered by the fact that the regularities of the inner structure and behavior of natural ecosystems of the Arctic and Subarctic are not understood in a proper measure. Thus, quite recently, the belief that landscapes of the North are conserved and ecologically stable was dominating; the problem of the dynamics of the boundary between forest and tundra is still open to discussion; the grave corrections are continuously introduced into the ideas of the stability of a soil-ground complex in the permafrost areas, and so on.

In our opinion, the elaboration and introduction of northern standards of maximum economical loads will result in the revision of some variants of optimum schemes of a territorial organization of industry in the North. For instance, the creation of very large territorial industrial complexes, which are rather effective economically in the south of Siberia and the Far East, is not expedient anywhere. According to preliminary evaluations, the nature of the North does not endure the high concentration of various manufactures giving rise to a multiaspect and strong anthropogenic alteration of the environment, therefore some of such complexes in the northern territories possibly will have to be dispersed.

For the same reason, a special approach to the systems and forms of settling is required. At the sites of large mining and other works, the fairly comfortable for the man's life parameters of the environment not always can be conserved. Therefore, settlements should be projected at such a distance from the works which vouches for optimum for the population environment.

The problem of determination of ecological and economical criteria of optimum dimensions for northern settlements requires a special attention of scientists. Norms for such settlements should be considerably lower than those for their midlatitudinal counterparts. There are many practical examples of northern towns which have been found to be more polluted then towns of the same size and the same traffic load in the middle latitudes.

All this makes an early ecological examination of economical construction projects in the North perhaps more urgent than in any other place. It should not be allowed to begin the construction of industrial, transport, and other objects without determination of ways and means of minimization of their negative influence upon the environment. In practice, unfortunately, it is still far from the realization.

Problems of methodology and methods of the economic estimation of natural resources and an environment as a whole as well as of an extent of the damage to the environment resulting from the man's activity in the North are very complicated and not completely founded. Such an estimation is quite necessary for the elaboration of an economic mechanism of the use of nature which is the most effective lever of influence upon the users. This estimation will permit to find an expediency criterion for the works on preservation of some or other natural resources or elements of the environment, on preventing disturbances of the natural equilibrium.

The conventional approach to the economic estimation of natural resources, the environment as a whole, and the damage inflicted upon the nature by man and machinery is based on a quite obvious practical gain received from the exploitation of natural resources and a territory. Such an approach permits economists to prove, for example, that opencast minings exploited in midlatitudinal more developed areas cause a considerably greater damage to the nature than the same minings in the North. They argue that losses from the vegatation destruction, soil degradation, hydroregime disturbances, etc. in developed areas are fairly great and expenditures for the restoration of natural equilibria disturbed by man are great as well. Similar disturbances in the undeveloped North at present do not cause an appreciable damage to the society and state, therefore the restoration of a forfeited natural equilibrium here, on the face of it, does not seem necessary.

The practice of the estimation of the damage to nature and of the compensation of this damage proceeds exclusively from the criteria of the present day. The so-called compensation measures (recultivation, soil restoration, etc.) absolutely don't take into account the future. Thus, such measures are not taken on the disturbed lands which are even potentially suitable for the agriculture but are not used at present. All the more, the problem of the compensation is not even raised with respect to resources and lands, the practical value of which is not yet evident.

These problems acquire especial significance in connection with a realization of major national economic projects, such as projects to transfer the part of the runoff of northern rivers in the USSR, USA, and Canada to the south. Without the completely new and scientifically grounded methods of calculation of positive and negative effects of such a transfer for northern regions, the comparison of benefits and damages from such measures can be made only in favor of southern regions.

To work out criteria of economical estimations of natural resources and environment which have no present-day visible social utility is a problem awaiting its solution and, mainly, its introduction into the planning and economical practice. In our opinion, it is most expedient to estimate resources and environment as well as a damage to the nature or, at least, to its renewable components by the cost of their restoration as it is suggested, in particular, by Yakut scientists. Of course, it will be methodically difficult to apply this approach to the North. The periods of a spontaneous renewal of the northern nature, e.g., a moss and lichen cover or forests adjacent to tundra zone, are very long. At the same time, so far the world practice does not know any examples of the artificial restoration of individual elements of the animate and inert nature and all the more, of the whole ecosystems and biogeocenoses of the North. However, such a situation will reflect mathematically the great, more exactly - infinitely great damage from the deterioration of the northern nature; perhaps, from a position of the necessity to preserve any natural resources and territories from an unwise destruction, that is correct in principle.

In this case, many interesting problems originate which can be studied not only by theorists in economics, but also by biologists and geographers. We believe, for example, that a theoretical dependence of the level of specific expenditures (calculated per area unit) for the restoration of the environment and its components on the zonal conditions of the North and midlatitudinal regions (e.g. tundra and steppe) should be investigated. A considerable duration of the restoration period and its biological and biotechnical difficulties make this process in the North more expensive. However, cannot the fact of the species monotony and the considerably smaller biomass act in an opposite direction?

In the light of the said, the imperfection of another aspect of the system of compensation of the damage caused to the nature can be clearly seen. In a number of cases the sum of the fine for the pollution of any component of the environment, for example, water, is determined by the cost of its purification. So, in this case, the damage caused to the water ecosystem itself is underestimated: the subsequent purification hardly can restore its original condition. This is correct for any place, and especially for northern and other regions with a sensitive nature which is difficult to restore.

On the whole, the problem of a reconsideration of ecological-economical criteria of the use of the nature, particularly for the North, is extremely urgent. In this connection, it should be noted that in the USSR the most interesting investigations on general economic problems of the use of the nature are carried out by the scientists of the Central Institute of Economics and Mathematics of the Academy of Sciences. The significance of the ecological-economical investigations for the North is not limited by the requirements of the practice of the exploitation of natural resources, of the development and populating of an area. These investigations are also important theoretically and for the exposure of the role of the North in the future.

First of all, it should be said that the northern continental areas of the Pacific region within the limits accepted by economists and economical geographers (in that case their southern boundary almost coincides with a boundary of the Subarctic as a physicogeographical unit) represent a largest land reserve. The area of northern territories amounts to about 4.5 million km^2 and is inhabited by a little more than 1 million people, including 700,000 (in 1972) in Magadan and Kamchatka Districts having the area of 1.7 million km^2.

Under the present-day conditions of the increase of ecological loads on the natural environment in the populated from old times, highly industrialized and urbanized regions of the USSR, USA, and Canada, the availability of free lands suggests the more versatile utilization of them than simply as sites to extract raw materials, fuels, fresh water, and energy. Even taking into consideration that concepts of an ecological capacity, limits of industrial and populating loads, etc., are very conditional and depending on very dynamic socio-economical and scientifical-technological factors, it is impossible now to deny the presence of ecological territorial restrictions in old regions.

We believe that in the future, and, perhaps, not so far future, a territorial redistribution of not only extractive but also manufacturing industry as well as population for the reasons including ecological ones, seems quite probable. The growing ecological tension in old industrial regions may result in that the losses (both calculable in terms of money and unamenable to calculation) from the sharp deterioration of the natural environment will surpass the additional investments for an expensive industrial construction and population of northern territories.

In the estimation of a multilateral significance of northern territories, their role as recreational areas, popular places for the rest and tourism should be taken into consideration. The number of tourists visiting northern regions is increasing every year. This growth is connected not only with the overload of conventional recreational areas, but also with a certain revision of the criteria of the value of rest sites by a considerable part of the people. An absence of the overpopulation, a comparatively untouched nature, a quiet, etc., become the main criteria. Such a reappraisal of criteria of residence sites influences, as it is shown by sociological investigations in the USSR, USA, and Canada, more and more the choice to move to the northern regions for a regular work.

Such an important factor of the increase of the significance of the North in the life of the modern society as the contribution of northern territories to the maintenance of a global biochemical equilibrium, is not sufficiently taken into account. At present, the northern margins are such parts of a general circulation system of the atmosphere where polluted air flows from West Europe and North America are purified. Northern, especially taiga, regions are stabilizers of the hydroregime of a considerable part of the hemisphere. This has been emphasized by the eminent Soviet ecologist, Academician S.S. Schwartz, the noted Siberian naturalist V.N.Skalon, and others.

The North is also of importance as a unique "proving ground" for various observations concerning the influence of the industrial activity upon natural ecosystems as well as for estimations of the level and force of anthropogenic impacts on vast territories. Under the conditions of the North, the experiments can yield comparatively "pure" results which are free from the influence of a multilayered, complex, and long interaction of man and nature characteristic of the territories populated from old times. In this connection, the North is of great interest for the development perfection, and mastering of the natural environment monitoring system.

The possibilities of a multilateral utilization of the North, including one of its main resources, the territory, suggest the following conclusion. Under conditions of a continuous decrease of the lands, free for the economical development and peopling, the natural territory as a geographical space assumes the greater significance in the human life and society development than the natural resources; the latter in most cases can have natural or artificial substitutes, and nothing can substitute the space. It has been already noted in literature. In some foreign countries, scientists have begun to think seriously about a more rational utilization of a territory, a space as a resource which becomes ever more scarce. Many modern works require for their organization spacious free areas; for instance, a large solar electric power plant (1 or 2 million kW) needs some tens of square kilometers for the placing of collectors.

On the whole, it should be said that the North is a potential people's wealth, the veritable value of which cannot be comprehensively determined at the present-day standard of knowledge. Nevertheless, the formulation of such a problem and determination of approaches to its solution are already urgent just now, at the present-day stage of the development of the North. Here more than elsewhere, impecuniary estimations, taking into account social factors and prospects should be widely introduced.

The broad view of estimation of resources and territories predetermines special criteria of the national wealth (of a country or a region) determination. Commonly, this concept embraces (in the part concerning the nature) lands, forests, mineral deposits, water resources which can be used for the economical purposes at the present-day level of science and technology. Taking into consideration the above-mentioned multilateral and not easily foreseeable significance of the North at the present and especially in the future, we believe that all the natural resources and environment components should be included in its national wealth. Then northern regions, as other undeveloped ones, where natural resources valuable from the today's point of view are not yet discovered but there are free territory and unpolluted environment, may prove to be "richer" than industrial, populated from old times regions, where there are such resources but the ecologic capacity is almost exhausted. Such an approach is practically of importance, since it increases the value of the North and other free territories and gives grounds to exploit them very cautiously.

The proposed criterion of the estimation of natural resources and territory, when the natural wealth itself and its potential significance for mankind as a condition and source of the society life are appraised rather than the value of utilization and consumption of this wealth, is supported by a number of Soviet geographers and economists, in particular, by V.A.Anuchin. Of course, this criterion needs a methodic elaboration.

It would be of great importance for northern regions to make account in main macro-economical indices of the development of a country or a region (national income, gross national output) of such components as the expenditure on the environment conservation, the damage from the pollution, overpopulation, urbanization - in other words, according to the terminology of Japanese scientists, the damage from the so-called environment wear. The general tendency revealed thereby is an increase of the damage with the increase of the degree of the environment wear and the growth of its pollution.

Such an approach can be of a considerable significance for a comparative estimation of gains and losses from the utilization of undeveloped regions and those peopled from old times. The distribution and development of works and branches of the economy within undeveloped regions with an unpolluted environment, despite increased capital and current expenses, may prove to be more efficient economically, since the damage from the environment wear in the above-mentioned broad sense will be less than within regions with an essentially greater environment wear.

It is possible that taking into account the environment wear, its physical quality, will result in an increase of the share of northern regions in the synthetic socio-economic indices of the country development. The necessity to determine the efficiency of production works by final national-economic results is emphasized in the Soviet economic policy. To include in these results a factor related to the environment conditions will be, undoubtedly, in favor of the North.

Finally, in the light of the said, we may contend that a widespread statement that an optimization of the utilization of a territory is predominantly a function of its economical development and peopling cannot be regarded as a universal one. In some cases, in a certain socio-economical and ecological situation, under conditions of aggravation of raw material, fuel, and energy problems, the preservation of resources and, especially, of a natural environment may prove to be more important for the society than the industrial development of the territory.

The example of the North demonstrates clearly that one of the leading Soviet economists, Academician N.P. Fedorenko, has been right stating that the economics of the nature utilization guided by today's data is a science of yesterday rather than of tomorrow. The economical efficiency of measures for the rationalization of a nature utilization results not only from the difference in expenditure and income of the near future, but also, as a socio-economic value, from the course of all the social development and from the interrelation between the society and its productive forces, including natural resources.

A special problem is an allocation of protected territories. The multilateral significance of the North, its great scientific-geographical importance, the high sensitivity of its ecosystems - all that requires a considerable expansion of the net of national parks, reservations, sanctuaries, and other kinds of protected territories. The North is important as the site for the creation of biosphere reservations which have to be sufficiently extensive and remote from the centers of technogenic and other anthropogenic activities.

The plans of expansion of the net of protected natural territories in the Pacific North are worked out in the USSR, but at present these are not numerous here. In this respect, the example of Alaska, where such territories occupy more than a third of all the area, is of interest.

In Canada and especially in the USA the tendencies to the so-called conservation of resources and territories of northern regions, to the withdrawal of vast areas from the economic exploitation gain strength. Digressing from the social and political nature of these tendencies reflecting well-known in the West global ecological theories of the restriction of an economical growth, we have to admit that an objectively rational principle also takes place here. It consists in a display of a maximum care of a largest reserve of space and comparatively pure nature which is represented by the North. The recognition of an irreversibility of natural equilibrium disturbances in northern regions is also rational. We believe that the tendencies to the conservation of resources and territories of the North,to their preservation for the future of the countries and planet require a profound scientific substantiation in conformity with certain natural and socio-economic conditions. In any case, deciding to exploit resources and territories of the North, more attention should be paid to the search for alternatives, for some substitution of northern resources as well as to the every kind of a saving of raw materials and fuels, which should reduce demands for the resources of the North.[1)]

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1) Canadian scientists have made such a calculation. Investments in the extraction and transportation of the natural gas from the islands of Canadian Arctic Archipelago to southern regions of the country should amount to $ 13 billion. Meanwhile, the radical improvement of the thermal insulation of houses and the perfection of the system of the fuel burning, which will cost only $ 5.6 billion, would make it possible to manage without the heat from Arctic gas.

As the conservation of natural resources and an environment in a number of cases may be more efficient in a socio-economic respect than their economical exploitation, we believe it quite rightful to raise a question of creating in the North not only protected natural territories in a conventional sense, but also territorial resource reserves for the conservation of lands and mineral resources for the future. Those territories and resources could be exploited when the need of them becomes greater than now or their more composite multilateral utilization becomes possible. We should not forget that the reserves of natural resources and territories are not endless, that the North is one of the last rich storerooms of these resources on the Earth, that we have to think about generations to come. Of course, we can only raise this problem in principle; the possibility and expediency to create state territorial resource reserve of a strategic nature should depend on a definite national-economic situation.

An essential aspect of investigations in the Arctic and Subarctic is an elaboration of a special system of normative legislative and administrative (regulating) acts of the nature protection. It is expedient to establish, parallel with the laws common for the country, the special codes for the North.

The specific character of the geographical environment of the North and the peculiarity of questions related to the nature protection require the creation of special coordinating and controlling bodies which have to manage the process of investigations and development of northern regions.

The complexity of ecological-economical problems in the North is clearly manifested in the interrelation between the nature and machinery. Contradictions between the economical and ecological efficiency with the installation of new technology in the North, as well as in other regions with extreme conditions, are pronounced, generally, more severely than in midlatitudinal regions. The efficient from the economical point of view machinery, in a number of cases and in the North more ferquently, is unacceptable from the point of view of its influence upon the natural environment. This can be said, for example, about heavy caterpillar tractors, advantageous to exploit but quickly destroying a soil and vegetation cover in tundra and forest-tundra.

Despite some environment conservation restrictions, so far advantages of economical nature are eventually pushed into the foreground. Such an approach can be changed, if quite new methods to calculate economical damages from the harm inflicted on the nature of the North and, which is more important, gains from its conservation are worked out. Then many engineering decisions which now seem to be unprofitable may become socio-economic priorities.

Such are, in our opinion, new approaches and new problems in the study of the possibilities to utilize natural resources and territories of the North as well as to conserve its natural environment. These problems are not only complex, but also, to some extent, conflicting. On the one hand, there is an exceptional sensitivity of natural ecosystems of the North to technogenic factors, their fragility, their vulnerability. On the other hand, there is a probability of the wise, multilateral use of northern territories. It is necessary to combine reasonably a care of a peculiar nature of the North with an efficient utilization of a territory and resources of this richest zone at present and in prospect.

A certain discrepancy in the approach to the present-day and future use of the resources of the North, difficulties in the determination of the economical (in terms of money) value of natural resources including the territory and environment of this zone - all this raises a problem of the application of special ways of research. The combination of various methods of research may be conducive to the solution of many important problems of the North. The system approach to the utilization of natural resources and the environment protection are successfully elaborated in our country, in particular by the institutions of the USSR Academy of Sciences. These ways and methods should be approbated under various conditions, especially in the north of the Pacific region, since the specificity and diversity of problems of research and development are pronounced here very strongly. For the successful solution of these problems in a planetary scale, efforts of a single country are not sufficient. An international cooperation, an exchange of experience, a joint search for ways and methods of a rational development of natural resources of the North are quite necessary.

AGRICULTURAL OPTIONS FOR THE PACIFIC ISLANDS

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Agriculture in the Pacific Islands takes place within a framework of aspirations, social forms, and commercial imperatives which are changing rapidly. These changes are tending to accentuate the disadvantages of small size of land area and population, fragmentation of land areas, and isolation from major market sources or imports. Over the last 100 years most Pacific Islanders have opted for increasing participation in the cash economy. The principal sector for this participation has been agriculture. Unfortunately, the characteristics of small size, which may be beneficial in a subsistence economy, become increasingly disadvantageous in a commercial economy. As aspirations change in response to greater awareness of the outside world, these disadvantages of small size are further accentuated.

This paper is based largely on data collected during a survey of the current state of agriculture and rural development is seven Pacific Island countries in the earlier part of 1979. The study was carried out by a multidisciplinary team of nine under the auspices of the Asian Development Bank. The countries concerned were the Cook Islands, Fiji, Kiribati (formerly the Gilbert Islands),Papua New Guinea, the Solomon Islands, Tonga, and Western Samoa. In the present paper Papua New Guinea is excluded. Although specific reference is not made to other small countries in the region,there is little doubt that many of the general tendencies noted in the six states under consideration are also found in other Pacific Island countries.

Agriculture plays a major role in the economy of all the six countries, whether measured in terms of employment, contribution to GDP, or to export earnings. Agriculture in all the countries is based on a relatively limited environment. This is particularly true in the case of atolls or raised limestone islands which include all the islands of Kiribati, all the Northern Cook Group,and some islands in all the other countries except Western Samoa.

From the viewpoint of agriculture, the atoll environment is one of the most limiting in the world. The inhabitable islets of atolls rise little more than 2 or 3 m above sea level. They have virtually no soil, being composed solely of coral rubble or sand overlying the coral limestone of the atoll. Surface water is nonexistent, and both vegetation and the human population are dependent on the lens of fresh water which floats on the denser sea-water which permeates the limestone. The fresh water lens, formed by rainfall, is often susceptible to drought or incursions of salt water. Very few crops can be grown under these conditions, and the coconut is the only significant cash crop.

Many of the Pacific atolls lie within or at the margins of the tongue of relatively low rainfall which extends across the equatorial Pacific from the west coast of the Americas approximately to longitude 165°E. Within this area rainfall variability is very high and the resulting droughts make agricultural activities precarious. Exposure to hazards such as tsunamis or tropical cyclones introduce a degree of environmental risk to small islands which larger land areas are unlikely ever to experience.

In the case of the higher islands, and particularly in Fiji and the Solomon Islands, landforms and soils are much more varied and the range of environmental conditions for agriculture is much wider. Soils derived from volcanic, sedimentary, and metamorphic materials offer suitable conditions for a broader range of crops. But even here the small size of many of the islands, when combined with their relative isolation one from the other, imposes transport and economic limitations on the agricultural potential. Furthermore, it must be noted that even in the larger countries very high proportions of the land area have been shown to be unsuitable for commercial agriculture. For example, in Fiji only 19% of the country is "first class" land suitable for permanent agriculture (including pastoral farming) without improvement, while a further 11% is suitable for permanent agriculture after minor improvements. Not less than 38% of the country is considered "quite unsuitable" for agriculture.

Soils in Western Samoa are derived from olivine basalt and are relatively fertile, yet 51% of the land area has soils of "low-to-very-low" natural fertility or is too steep or poorly drained to be of significant use for agriculture. A further 35% is generally too rocky for mechanized agriculture. The Solomon Islands has more unused land suitable for agriculture than any other Pacific Island country (excluding Papua New Guinea), but even here the fragmentation of this land into over 40 separate areas scattered throughout the archipelago severely limits the opportunities for its development within the commercial sector.

In terms of agricultural potential, the above features of the land environments accentuate the small size of the island countries. In many cases the limited land area precludes the establishment of large-scale operations which might achieve economies of scale in production. Furthermore, insularity, isolation, and fragmentation increase the problems of aggregating export produce to achieve scale economies in marketing or in the provision of infrastructural services or imported inputs for agricultural production. In recent years the relative isolation of many of the Pacific Islands has been increasing as technological changes, spurred by commerical imperatives, have led to increasing size of vessels (or aircraft) and cargo handling units. This trend, advantageous to larger countries, has been detrimental to the small archipelagic states of the Pacific and no clear technological solution is in sight.

In four of the countries under consideration, agricultural exports contribute over 50% of the total exports. With the cessation of phosphate exports this year, Kiribati's exports will be restricted almost entirely to copra. Only the Solomon Islands has shown any significant trend away from dependence on agricultural exports in recent years, with fish and timber contributing 45% of exports in 1978. In the last year for which figures are available (1977 or 1978), four of the six countries had trade deficits, and Kiribati will certainly join them in 1980. Only the Solomon Islands had a small favorable balance of trade (in 1978).

Fishing within the 200 nautical mile Extended Economic Zones offers opportunities for some countries, especially in Melanesia, but fishing for migratory species is not likely to provide more than a partial solution to the economic problems of countries such as Kiribati, Western Samoa, or Tonga. Neither is manufacturing. Against this background and the slight chances of finding other significant sources of foreign exchange, the emphasis placed on boosting agricultural exports in most development plans is understandable. So is the hope that expanded commercialization of agriculture will improve the revenue base for Pacific Island governments. If economic strategy is to be based on export agriculture, and agriculture is to be the source for increased government revenue, there are important implications for the nature of Pacific Island agriculture in the mid-term future.

ASPIRATIONS AND LABOR SUPPLY

A striking feature of several of the Pacific Island States is the relatively high level of the aspirations held by many islanders. In the absence of other models, the desired levels of material living tend to be derived from the income levels and life styles of New Zealand and the United States, where large numbers of Polynesians from the Cook Islands, Tonga, Western Samoa, Niue, and the

Tokelau Islands now live. Whereas such aspirations might be considered unattainable and unrealistic in most developing countries, in much of Polynesia they are not so unrealistic, as many do attain them by migration, by employment in the public service, by dependence on remittances, or by provision of basic services through international aid.

The effects on agriculture of emigration, and of internal out-migration, in several of the small countries of the Pacific Islands do not appear to have been widely recognized. In most of these countries rural populations are now relatively stable. Emigration to New Zealand resulted in a 15% decline in the total resident population of the Cook Islands between 1971 and 1976. In 1976 only 21% of the Cook Islands work force were engaged in agriculture compared with well over 40% in 1966. In Western Samoa the number of people employed in agriculture, forestry, and fisheries fell by 10.5% between 1966 and 1976. In Tonga 74% of the economically active population were engaged in agriculture in 1966 compared with 51% in 1976.

Although the evidence has not been analyzed as thoroughly as it might, it appears that several of the Pacific Island countries now experience a significant labor shortage in commercial agriculture. This is not due solely to out-migration (e.g., to urban centres) or emigration, but also to the nature of the interaction (social and economic) between subsistence and commerical activity in the mixed subsistence-cash cropping mode of production, and the relative real rewards to be attained in subsistence as against commercial agriculture, and in agriculture as against non-agricultural wage employment. There are few avenues in which Pacific Island smallholders operating in the mixed subsistence-cash cropping mode can expect annual gross earnings of over US $ 1000. This compares unfavorably with incomes achievable in the wage sector (or after emigration) and appears to depress the numbers willing to engage in commercial agriculture.

For those who do wish to participate more fully in commercial agriculture, systems of land tenure, social organization, and labor mobilization, which are based primarily on the requirements of subsistence modes of production, frequently inhibit effective participation in cash cropping. Many Pacific Island farmers are now caught between their own aspirations for higher levels of living, which they hope to meet through commercial agriculture, and the demands on their time from kin, traditional leaders, church, or other community groups. Commercial agriculture often requires long and regular periods of work. Yet alternative calls on time to participate in village activities are difficult to ignore, especially when the farmer himself is partially dependent on reciprocity for assistance. Until a significant proportion of subsistence-oriented labor is specialized or rewarded with cash rather than reciprocity on demand, commercial farming projects are likely to face sub-optimal labor inputs. Acceptance of this condition is often a rational, welfare-maximizing strategy for those operating in a viable mixed subsistence-cash cropping mode, but changing attitudes and commercial and governmental pressures are making this less and less the common situation throughout the region.

AGRICULTURAL PRODUCTION SYSTEMS

Four basic agricultural production systems can be recognized in the Pacific Islands. The first, oldest, and now the rarest of these is the integral subsistence system in which virtually all the requirements of the community are produced locally; there is little specialization of labor; monetary exchange is absent and production and consumption units tend to coincide. Social organization is intimately related to the whole production and consumption system. The forms of technology employed vary from swidden cultivation with simple tools to complex systems of water control, terracing, and creation of garden plots. Land tends to be held by the community, and any form of individual or nuclear family ownership normally lies in the crop rather than the land, though terraces or other permanent man-made gardens may offer exceptions to this. Labor tends to be mobilized, as part of the total social organization and operation of the community, on a village or clan-wide basis for many activities, although it is important to note that agricultural work was frequently carried out on an individual or extended family basis rather than by the community as a whole.

In the integral subsistence system a wide range of root, tree, and other food and "industrial" crops are grown. Except in the case of irrigated taro gardens and on the atolls, most of the food gardens are multispecies and multivarietal. Apart from advantages of continued productivity over a longer period than is possible with monovarietal or monospecies gardens, the very mixed character of swidden gardens in this production system provides insurance against viral and other diseases, or hazards such as drought. It also assists in the provision of a widely varied diet.

The integral subsistence systems were most varied and complex in the more favorably endowed islands of Melanesia. Within Polynesia and Micronesia environmental limitations, most marked on the atolls, often limited the possibilities for elaborations such as irrigation or terracing. The absence of soil on the atolls meant that the range of crops which could be grown was extremely limited and in general atoll dwellers depended primarily on the coconut and pandanus and, in some cases, on elaborate techniques of cultivating Cyrtosperma chamissonis.

The integral subsistence mode of production in its "pure" form is now extremely rare in the insular Pacific and has generally given way to the second production system, that of mixed subsistence-cash cropping. Shortly after the arrival of European traders, administrators, and missionaries, Pacific Islanders began to add introduced crops to their agricultural repertoire and to sell (for cash or barter) to visiting European ships or the resident European population. The area under coconuts in particular was extended rapidly in response to government or missionary edict, or to perceived market opportunities. For the most part the accommodation of this additional production was made possible by the introduction of steel tools, the reduction in integroup warfare and, increasingly, through the diversion of effort from the minor and more labor demanding traditional crops or cultivation systems. The past century or so has seen a steady disintensification of subsistence agriculture through much of the region as labor has been diverted towards commercial rather than subsistence production.

Until relatively recently, the overwhelming proportion of smallholder production within the Pacific has come from the mixed subsistence-cash crop system. As noted above, this system creates inbuilt tensions between its separate components. It is no longer integrated into the whole community structure and, apparently inevitably, appears to stimulate increasing individualism. It is clear that this system cannot fully meet a number of the increasingly rigid requirements of modern commercial marketing. This problem is considered in more detail below.

The third agricultural production system, the plantation or estate mode, is entirely exogenous and, in the past, apart from its requirements of land and labor, operated in almost complete isolation from indigenous production systems. Expatriate owned and managed, and with relatively large resident labor forces, estate production was directed almost entirely for export. Units were relatively large, and monocropping predominated. Economies of scale and increasingly skilled management were the keys to success in this mode of production.

In recent years a fourth agricultural production system has emerged in a variety of forms. In many respects this system is also based on the plantation mode of management. The benefits of skilled management and large-scale production are achieved through the aggregating of smallholder production into centralized marketing, and sometimes management. The first example of this to emerge in the region was in the sugar industry of Fiji. When the indentured labor system collapsed in the second decade of the 20th century, the industry converted from an essentially plantation system to one of small-holder tenant farmers producing under the general direction of the sugar millers. More recently, the oil palm industry of Papua New Guinea has been developed on the nucleus estate with associated smallholders principle in imitation of the Malaysian Federal Land Development Authority projects. Other cases include the Tongan Farmers Federation producing tomatoes and other fresh vegetables for export to New Zealand, nucleus farm and associated smallholder cattle projects in Papua New Guinea, and proposals for citrus production in Fiji. Thus a smallholder farming system under centralized management is emerging as a response to the evident failure of the subsistence-cash cropping mode to meet the demand for both increased export production (and revenue generation) and increasingly higher levels of income for individual farmers.

PROBLEMS IN MEETING GOALS

The modes outlined above suffer from constraints - economic, social, or political - in attempting to meet the demands of either governments seeking revenue generation by export expansion or individuals seeking higher levels of material well-being. It is self-evident that the integral subsistence systems cannot contribute to government revenue. Neither do they produce an entry to the money sector. They do however, with some exceptions such as under conditions of population pressure, provide a relatively robust and ecologically sound basis for a no-growth economic system with limited opportunities for variation in individual goals.

For most of the last hundred years the greater share of the agricultural exports has come from the plantation sector except in the case of Kiribati, Tonga, and the Cook Islands, and the infrastructure of commerce has been built largely on the basis of plantation production. Expansion of the estate sector <u>per se</u> is now restricted for political or other reasons. Few Pacific Island countries are anxious to see expansion of foreign ownership within agriculture, although there are signs of some relaxation of this attitude in some countries. Furthermore, the small-island countries of Kiribati, the Cook Islands, Tonga, and Western Samoa have limited land, in the absolute sense, on which such large-scale development could take place. On the other hand, the need for government revenue at both national and sub-national levels has led to further consideration of the "state farms" concept. It is likely that within the next decade government-owned plantations, or large cattle or other primary enterprises, will become more common in this region. The success of the Solomon Islands in developing a favorable balance of trade based on enclave type development in oil palm, timber, fisheries,and, to some extent, rice production is indicative of the attraction such enterprises may have for other governments. However, even where the physical resources of land exist, the constraints on alienation imposed by land legislation do restrict the possibilities for extensive development in the plantation mode. There are, however, a number of incipient programs for large-scale export-oriented development which fall into the plantation mode system for at least part of their developmental life. For example, it has been suggested that the cocoa industry of Fiji might be encouraged through the establishment of cocoa plantations by government on Fijian land. These plantations would be developed by the state and, after all or a proportion of developmental costs had been recouped from the initial production, the venture would be turned over to the landowners for continued operation either as single units or as groups of smallholder farms.

For the last 30 years most emphasis in the encouragement of export agriculture has been given to production in the mixed subsistence-cash cropping system. The production of coffee in Papua New Guinea, cocoa in Western Samoa, citrus in the Cook Islands, and copra in all the countries has been promoted within this system. The banana export trade, which was extremely important for Tonga, Western Samoa, and Fiji until relatively recently, was also based on production by village farmers operating within the mixed subsistence-cash cropping mode. For a variety of reasons it seems unlikely that this production system can continue to meet the growing demands which both governments and farmers place on commercial agriculture. In the first place, apart from returns from export levies, which for obvious reasons governments are reluctant to increase, relatively little revenue is obtained from incomes generated by smallholder agriculture. In most cases, the impossibility of collecting income tax from self-employed smallholders, even where their incomes exceed that which would be liable for taxation if obtained within the wage sector, means that smallholder agriculture is of limited attraction to government as a revenue source. From the viewpoint of many farmers the area of land available to them is frequently inadequate. Absolute land shortage or social barriers to access to land prevent the establishment of holdings which would be commercially viable in a dominantly commericial system. For example, in Kiribati the total land area of the Gilbert Group, excluding Tarawa and Banaba, would be sufficient for only about 3,000 coconut holdings of a size sufficient to provide a gross income of US $1,000 with average copra prices. These islands already have a population equivalent to over 5,000 families, and few, if any, commercial alternatives to copra production are available within agriculture. The same situation exists in parts of the Cook Islands and Tonga, and, although no careful analysis has been done, the problem of inadequate land for fully commercial farming also exists in some parts at least of the better endowed islands of Melanesia.

In almost all Pacific Island countries infrequent or irregular inter-island shipping services restrict the possibilities for development of export production of anything other than non-perishable products. Furthermore, the role of inter-island shipping services as providers of agricultural inputs and consumer goods, which are key elements in the motivation of farmers for increased production, tends to be underemphasized in many assessments of shipping services. In a country like the Solomon Islands, the whole prospect for development of the quite extensive areas of potentially productive land depends on a solution to the problem of providing adequate transport and service systems for outer islands.

One of the important trends in export agriculture, particularly items such as bananas and other perishable foods, has been for the standards of packing and marketing to rise in the importing countries. An example is provided by the import of bananas into New Zealand. Until the mid-1960's, Fiji, Tonga, and Western Samoa supplied the whole market, and production came almost entirely from small village producers. When problems of disease, shipping, and hurricane damage prevented these countries from maintaining a supply (a situation in itself closely related to their small size) New Zealand turned to Ecuador for its banana requirements. Despite the longer distances from source of supply, the Ecuadorian fruit arrived in New Zealand in much better condition than the average Pacific Island product. In particular, the standardized size, evenness in stage of ripeness, and absence of marking and bruising, all made the product much more attractive to whole-salers, retailers, and, apparently, the consumers, despite some preference for the taste of Pacific Island bananas. These qualities, which are now what the market prefers, are achieved through large-scale production employing a high level of agronomic technology, careful handling and packing, grading for size, and the chemical control of the ripening process. Until the Pacific Island countries can match the reliability of supply, standardization of product, and quality of production from Ecuadorian estates, there is little prospect of recapturing the New Zealand market. It is doubtful if this can be done under the mixed subsistence-cash cropping system.

The same type of problem bedevils attempts at other forms of export production. Several of the Polynesian countries now export root crops to New Zealand, but it is unlikely that production from smallholders, the present major source, can match that from larger holdings in terms of price. The export of tomatoes, beans, and other vegetables to New Zealand for the winter market also suffers from the inability of small growers to produce a sufficient volume to allow effective grading and quality control. In the case of tomatoes, the political influence of New Zealand glasshouse growers has led to imposition of quotas. The frequently suggested solution of processing that part of the crop which is surplus to export requirements does not appear to be a viable alternative, as processing, with its high capital investment, also has imperatives in maintenance of supply at rigid levels of uniformity and quality which are difficult to meet when production is supplied by scattered and only partially commercial smallholders.

Most of the strategies which have been proposed for raising the income levels of Pacific Island smallholders call for some form of more intensive agriculture and require greater labor inputs into the commercial part of the agricultural system. The apparent decline in the rural workforce in a number of Pacific Island countries has already been noted, as has been noted the general tendency for agriculture to become less, rather than more, labor intensive. Examination of the age structure of rural populations in many parts of the region reveals high and increasing dependency ratios as more and more people migrate to urban or peri-urban areas both within the islands or in New Zealand or the United States. With few exceptions, it seems unlikely that an adequate labor supply will be offering in the medium term for intensification of agriculture (e.g. through intercropping) unless this intensification is brought about through increased levels of capital investment. It seems unlikely that this will come about within the mixed subsistence-cash cropping system.

OPTIONS FOR AGRICULTURAL DEVELOPMENT

The Pacific Island countries, particularly the smaller ones, are faced with a number of dilemmas in assessing alternative agricultural strategies for the next one or two decades. The underlying elements include the restricted environment; constraints imposed by isolation, fragmentation, and small size; the conflict between governments' need for revenue and export generation on the one hand and the social desire to promote smallholder rather than large-scale units on the other hand; and the depressing effects of emigration and remittance income on agricultural activity. Obviously not all these apply in every country and some countries have particular problems to accommodate.

The options open to Pacific Island countries for planning their future agricultural development can be illustrated by taking a range of examples from different countries. Perhaps the starkest situation is that facing Kiribati. Given the extremely restricted physical environment of this atoll state and the absence of any alternative basis for sustained economic growth, it may be necessary to examine the prospect for returning to a more self-sufficient form of rural production. Even if the existing level of civil service employment and government services can eventually be maintained from income received from the Revenue Equalisation Reserve Fund, built up in recent years from royalties on phosphate exports, it is clear that at least the existing rural population will have to be supported by agriculture. At present an extremely high proportion of food is imported, and environmental conditions make import replacement through local production of starchy root crops virtually impossible. The possibilities for import substitution with alternative foods are also limited. The only option appears to lie in intensification of multistorey cropping using a range of nut and fruit trees which are grown in a number of Pacific countries on relatively poor sandy soils. These include breadfruit and pandanus, the latter already being a major staple food. Bananas are said not to grow well in Kiribati, but with improved techniques of mulching and composting, and trials with varieties which appear to survive on sandy soils elsewhere in the Pacific, they might be added to the range. Other crops such as Polynesian arrowroot (Tacca sp.) and Alocasia might also be added. But the best possibilities probably lie in fruit and nut trees. If the "compound gardens," comparable to those found in villages in Southeast Asia and elsewhere in the Pacific, could be deliberately expanded and diversified, a stable and more varied form of production might be developed.

For commercial production, the coconut appears to be the only significant potential source of the cash crop. The impossibility of supporting the existing populations entirely from commercial copra production has already been noted, but it might be possible to extend the range of commercial products derived from the coconut. The export of "heart of palm" might be developed in conjunction with the existing program for replacement of aging palms and the growing of new selected planting material. Whether hybrid palms can be developed for atoll conditions is an open question, but it could be examined. Coir, charcoal, materials for pharmaceutical use, synthetic resins, fillers, and building material are all possible products. But whether production of these would be economic from smallholdings on widely scattered islands is unknown. The use of coconut stem timber, now possible through the recent development of new milling technology, might also assist and provide additional income sources to planters with aging coconut stands. This strategy of developing a stable and diversified agriculture for both export and subsistence may be the only long-term prospect for agriculture not only in Kiribati but also in the North Cook Islands and on other atolls or isolated islands.

Those island countries, such as the Cook Islands, which have special relationships with metropolitan countries, may have certain advantages, at least in market access. This is the basis of previous attempts in the Cook Islands to develop an export trade in tomatoes and other fresh vegetables and is also crucial for the canning of orange juice and pineapple which has provided one of the bases for the Cook Islands' export agriculture. At present these industries are hampered by the fact that canning takes place in a relatively large plant in Rarotonga whereas much of the production occurs on the other islands. Thus bulky and perishable materials must be transported long distances at relatively high cost prior to processing. The commercial viability of this operation is questionable, and it may be that small-scale processing on several islands would be more economic. Yet the whole tendency towards the increasing scale of processing units militates against this solution. Furthermore, it is questionable, given the free access which Cook Islanders have to New Zealand and the levels of income they can earn there, whether the necessary labor will be forthcoming for expansion of commercial agriculture. Ultimately it may be that the only really viable form of agriculture in the southern Cook Islands will be for local, urban, and rural food consumption.

The only country currently supplying the New Zealand fresh vegetable market which appears to have a prospect of meeting the labor requirements of intensive agriculture while having suitable soils for intensive market-garden production is Tonga, and then only on the island of Tongatapu, the destination for most internal migrants. A dual strategy may be possible in Tonga. On the one hand, in the outer islands that have stable or declining work forces, farmers may have to rely on relatively extensive forms of production based on the coconut. On the other hand, in Tongatapu the creation of an export industry based on a relatively wide range of food crops may be possible. Such an industry would probably require a high level of centralized management which might be based on some form of cooperative organization or a centralized marketing authority. The need to maintain steady production levels might require a core of relatively large holdings, but these could well be supplemented by smallholder producers. This implies increased polarization between large and small operators, and although this might be viewed as socially undesirable, it is a trend which appears to be developing already. The large holdings need not be individually owned. Some form of processing is probably an essential ingredient of such an agricultural complex, and this will also impose different but no less rigid requirements. In essence it would require a "plantation management system" overlying a mosiac of large and small producers who, if the industry is to be successful, would have to accept a high degree of direction both in their agronomic and marketing operations.

In the Solomon Islands the dichotomy between enclave plantation agriculture and village-based mixed subsistence-cash cropping is marked. Social resistance to settlement of migrant smallholders may well limit the possibilities for establishment of projects embracing grouped smallholders under general management. Given the apparent availability of land, provincial governments in the Solomon Islands may well opt for further large-scale plantation development under some form of state management. The extent to which the technologies employed on such estates will diffuse to village agriculture is uncertain, but the need of governments for revenue may well take precedence over other goals in the design of future development programming.

In Western Samoa the plantations operated by the Western Samoa Trust Estate Corporation (WSTEC) might well be developed to provide a revenue base for government and a stable core for export production. A previous choice of unsuitable planting material resulted in a major decline in WSTEC's cocoa production and demonstrated some of the risks involved in dependence on a narrow crop range in small countries. It also demonstrates the need for extremely high levels of managerial and agronomic competence.

WSTEC provides an example of a form of state-owned plantations which may become increasingly attractive to both national and sub-national governments in several Melanesian countries. Whether such enterprises will have much impact on smallholder producers is doubtful, unless deliberate attempts are made to utilize management and technical skills available on the estates to provide a supra-structure for neighboring smallholders, both independent farmers and those producing within the village systems. For those countries where land is more plentiful the long-term goal should probably be to develop a variety of systems under which smallholders can combine under some form of joint marketing and input provision.

This last option implies major social changes. One implication is a move away from traditional subsistence forms of communal organization and an increasing degree of individualism both in production and social organization. It is clear, however, that this trend is much further advanced in several Pacific Island countries than is commonly acknowledged.

Fiji, with its varied environment, variety of export crops, and its long experience of smallholder production under centralized control, is clearly the most "advanced" country in the region in terms of the maturity of its agricultural economy. The mixed ethnic composition of its population imposes certain prerequisites on development policies if income differences between communities are to be reduced. However, Fiji with its relatively high levels of education, wide range of tertiary training institutions, professional resources, and institutional infrastructure may have the possibility of moving into a more complex agricultural economy than any other Pacific Island country. This would entail further industrialization on an agricultural base, exploiting the relatively wide range of products in order to produce more highly valued items such as confectionery, processed coconut products, and a wider range of commodities derived from sugar cane.

It is clear that a number of options are possible for states within this region. However, only the largest countries, and those with the most varied resource base, have much hope of taking advantage of those opportunities which are likely to produce, on a commercial basis, the levels of living which people from the Pacific now appear to seek. Agriculture in the past has been the basis for the economies of virtually all Pacific Island countries. For some countries at least it would appear that this sector will not be able to provide levels of living approximating those which people have come to accept, unless emigration and foreign aid continue for a long period.

LAND, FOREST, AND PEOPLE

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> The forest is unique organism of unlimited kindness and benevolence that makes no demands for its sustenance and extends generously the products of its life activity; it affords protection to all beings, offering shade even to the axe men who destroy it.
>
> Buddha

Introduction

The human race began in the tropical area of the world. The date of human occupation of Papua New Guinea is estimated to be around 30,000 years B.P., and man developed agriculture to the point where he could feed domesticated pigs 8000 years ago. So agricultural techniques must have started much earlier.

Now Papua New Guinea and parts of the Pacific Islands are one of the very few areas of the world left with much of their natural environment intact. This indicates clearly the success of the ecological adaptation of the small communities in the Island World: they had intensive root cultivation, and their political organization was centered around relatively small but elaborate social system before Europeans entered the region.

Now, in less than 100 years, the rest of the world is getting close to robbing these natural resources in the Pacific Ocean. This region and its resources has become a larder for the capitalist countries to raid at a time when one of the greatest problems that faces the world is its misuse of natural resources. The most important part the island communities could play is to teach the rest of the world the need to live in harmony with the environment, preserving a lifestyle for the future generations. For example,the national constitution of Papua New Guinea says: "We declare our fourth goal to be for Papua New Guinea's natural resources to be conserved and used for the collective benefit of us all, and be replenished for the benefit of future generations." Since Independence the national government has passed several laws on environmental considerations.

The political movements for independence in the island societies ranging from West Papua against Indonesian control to the French domination of "her" part of Polynesia are not struggle against imperialism only; they are also instances of different cultures warring over ecological concern. They are struggles between two views of man and nature: the view that man must conquer nature which leads to the destruction of man's natural habitat versus the view that man must use and at the same time conserve the riches of nature. This ideological conflict takes place at a time when the world as a whole is facing ecological crisis. It will avail us little if we attain world-wide communism in a world made unfit to live in by pollution poisoning and exhaustion of energy sources,not to mention the loss of all natural beauty.

The struggles of the villagers against multinational corporations are not only the struggles against the hegemony of the global economic system of exploitation; they are also political stances against the destruction of the resources and mismanagement of environment. Some international organisations such as Man and Biosphere, are becoming aware of the importance of ecosystem. For example, MAB's objectives are "to develop the basis within the natural and social science for the national use and conservation of the resources of the biosphere and for the improvement of the global relationship between man and the environment; to predict the consequences of today's actions for tomorrow's world and thereby to increase man's ability to manage efficiently the natural resources of the biosphere."

I do not intend to detail these struggles of the various island communities. I will confine my analysis to Papua New Guinea. The paper starts with brief backgrounds of the small community to which I belong and particulars of a multinational corporation which rushed to exploit forest resources before national independence on 16th September 1975. It goes on to outline some of the major issues and to describe the struggle between the villagers and the government.

BINANDERE AND PARSONS AND WHITMORE

Binandere struggle against imperialism

Papua New Guinea's land mass is estimated to be around 46 million hectares; and it is said that 86% of it is covered with forest that comprises more than 200 tree species; and there are about 3 million people most of whom live on the land and inhabit the forest.

This paper is concerned with a portion of the total land mass which is about 76,500 ha of which around 60,000 ha are heavily forested; and there are about 40,000 inhabitants in the relevant two provinces. More specifically I want to concentrate on a group of people called Binandere who occupy a central part of this area and whose population is about 5,000. The Binandere provided the basis of a political struggle against several transnational companies during 1973 and 1974, when the villagers rejected the proposals of the corporations and the national government accepted that rejection. As a result, the companies were prevented from installing a paper pulp mill in the area or in any other part of Papua New Guinea.

Binandere occupy the lower plains of Mamba, Gira, and Eia Rivers in the Northern Province of Papua New Guinea. They are subsistence farmers and warlike people. The warriors defended their land against any enemies, but their violent fight against imperialism began with the arrival of Captain John Moresby in his ship Basilisk in 1873. Moresby thus described the confrontation: "Suddenly they sprang from the bush to open beach, and formed in two regular lines ten yards to my port - the first line of men armed with spears, which they held quivering to throw, whilst they moved with a short quick step from side to side, as if to distract an enemy's aim,guarding themselves with shields. The second line was armed with clubs. For some seconds I forbade to fire, hoping to win them round, but finding this hopeless, and that in another second I should be a target for fifty spears, I fired with a snap shot at a leading savage."

Two decades later the villagers fought against the British colonial administration with clubs, spears, and sticks. The warriors killed about four gold miners and an official. During the last six decades, from 1900 up to the present, Binandere organized sporadic resistance against colonial rule through organized political movements.

The recent struggle against multinationals began in 1972, when some of the leaders physically confronted officers of the Forest Department who were taking tree samples without the permission of the village landowners. The villagers realized that these samples were to be used in feasibility studies for forest exploitation by transnational corporations.

For the Binandere, who were the major contenders, the events of the period from September 1973 to June 1974 were inextricably bound up with the history of the previous century.

Parsons and Whitmore and its tentacles

Let us now turn to the background of a particular international corporation. This is Parsons and Whitmore which is an international group of companies. These are two giants which merged into one under the name of Parsons and Whitmore. The first is P & W and the other is Black and Clawson, both of which originated from the USA and Canada. Both seem to have started around 1853 and to have come together under one name around 1950. By 1973 this multinational has spread its tentacles around the entire world. The organization of Parsons and Whitmore has three divisions for operation and specialization purposes. The first consists of project companies which built 55 projects in 27 countries around the entire globe with a total investment of $ 1.3 billion. P & W projects include the following: 1 in the USA; 2 in Canada; 3 in Southeast Asia - India, Vietnam, and Japan; 8 in South America including Mexico, Brazil, Argentina, Chile, and Cuba among others; 8 in Africa - in Tunisia, Algeria, Madagascar, Ethiopia, Egypt, and three other countries; 23 in such European countries as England, France, Spain, Austria, Italy, Greece, and other.

The second division of P & W involves the operation of pulp and paper mills. The third area of specialization covers machinery manufacturing. Parsons and Whitmore uses raw materials ranging from various species of straw to diverse landwoods and its products range from bag papers to newsprint and to electrical appliances.

THE CONFRONTATION BETWEEN THE PEASANTS AND THE INDUSTRIALISTS

Industrialists approach to Papua New Guinea government. Having presented the backgrounds of the Binandere and Parsons and Whitmore, I would like to turn to the events and issues that brought the two groups into confrontation. What was at stake and how did the situation develop? Let us bear in mind the political context of the confrontation.

Papua New Guinea was to receive Home Rule on December 1, 1973. With the possibility of exploitation under direct colonial rule coming to an end, P & W hoped to find in Papua New Guinea one of its last victims. The first step in this process was the international company's approach to the PNG government.

This is what the P & W company said when it came to present its feasibility study to the PNG government: "Do you want development? If you do, there are three important keys. The first key is capital." P & W proposed to invest $ 124 million in PNG. "The second key is technical expertise." P & W intended to install the latest most modern and sophisticated technology in the construction of a pulp mill for paper production.

There is the important issue of the machines and technology. The multinational has certain machinery to exploit natural resources that the colonized country does not have. The more complex the machinery, the less likely Papua New Guineans are to be able to replace it, built it themselves, or service spare parts by themselves. This allows for unequal exchange, as the multinational companies are placed in dominations because they have full control over the means of production. Needless to say that the heavy machinery is not ideal for the tropical forest ecology, and high consumption of energy where all the fuel has to be imported make it costly. Thus the question of what techniques and machinery should be used in terms of least degradation to environment and the cost for output is not really considered.

Nevertheless, Parsons and Whitmore convinced the Papua New Guinea government that it has two keys, but the third and fourth keys - forest resources and human labor - remained with the government and the villagers. The capitalist ideology advocated that there are four keys to bring about "development," and that they have the vital first two.

The second step involved the PNG government's approach to the village people. The national leaders accept the capitalist system - possibly as a good thing in itself, certainly as a means to an end - the end being "development." And the government imposes this system through ideas and practice. This ideology and its practical results reach the mass of the PNG population through the national government asking the same set of questions without putting forward alternative choices. But let us look at some of the issues and conditions the multinationals impose in order for the primary resources to be sacrificed at the altar of "development."

One of the major issues in the discussion of the proposal of this "development" was the question of benefits to the villagers. The big selling point of the "development" proposal was that a town was to be established in which there will be "free" hospitals, roads, welfare services, an interdenominational church, a school, etc.

Secondly, some cash was to be paid out in the form of royalties. Early capitalist exploiters give their often unwilling host only the minor incidentals of extremely low paid employment at whatever physical plant the company required. Since most countries are now independent and there is an increase in Third World expectation, the capitalist ideology adopts a principle by which some money is given back in return for <u>cheap</u> resources and labor. There was a yardstick by which P & W intended to pay for the trees cut: 75% this royalty money would go to the government and 25% to the owners of trees. According to the schedule that was issued, the company indicated that the villagers would be given K 50,000[1] in the first 4 years. But according to the feasibility study the company promised the government about K 10 million per annum when the company

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[1] The currency unit of Papua New Guinea - 1 K (kina) = 100 toea equals approximately US $ 1.5.

was in full operation. It is to be noted that the villagers were not going to be given 25% of K 10 million. Divide K 50,000 among 40,000 people and each person was to get a little over K 1.00. But further divide K 1.00 by 4 years and each person was to get about 20 toea per annum.

It has been experienced in other large timber and oil palm projects in this country that such royalties are not useful to the people. In reality the payments for land, timber rights, and royalties could hardly support a nucleus family let along clans. In West New Britain Province the PNG government and British Development Corporation jointly own a large Oil palm project. The compensation paid between 1968 and 1978 averaged K 36.00 per person for land, about K 8 for timber rights, and K 10 for royalties. In the Madang Province a Japan-based multinational has cut forest over a large area of land. But, when the tree owners approach to buy some timber they are obliged to pay sums which exceed considerably the royalties paid for the same amount of timber.

The point to stress is that tropical forest never regenerates because the soil is enriched only by the forest itself as it is clear from the example of the Trans-Gogol in the Madang Province in Papua New Guinea[1]. Thus the royalty yardstick is a good example to illustrate that it is extremely difficult to see any concern for quality of "development" in the face of the demand for quantity of exploitation inherent in the capitalist ideology; and the fundamental issue of environmental impact is avoided completely.

The third issue was employment. Bearing in mind that there are 40,000 inhabitants who stood to lose their natural forest, the birds and animals that contribute much needed protein to their diet and that figure in their social, psychological, and ceremonial life, and the regenerative capacity of the land, P & W proposed that only 119 nationals or Kanakas would be employed: and this number would decrease when the project got established. Moreover, the Kanakas would get between K 500 and K 1000 per year, while the foreigners receive between K 10,000 and K 14,000 during the same time.

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1) Here we pass over the need for capitalist multinational companies to expand, their constant search for new areas to exploit and the issue of how they learn about new potential areas. Reports such as "Papua New Guinea, Its Economic Situation and Prospects for Development" was presumably an important stimulus for Parsons and Whitmore.

Papua New Guinea's government's aim to exploit forest resources for the interest of the nation enhances capitalist exploitation. It happens in this way. Multinational corporations and the national bureaucratic elite colloborate together, to make exploitative decisions against people interests.

For all these reasons, some politicians have fought for Papua New Guinea to have a policy of decentralization since Independence. Small community control over their forces of production and the planning on local level is thought to be better by these leaders than centralized planning. I agree with this as an environmentalist, because the villagers will conserve and regenerate their environment, which they live with and love for, better than any other person.

Developed countries still have a few non-tropical forest resources but they prefer to keep those for their future generations while they push to destroy forest resources in tropical countries including PNG. The excuse they offer is that they find exploitation uneconomical because of the high cost of labor in the developed countries. The USA, for example, having been forced to release its slaves, could not get timber because it has to pay its labor $ 500 per month; therefore its businessmen and companies hope to come to places like PNG and pay $ 500 per year. Now I want to turn to the actual struggle itself.

THE STRUGGLE BETWEEN VILLAGERS AND NATIONAL GOVERNMENT

Selling ideology

Some of the national politicians accepted the wish of the company in principle or most of the major issues outlined above, because the government was reluctant to lose a source of revenue and the possibility of employment created through foreign investment. Foreign economic and financial advisers influenced the politicians to persuade the landowners to sell their timber rights. This was the way in which the government organized to sell the capitalist ideology to the villagers. But before I describe this, let me emphasize that the struggle was not between the government and the 40,000 inhabitants but between the government and the Binandere whose population is about 5,000. Their land was important because it had some of the best quality forest resources such as hardwoods.

The land and forest is a capital resource. That is, it is a vital force of production which has the capacity to renew itself, and keeps the owner of the land all his life, his children, and the future generation. The energy of the forest is the energy that PNG forest agricultural dwellers tap in the practice of swidden gardening. This form of gardening gives the higher return per unit of human labor than any other system, even higher than the industrialized agriculture. This is why the Binandere were prepared to violently oppose exploitation of their resources. The government was alerted to this opposition. Therefore, some politicians and other officials organized to go to the Binandere country with helicopters. They only landed at three villages, and spent three days to conduct their "initial consultation." The officials returned to Port Moresby and announced: "Yes, the people want development." Officials went to the villages and presented P & W capitalist ideology and asked exactly the same questions that P & W had asked the PNG government. "Do you want development? If you do, P & W say that there are three keys - capital, technology and forest resources. You give this company the rights to clear out your national forest and within 20 years we will bring development to you." The government had no alternative choice to offer to the villagers, because the government had already decided what it wanted without reference to the villagers and presented the P & W plan as the only way towards "development." The philosophy of self-reliance was pushed aside. The ideal of self-reliance was one of the major bases that posed a challenge for some of us to engage in struggle against the acceptance of the proposals being made by P & W and the PNG government.

Villages' reaction

How did we organize against the acceptance of the proposals? Mr. M. Jiregari, Mr. R. Tamanabae, and I were involved in the struggle. There were three levels of organization and coordination.

1. National. On the national level, the three of us were invited to take part in the helicopter trip. We all refused flatly on the following grounds. Firstly, we did not want the people to see us as the agents of the company as this would later affect our relationship with the villagers whom we were trying to represent. Secondly, the feasibility study, detailed proposals, and other technical and legal information were not made available to us. Thirdly, the politicians took a "now or never" standpoint: "Accept P & W's proposals or there will be no development." The government's priority was to get immediate permission for the company to establish its operation in the area, but the government was not working to get a better deal from P & W for the villagers.

2. Provincial. On the provincial level there was an association called Komge Oro. This association emerged in 1967 and by 1973 it had some influence among some people whose land was of interest to P & W. The association has several objectives one of which was to

"protect exploitation of all the resources by outsiders until such time as the local people are in a position to exploit the resources themselves." Mr.Jiregari, Mr. Tamanabae, and I were executive members of the association, so that we were able to influence some leaders and the members to take their stand against the approach of the government. The President of the association, for example, traveled with the officials in the helicopter and represented the association.

3. Local. On the local level there were three important groups of people. Firstly, the Local Government Council which was responsible for the Binandere as well as another tribe, the Aega. The councillors were divided: some took sides with the national government and argued that P & W's proposal be accepted. The others, including the President of the Local Government Council, articulated the voice of the villagers against the national politicians and the P & W proposals. Secondly, the Anglican Church, especially the leader, Rt. Rev. Bishop Hand was suspicious about the intention of P & W and took the side of the villagers who were opposing the multinationals. The third, most important group on the local level, were the ordinary Binandere themselves in the villages. In terms of strategy, a relay of communication between the villages and Port Moresby was essential.

Harnessing the supporting elements in the local, provincial, and national levels in the campaign determined the strength of opposition. But the spearhead of our opposition began in this way. In the beginning of 1974 I was in my village after an absence of 14 months overseas. I was called upon to represent the association and villagers at the conference table. I came to Port Moresby to attend these meetings and negotiate timber rights. During the first meeting it became obvious that P & W were determined to go ahead with its operation, and that the project had reached an advanced stage without the landowners having heard anything about it., let alone being consulted. It was clear to me that the participation of the people at every point, a fundamental principle for negotiation, had been ignored from the outset. I had to decide whether to serve the interests of P & W or to represent the villagers. I chose the latter because of my strong commitment to village life as well as my ideological views. This meant that my colleagues and I committed ourselves to a number of activities. Jiregari, Tamanabae, and I had to mobilize the Binandere in Port Moresby and at Popondetta Town as well as the villagers themselves. We had to pool together resources - money, technical information, and legal advice. We had to organize deputations from the villages to meet with government officials in Port Moresby. We had to coordinate the flow of information between the villages and Port Moresby via Popondetta.

The real challenge on our part was embarked upon after the government had concluded its tour of initial consultation in the helicopter. Jiregari, Tamanabae, and I went to the Binandere land to test the government claim that the people accepted the proposals. It took us about three weeks and this is what we did. Tamanabae visited all the villages on the Mamba River, Jiregari visited the ones on the Eia River and I visited the villages on the Gira River. Then the three of us held meetings with some of the leaders and the village representatives in the three villages where the government officials landed in the helicopter, i.e., Manau, Nindewari, and Tave.

At Tave village, after we explained P & W's intentions, Jigede, a big man who confronted the officers of the Forest Department earlier, said to us about the value of his forest.

"I did not ask the national parliamentarians to invite the whiteman's company to destroy my land. I told them to tell the company that I only want a road outlet for selling cash crops. The trees near the road can be cut for the company. But now I know that it intends to clear-cut my forest. Trees do not grow in the air, but on the land. The forest is a source of my medicines, my wealth, and my everything. Our ancestors owned the place, and we have the hunting rights. Not only will the ancestors curse me for accepting a few dollars in exchange for the irreplaceable resource, but also the young generations will condemn me for my decision to invite the company. Ancestors have lived here. I am living on the same land and I want the future generations to have good gardening land.

If the company ignores my words, say to it that Jigede has said so, and if it ingores again, I will impose this condition: the company must pay me, my wife, and each member of the family and the extended family a sum of $ 1000 every day for ever. Every Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday they must all be paid $ 1000. Not on Sunday, because it is God's day of rest. My children and their children's children must get this sum daily in order to live. These sums added together are nowhere near the price for my land and forest. If this company is mean and does not want to give this token gesture for destroying my livelihood, not only mine and my families, but also that of every single person in the village, warn the company to forget about my trees on the land."

Jigede is concerned about the capital resource. He fears that it would be replaced with money, a small amount of money which is not capital; you and I know that, There are no means of production that my people can buy with that money more productive than that forest! My people do not want to be laborers nor do they want others to be wage slaves.There is no human pool of wage slaves we can employ with that money.Nor do we want to create any.That money is not potential capital; it is cigarette money only, as we have already noted that compensation payments for land, timber rights, and royalties do not sustain a nuclear family.

Thirdly, after consulting with the villagers we met with councillors in their chamber at Ioma and discussed with them our findings. Fourth, we held a meeting at Popondetta Town to inform the supporters as to the decision of the villagers. Fifth, we returned to Port Moresby and declared to the government: "No, the people do not want the type of development presented by P & W and accepted by the government." The latter's response was "never trust the educated big 'communist agitators.'" The officials organized a plane and they invited us to go with them to a village for a confrontation in June 1974. This was near Ioma where some village leaders of the entire Binandere population as well as the councillors had gathered for the occasion. The confrontation was organized so that each party had a chance to present its case. Two national Ministers, an ordinary Member of Parliament, plus other officials sat on one side; Jiregari, Tamanabae, other leaders, and I sat on the other side; and the village representatives, councillors, and some villagers sat in the middle. The middle party heard the views of either party, and the meeting ended in a violent manner. Jigede, the big man, decorated himself in a traditional costume. He brandished his pineapple club in the air and chanted a war cry and gave the club to Mr. Jiregari saying: "This is the power of the people, a symbolic power, that you continue to defend the land and the people against the system of exploitation. Our ancestors have done it against any intruders. We must fight the company in order to save the future of our grandchildren." No one had dared to speak after Jigede had spoken and the issue had been decided; the majority of the representatives of the Binandere people rejected the proposal of the company.

Jigede's warnings against the multinationals remind me of the statements of a leading international trade unionist, Charles Levinson. He warns that the transnational corporations "control directly about 75% of industrial production around the world, 60% of exports and have about 80% of the world's financial markets - virtually creating a whole new international economy. We have to tell our people that these are becoming the dominant new force in the world." Jigede and Levinson would agree that multinationals reduce human beings into units, and therefore the sturggle is to fight for their rights against the transnational system of exploitation. As Levinson concludes: "You can't expect anyone operating in sums of billions of dollars (such as P & W) to be overly concerned about the rights of people (Papua New Guineans) who themselves might number millions, but who in economic terms become the masses - just ciphers."

So far I have described the struggle of the Binandere community against P & W. Now I would like to turn to their aspirations. During the struggle one important factor that emerged was that the villagers, or most of them wanted to remain owners of the land and trees, and that village development has to be built on what there is - the villagers, and their resources, especially subsistence farming. Secondly, there was a need to organize transport on the natural river system to take cash crops out for sale and bring in goods for sale in the villages - a kind of producer and consumer cooperative.

Since the overthrow of P & W in 1974 the Komge Oro Association described earlier has tried to put into action what the Binandere wanted. Komge tried to introduce several projects. One project is a pig and poultry center and the other is to establish a base to which the people could bring cash crops to be transported to main ports for sale; and to distribute consumer goods at the village level. The association bought a 20-foot boat and several dinghies for this purpose. Between 1975 and 1978 some projects, although started well, failed to materialize, because of poor management, lack of leadership, and lack of any assistance.

This failure had provided a pretext and a powerful weapon for our opponents to reissue their call to invite multinational corporations in investing in the area. The opposition consists of those villagers who supported the government during the fight against P & W and the national and provincial politicians. During 1978 some politicians paid several visits to the Binandere territory in order to sound out opinions in preparation to reopen negotiations on behalf of the multinational corporations. By the end of 1978 a combined Hong Kong and Saudi Arabian company presented their proposal for logging and sawmilling. On New Year's Day, 1979, Mr. Tago, Minister for Home Affairs, Mr. Bonga, provincial Minister for Transport, and Mr. Dickson, provincial Minister for Education presented the proposal to the Binandere. M. Jiregari's father who is also a big man and a powerful village magistrate declared the position of the Binandere.

"I warn that this is the last meeting of this kind. The Binandere conquered tribes to occupy its territory. From now on if any clans collaborate with foreigners to exploit us and our resources, those collaborators, including politicians, will be our enemy and there will be killings. In doing so the Binandere will kill off itself, and the land will be empty of its owners. Until then the foreigners will not use our land."

The villagers celebrated New Year's Day with a political victory.

The Binandere case brings out several important lessons. Firstly, too many administrators and politicians hold the villagers in contempt, avoiding even a semblance of real consultation. Only if there is an opposition expressed through a sophisticated medium, are they forced into real consultation. That is to say the PNG government does not believe that the views of the villagers based on their attachment to subsistence farming should be seriously taken into account when making major decisions that affect the people and their resources. The reason is simple: the government wants to set the basis and the pace of the "development" of this country with contacts made with the expertise and capital of the multinational companies. One major consequence of this is that this type of development is doing much to destroy the subsistence base. In a nutshell, PNG, its citizens, and its resources are daily drawn into the orbit of multinational hegemony whose roots are based in the West and East, and whose branches have spread to north and south, and whose tentacles of economic exploitation are swamping across the Pacific Ocean.

Conclusion

In the international context, the Binandere struggle against transnational exploitation is like a small dog barking, barking at a big wolf only to be swallowed and eaten sooner or later. Within the PNG context the struggle is like a dog barking at a huge wild pig which is uprooting the forest resources. There is a proverb from the backgrounds of Parsons and Whitmore's origins which says: "The bark is worse than the bite" i.e., don't worry about it. But I believe that Papua New Guinea people hold a different view. And I must hasten to conclude with the Binandere proverb: "The dog does not bark without biting to inflict a wound," and I hope that blood poisoning will set in.

MEDICAL ASPECTS OF ENVIRONMENTAL PROTECTION IN THE COUNTRIES OF THE PACIFIC REGION

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The International Pacific Science Association created in the 1920's aims at solving major problems concerning all the countries in this region. A remarkable diversity of problems is a result of the fact that the Pacific region occupies a considerable part of the globe and is characterized by a tremendous diversity of natural and climatic conditions, so the second name of the Pacific Ocean - the Great Ocean - is well justified.

Along with such industrialized countries as Australia, Japan, the USA, and the USSR, the region incorporates many developing states, varying in the stage of their social and economic development. Geographically, the Pacific region stretches from the Extreme North - Chukotka and Alaska - to the Extreme South - the Antarctic.

At present, there exists a number of global problems which receive primary attention on the part of both general public and governments of these countries. The key problems include peace maintenance, and the promotion of multilateral advantageous cooperation in such vitally important areas as the preservation of energy and natural resources, the provision of population with food products, the improvement of living conditions, a comprehensive study of the Pacific Ocean as a source of various resources, etc. In recent years very important is the problem of environmental protection from chemical, physical, and biological pollution. The reasons for its emergence are well known.

The urgency of this problem in the developed countries is explained by the scientific and technological revolution, urbanization, and the growth of industrial production which is accompanied by a growing impact of chemical, physical, and biological factors on the population. These factors pose a potential threat to the health of the present generation, and in a number of cases, threaten the health of the future generations, too. In the developing countries this problem has its specific features, and the top priority among them belongs to the fight against infectious diseases caused by microbes and protozoans. Such diseases are the main cause for mortality, primarily among children. Most populated areas have neither sewerage, nor central water supply, nor domestic waste disposal. Besides, there is a shortage of good-quality food stuffs. The growth of industrial development accentuates the importance of environmental protection from chemical pollution.

The well-known influence of bad-quality water on the onset of human diseases has been once more confirmed by the outbreaks of diseases in the USA, Puerto Rico, and Portugal in 1974-76. These outbreaks were caused either by chemicals (ethylacrylate, herbicides, lead, polychlorinated biphenyl) or infectious agents, such as Lamblia intestinalis, Shigella, Salmonella, hepatitis inducers, and cholera vibriones. Iersinose outbreaks in 1974 resulting from the consumption of contaminated surface and well water can also vividly illustrate the significance of drinking water in the origin of diseases.

The environmental problem is characterized by an exceptional complexity; it is incorporated into various aspects of interaction between the human community and the environment. Of paramount importance, in our opinion, are medical, biological, and hygienic problems. The emphasis on these aspects is only natural for medical specialists who are well aware of their vocation to protect the environment in the interests of man's health. Specialists in other fields will agree that the contaminated and deteriorating environment can have a direct adverse effect on the state of public health. At the same time, various negative changes in the environment causing economic damage, violating a natural balance of different ecological systems, and provoking aesthetic and moral damage should be regarded from a medical point of view, too, as, in the long run, all the above-mentioned changes produce direct unfavorable impact on the conditions of human life, and consequently, can deteriorate man's health.

The major objective of environmental protection in terms of medical aspects for the industrial countries is to prevent the unfavorable action of chemical, physical, and biological factors on the population. As for the developing states, the priority issues are concerned with the control of infectious diseases, reduction in children's mortality, adequate food supplies for the community, adequate water supply system, etc.

It should be pointed out that the state of the environment is an essential component in the system of the initial medical and sanitary assistance for the population. These problems were discussed in detail at the International Conference held in Alma-Ata last year. The participants acknowledged that the conference was a noticeable step forward on the way to improve the living conditions of people, first of all, in the developing states.

There is sifficient literature concerning the influence of natural and climatic conditions on the relationship of man and chemical, biological, and physical factors.

In view of this, there is a need to elaborate a regional approach to the regulation of pollution. In the "man-environment" system, environmental pollution is a component of the environment, which influences the health both of any individual and of the population as a whole. The degree of direct and indirect influence of the regional peculiarities may vary, and sometimes the indirect effect can prove to be more pronounced.

The urgency of environmental protection can be illustrated by the present state of sea and ocean pollution. In fact, the seas and oceans are the ultimate receptacle of multiple wastes produced by man's economic activity.

Toxic chemicals and fertilizers used in agriculture, industrial and domestic sewage discharged into rivers, contaminated atmospheric precipitation - all this eventually finds its way into the seas and oceans. At present, the World Ocean cannot be regarded either as an inexhaustible source of natural resources, or as an invariable receptacle of the unlimited amount of various pollutants. The hazardous sanitary and epidemiological consequences produced by industrial and domestic contamination of the ocean waters are made more and more manifest. The epidemiological importance of coastal sea water pollution is confirmed by numerous data showing the connection between the use of polluted sea waters and various sea products by the population and the outbreaks of acute intestinal, upper respiratory, and skin diseases, helmintosis, conjunctivitis, and otitis. The deterioration of the sanitary state of coastal sea waters in most parts of the world verifies the fallibility of the concept of the unlimited capability of seas and oceans for self-purification and makes it necessary to carry out measures aimed at the protection and sanitation of the World Ocean.

At present, about ten million tons of oil and oil products get into the World Ocean. Their persistent presence in the sea water not only has a hazardous effect on its flora and fauna, but also can impair the exchange of energy, heat, humidity, and gases between the ocean and the atmosphere.

Radioactive contamination of seas and oceans holds a special place in the wide range of chemical pollutants that differ in their origin and chemical structure. According to the data published by UNESCO, fresh and sea water ecosystems are contaminated by man-made radionuclides such as strontium-90, cesium-137, etc. High concentrations of such products as zinc-65, cobalt-56, chromium-51, and iron-55 accumulate in the tissues of sea organisms.

The original sources of radioactive contamination of sea water were A-bomb tests in the atmosphere conducted after the World War II in the southern part of the Pacific; in subsequent years radioactive water contamination related to the operation of the first A-reactors was recorded in the USA and Ireland. Relatively high concentrations of chromium-51 and phosphorus-32 were detected in sea water.

Among the most common and hazardous pollutants are certain heavy metals, above-mentioned oil and oil products, chloro- and phospho-organic pesticides, radioactive substances. The compounds of such heavy metals as mercury, lead, cadmium, zinc, copper, nickel, cobalt, silver, etc., represent the greatest danger to seas and oceans as far as their pollution is concerned. It is well known that even low concentrations of these metals can produce an adverse effect on man and marine hydrobionts. As a result of the consumption of sea products, heavy metals and other chemicals can get into the man's organism through trophic chains. The significance of this problem can be assessed by the recorded cases of large-scale poisoning in Japan.

Such diseases as mina-mata and itai-itai resulted from water contamination with salts of heavy metals. Mina-mata occurred as a result of poisoning by alkyl-mercury accumulated in fish; itai-itai was caused by a chronic cadmium poisoning. This example is not the only case of poisoning related to the accumulation of toxic substances in the food products of the ocean origin. Such a situation is likely to be a recurrent one,as the salts of heavy metals can continuously preserve an active form and accumulate in water and in sediments. There are the reasons for making the problem of water contamination with heavy metals a top-priority one, though it should be noted that at present, the sea environment is more contaminated with such common pollutants as oil products, chlorinated hydrocarbons and man-made radionuclides. Undoubtedly, these circumstances should be taken into account in solving the problems of the use of food resources of the Pacific Ocean.

It is a common practice to discharge sewage into the ocean. About 228×10^6 L of unpurified sewage is discharged daily in Honolulu (Hawaii). Inadequate sanitary conditions of the community and high population density result in the high content of enteroviruses in the sewage. The water samples showed that the number of viruses was about 12-850 units per liter, while the average 24-hour samples demonstrated that the amount of viruses could reach 8.5×10^{10} units per liter. All this amount finds its way into the coastal waters of one of the most fashionable resorts of the world, making it dangerous for man to use the ocean water in recreational purposes.

It is known that economic activity brings about an increased content of chemical pollutants in the environment. For example, cases of arsenic poisoning were recorded in Canada in 1976;arsenic was detected in the well water of gold-mining areas. Arsenic compounds are present in quartz, and can be washed out by underground waters from the dumped rocks and abandoned mines. The arsenic content of one of the wells reached the level of 5 mg/L. This amount greatly exceeds the permissible content accepted in Canada (0.05 mg/L). Arsenic was also detected in fish caught in the open sea and in the coastal waters of Canada in concentrations which greatly exceeded the MAC (in terms of man's health) for the food products (0.013 mg/L).

Besides data on heavy metals and arsenic, there is also evidence that fish caught in the internal water bodies of the USA and Canada contained DDT (Hallston River, Virginia), mirex, PCB and dioxine (Lake Ontario).

Numerous examples of air pollution in industrial countries, causing the deterioration of living conditions and a threatening growth of human diseases, could be given. A high level of atmospheric pollution in Japanese cities is well known. According to the data obtained by Japanese scientists in 1975-76, an increased content of such pollutants as ozone, nitrogen oxide and dioxide, hydrocarbons, sulphur dioxide, and suspended matter in the air of Tokyo resulted in the impairment of respiratory functions of the lungs of the population. It was also shown that elevated nitrogen dioxide concentrations were associated with an increase of chronic respiratory diseases among the population of the Osaka Prefecture. A comparative study of two Japanese regions different in the level of air contamination with sulphur and nitrogen oxides and suspended matter showed that the sputum of the people in the area of greater pollution had an increased number of cells characteristic of inflammatory reaction which may indicate an impairment of the lung tissues. The district of Tokyo may provide a most striking example: the industrial discharges released from 75,000 factory chimneys caused a sharp (50 times) reduction in the visibility on the Tokyo-Yokosuka highway; visibility reduction, in its turn, led to hundred ship collisions. Mt. Fujiyama is hidden from view by the clouds of smog eight days out of nine. Industrial pollution of the air in this area brought about the extinction of sakura, the national Japanese tree, and a sharp increase of respiratory diseases among the population.

These are only a few examples of environmental pollution in the economically developed countries. In our country the level of atmospheric air, water, and soil pollution has never reached a disastrous magnitude, which could produce harmful effects on human health. This can be explained by the fact that already in 1919 the Program of the Russian Communist Party (Bolsheviks) included a section devoted to the protection of public health, which stated that the primary objective of the Party in this field was "the sanitation of community areas (protection of soil, water, air), and the establishment of sanitary legislation." In 1935 the Sanitary Norms for Designing the Industrial Enterprises included the sanitary classification of industrial enterprises as sources for atmospheric air pollution and specified the dimensions of sanitary-protective zones in accordance with this classification.

Working out a system of state legislation in the field of environmental protection continued in later years. Thus the decision on the Measures Against the Atmospheric Air Pollution was adopted by the Counsil of Ministers of the USSR in 1949. Of paramount importance are the laws on nature protection adopted by all Union Republics between 1957 and 1968. A number of state resolutions, including Fundamentals of Land Legislation of the USSR and Union Republics (1968), Fundamentals of Water Legislation of the USSR and Union Republics (1970), and others, reflected new developments in the environmental protection policy. Of great importance in the environmental protection activity was the Resolution of the CPSU Central Committee and the Council of Ministers of the USSR on the Intensification of Nature Protection and Improvement of the Use of Natural Resources (1972) which outlined the precise legal bases for environmental protection in the USSR and placed the responsibility for nature protection and implementation of sanitation measures on the appropriate Ministries and Departments of the USSR and Union Republics.

Among the key directions of scientific research in the field of natural and technical sciences stands out the necessity for a comprehensive study of issues linked with occupation hygiene, control over occupational diseases, and with the development of rational use and conservation of soil, mineral resources, flora and fauna, air and water. Different norms and regulations enacted into the state laws should be regarded as major components and steps on the way to solving environmental issues; they have to regulate the efficiency of nature protective, prophylactic, and sanitation measures.

Resolution of the CPSU Central Committee and the Council of Ministers of the USSR on Additional Measures on the Intensification of Nature Protection and Improvement of the Use of Natural

Resources (December 1, 1978) is another evidence of the untiring concern of the CPSU and the Soviet Government about these problems. This document emphasizes a tremendous economic and social significance of nature protection and rational use of natural resources.

Our state's concern about environmental protection is reflected in Article 18 of the Constitution of the USSR, which states: "In the interests of the present and future generations, the necessary steps are taken in the USSR to protect and make scientific, rational use of the land and its mineral and water resources and the plant and animal kingdoms, to preserve the purity of air and water, ensure reproduction of natural wealth, and improve the human environment." To verify this, 11 billion roubles have been allocated for the immediate expenses connected with the construction of purification installations and the implementation of other environmental protection programs of the Tenth Five-Year Plan period.

At the same time, the environmental protection became a problem of a global character, for the pollutants can spread over the distances of hundreds of kilometers from their source, both in the air and in water bodies and can be transported through the state boundaries. Besides, in a number of cases certain problems of environmental protection cannot be solved by one, individual country. The only sensible and realistic alternative to this is an international cooperation in such a humane field as the protection of human health from the adverse effects of the environmental factors.

It is natural, therefore, that international cooperation in the field of environmental protection is continuously gaining momentum which is evidenced, in particular, by the subjects of this Congress.

Such international organizations as the UN, WHO, UNESCO, MAIR, MOT, etc., actively participate in the programs aimed at the protection of public health from hazardous effects of environmental pollution and at the sanitation of environmental objects. Among various undertakings in this field we would mention the UN Environmental Protection Program, the International Register of Potentially Hazardous Chemical Agents, the WHO Program for Environmental Criteria, the International Drinking Water and Sanitation Decade (1981-1990) aimed at providing the developing countries with adequate, good-quality drinking water, and other initiatives.

Sanitary legislation of our country is the most comprehensive and scientifically substantiated in the world.

The Soviet environmental health scientists were the first to develop a sound scientific conception of hygienic norm setting of maximum allowable levels for hazardous environmental factors. The observance of these standards protects the population from harmful consequences.

At present, the USSR has scientifically substantiated standards for more than 600 chemical water pollutants, 200 atmospheric air chemicals, for certain pesticides and heavy metals in soil; the state standards have been worked out for the quality of drinking water and the choice of water sources for water supply used for economic and drinking purposes; the allowable standards have been established for a number of physical factors - urban and industrial noise, electromagnetic fields, and radio frequencies; norms for biological pollutants are being developed.

Many countries have gained rich experience in solving the medical problems of environmental protection, so the further promotion of international cooperation, on a bilateral and multilateral basis, would be, in our view, the most desirable outcome of the present Congress.

A NATION-WIDE SYSTEM OF NUTRITION INTERVENTION IN THE PHILIPPINES

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The most pressing problems of the nutrition situation in the Philippines are protein-energy malnutrition, vitamin A deficiency, iron-deficiency anemia, goiter, etc. The excuses include poverty, ignorance, prevalence of infections diseases, and overpopulation. This paper deals with what is being done about the problem.

THE PHILIPPINE NUTRITION PROGRAM

In June 1974, President Ferdinand E. Marcos created the National Nutrition Council, a policy-making and coordinating body in charge of the formulation of a national nutrition program and coordination of all nutrition-related activities of both government and private sectors. At the same time, he signed the Nutrition Law of 1974, making the works on nutrition problems a development program of the government.

Simultaneously, the Nutrition Center of the Philippines was established by the First Lady, Mrs. Imelda Romualdez-Marcos, to maximize the involvement of the private sector.

For effective implementation of the Philippine Nutrition Program (PNP), a system of organization and programming at all levels has been adopted.

At the national level is the National Nutrition Council composed of six ministries and three private agencies. Nutrition committees are organized at each political level: regional, provincial/city, municipal, and village. The chairman at each level is the chief executive of the corresponding political subdivision (e.g. governor for the province, mayor for the city or municipality, barangay chairman for the village). An action officer is provided at each level to act as coordinator for program implementation. The link between barangay nutrition committee and the households is taken care of by a semivoluntary multipurpose worker called the Barangay Nutrition Scholar who is trained to deliver nutrition and health services to the target households. As of 1978, there were already 2,434 BNS trained.

Operation Timbang,a nation-wide mass weighing of preschool children is being conducted at least once a year to pinpoint the location of families with malnourished children who then become the target of nutrition interventions. Latest results (1978) showed that of the 4.5 million preschoolers weighed 30.6% were found to be suffering from second and third degree malnutrition.

The PNP covers a package of nutrition interventions, namely: Food assistance, Food production, Health protection, and Nutrition education.

Food assistance is an emergency measure to provide food supplements to the severely malnourished children. Besides locally available foods and donated commodities, nutripak, a high-protein, high-calorie, ready-to-cook food supplement produced in small plants now numbering 133 is provided for severely malnourished children below six years. Home delivery and center feeding systems are utilized. School feeding programs using local and donated foods are also in operation.

Health protection in the form of preventive and curative medical services are extended to the malnourished children. Malnutrition Wards now numbering 153 and their rural counterparts - Nutrihuts numbering 256 - are already existing and serving the population. Programs like vitamin A supplementation, anemia programs, and iodine fortification are also being undertaken in a limited scale.

Food production intervention aims at increasing availability of local foods through the establishment of home, school, and community gardens, seed banks and nurseries, livestock and poultry raising.

Nutrition education and information campaign uses person-to-person approach like home visits, mothers' classes, and demonstration techniques. Mass communication approach utilizes print, radio, TV, and film to reach a broader segment of the population. Nutribuses, vehicles equipped with VTR playback facilities and nutrition information materials, are presently delivering nutrition information services in support of the Barangay Nutrition Scholars.

To support the PNP, training of manpower from the national to the local levels has been carried on through seminars and workshops. Research activities and projects center on basic and applied nutrition. Food consumption surveys, socio-economic studies, nutritional requirement studies, etc., help in the formulation of policies and programs.

To provide a continuous data gathering system, the Nutrition Surveillance and the Project Monitoring and Information System (PMIS) were adopted. The Surveillance Project collects data to provide information on the nutritional condition of the population and the factors related to this. On the other hand, the PMIS generates statistics on intervention services performed by the field workers.

EVALUATION RESULTS

To provide an evaluation of the effectiveness of the program while waiting for the nation-wide implementation of the nutrition surveillance scheme, several approaches have been utilized. Trends in the results of Operation Timbang in areas where this has been a regular activity or where validation could be performed provide indication of program impact. In addition, an external and private auditing firm (Sycip, Gorres, Velayo and Co. - SGV) has been commissioned to gather information on strategies accomplishments. The results of these evaluations are summarized below.

Over-all PNP accomplishments: improvement of the nutritional status of preschool children

A general improvement in nutritional status of preschool children was seen for 17 provinces in an exploratory study conducted by the National Nutrition Council from 1975-1977. The proportion of third degree malnourished children decreased by 8.6% while proportion of normal preschoolers increased by 4.7% from initial weighing to reweighing. The proportion of first degree malnourished children likewise decreased by 3.6% while the proportion of second degree malnourished increased by 4.6%.

These results were supported by the 1978 SGV survey in an independent test of the progress in nutritional status of second and third degree cases. On-the-spot weighing of randomly selected participants and comparisons of actual weighing results with latest available Operation Timbang records were undertaken. Of the second and third degree malnourished children included in the study, 49% have improved in nutritional status, 48% maintained their nutritional status, while only 3% deteriorated from second to third degree status.

Strategic PNP accomplishments

Operation Timbang. Operation Timbang has covered 4.4 million or 41% of the estimated total population of 10.8 million preschoolers.

This incomplete accomplishment in both initial weighing and reweighing is due mainly to insufficiency of weighing scales (since only 1/3 of the budgeted number of scales were distributed, due to lack of funds). Other factors responsible for incomplete coverage of Operation Timbang are the slow pace of organization of the Barangay Nutrition Committees, delays in reporting, and some inaccuracies in Operation Timbang data.

Food production. This strategy had the highest level of involvement both in terms of number of respondents undertaking gardening and animal raising activities and length of involvement. It was also the most practiced activity for the period of 1975 and 1978 evaluations.

Gardening is the most popular activity at the home, school, and community levels, while animal raising was not extensively practiced. Home garden produce is usually for home consumption use, although some families sell the food items to augment family income. Reliance on their own sources of seeds and breeds, rather than dependence on agency donations was also observed.

The degree of success is reflected in the practice of planting the right kinds of food crops (i.e. with high nutritive value) and raising animals; and their attitude towards food production activities as a means of increasing home food supply aside from the nutritive value they can derive from it.

Food assistance. In 1978, Food assistance involved 1.2 million preschoolers and 3 million school children under various feeding programs. Home based feeding was most prevalent and effective based on high completion rates of feeding programs and improvements in nutritional status. Shortages in food supply, primarily of foreign donated food commodities resulted in program suspension in some areas.

For community center feeding, non-completion of feeding programs was due to inaccessibility of centers to respondents.

School feeding on the other hand showed the highest program completion rates, because all grade school children are required to participate. This, however, was not effectively translated into improvement of nutritional status.

Nutrition information and education (NIE). Comparing the 1975 and 1978 SGV evaluations, the highest degree of improvement was observed in the NIE strategy in terms of involvement in various activities as well as effectiveness in reaching the target audience. The target audience was observed to be consistently aware of priority messages and various NIE related concepts. Pregnant and lactating mothers' performance was the most outstanding, exhibiting high levels of awareness, attitudes, and practice of various nutrition concepts.

Health protection. A low recipient involvement in health protection activities with little more than half of general recipients involved primarily in immunization and deworming was seen in the 1978 evaluation. It was apparent that the number of rehabilitation centers where malnutrition cases could be referred is still inadequate. However, in localities where these rehabilitation centers are avilable, nutritional status of third degree cases discharged showed improvements, although follow-ups of these discharged cases were not usually made.

Philippine Nutrition Program organizational effectiveness

Management Committee. The Management Committee appeared to be an effective coordinating and policy making body at the national level. Philippine Nutrition Program objectives and priorities were clearly defined.. Interest and good participation by members were shown by the frequency of meetings and the good attendance of members. There is periodical evaluation of reports submitted by various organizational bodies, and problem areas were translated into policies and programs and recommended for approval.

Lack of funds and program inputs together with inadequate staffing were considered by the Management Committee members as the primary problems of PNP.

Governors and mayors. Governors and mayors act as heads of nutrition committees and approve nutrition plans for implementation by agency and field workers. While both groups devoted considerable time to logistic support, actual budgets were provided by more than half of governors but by a much smaller number of mayors. Other than logistics, governors emphasized moral/motivational support in terms of campaigning for government and private participation in the PNP.

Nutrition committees. As of June 1978, nutrition committees have been established in all regions, provinces, and cities, while only 93% of 1,474 target municipalities and 74% of 40,377 barangays have established such committees.

Most committee members performed mainly line/executory tasks, except for regional nutrition committees which undertook primarily administrative function.

Meetings and monthly reports were generally carried out by a good percentage of committee members. With these two areas receiving attention, the communication process appears to be effective and sufficient.

Coordination among various agencies appears to be more than satisfactory and the same is true for participation in different PNP activities.

Training involvement showed slightly better performance than with governors and mayors.

Periodic evaluation of committee performance is carried out through internal and external estimation to check the progress of program implementation.

C o n c l u s i o n s

The Philippine Nutrition Program in its five years of existence has generated significant results that more or less promises a bright future.

Its success has been attributed much to the dedicated involvement of the community, to the continuous cooperation of related agencies and private sectors, and to the support being given by the highest political leaders.

Despite some limitations of program resources to cope with the magnitude of the problem and the immensity of the challenges confronting it, the program still manages to make significant progress towards its goal of better nutrition for all Filipinos.

Thus, to date we can say that the PNP is truly a national program and hopefully it will also serve as a motivation for other developing countries undertaking similar large-scale effort for the eradication of the malnutrition problem.

SCIENTIFIC ASPECTS OF INTERDISCIPLINARY INVESTIGATIONS IN THE PACIFIC FOR THE PREVENTION OF ITS POLLUTION

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The Pacific contributes a half of all the water and a half of all the area to the World Ocean, which is of immense importance for the life on our planet. The World Ocean supplies about 50% of oxygen necessary for life on the Earth, and its thermal energy and interaction with atmosphere are largely responsible for weather and climate. The ocean contains a wealth of minerals and food products. The Pacific provides for almost a half of seafood in the world. Biochemical processes and water circulation in the Pacific determine the distribution of oxygen and biogenic elements in the bulk of water.

Theoretically, the ocean as a natural entity is as ancient as the Earth's crust. The temperature and chemical composition of the ocean were almost the same as today several billion years ago, as were the characteristic temperature regime, the low abyssal temperatures and the gas regime favorable for the evolution of life.

Over the recent decades the pronounced anthropogenic impact has been leading to substantial changes in the World Ocean.

Among the many substances polluting the World Ocean, it is necessary to single out the chemical compounds possessing the greatest potential danger. These include oil and hydrocarbons, especially polycyclic and polyaromatic ones, heavy metals (mercury, lead, cadmium, zinc, and copper) and chlorohydrocarbons.

The problem of microbiological pollution of marine environment is particularly acute in terms of protecting the offshore biotopes from pathogenic microbes.

The processes of eutrophy and hypereutrophy of marine environment are at present confined to offshore regions; however, they may become widespread and cause large-scale suffocations of fish and secondary pollution.

Oil and oil products are the main pollutants in the Pacific. The content of oil hydrocarbons reaches 200 ppb in the northwest and southeast areas and 350 ppb in the southwest area and in the Sea of Japan.

In a number of areas the ocean surface is covered by an oil film. Oil lumps are widely distributed all over the Kuroshio system, near the Panama Canal, in the South China and Yellow Seas, over the vast area from the Hawaii to the north up to Alaska and to the east up to the shores of North America. Their concentration is notably high (up to 100 mg/m^2) in the areas south of Japan and between the Hawaii and North America, i.e. in the areas of intense navigation. In the near-surface biotope of the ocean oil aggregates populated by periphytic hydrobionts form floating biocenoses which jeopardize neustonic and pleustonic organisms.

By distorting the structure of marine biological communities and decreasing the stability of ecosystems, oil and oil products give negative physiological, biochemical, ethological, morphological, and genetic consequences.

Apart from oil, a thin surficial microlayer of the ocean contains other pollutants.

Heavy metals are highly toxic pollutants actively circulating in the hydrosphere. The average concentration of metals in the Pacific reaches 0.2 ppb for mercury, 0.1 ppb for cadmium and 0.23 ppb for lead.

Certain marine organisms tend to accumulate heavy metals such as zinc or cadmium. The Soviet-American expedition in the Bering Sea in July 1977 found that the coefficients of metal accumulation in the plankton varied from 10^2 to 10^4, the highest values being observed for mercury.

The average concentration of mercury in the food fish of the Bering Sea and Seas of Okhotsk and Japan reaches 60 ppb (in the raw samples); the concentration of mercury in internal basins such as the Baltic Sea is by an order of magnitude higher.

High concentrations of copper and zinc in water decrease the resistance of fish and cause epidemic diseases. Toxic metals also directly affect the chromosomes of hydrobionts and bring about genetic damages.

Nuclear tests, especially those in the Pacific, polluted its waters by radioactive substances. The observations carried out by Hydrometeorological Service of the USSR from 1962 to 1977 have shown that the highest concentrations (about 1 pCi/L) were characteristic of the Northeastern Pacific in 1964-1965. During the following years the concentrations gradually decreased and leveled up over the whole area of the ocean. In the 1974-1977 the concentration of strontium-90 in the Northern Pacific (20-46° N) was as low as 0.15 pCi/L.

In contrast to oil and heavy metals, chlorohydrocarbons are a group of non-natural components.

DDT, its derivatives, and polychlorinated biphenyls (PCB) are supplied to the marine environment primarily by atmospheric transfer. These compounds are incorporated in the lipide fractions of marine organisms. The coefficients of PCB accumulation by microplankton are about 1.7×10^5, and by small shrimps up to 5×10^4.

PCB are a cause of a negative hematological response and hystopathology of internal organs, particularly liver, in fish, and pesticides suppress the activity of certain enzymes.

It is important to note that marine microflora has recently been found to be capable of development in the presence of PCB by means of co-oxidation. The high concentration of PCB in the bulk of the ocean indicates that microflora can adapt to them and thus aggravate pollution.

During recent years numerous data have shown that the presence of polycyclic aromatic hydrocarbons (PAH) in sea water results in manifestations of mutagenic and cancerogenic effects. The indicator currently accepted for the assessment of environmental pollution by cancerogenic agents is the well-known benz(a)pyrene (BaP), which is on the list of controlled chemical substances according to the program of global environment monitoring.

Along with the biotic source (metabolism of microorganisms and phytoplankton), BaP is introduced into the World Ocean by means of microbe conversion of oil hydrocarbons and of atmospheric transfer and precipitation of PAH on the surface of the ocean.

The Soviet-American expedition in the Bering Sea (1978) found that the concentration of BaP in the bulk of water at the working polygone varied from 0.005 to 0.035 ppb. In the near-surface microhorizon the concentration was higher, the accumulation coefficient being equal to 9. Of particular danger is the accumulation of PAH, particularly BaP, by hydrobionts; the coefficient of BaP accumulation in the hydrobionts of the Bering Sea reached 2900.

Recent Soviet studies have shown that certain sea microorganisms have been adapted to these toxicants and show an ability for destructing them,using BaP as a source of carbon. Significantly, cooxidation in the presence of easily oxidized organic substances increases the efficiency of BaP microbe decomposition to 80-95%. The flourishing of hydrocarbon-oxidizing microflora, particularly the PAH-oxidizing species, may be regarded as a secondary pollution of marine environment.

The continental shelf is perhaps the most important object of the Pacific environmental protection. The significance of this problem is due to the two basic factors:

1. The high biological productivity of the shelves, which provide for more than 80% of sea products.

2. The wealth of shelves in commercial minerals.

Industrial development of the shelf may give rise to pollution of the ocean and the disturbance of ecosystems.

The considerable pollution of offshore waters by substances coming directly from shores, from rivers and sea ports makes the special demands of the formation and development of economy at the Pacific coast quite necessary.

An analysis of the basic aspects of man's impact on marine ecosystems shows that the following main directions of research on pollution and its biological consequences in the Pacific basin may be suggested at the national and the international level.

1. The study of the dynamics and the background level of pollution by heavy metals, chloro- and petroleum hydrocarbons in coastal waters including estuaries, shelf waters, and open ocean waters.

2. Investigation of the dynamics and metabolism of pollutants in marine environment, including their distribution, destruction, biological assimilation, and exchange through interfaces.

3. The study of the influence of the pollution of the surficial layer upon energy, heat, gas, and moisture exchange between the ocean and atmosphere.

4. An analysis of the biological consequences of pollution in the ocean at the population-biocenotic level.

5. The ecological zonation of the Pacific with a distinguishing of the zones where the intensity and duration of pollution are critical.

6. The study of the effect of atmospheric transfer of pollutants on the development of neuston and pleuston communities.

An important problem of the strategy of environmental control is the organization of an environment monitoring system.

The monitoring of anthropogenic impact on natural environment includes: (1) observation of environment and the factors (sources) affecting it, (2) assessments of the actual conditions of environment and these factors, (3) predictions of environmental processes.

The monitoring systems may be classified in terms of the objects of observation as the biotic (biological monitoring) and the abiotic (geophysical monitoring) ones. The most universal types are the ecological and the climatic monitoring. The first one includes the monitoring of environmental pollution and the reaction of biosphere to such pollution, as well as the monitoring of the ability of the biosphere to reproduce bioresources.The climatic monitoring involves measuring the parametres which characterize the climate itself, the state of the climatic system "atmosphere - ocean - land surface - cryosphere - biota", and the factors affecting this system.

The biological monitoring is of special importance, since it provides for the direct assessment of the conditions of water ecosystems. At the level of individual organisms the biological indices should combine morphological, ecological, biochemical, physiological, and genetical characteristics essential for the species.

At the population-biocenotic level the biological criteria should be made with regard for the interaction between structural and functional parametres. The biological consequences of pollution in marine ecosystems may be understood by means of the studies which are based on:

1. Determination of the species diversity index. It has been found that sea pollution sharply decreases the taxonomic diversity in a community.
2. The use of production-destruction characteristics.
3. The use of microbiological indices.
4. The use of indicator hydrobionts.
5. Determination of the basic structural and functional characteristics in marine communities.

Taking into account the current knowledge of the nature of the Pacific, its pollution, and the biological consequences of this process, we think that the long-term systematic observations at the international level are to be carried out in certain areas:

1. In the highly productive upwelling regions, in the Bering Sea, Gulf of Alaska, and in the oligotrophic areas near the Southern Line Islands and the Mariana Islands.
2. In the areas of the ocean ecosystems remote from the direct pollution sources.
3. In the areas of vulnerable and poorly rehabilitating ecosystems of the ocean (Great Barrier Reef, the oligotrophic areas of the open ocean, etc.).
4. In the regions where industrial mining is going on or being planned (Bering Sea, Gulf of Alaska).

Such a system of marine environment monitoring should involve systematic long-term observations of the back-ground levels of environment changes in ten to twelve regions of the Pacific in accordance with the program on biosphere reservations. The USSR has organized such a station in the Atlantic and is ready to begin observations in two or three regions of the Pacific.

The polygones for the observations of background levels of biotic and abiotic components of marine ecosystems may be distributed in the regions of the Bering Sea, the Gulf of Alaska, near the Japanese Islands, in the Oregon upwelling (California), near the Mariana Islands, in the equatorial trade-wind stream, the Peru upwelling, the Great Barrier Reef, and the open ocean oligotrophic region near the Southern Line Islands.

To set up this system it will be necessary to work out standard programs of environment observations at the shelf and in the offshore zone and to organize complex international expeditions to calibrate research techniques.

For the climatic monitoring, the ocean zones responsible for the weather regime in the future should be chosen.

Along with the background monitoring system at the national and the international level, the Pacific environment conservation could be promoted by international agreements restricting the anthropogenic impact on the ocean. These should envisage the organization of biospherical reservations, restriction or ban on the discharge of pollutants, control over the pollution spreading across the boundaries of economic zones, etc.

Such agreements may be realized as international conventions. There is a sufficient experience in preparing and realization of such conventions. The politics of the USSR is based upon the vital importance of environmental control for the whole mankind.

TOXICOLOGICAL GROUNDS OF BIOASSAYS OF MARINE AND WASTE WATERS

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In the last years, among the general studies of a biological influence of pollutants upon marine organisms, an area of applied works aimed at the practical measures against pollution is outlined more clearly. Of great interest in this respect is the use of bioassays strictly standardized qualitative estimations of the reaction of hydrobionts upon one or another toxic substance. The selection of objects should be determined, first of all, by general regularities of the reaction of marine organisms upon harmful factors of the environment.

We have established one of such regularities on the basis of literary (more than 300 published works) and experimental data. The regularity is represented by an essential rise of the sensibility of reactions of marine organisms in acute (by indices of survival) experiments with a decrease of dimensions of hydrobionts. The correlation coefficients of values of median lethal concentrations in experiments during 48 to 96 hours with marine organisms of medium size are equal (in logarithmic scale): 0.87 for mercury, 0.78 for copper, 0.88 for zinc, 0.84 for cadmium, 0.87 for lead, 0.91 for polychlorinated biphenyls, 0.47 for the whole group of chlororganic substances, and 0.73 for dissolved petroleum products.

One of the probable causes of the mentioned correlations is related to the formation of dose loads of toxicants in hydrobionts of various dimensions.

An analysis of the intensity of the process and of mechanisms of biological accumulation of some environment microcomponents in various organisms permitted us to reveal heightened levels of accumulation of admixtures in hydrobionts with more developed surfaces. These objects are of small dimensions, and just in them especially high dose loads of toxicants are formed. In our opinion, this fact predetermines to some extent that small forms are more sensible and vulnerable to toxicants than large ones.

Another cause of a low resistance of small forms to toxicants is the fact that small forms are represented by organisms which are at early stages of ontogenesis. Problems of the nature and mechanism of the low resistance of small forms to toxicants are not yet studied sufficiently in spite of their great importance for some questions of aqueous toxicology.

In explaining obtained correlations one should take into consideration that the period of exposure of hydrobionts in toxic media of two to four days is negligible in comparison with the life duration of relatively large forms, e.g. fish, however it makes up a considerable part of a whole life cycle of small hydrobionts, e.g. planktonic crustaceans.

The high rate of reproduction of small animals, on the one hand, increases their adaptation possibilities, on the other hand, puts them under less favorable conditions in comparison with larger forms: the period of reproduction and time of embryonic and larval stages make up a considerably larger part of a life of small organisms than of larger hydrobionts. The low resistance of small marine animals depends on this circumstance, too.

Concepts of heterogeneity of biologic reactions of various hydrobionts on the presence of toxic factors in the medium give grounds for the suggestion that the peculiar "ecologic targets" exist in the sea, i.e. such species, pupulations, and, possibly, larger aggregations which are most vulnerable in relation to the influence of pollution.

Experimental results and literary data suggest that most vulnerable and quick-reacting on the pollution components of marine communities are species and forms of hydrobionts of small dimensions, including unicellular algae whose producing and structural characteristics can be easily upset even at low levels of pollution; zooplanktonic filtrators represented by some species of protozoans, copepods, and other small invertebrates: benthic and nektonic animals which are at earlier stages of ontogenesis. On the basis of these results we have worked out a system of marine toxicological bioassays. The system is notable for its relative simplicity of experimenting and at the same time for its comparative rapidity. All this, alongside with a high sensibility to toxic admixtures, permits to use the bioassay system for the establishment of permissible levels of pollution of the marine environment, for the toxicological control of the efficiency of sewage purification, for the exposure and removal of the most dangerous ingredients of waste waters, for the complete and express tests of the toxicity of various substances received by sea water, and so on. Our first praçtical experiment in the bioassays of such a kind has shown their indubitable practical value and the expediency to introduce them into the monitoring practice.

OCEAN THERMAL ENERGY CONVERSION - AN OVERVIEW

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I n t r o d u c t i o n

Ocean thermal energy conversion, OTEC, has been considered for some time. In 1881, Jacques D'Arnsonval proposed the concept of using the temperature difference in the ocean as a source of energy. In 1930, Georges Claude built a small ocean thermal conversion plant in Matanzas Bay, Cuba. His plant generated about 22 kW and was destroyed by heavy seas barely two weeks after being erected.

There is a potential for a substantial amount of available energy due to the temperature differences of water in the upper and lower levels of depth in the ocean. The exploitation of this thermal energy is intriguing provided it can be harnessed economically.

Ocean thermal energy is available on a continuous basis 24 hours per day. Therefore, no energy storage system is required for continuous power generation. The oceans serve as a natural collector of solar energy and simultaneously as a storage system. The ocean currents keep the water at depth reliably at a colder temperature, thus providing for the temperature difference which is the source of energy. Studies have been made to estimate available power from the ocean as the result of waves, tides, currents, and temperature differences, indicating that the OTEC principle is indeed by far the largest source of available energy among the above mentioned energy sources, amounting possibly to as much as 40,000 million megawatts.

RESOURCES AND SUPPORT

Solar power arrives continuously at the surface of the Earth in very large quantities, about 82,000 x 10^{12} W on the average. In 1977, the energy use by all mankind for all purposes was at a rate of about 8 x 10^{12} W. A large part of the solar energy is transformed into thermal energy of the surface water of the Earth. The distribution of the thermal energy in the surface water changes with the geography of the Earth, and to a much lesser degree, with the seasons.

For an OTEC plant, the most valuable areas are those where the average temperature difference is 20°C or larger. There are many ocean areas where this temperature differential exists. For the United States, there are such ocean resources in the Gulf of

Mexico and near islands, such as Puerto Rico, the Virgin Islands, Guam, and the Hawaiian Islands. It is also evident that perhaps the largest ocean thermal resource exists in the Pacific with many Pacific islands being located in areas where the temperature difference between the surface and bottom waters is well above 20°C. Generally, the ocean thermal resource at a given location is stable from day to day. There are some seasonal variations, and the degree of these variations increases with the distance from the equator. There are many potential sites for OTEC power plants, but some locations are not in the vicinity of industrial nations. If an OTEC plant is to be moored, then the location is limited to ocean depths of 1000 to 2000 m, considering present mooring technology for large ocean structures. Thus, it has been proposed to use OTEC power plants at a fixed location being moored with appropriate cables, and, as an alternate, use OTEC power plants which can move according to a predetermined system and thus are independent of mooring and ocean depth.

In 1972, the United States government began to support research and development of solar energy. The program began as a research project in the National Science Foundation. Subsequently, as the program increased in scope, it was transferred to the Energy Research and Development Administration in 1975 and became part of the U.S. Department of Energy in 1977. The research expenditure on ocean energy resources were increasing from $ 3 million in 1975 up to $ 37.5 million in 1979. Only a small amount of these expenditures was directed towards the development of such energy sources as waves, currents, and salinity gradients, the majority of the financial resources being directed towards the OTEC program. In the seven year period, the OTEC program has moved from analytical studies to laboratory experiments and to the testing of components in significant size. At present, some components are being tested in the ocean environment. In 1979, the first small OTEC plant is to begin operation in Hawaii.

OTEC SYSTEMS

Claude's experimental OTEC plant was based on land with water pipes bringing in the warm and cold water, and this plant operated as an open cycle using seawater as the operating fluid. In the various studies, both open cycle and closed cycle systems have been analyzed. For an electric base load plant, the size will be inherently large, on the order of 100 MW or larger. For large plants, it was found that the entire plant should be located at sea, electric power should be transmitted to shore by cable, and a closed cycle with an operating fluid other than water will be more advantageous. OTEC plants for islands may require smaller amounts of power, with units as small as 10 MW and up to sizes of several hundred megawatts. The economics of electric power generation determine plant size as well as plant location. For all OTEC plants, the temperature difference between the hot and cold water is relatively small, and the heat exchangers must have a very large surface area. The quantity of seawater passing through the heat exchangers is very large and require pumps of large capacity and power.

The maximum theoretical efficiency for an ideal Carnot cycle operating between 25°C and 5°C is 6.7%. In actual operation, the maximum achievable efficiency is considerably less, perhaps on the order of 2.5% for the closed system because of the losses in the heat exchangers and the power required to drive the warm water and cold water pumps.

The open cycle uses seawater as a working fluid. Before the evaporation, a deaerator is required to remove non-condensable gases which must be compressed and discharged. The seawater is evaporated under a fairly high vacuum. Low pressure steam is passed through a turbine which extracts energy from the steam.The vapor is discharged into a condenser which uses the cold water from the deep ocean to complete the cycle. The open cycle does not require the fluid to be returned to the evaporator. As a matter of fact, the condensate can be used as desalinated water if a surface condenser is used. Thus, the open cycle is of distinct advantage in applications where there is a need for energy and for fresh water. This is indeed the case in many island applications. Because the open cycle uses low pressure steam, very large turbines operating at very low speed are needed for large capacity power plants. For large capacity, the deaerators which remove gases dissolved in the seawater also become large, and the compressors require substantial power. It is recognized that in the open cycle, there is no heat transfer problem in the evaporator, and the effects of biofouling are substantially reduced. However, the steam turbine operates in a fluid of less cleanliness and may require special attention.

A variation of the open cycle is the mist flow plant. It consists of a nucleation chamber creating a foam or mist flow either directly or by means of additives. The mist flow moves upward in the main chamber and enters a separation chamber which separates gases. The mist flow converts the temperature difference into a hydraulic head by using cold water to condense the mist flow in the upper part of the chamber. The condensed water with the static head from the upper chamber is then used in a hydraulic turbine to generate electric power. The process has its problems in the potential stability or instability of the mist flow or bubbles and in the relatively large chamber which is required to make this process work. This system is now in its early stages of research, and its success cannot be predicted at this time.

In the closed cycle OTEC plant using ammonia as the secondary fluid, warm water enters the plant at a temperature of 25°C and is pumped through the boiler leaving the plant at a slightly lower temperature. The boiler-evaporator produces vapor of the working fluid. This ammonia vapor is expanded in a turbine and leaves the turbine to enter the condenser. From there a pump returns the secondary fluid to the boiler-evaporator. The cold water enters the plant at approximately 5°C, flows through the condenser and leaves the plant at a slightly higher temperature. The turbine drives the electric generator providing electric power to the user. A number of candidate working fluids have been proposed for the closed cycle such as ammonia, propane, and a mixture of Freon refrigerants. Of the three fluids, ammonia has the lowest molecular weight, has a relatively high volume, good heat transfer characteristics, and permits a high turbine speed. Freon has the highest molecular weight, a relatively low volume, and a low turbine speed. It also requires the largest amount of mass flow and, therefore, a considerable inventory of fluid in the system. Propane has characteristics which are between the above two extremes. Because of its excellent thermodynamic properties, ammonia is usually preferred.

Another basic consideration for the OTEC system is the nature of its product. While the initial plants will undoubtedly be located so that they generate electricity to be carried ashore by sea floor transmission lines, this will require some technological developments, especially in the riser cable that connects the plant to the sea floor transmission line. A DC transmission cable would cut down transmission losses for plants 30 km or more offshore. For OTEC plants located a substantial distance from shore, it may prove most practical to produce energy-intensive products - like aluminum or ammonia - which can be shipped to shore. Another possibility is the production of energy carriers like hydrogen, from the electrolysis of seawater, or the reprocessing of chemicals such as molten salts, which can be shipped easily both ways, to and from the OTEC plant. Depending on the product, the plant may be moored to the ocean bottom or allowed to "graze" the tropical seas in order to maintain an optimum temperature at the site.

A summary of the work in the above described areas have been discussed in the OTEC workshops and have been published in their *Proceedings*.

HEAT EXCHANGER AND MACHINERY

The heat exchanger is by far the most important component of the closed cycle ocean thermal power plant in terms of size, cost, and performance. If the heat exchanger does not meet the expected performance, the entire thermal cycle could be degraded so that the amount of power which can be generated becomes substantially lower. Therefore, the heat exchanger becomes an important subsystem to make ocean thermal energy conversion practical. The performance and size of the heat exchanger are greatly affected by the heat transfer coefficient which is a function of the heat exchanger design. There exist considerable differences of opinion regarding the types of heat exchangers best suitable for an OTEC plant. Conventional boiling/vapor generation equipment has generally been thought not suitable because the small allowable temperature difference between the warm seawater and the working fluid is insufficient to cause bubble nucleation on a conventional heat exchange surface. Special surfaces of the Linde or Hitachi type do nucleate at suitable Δ T's (0.1 - 1^{o}C), but they are expensive. Price reductions on these surfaces would increase their use.

Most of the condensers proposed are fairly conventional,except for the vertical fluted tube configuration of Carnegie-Mellon. Its principle provides that surface tension forces draw the condensate from the convex surfaces into the troughs, leaving a very thin condensate film and extremely high heat transfer rates on the tips of the flutes. Attention to heat transfer on the seawater side has mainly concentrated upon the possibilities of using enhanced surfaces, such as fluted, grooved, ribbed, or corrugated tubes. Because of the high ammonia heat transfer coefficient, the improvement in coefficient offered by these tubes on the seawater side is very attractive, but it may result in a higher pressure drop which is already in short supply.

Heat exchangers in marine or industrial systems have an overall heat transfer coefficient of approximately 1700 W/m^2 ^{o}K. For OTEC systems, it will be desirable to achieve substantially higher heat transfer coefficients by means of heat transfer enhancement devices as described above. The augmentation of the heat transfer has been studied, and a substantial number of designs have been tested. Most of the heat transfer augmentation results in some additional cost. Thus, an optimization analysis must be made to consider the effectiveness between heat transfer enhancement and production costs. In addition, consideration must be given to control biofouling within the heat exchanger and integrate the various design parameters such as fluid velocities and pressure drops within the overall system analysis.

The first of the candidate OTEC heat exchangers which are presently tested in the laboratory in sizes as required for 1 MW units, is the conventional, horizontal shell and tube units which are widely used in marine applications. The other systems include the plate and fin heat exchanger, the vertical falling film heat exchanger, and the trobmone evaporator. Ammonia has been selected as a fluid to test the various heat exchangers. For the final applications, propane and halocarbon are still under consideration. During the last year, considerable testing of various heat exchanger types has been undertaken at the Argonne National Laboratory using heat exchangers of substantial size, about equivalent to a 1 MW unit. The tests have indicated that for heat exchangers which employ heat transfer enhancement only on the working fluid side, substantial improvements in the heat transfer coefficient can be achieved, and heat transfer coefficients on the order of 3500 to 5000 W/m^2 ^oK have been demonstrated for a considerable length of time.

Boilers and condensers can be arranged at a water level in the ocean where the vapor pressure of the fluid used in the power plant system is equal to the ocean water pressure so that the pressure differential across the heat exchanger is a minimum. This permits the use of thin-walled heat exchangers having a good heat transfer coefficient. The heat exchangers should be reasonably accessible for underwater maintenance, and this makes it desirable to keep submergence at less than 300 feet.

Turbines of the proposed sizes and fluids are not at present commercially available, although similar units having been in use in the chemical industry. Ammonia requires the smallest diameter and highest speed whereas Freon requires the largest turbine diameter operating at the lowest speed. Careful attention must be given to the selection of seals, bearings, and the method of lubrication for the three recommended fluids. The proposed 90% turbine efficiency may require some development, and there is a need for careful material selection to avoid corrosion.

For the OTEC power plants, three major pumps are required - a cold water pump, warm water pump, and a working fluid pressurization pump. The working fluid pump resembles a boiler feed pump. It operates at a moderate temperature of about 10^{o}C and has a relatively small pressure increase. This pump is entirely within the present state of the art. The hot and cold water pumps, on the other hand, must deliver very large quantities of water against a very small head. Consequently, the specific speed is very high and their shaft speed will be low. By using modular construction of the power plants and parallel pump operation, the capacity of each pump can be reduced. However, it is still very high, requiring pump dimensions and flow rates which exceed the largest pumps ever built. For a 100 MW OTEC plant, the cold water pumps need a combined capacity of 400 m^3/s (6,000,000 gal/min) with a head of about 3 m and shaft power of about 12 MW (15,000 hp); the warm water pumps require capacities of about 350 m^3/s (5,000,000 gal/min) with a head of about 1.5 to 2 m and shaft power of about 8 MW (10,000 hp). Pump efficiency has been estimated to be up to 86%. The cold and warm water pumps operate at relatively slow speed, on the order of 40 to 60 r/min. This requires special attention to the bearings, particularly the thrust bearing, due to the size of the pump. Both electric and turbine drives have been suggested. In either case, a reduction gear may be required to reduce the size and cost of the prime mover. Thus, the number and location of pumps for each of the modules must be carefully analyzed.

MATERIALS AND FOULING

Several materials have been proposed for the heat exchanger. Aluminum has been given serious consideration because it has excellent heat transfer characteristics and is readily available at reasonable cost. Other materials for the heat exchanger are 90-10 cupronickel and titanium. Cupronickel is presently used extensively for condensers and feed water heaters in marine service. It must be protected from direct contact with ammonia, possibly by using it as a liner in a carbon steel or aluminum tube. It is fairly expensive and more so in bimetallic tubes. Titanium has been used to a limited extent in seawater service. It has excellent corrosion and strength characteristics, but its price is considerably above that of other materials.

Seawater contains salts in solution and organic matter which can produce fouling and scaling and thus reduce the heat transfer effectiveness of the heat exchanger. In the ocean environment, the organic substances produce a layer of slime which will eventually accumulate on the water side of the heat exchanger. The slime is composed of microorganisms and is known as biofouling. If the slime is not removed, additional fouling can become attached and augment the slime layer. In addition, mineral deposits can also accumulate on the water side and contribute to both fouling and corrosion. These deposits will also reduce the heat transfer, and the combined effect is considered thermal resistance. The thermal resistance is the reciprocal of the corresponding heat transfer coefficient of the fouling film. It is important that any significant fouling be removed from the heat exchangers and appropriate provisions must be made. The removal of the fouling layer can be done by cleaning the heat exchanger surfaces mechanically, chemically, or by ultrasonic means. A substantial number of tests have been made to determine the growth of fouling and the thermal resistance factor. These tests have indicated that fouling can be controlled, and present available technology for the shell and tube heat exchangers is quite satisfactory. It is noted that in the open ocean, the fouling of heat exchangers is expected to develop much slower than in coastal regions, since considerably more nutrients exist in coastal waters.

The tests have been made for two materials, titanium and aluminum, and for two different water velocities. The fouling can be removed mechanically by means of special brushes. Chemical cleaning is possible, and the use of small amounts of chlorine have been suggested. In addition, abrasive slurries, water jets, and ultrasonic methods have been considered. It is noted that the test data to date indicate that the problem of fouling can be solved, and the task is to select a safe and economical method. A large testing program is presently in progress.

Titanium is the best material from the point of view of corrosion and is presently contemplated for use in the first experimental OTEC plants. Aluminum has considerable advantages in regard to availability and cost, but tests must be made to prove that the material will withstand corrosion and erosion in conjunction with the proposed cleaning methods. In the selection of materials, some investigators placed greatest emphasis on the prevention of biofouling, others on high overall heat transfer coefficient or light weight and low cost. While the material characteristics for the heat exchanger are most important,the effects of corrosion and biofouling must also be considered for the rest of the components, i.e., pumps, turbines and piping, and for the entire platform.

PLATFORM AND MOORING

A great number of hull configurations have been studied.They cover various configurations of surface vessels, semi-submersibles, submerisibles and spar buoys. For a 100 MW OTEC plant, a cylindrical vertical surface vessel of about 180,000 t displacement having a draft on the order of 30 m was selected. Another choice is a vertically oriented spar-type platform of about 230,000 t with a 75 m diameter central core and a 20 m diameter cylinder penetrating the water surface. The two configurations differ in their detail arrangements of components but they are basically similar and have enough reserve buoyance with associated systems to reduce risks in case of casualties due to collision or hurricanes. The platforms are to be built of reinforced concrete, and this seems to be well within the state of the art when considering the Ekofisk and Condeep structures. For smaller OTEC plants and for component testing, other hull configurations are being considered, for instance a converted surface ship will be used for the 5 to 10 MW test platform.

The cold water pipe requires a length up to 1000 m or more and a diameter up to approximately 30 m. It must withstand the force of ocean currents and should be light in weight. In some designs, it must swivel within certain limits and there should be a watertight connection within the platform. To meet these requirements, a certain amount of technology development is needed. Various materials and methods of construction have been proposed. One design proposes a telescoping cold water pipe of reinforced concrete made in 60 m long sections. The pipe walls are 0.5 m thick. Another design considers fiber-reinforced plastic made in 20 m long sections with special connections between the sections. To determine the necessary strength of the cold water pipe, the complete internal and external hydrodynamic forces must be known. There is a need to analyze pipe vibrations and the transmission of fluctuating loads. Appropriate coatings to protect the pipe against corrosion and fouling may be necessary, and this may require periodic inspection. In addition, a flexible cold water pipe has been proposed in order to meet the various requirements of forces. Presently, numerous studies are underway to analyze the forces and requirements for a cold water pipe.

The plant construction and deployment has been studied to assure feasibility. The power modules can be built and assembled in shipyards using existing facilities. The erection and assembly of the heat exchangers may require special tools and fixtures, but their size should not present problems for the presently proposed OTEC plants. The heat exchanger must be designed to take the loads which will occur during installation, mounting, and transport. It has been proposed that the major elements of the OTEC plant be towed to the selected operating site after construction, and using appropriate facilities such as barges, cranes, mooring lines, and anchors for assembly. Another concept envisions complete assembly of the OTEC plant near the construction site and towing the complete unit except for the cold water pipe.

There are two different concepts for mooring and positioning of the platform. The station keeping can be accomplished by a dynamic system using various forms of thrusters, or by a static system using anchors to moor the OTEC platform to the ocean floor. For small ocean currents, the dynamic system with thrusters is usually competitive with mooring. For higher currents, the power required for the thrusters becomes too large and mooring is selected. There is a limitation in depth for wire type moorings. OTEC plants have been suggested for locations of varying depths up to 6000 m. A moored OTEC platform will rotate about a circle as a function of ocean currents and the depth of the mooring. In cases where mooring is necessary, the optimum OTEC site may be determined by both the mooring requirements and the ocean thermal resource. It may thus be necessary to limit for the near future moored OTEC plants to ocean depth of approximately 2000 m until more advanced technology for reliable mooring becomes available. For the dynamic mooring, it has been suggested to use the kinetic energy of the large amounts of water which must be processed. Both cold water and warm water discharge can be used. It is thus possible to control the positioning of the platform downwind or upwind, as desired.

If the OTEC plant delivers electric current, provisions must be made for an electric cable to connect the sea-based OTEC plant with the user on land. Since the OTEC plant is subject to various motions as a function of ocean currents and motions of the sea, a riser cable must provide for appropriate mobility.

OTEC ECONOMICS AND APPLICATIONS

In 1974, OTEC plant costs for a 100 MW unit were estimated at \$ 2100/kW to \$ 2600/kW. These costs envision existing state of the art technology and materials. With improved technology, the cost estimates have been reduced to possibly 55% of the above quoted values. Since that time, component tests of substantial size have been made particularly of heat exchangers, thus permitting cost estimates based on units which had been built. OTEC plant costs are a function of plant size, plant location, power output, and many other factors. Energy costs are generally quoted in mills/kWh, and capital costs are quoted in \$ /kW for a certain plant size. Recent cost estimates for the Gulf Coast and the Islands indicate that in the year 2000 for these locations, the

OTEC plant will be the lowest cost producer of electric energy. It is noted that better cost estimates will undoubtedly become available as soon as the first OTEC plants have reached operation and actual experience is available. From the present studies, it is indicated that OTEC power plants will be competitive if the remaining technological developments can be satisfactorily solved.

As indicated in the temperature charts of ocean thermal resources, OTEC power plants can provide a large amount of the world's energy in certain geographical regions. In the tropical regions of the Pacific, a substantial part of the required electric energy can be supplied from OTEC plants by submarine cable. In other parts of the world, energy-intensive products can be manufactured and supplied world wide. In the United States, the main areas of the thermal resource are in the Gulf of Mexico and in the islands of Puerto Rico, Virgin Islands, Hawaii, Guam, and Micronesia. In these locations, OTEC energy can be supplied by means of cable, and in the Gulf of Mexico, this would permit supplying energy to a number of major industrial centers and the associated regions inland. It has been estimated that eventually, energy up to 600 GW can be supplied. If this power can be provided, it would cover the entire electrical expansion requirements for a substantial number of years in the future. For some of the above-mentioned islands, OTEC energy could supply the entire energy for the next several decades.

On the basis that OTEC can produce electric energy at a competitive price for the United States Gulf Coast area, a study has been made analyzing the growth of OTEC for the southern United States when generating base load electricity from OTEC plants. One could expect a substantial increase in OTEC energy during the next 40 years even though the first OTEC plants may not be available until late in the next decade.

It is most likely that islands such as Hawaii and Puerto Rico will be the best location for an early application for OTEC energy supplying electricity for public consumption. In these locations, the cost of electricity is generally higher than at the United States mainland, because most of the electricity is generated from imported oil and the power generating plants are essentially of smaller size than on the United States mainland. The comparison of the expected cost of electric power in mills/kWh for Puerto Rico over the next 20 years and OTEC plant costs indicates that the OTEC plant will be cost competitive beginning with the first plant in 1990 and will become less expensive with subsequent plants.This study assumes the first OTEC plant will have an approximate cost of $ 2800/kW. It could be likely that for the United States islands, existing oil fired power plants will be phased out during the next several decades and will subsequently be replaced with OTEC plants. It must be realized that OTEC power plants require a substantial capital investment at the beginning while operating costs will be low since no fuel is used. Considering the present world energy situation, it can be expected that OTEC plants will slowly become available at the end of the next decade. Their location and numbers will be substantially affected by the overall economics and the world energy situation.

OTEC DEVELOPMENT PROGRAM

The United States OTEC development program has progressed from analytical studies to experimentation. There are small scale tests in laboratories related to single tubes and research on corrosion, biofouling, cleaning, and thermal performance. Components are in size up to a 1 MW configuration. This will be followed by an ocean test facility aboard ship covering tests on heat exchangers, materials, biofouling control, the cold water pipe, and configurations of the various components. These tests will be done on the OTEC-1 platform which consists of a T-2 tanker conversion. The entire OTEC-1 plant will be housed within the existing hull, and the cold water pipe will be installed in a well in close proximity to the power plant. The cold water pipe is approximately 700 m long and will consist of three polyethylene pipes. The ship is expected to be moored at an appropriate location, and the test site is expected to be in Hawaii. The tests may begin in 1981. In addition to the total system tests, subsystem tests will continue in the areas of corrosion, biofouling, cleaning, and associated material experiments. Subsequently, a pilot plant of 5 to 10 MW size is planned to be operated at sea about 1985.

There is interfacing between the major OTEC subsystems, namely the power system, the cold water pipe, the station keeping system, the electric power transmission system, and the platform. Finally, an environmental impact assessment must be made, covering the electric power transmission system, the cold water pipe, the platform, the power system, and the station keeping system. These, together with the water discharge, will affect the entire environment at the site.

Independent of the above developments is the Mini-OTEC program. This project is supported by a consortium of participants, including the State of Hawaii, Dillingham, Alfa-Laval Energy Systems, and Lockheed Missiles and Space Company, Inc. (LMSC). The Mini-OTEC project has been established at sea in June 1979 and is expected to be in operation shortly thereafter. It will be the world's first closed cycle floating at sea OTEC plant. It contains all the subsystems of a full scale OTEC power plant and will produce 50 kW gross power. The Mini-OTEC plant is installed on a moored barge, and it includes a cold water pipe in a single anchor leg. It will permit assessment of the power plant control system, including the performance of ammonia as a power plant fluid. Experiments will be conducted for about six months, and subsequently, the plant will be turned over to the State of Hawaii.

With the advent of Mini-OTEC and OTEC-1 at sea experience will be available. This information will be of substantial value in making technical decisions regarding future developments of OTEC systems. Thus, improved OTEC power plants for competitive costs may become available during the next decade.

Conclusions

A summary has been presented covering the major OTEC studies, the associated experimentation, and the subsystem testing. The test results have been encouraging so that full scale experimental OTEC plants are now under development. With the beginning of large scale experiments and the establishment of the first at sea OTEC experimental plants, the future of OTEC performance can be predicted with substantially more confidence than in the past. It is still too early to predict when OTEC energy will be a viable alternative energy source. The potential is enormous, and the need for a renewable energy source is here today. This certainly justifies a major effort to resolve the technical development, the manufacturing requirement, and development of a plant operating system. From the existing data, it is quite evident that the various islands and, specifically, the Pacific islands, have a great opportunity to solve their energy requirements by considering the acquisition of OTEC energy systems. The timing and location will depend on both resources and the economic requirements. The availability of OTEC will offer a great opportunity for the Pacific islands.

ENERGY UTILIZATION OF OCEAN TEMPERATURE GRADIENTS

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Because of ever-increasing difficulties in meeting energy demands and more pressing environmental protection requirements,there is now a trend to intensify search for new energy sources. In this connection, the energy research and development programs of the USSR and other nations include investigations on the energy potential of the ocean.

Today, several approaches to the utilization of the ocean energy may be considered: the construction of tidal and wave power plants as well as of plants using the energy of ocean currents. Characteristic of these power plants is a conversion of the mechanic energy of the ocean into the electrical energy. All these approaches are under testing, development, or investigation. Some of them are rather advanced. For example, there are already working tidal power plants; the next step in their development should include improvements in design or in their operational and economic characteristics.

Hydrothermal electric plants represent the least developed field. The concept is based on the conversion of ocean thermal potential into other forms of energy, including electricity and heat with simultaneous production of various by-products. Before World War II the hydrothermal plants received a rather close attention, particularly in France. The most advanced investigations reached a stage of experiments (e.g., Claude and Boucherot installations). However, the state of the art within this field of technology was then inadequate for developing plants capable to operate at very low temperature gradients (25-28°C) with an acceptable efficiency and economy.

Nowadays, due to technological achievements, first of all in the refrigeration technology, which have stimulated production and utilization of new working fluids with low boiling points (ammonia, Freons), it became possible to organize the development of hydrothermal electric power plants at a qualitatively new level.

The hydrothermal electric power plants utilize temperature gradients between the layers of ocean water (southern regions) or between ocean water and air in northern regions.Therefore, two different approaches to ocean thermal energy conversion may exist.

Generally, the plants may be classified as coastal or floating ones according to their site and as one- (electricity production), two- (production of electricity and by-products) and multipurpose (production of electrical power, by-products and fresh water) installations. Two other possible trends in utilizing ocean energy resources may be also mentioned. These are the utilization of biological resources of the ocean and the use of the effects associated with the interaction between salt solutions of different concentrations. These two trends are quite independent field of the possible ocean energy utilization, involving biological or chemical and physical processes.

The main technological problem in developing the hydrothermal plants of the first type (utilization of the temperature gradient between the layers of ocean water) stems from the following. With an increasing depth of water intake and, therefore, with the increase in the distance between the water layers, the temperature gradients ΔT rises as well as the Carnot cycle efficiency. However, with a greater depth, hydrodynamic losses associated with the pumping of working fluid rise; capital investments into the plant also rise due to a longer distance between plant units. Thus, production-economic indices of the plant deteriorate. Generally, the optimization problem may be solved using the expression $dC/dh = 0$, where C - is an energy production cost and h - is a depth of the condenser location. The solution of the problem lies between two extreme cases. At h_{min} capital investments necessary for reaching the required temperature layer and power consumed by the plant equipment itself are lowest, but the useful power tends to zero since the cycle temperature gradient also tends to zero. On the contrary, at h_{max} the power produced increases but the capital investments and the plant power consumption are growing. As a consequence, the useful power falls down relative to its optimal value.

An attractive approach to meeting these contradictory requirements, that is, to rise the power produced while keeping the capital investments and power consumption as low as possible, consists in the application of the combined scheme. The temperature of upper water layers in special insulated basins is increased at the expense of solar energy. The scheme could involve the simplest solar water heaters finding today an ever-increasing application in heat and hot-water supply in the USSR and other countries. When used in circulation systems, such heaters rise the water temperature by 50-60°C. When the temperature of the upper layer equals to 25°C and that of the lower layer equals to 5-10°C (this temperature range could be achieved at a depth of 300-500 m depending on the nature of underwater currents and site location) the efficiency of available Carnot cycle could reach 5 - 6.7%. At the same temperature in the cooler and with the increase of the initial temperature in the solar water heater up to $70^{o}C$, the efficiency of available Carnot cycle would be 17.6 or even 19%.

Widening the temperature range through the utilization of solar water heaters makes it possible to slacken the trend to achieve the maximum lowering of the cycle output temperature by increasing the depth of cold water intake and corresponding investments. When the cold source has a temperature of $15^{o}C$ (which may be achieved in the coastal shelf zone at a depth up to 100 m) and the initial temperature equals to $70^{o}C$, the Carnot cycle efficiency is about 16.2%. Therefore, it is more economically attractive to widen the cycle temperature range by rising the initial temperature rather than through the lowering of the outlet cycle temperature.

For two versions of hydrothermal power plants, estimations were carried out under the assumption of using ammonia and Freon-12 as working fluids. In all cases the electric output was assumed to be equal to 500 kW and the adiabatic efficiencies of turbine and pump to 0.75 and 0.5, respectively. The mass-flow rate of a heat carrier and thermal output of the evaporator and condenser were determined by the given electrical output. Then, the required heat transfer surface and the main costs of heat exchange equipment were estimated. The turbine cost was extrapolated on the basis of its output and the cost of a turbine fabricated for and installed at the Paratunka geothermal experimental power plant. Costs of the auxiliary equipment were determined in a similar manner. The goal of the problem solution consisted in a tentative evaluation of the cost of the installed power for such a plant:

$$n = \frac{K_i}{N} = \frac{K_t + K_e + K_c + K_p + K_a}{N}$$

where K_t, K_e, K_c, K_p and K_a are costs of the turbine, evaporator, condenser, pump, and auxiliary equipment, respectively, and N is plant power.

At initial conditions $T_1 = 25^{o}C$, $T_2 = 10^{o}C$ (efficiency is 5%), the actual efficiency of a plant is 2.8% with ammonia and 3.4% with Freon used as a heat carrier. On the other hand, at initial conditions $T_1 = 50^{o}C$, $T_2 = 10^{o}C$ (efficiency is 12.4%), the actual efficiency of a plant is 7.2% with ammonia. Due to peculiar thermal and physical properties of Freon and ammonia, the latter requires about a half of the power necessary for compression of Freon. With these working fluids and at the minimal temperature difference ($\Delta T = 15^{o}C$), the capital investments per unit of plant power fall within a range of 600 - 1100 rouble/kW, while at the maximum temperature difference ($\Delta T - 40^{\circ}C$) this economic parameter appeared to be equal to 200 - 600 rouble/kW. Available foreign sources give greatly differing estimates of this parameter which can be partly attributed to different conditions at the sites of power plants. Thus, floating hydrothermal power plants seem to be much more expensive than coastal stations.

At present, the USA take efforts on the Program on Ocean Thermal Energy Conversion (OTEC) which envisages the construction of a power plant using ocean heat potential. The plant would include 200 kW units totaling a capacity of 1 MW. An accurate production-economic evaluation of the plant should be made after the completion of the plant, but it is expected that the cost of the installation of the plant would range from $ 160 to 500 per 1kW of its power. Tables 1,2 compare some parameters of hydrothermal power plants being under development in different countries.

Beside the electricity generation, one of the most promising approach to utilizing ocean thermal energy is heat production. Recently, great advances have been made in the field of heat pumps for raising temperatures of low-grade heat flows. As compared to the described cycle of electric energy production using low-boiling working fluid (Freon), the processes in a heat pump represent a reversed thermodynamic cycle.

In the course of evaporation, the heat is taken away at a low-temperature level, for example, in the process of heat exchange with ocean water. Then, Freon vapors are compressed and their temperature rises; the heat may be transferred to the consumer while Freon is again delivered to the evaporator after the condensation and pressure reduction in a damper. Thus, when the electrical power consumption is low, the heat pumps make it possible to supply heat, rising the temperature level of a low-grade heat source. The conversion factor of a heat pump, $\varphi = Q/N$, indicates a ratio between the heat received by a consumer to the spent electric power. Depending on the temperature range of low-grade heat sourse and parameters of the heat carrier the factor φ varies from 3 to 4. Foreign heat pumping plants are now sufficiently developed for practical application. Partly, this is due to the sky-rocketing prices of fossil organic fuels after the recent energy crisis. There are also several operating heat pumping plants in the USSR; besides, some larger plants of the type are under development. Evidently, the ocean thermal energy utilization should play a prominent role in the heat supply systems using heat pumps.

Thus, the utilization of ocean temperature gradient for electrical power production involves several unsolved scientific, technological, and engineering problems. However, technical and economical estimates justify the extensive research and development efforts in the field. The heat supply systems with heat pumps using low-grade ocean heat and involving existing technology, equipment, and operational expierence already gained, may be introduced into the economy right now.

Table 1. Some characteristics of ocean thermal energy power stations being under development in the USA and Japan

Characteristics \ Country	USA (offshore)	USA (coastal)	Japan
Capacity, MW	160	100	100
Working fluid	-	-	propane, butane, isobutane
Temperature gradient, °C	28	-	28
Depth of cold water suction, m	300	915	900
Capital investments, $ /kW	2660	450	1950
Cost of electric power production, cent/kWh	-	-	3-4

Table 2. Estimates for ocean thermal energy power stations based on the calculations of this paper

Characteristics	Type of energy conversion			
	Stations without additional conversion equipment		Stations with solar heating	
Capacity, MW	0.5		0.5	
Working fluid	Freon	Ammonia	Freon	Ammonia
Temperature gradient, °C	15	15	40	40
Carnot efficiency in a given temperature range, %	5	5	12.4	12.4
Actual efficiency, %	2.8	3.4	-	7.2
Depth of water suction, m	400	400	400	400
Capital investments, rouble/kW	600 - 1100		200 - 600	
Cost of electric power production, copeck/kWh	2		1.5	

PROBLEMS OF OCEAN ENERGY UTILIZATION IN THE NORTHWESTERN PACIFIC

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In recent years, in connection with future depletion of traditional energy sources such as oil, gas, and coal, the utilization of nontraditional sources of energy has become a necessity. These sources should satisfy two requirements. First of all, they should have unlimited resources or be completely renewable. Secondly, they should not make harmful environmental impacts and add to the ecological problems connected with energy consumption at the present-day scale. These requirements are fully satisfied with the use of energy sources of the World Ocean.

The total amount of solar energy absorbed by the World Ocean is equal to approximately 10^{24} J/yr. It exceeds significantly the energy consumed on the Earth. At the present time the energy obtained annually from conventional energy sources totals approximately 10^{20} J. Solar energy is chiefly accumulated in the form of thermal energy a part of which induces currents, circulations, and surface and internal waves. With all this, dynamic phenomena depend also on the Earth's revolution and its gravity.

The greatest part of energy is stored in the form of heat the utilization of which is possible only owing to the difference of the temperature T_1 at the depth from the temperature T_2 at the ocean surface. The parameter $\varkappa = (T_2-T_1)/T$, where T, the mean temperature, equals to $(T_2+T_1)/2$, is one of the most important characteristics of energy conversion determining the maximum efficiency possible with the use of thermal energy. At temperature differences of $T_2-T_1 = 10^\circ C$ (e.g., at the depth of 100 m) which are typical of the upper ocean surface layer, the parameter $\varkappa$ equals about 0.03. This small value is indicative of a small energy potential. If one takes into account that technical systems of thermal energy conversion (thermomechanical or direct thermoelectric conversion) have efficiency of not less than 0.1, the general conversion coefficient ($\varkappa\eta$) in the oceans is very small and equals tenth parts of 1%. However, this is a certain advantage of thermal sources in the ocean, since in the process of energy consumption they remain almost unchanged and one can talk about ecological harmlessness of their utilization.

Taking into consideration such small values of the conversion coefficient in the ocean, with a temperature difference of $10^\circ C$

at depths of 100 m, one can obtain from the area of 1 km^2 electric power of about 10^9 W. This power coresponds to the power of a modern atomic electric power station, yet the plant system of ocean thermal energy conversion (OTEC) is simpler and more reliable than an atomic electric power station. At the same time, the OTEC plant system is more bulky. Its overall volume under the above-stated conditions comes up to 10^8 m^3.

Being assembled in the form of a volume grid, it can be submerged so as not to disturb communications and, besides, it can be used as a structural base for aquaculture cultivation. The operation of OTEC plant systems for an unlimited time is possible in the presence of horizontal water convection in the given ocean area. If the depth difference is designated as ΔH and the temperature difference T_2-T_1 as ΔT, then the power of the OTEC plant system may be estimated by the formula

$$W = \rho c \Delta H \Delta T S u \varkappa \eta / L$$

where ρ is the water density, c is heat capacity, u is convection velocity, S is the ocean surface area occupied by the plant, and L is a horizontal size of the plant along the direction of the horizontal convection. It is clearly apparent that under other equal conditions, the energy potential of the plant is linearly dependent on the rate of the horizontal convection u.

Thus, it is expedient to place OTEC plants in ocean areas with large currents. In this respect, the operation of OTEC plants in the vicinity of the Kuroshio current is of interest, since it is situated near possible consumers of energy and delivery of the energy to the consumer will not be very costly. It is also advisable to use OTEC plant systems in the areas of great tidal streams because in this case horizontal velocity values may prove to be essentially greater than those of common stationary currents. A shortcoming of such OTEC plant positioning is a cyclic nature of energy production due to the cyclic nature of tides. Yet the main thing is that when using OTEC plant systems in the areas of great tidal currents, one can eventially obtain greater energy than when using traditional tidal hydrodynamic energy conversion.

It is known that the tidal hydrodynamic energy is not related to solar light radiation but depends on the action of gravitational forces of the moon and sun and totals 10^{19} J/yr. Its utilization in the northwestern part of the Pacific Ocean is possible in the Sea of Okhotsk in the Tugur and Penzhyna Bays where the height of tidal waves may reach considerable values.

The power of hydrodynamic manifestation of tides may be estimated according to Bernard Le Méhauté (1969) by the formula

$$\omega=\frac{1}{8}\rho A^2 gL(gH)^{\frac{1}{2}}$$

where ρ is water density, g is gravity acceleration, H is depth, and A is height of the tidal wave. Thus the tidal power in the Tugur and Penzhyna Bays equals approximately 2×10^9 W and 14×10^9 W, respectively. However, after conversion of hydrodynamic energy of tides into electric energy, essentially smaller power can be used.

The energy of all stationary and quasi-stationary currents and circulations in the World Ocean makes up about 10^{19} J/yr. The power of the current is determined by the velocity u and the vertical cross-section area S_1. It can be calculated with the formula

$$\omega=\rho u^3 S_1$$

This power proved to be not very great as compared to that of the above-mentioned energy sources. For example, the power of the Kuroshio current may be estimated as 10^9 W.

Practical utilization of surface waves is possible in many areas of the Northwestern Pacific, since this part of the ocean is subjected to considerable weather disturbances. The power of such sources of ocean energy can be estimated according to Bernard Le Méhauté (1969) by the formula

$$\omega=\frac{1}{4}\rho A^2 gL\nu$$

where v is the rate of wave propagation which is equal to $(g\lambda/2\pi)^{\frac{1}{2}}$ where λ is the wave length. The density of this energy is very small and the use of ocean surface waves is therefore reasonable only in the case of low-energy consumers.

The total energy of cyclones can be evaluated as 10^{18} J/yr, taking into account that each of them has an energy of the order of 10^{14} J and their number reachs 10^4 per year.

When rivers flow into the ocean, osmotic pressure p_0 is induced which in the presence of the horizontal convection may continuously create a renewable energy source with a power of

$$W = p_0 u S_1$$

where S_1 is the vertical cross-section area of the river mouth. Osmotic pressure p_0 is determined by the gradient of molar concentration Δc_m at the boundary surface S_1 by the formula

$$p_0 = RT \ \Delta c$$

where R is the universal gas constant. This energy can be converted and used only in the case of stable or weakly migrating river mouths.

A B S T R A C T S

STABILITY AND EQUILIBRIUM IN GALAPAGOS ISLAND ECOSYSTEMS

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The Galapagos Islands experience two different kinds of environment, each with its characteristic stability. The moist uplands of the larger islands are almost permanently covered in cloud and have been so for 10,000 years. Occasional dispersing of the clouds, together with heavy rain, are associated with the annual El Niño event, but the conditions for life in the upland habitats is not drastically different in these El Niño periods. The lowland deserts, however, become radically altered during some El Niño episodes as rain induces a short-lived time of rapid plant growth. The occurrence of rain appears to be unpredictable in terms of any cues that can be used by the biota of the deserts. In a like manner, the conditions for life of coastal biota change unpredictably with the arrival or departure of ocean current systems, some of which are themselves associated with El Niño. Breeding strategies of long-lived Galapagos shore birds like penguins and flightless cormorants can be seen to be adapted to the unpredictability of the coastal current systems. Reconstruction of the population history of another Galapagos-based ocean bird, the red-footed booby, over several thousand years has been possible from phosphorus assay of sediments in the lake round which the boobies breed. The booby population has been stable in spite of the unpredictable fluctuations in local environmental conditions, suggesting that populations of other long-lived Galapagos sea birds with similar breeding strategies may be stable also. Pollen histories suggest that vegetation of the desert elevations on the Galapagos also contains many species that maintain stable populations in spite of the environmental fluctuations. The plants, like the shore birds, apparently maintain their stability by having long lives in terms of

the time that separated episodes when high production and seed-set are possible. Pollen diagrams from all Galapagos elevations suggest that other plant species that are short-lived and opportunists have strategies that lead to large population fluxes. It is likely that short-lived birds have population histories similar to weed plants on the Galapagos. In Galapagos lakes there is evidence that phytoplankton achieve population equilibria that are long maintained. This conclusion comes from the observation that the species richness of phytoplankton in Galapagos lakes occupying closed basins is strongly correlated with lake area. A similar finding in mainland Ecuador supports this conclusion. Whether population stability and species equilibrium is attained in the ecosystems of the Galapagos depends on the longevity of the organisms and the spacing between reproductive episodes.

NEW ZEALAND NATIONAL PARKS AND ALLIED RESERVES: THEIR ROLE IN ENVIRONMENTAL PROTECTION

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New Zealand's national parks and reserves established to preserve natural ecosystems are outlined in terms of their geographical and ecological extent and critically examined to assess their relative significance, both nationally and internationally for environmental protection.

A discussion of the legislative and administrative basis for the system of parks and reserves is used to reveal the essential elements of the philosophy underlying the parks and reserves movement in New Zealand. Some of the important strategies adopted to cope with management problems peculiar to the New Zealand situation are illustrated. These include, among other, the management of rare and endangered native plants and animals, the control of undesirable introduced plants and animals, and the protection of natural landscapes in the face of continually increasing pressures from tourism and other recreational users of parks and reserves.

Emphasis is given to the special role played by scientific research and resource assessment as a basis for management planning, and the unique provisions for public involvement in decision-making on matter of administration and management of parks and reserves.

OBSERVATIONS ON FOREST CHANGE IN MONTANE NEW GUINEA

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The great majority of New Guinea, excepting certain southern and high altitude areas, was originally covered with dense rain forests. Traditional slash-burn gardening methods permitted natural regeneration of plants in the forests. Plots were used for periods of two years or so for food crops and then abandoned, and could be cut again in about 20 years after humus had accumulated. Now, with rapid human population increase, the old system is failing as forest is being cut too rapidly. Moreover, with frequent burning of grass the forests cannot regenerate, so large areas of man-induced grasslands are extending. The highland valleys, above the malaria zone, before recent movements of peoples were the most densely populated parts of the island. These, where not cultivated, were largely transformed to grasslands except for scattered *Casuarina papuana*, *Alphitonia incana*, or *Dodonaea*, before European contact. Now some of this land is converted to coffee or tea, while other areas are going to grassland. But such land is often abandoned, with recurrent burning and no tree-planting. Landslides and severe erosion are having great impact.

Areas between 1200 and 2362 m altitude on Mt. Kaindi in northeastern New Guinea have been observed for forest advance or recession, over a period of about 15 years. Changes have been compared with similar environments in Hawaii, with great contrasts noted. Near the summit, above 2000 m, clearings which have been abandoned have started self-revegetation almost immediately. Within three years there is usually a 2 m growth of mixed species of trees, sometimes with *Macaranga*, *Homalanthus*, *Ficus*, and *Rubus*, and in other spots with dominance of *Nothofagus*, with *Elaeocarpus*, *Evodia*, and others of the climax forest - but in any case all native species of the adjacent forest. This contrasts with the frequent results in similar situations in Hawaii, where any re-growth is usually of exotic plants.

At lower altitudes on the mountain some areas cut long ago have been burned annually, preventing forest re-growth. Another grassy area apparently represents a landslide of a century of more ago, also regularly burned until Wau Ecology Institute started planting trees and making firebreaks in 1970. Some lower slopes denuded for agriculture are being partly burned and partly planted with trees. In 15 years observations on areas near the summit ridge, partly bulldozed in 1966, young forest 7 m tall of very similar speciesmakeup to the climax Southern beech forest has regenerated.

Among the factors relating to these contrasts between Hawaii and New Guinea are feral hoofed animals in Hawaii, and their lack in New Guinea, except for feral pigs in some areas and free-ranging domestic pigs in some other areas. The rain forests are evidently too dense and shady for deer, goats, etc., and much of the country is too steep, or too swampy for cattle. The situation in Hawaii is aggravated by the native biota being evolved in extreme isolation, with absence of many groups such as hoofed animals, and with many plants weakly competing when confronted with vigorous weeds, many of which are woody plants. The biota of New Guinea are much more varied, and introduced species encounter great competition and rarely penetrate rain forest.

VEGETATION CLASSIFICATION IN ISLAND ECOSYSTEMS

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Developments in the field of classifying vegetation in island ecosystems are briefly reviewed. It is shown that there is much terminological conflict and a general assumption that "climax" or edaphically "stable" units provide the only basis for effective classification.

There are many cases known to the author where island vegetation is rarely stable. A classificatory approach is therefore described that takes dynamic aspects into account, and allows a basis for uniform comparison and monitoring of temporal sequences.

A method of rapid reconnaissance sampling along major geoclimatic gradients is briefly outlined together with a system for recording basic parameters or core units that relate to functionally (physiologically) oriented plant structural attributes and associated life-form strategies. It is shown that these data together with aspects of the biophysical environment can be rapidly collected in the field and processed using available numerical classification techniques.

It is emphasized that floristic data play a very secondary role in this approach. Because of the physiological and strategic nature of the plant descriptors, the core-unit information is relevant to a wide diversity of terrestrial vegetation types. The attribute set is open-ended so that survey data relating to other biota can be added to the core-unit where desired. Reference is made to the general application of the technique to perturbed ecosystems and to its relevance in estimating actual and potential phytomass.

NATURAL AND ANTHROPOGENIC VEGETATION CHANGES IN NEW CALEDONIA

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The changes which happen in the plant cover on ultrabasic rocks and on sedimentary and metamorphic rocks will be examined successively.

Outcrops of ultrabasic rocks occupy one-third of the surface of New Caledonia. They appeared during the Oligocene and have given rise to unusual soils carrying a specialized vegetation closely adapted to the edaphic conditions. Variations in altitude and broken topography produce very varied plant associations whose distribution is illustrated by a vegetation map of Mt.Koniambo on the scale of 1:50,000. Ecological isolation due to diversity of biotopes and separation of ultrabasic outcrops has contributed to the differentiation of a rich flora which is highly original because of its insular origin and its strict adaptation to ultrabasic substrata. The species are almost all endemic in New Caledonia and mostly confined to ultrabasic rocks; among them are some relics of a great interest.

The peculiarities of the soils discourage invasion by gregarious introduced plants and protect the original flora from their competition. Changes observed in the plant cover of ultrabasic regions after burning and mining operations are restriction of forest to the valley floors and occupation of the affected areas by floristically poor pioneer associations which evolve very slowly towards a higher and thicker vegetal cover and therefore do not protect the soil against erosion. Some species confined to restricted areas and closely adapted to their environment are threatened to disappear.

On sedimentary and metamorphic rocks, former changes due to fires have contributed to the establishment of Melaleuca leucadendron savanna. Nowadays, repeated fires contribute to the keeping up and the extension of the secondary plant cover which would otherwise frequently evolve naturally toward a forest cover.

RECENT DEVELOPMENT IN RESTORATION STRATEGIES FOR NORTHERN TERRESTRIAL ECOSYSTEMS

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As terrestrial disturbances in the Arctic and the Subarctic have increased in number and extent, development of new methods for restoration of biological functions of damaged esosystems has accelerated. Private companies involved in petroleum development have sponsored much of the research but during the last five years public agencies have also become involved.

There is increased emphasis upon the use of native species and materials, (e.g., soils, mulches) for restoration. Although agronomic grass species and commercial fertilizers are commonly employed for revegetation of northern areas, other methods are either under development or in limited use. These include cuttings of native woody shrubs, sod from natural vegetation, commercial sources of seed from native species, and fertilization of vegetation adjacent to disturbances to encourage seed production.

Increased knowledge of natural rates of succession and reproductive habits of promising native species may lead to decreased use of agronomic seed on some disturbed sites. The importance of favorable substrata in cold regions has become more apparent as restoration efforts have increased. Topsoil and fine-grained subsoils are sometimes reused while ongoing research examines the use of soil amendments such as sludge.

The variety of techniques for northern restoration has only recently begun to increase. As research continues more methods for restoration will become available for restoring damaged ecosystems.

THE CONTRIBUTION OF FORESTS TO ENERGY CONSERVATION AND TO SUPPLY OF PROCESS ENERGY IN A CHANGING WORLD

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This paper examines the role of wood as a renewable energy source; past, present, and future.

As non-renewable materials, used for structural purposes and for fuel, become more costly in terms of energy, capital, and labor, renewable materials assume increasingly important roles. The paper compares renewable with non-renewable industrial materials in terms of the process energy required in extraction, transportation, conversion, and installation to put various structural components in place for use. The basis for the conservation of energy through substitution of renewable for non-renewable materials is examined.

Wood, a renewable fuel, is compared with fossil fuels in terms of availability, cost, environmental impact, and continuity of supply. The various solid, liquid, and gaseous forms of wood fuel are considered. Supplies of wood for fuel are assessed.

THE SIGNIFICANCE OF ECOLOGICAL PLASTICITY IN THE FORMATION OF ISLAND FAUNAS

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Islands offer a reduced number of ecological factors and,hence, of habitats. Conditions there may differ sharply from those in mainland habitats occupied by the same species while other species do not find adequate chances at all or live in an unfavorable environment. These well-known facts are explicable as due to size and degree of isolation of the island concerned.

Partitioning of exploitable environment among animals is controlled by two distinct though cooperative principles: annidation allots resources to species whereas territoriality subdivides space into units occupied by conspecific individuals. Annidation and colonizing success are (or are said to be) dependent, firstly, on extent of ecological differences from conditions on mainland or on other islands and, secondly, on competitive exclusion. Evaluation of these interactions has to regard the role that plasticity might play in such processes of zoogeographical and evolutionary bearing.

The specific internal system of niche utilization (named "econ") realizes and controls interrelations between animal and environment. It is composed of (1) selection and control mechanisms, (2) structures (including behavior patterns) necessary for utilization, (3) specific adaptive physiological (sensory, nervous, metabolic, energetic) abilities.

Plasticity as understood here is an enlargement of the frame given by the open genetic program and may consist of (1) discovery and utilization of new resources, (2) new utilization techniques, (3) new strategic combinations of elements of the econtic system, and (4) techniques and couplings which resort to group-specific elements in the hierarchy of the species-specific system. Plasticity of populations results from ranges of individual plasticity, individual (genetical) variability, and variants enabled by imprinting. Plasticity displays a mode of operation that is a result of the coupling and switching pattern characteristic of the specific econ. This system acts like a multistable system in the sense of cybernetics. Then, plasticity may be considered as an ultrastable reaction to casual events. This interpretation of plastic phenomena is a part of a new evolutionistic hypothesis of "niche utilization."

As may be deduced from comparative studies of island avifaunas, ecological differences in the same species (such as habitat selection, choice of food, nest site, nesting material, and further parameters of the econtic system) are due to either imprinting, or to genetical differences between the populations (at least, in amount of genotypic variability) or to the species high plasticity.

In several cases of habitat shift, especially such as urbanization, explained as shift (or widening) of the specific "niche," the essential factors appear to be identical and, thus, match the same searching images. "Ecological release," on the other hand, reveals the actual faculty of utilizing sources which usually (a closely related competitor being present) are not exploited. This is a plastic phenomenon, and it must be expected to play a part in the formation of island faunas.

DEVELOPMENT OF KRAFT PULP INDUSTRY FOR THE ABATEMENT OF ENVIRONMENTAL POLLUTION

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In recent years, the kraft-pulp industry has developed remarkably in every country or in the islands with oceanic environment and forest resources. But generally, the chemical pulp industry has been considered a representative which heavily polluted air and water.

According to the history of the pulp industries in Japanese Islands, the sulphite pulping (S.P.) started at 1890 in the forest zone of Mt. Fuji, and had developed to cover 97% of the total productions of the chemical pulps in 1926.

But the S.P. method had required very superior kinds of soft wood such as Picea and Abies, and besides, on the other hand, exhausted so much environmental pollutants that influenced the fisheries or ecosystems.

In 1921 the kraft-pulping (K.P.) process had started and then grown up from 1948, after the World War II, very rapidly, to overcome the sulphite pulping in 1957. The K.P. production has developed to occupy 91% of the total chemical pulp production in 1976. This has restulted from the fact that the K.P.process can digest the wider range of wood and cause lesser water pollution.

After an introduction of pollution control regulation such as the Water Pollution Prevention Acts (1962, 1971, 1976) the Air Pollution Control Act (1971) and the Odor Control Act (1972), many kraft mills began reconstructions for the abatement of pollutions.

Some of the mills had been moved to remote country from cities or to seaside from inland. But, if a river had a natural capability of the self-purification of water, the river-side mills could remain inland. Not merely the new-established, but also the major old factories have introduced continuous systems of digesters, the oxidation facilities of waste liquid, the closed systems of washers, the active sludge process for waste water, and the Less Odor Recovery Boilers instead of the conventional recovery boilers into their processes for the protection of environments.

In spite of their efforts, and assertions that major mills have succeeded in abating the pollutions under maximum allowable level, the grievances for the malodor from the mills have not yet vanished. Of course, solution of the problems of the odor control is very difficult, because the limit concentrations of the malodorous substances such as mercaptane and other reduced sulphur compounds for the olfactory sense are very low, under few ppb values.

From an opposite standpoint, some studies on new processes, the so-called none-pollutant ones,have been carried out at several laboratories. For example, the oxygen alkaline pulping with anthraquinone method, the biochemical pulping method, etc.,were suggested and attracted attention of specialists.

In order to solve the other dificult, but very important problem, that is, the decolorization of the K.P. waste effluent, a research on a reusable industrial inorganic adsorbent has been recently advanced by a group of some researchers in Japan.

Thus, according to the latest information it is believed that the kraft pulping will be feasible technologically and economically to abate the environmental pollutions to a certain level requested by the communities, and, on the other hand, that a new pollution-free pulping method will be born in future to replace the kraft pulping.

WASTE RECYCLING THROUGH THE BIOGAS SYSTEM

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This paper describes the development of waste recycling through the biogas system as practiced at the Maya Farms Division of the Liberty Flour Mills, Inc.

Liberty Flour Mills started operations as a wheat flour mill in Mandaluyong, Metro Manila. By utilizing the by-product pollard, it expanded its activities into feed manufacturing. Because of its success in hog feed, it further expanded into a piggery which was set up at Maya Farms in Antipolo Hills. Anaerobic fermentation (biogas plant) was adopted to control pollution caused by the manure. The biogas plant was found to be effective in the control of air pollution but the sludge was still a water pollutant. Maya Farms developed the sludge-conditioning plant to control water pollution.

The liquid portion of the sludge after treatment in the sludge-conditioning plant was found to be a good fertilizer; thus the use of chemical fertilizer was completely dispensed with. It also fertilized the fishponds. The solid portion of the sludge was processed into livestock feed ingredients constituting 10% of the hog feed.

Because of the success in producing high quality pork suitable for meat processing, Liberty Flour Mills put up a meat processing venture.

After the oil embargo in 1973, Liberty Flour Mills started experimenting on the industrial use of biogas. After finding various uses, the next aim was to produce more gas through improved designs and by producing the biogas at lower cost. A search for new raw materials started. Crop residues and weeds were used. It was found more economical to feed the crop residues and weeds to ruminants and then use the manure as the raw material for the biogas plant. This led to the raising of carabaos (buffaloes) and cows.

The wash waters from the pig pens and the meat-processing plant were treated in lagoons. A large amount of scum formed on the surface of lagoons. This scum was later used as 50% of the ingredients for duck feed. It was also used to grow zooplanktons in the fishpond.

All diseased plants and livestock are burnt in the incinerator. The ashes are used as potash fertilizer for the croplands.

Seven types of recycling system are presented illustrating an actual practice of the utilization of natural renewable resources:

1. animal waste → biogas + sludge solids
   livestock ← animal feed
2. meat-processing wastes → animal feed
   ← pigs
3. crop residues → ruminant feed → feed rejects
   crops ← compost
4. crop residues → ruminants → animal waste
   maize ← fertilizer/irrigation ← liquid sludge
5. animal waste → biogas + sludge
   livestock ← crop residues ← crops ← fertilizer
6. animal waste → biogas + liquid sludge
   pigs ← animal feed ← aquaculture

7. animal waste ——→ biogas + sludge
livestock ←—— feed ←— crop, grass ←— N P K

A material balance is described where a daily output of 15 t of animal waste produces 1000 m^3 of biogas, 1.5 t of dry sludge solids and 30 m^3 of liquid sludge.

MARINE POLLUTION BIOASSAY BY USING SEA URCHINS AT DIFFERENT DEVELOPMENTAL STAGES

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The present paper deals with the sensitivity of various developmental processes of sea urchins to some kinds of pollutants. The sea urchins mainly used at the Seto Marine Biological Laboratory, Shirahama, Japan were Hemicentrotus pulcherrimus (A.Agassiz) and, partly, Pseudocentrotus depressus (A.Agassiz). The effects of Cu, Zn, ABS, and NH_4 on fertilization success, first cleavage, blastulation, gastrulation,and survival of young adult sea urchins were tested.The eggs and sea urchins at all developmental stages up to adults were immersed in each test water, and rates of fertilization, first cleavage, gastrulation, pluteus formation, and some anomalies in development or survival in adult were checked. Maximum ineffective concentrations of four chemicals on various developmental processes about Hemicentrotus are shown in Table 1. The sensitivity of sea urchins to some chemicals varies during development from fertilization through maturity. Fertilization

Table 1
Maximum ineffective concentrations of four chemicals on various developmental processes of Hemicentrotus. Test water temperature: 17°C

Developmental processes Chemicals ppm	Fertilization 0 min.	First cleavage 30 min.	Blastulation 12 hrs.	Gastrulation 24 hrs.	Young adult 1 year
$CuSO_4 \cdot 5H_2O$	0.05	0.1	0.1	0.05	1
$ZnCl_2$	0.05	0.1	0.2	0.05	5
ABS	1.0	2.0	2.0	1.0	100
NH_4Cl	1.0	2.0	1.0	0.5	100

and gastrulation seem to be more sensitive than first cleavage, blastulation,and especially survival of adult to these chemicals. It may be necessary to observe the sensitivity on early pluteus formation and sperm activity.

LETHAL EFFECTS OF COPPER SULFATE IN *PENAEUS SCHMITTI* (WHITE SHRIMP) AND *MUGIL CUREMA* (MULLET) IN ESTUARINE WATERS

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The damage to the quality of natural bodies of water as a result of pollution is something that has concerned many people in our country. Lake Maracaibo, a water reservoir of great economic, social, and recreational importance shows a picture of accelerated pollution, because it receives a large amount of industrial effluents, sewage, chemical wastes, etc. This situation has worsened due to the demografic explosion and the resulting rapid growth in the economic activities. The scope of the eutrophication problem of the lake became evident when copper sulfate was used as a means of control in order to arrest the bloom of green-blue algae which, when in the process of decay, produce strong odors that cause extreme annoyance to the people who live on the water front. For this reason, when the responsible governmental institutions took knowledge of this situation, a study was instigated of the lethal effects of copper sulfate on two representative species of the fishery potential of Lake Maracaibo. These species were Mugil curema (mullet) and Penaeus schmitti (white shrimp). Bioassays were made using copper sulfate($SO_4Cu \cdot 5H_2O$),which were evaluated by standard procedures in order to determine the LC_{50} for a period of seven days of exposure (168 hours) to it. The intermediate periods of mortality were determined for intervals of 24,48,72, and 96 hours by calculating 0 and 100% mortality and copper sulfate concentration, and by grafic analysis for 168 hours between 16 and 84% mortality. The mean lethal concentration (168 h, LC_{50}), its 95% limits of confiability, the X^2 test, mean lethal time, and the percentage of accumulation were evaluated in the bioassays for the two studied species. By means of the progressive bisection of intervals in a logarthimic scale, the concentrations to be utilized were chosen to be 2.25, 1.17, 0.70, 0.43, and 0.16 ppm of copper.

The toxicity of copper sulfate for Penaeus schmitti and Mugil curema was 0.62 ppm and 0.34 ppm, respectively. The percentage of mortality observed in the seven day test (168 hours) was 100, 90, 60, 30, and 0 % for Penaeus schmitti and 100,90, 70, and 20% for

Mugil curema, after they were exposed to 2.25, 1.17, 0.70, 0.43, and 0.16 ppm of copper sulfate. The lethal concentrations to the 50% of the organisms were for white shrimp at 20, 90, and 156 hours of exposure to 2.25, 1.17, and 0.70 ppm, respectively, and for mullet at 13.5, 48, and 96 hours of exposure to 1.17, 0.70, and 0.43 ppm. No lethal means for 0.16 and 2.25 ppm in Mugil curema and 0.43 ppm in Penaeus schmitti were found.

After the results were compared and analyzed it was found that copper sulfate was toxic for both fish and crustaceans, but its toxicity was greater for fish. This suggests that copper sulfate is without any doubt a major cause of irreparable damages on the Lake Maracaibo biota, and that it should not be used as a means of control of excessive algal growth because its lethal effect is demonstrated at a very low concentration. The chronic and sublethal effects, that can be caused on these species that are of great economic importance for this region, remain to be demonstrated.

RESEARCH OF TRANSFORMATION OF HYDROLOGICAL REGIME OF SMALL WATERSHEDS UNDER URBANIZATION

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Urban catchments are complicated by complexities of the hydrologic system brought about by urbanization. Since urbanization entails the change in land-surface infiltration and in interception by the vegetation, the percentage of impervious areas increases and its counterpart decreases as urbanization proceeds. As a result, the changes in the quantity and timing of storm runoff are expected to occur.

The aims of the present study are to elucidate the effects of urbanization on the hydrologic cycle and to predict future change in the hydrologic system with development of urbanization in and around Tsukuba Academic Town at the southern foot of Mt.Tsukuba, about 60 km northeast of Tokyo. There are four small watersheds in and around Tsukuba Academic Town, and among them two watersheds are being urbanized.

Detailed hydrological records from the drainage basins of the Hanamuro River, Ono River, Yata River, and Nishiyata River were analyzed for the present study. These rivers drain a total area of approximately 190 km^2. This area was selected for investigation.

The areal distribution of ground water in the studied area can be described by dividing the area into three ground-water provinces. The present valley floors are considered to be the inheritage of buried valleys and all the present rivers are gaining streams.

The figures indicate that no distinctive differences between shapes of ground-water surface exist each year. However, the ground-water level of November 1977 in the Hanamuro and Hasunuma river basins which are urbanized areas dropped down compared with that of March 1971.

Secular ground-water level variations were determined using data from 10 automatic ground-water level recorders. These records of ground-water level fluctuations in wells located in urbanized areas, indicated that minimum ground-water level occurred in February or March and that the ground-water level would drop down in the future.

Rainfall and runoff hydrographs of the Hanamuro, Hasunuma, Ono and Nishiyata rivers were made. The watersheds of the first two rivers are being urbanized, and their hydrographs rise rapidly immediately after rainfall, reach a peak in a very short period of time and recede rapidly after the runoff. The watersheds of the last two rivers are not urbanized or rural, and their hydrographs are very flat and indicate the distinctive contrast to those of the urbanized river basins.

The surface-runoff characteristics of rapid and short-term runoff phenomena such as floods were analyzed by the author.

It has been assumed that the surface overland flow obeys the law similar to Manning's friction law, which the natural channel flow follows. Therefore, the author introduced the concept of an equivalent roughness coefficient in order to explain the change in discharge induced by urbanization.

THE WATER BALANCE OF SEMI-ENCLOSED SEAS

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Semi-enclosed seas are continental or marginal seas, having a limited contact with open seas or oceans, and influenced by two main hydrological factors: (1) inflow of fresh inland water and (2) inflow of salt sea water. The interrelation of these factors is of great importance to the formation of the hydrological regime of these seas as evidenced by their water balance.

The water balance of semi-enclosed seas is formed under the effect of surface and subsurface water inflow from the basin L, precipitation on the sea surface P, evaporation E, inflow of water from the ocean or open sea M, and outflow of water from the semi-enclosed sea to the open sea or ocean H. The water level of the sea is the result of the interaction between the components of its water balance. Precipitation and evaporation represent vertical water circulation, the inflow of water from the basin and the water circulation between the semi-enclosed sea and the open sea or ocean represent horizontal water circulation, and the increment or loss of water in the sea is accumulation difference ΔV.

The full equation of the water balance is

$$(P - E) + (L + M - H) = \Delta V$$

Vertical circulation	Horizontal circulation	Accumulation difference

This equation may be presented as

$$(P - E + L) + (M - H) = \Delta V$$

Fresh-water recharge	Exchange with ocean	Accumulation difference

The terms of both equations may be expressed volumetrically in cubic kilometers or as water-column height in centimeters. In the last case, the accumulation difference is determined by the difference in the sea-level fluctuations at the start and the end of the balance period.

The water exchange with the open sea or ocean is a decisive factor in the formation of the water balance of a semi-enclosed sea. Depending on the ratio between the inflow of ocean water and the water outflow, semi-enclosed seas with a positive or negative water balance are distinguished. Another equally important factor is streamflow, which causes desalting of the sea water (particularly in the coastal area) and may induce sea-level fluctuations in flood periods. Precipitation and evaporation play a somewhat less significant role, depending on the geographical latitude. The rate of water circulation in the sea, determined by the ratio between the sea volume and the balance total, is a major indicator of the hydrological regime of a semi-enclosed sea. The value of this circulation may vary in a fairly broad range.

The estimation of the components of the water balance of semi-enclosed seas and the rate of water circulation is the main hydrological problem, the solution of which allows us to understand the formation of the sea environment and find the ways of its conservation and development.

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ИЗДАТЕЛЬСТВО • НАУКА