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Global Marine Pollution: An Overview

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Preface

The United Nations Educational, Scientific and Cultural Organization, through its Intergovernmental Oceanographic Commission (IOC), has for several years played a leading role within the United Nations system in focusing the attention of Member States on the problems of marine pollution.

The amount of effort given by the United Nations system and other international bodies, governmental or non-governmental, has increased dramatically in recent years, in keeping with the equally dramatic increase in concern for the state of the world's oceans and seas. Consequently, the dangers of duplication of effort have also multiplied.

At the request of the United Nations Environment Programme, the Intergovernmental Oceanographic Commission asked Dr. Michael Waldichuk, a leading Canadian marine scientist, to prepare an overview of marine pollution and of the efforts being made to study it internationally. By virtue of his wide experience of international marine science and marine pollution research, acquired largely through personal participation in international meetings and expert groups on the subject, Dr. Waldichuk is well qualified for the task given to him. In describing briefly the state of marine pollution, as far as it is know or understood at this time, Dr. Waldichuk has drawn not only from his own wide knowledge but also from the book entitled "The Health of the Oceans" published in 1976 by the Unesco Press. The main part of the present report, however, describes the actions being taken by the international bodies mainly concerned with the problem. Dr. Waldichuk has updated the report to June 1977. The views expressed are the author's and not necessarily those of Unesco or the Intergovernmental Oceanographic Commission.

Unesco and the Intergovernmental Oceanographic Commission wish to thank the United Nations Environment Programme for permission to print the report in the IOC Technical Series.

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Foreword

The original version of this report was prepared on behalf of the Intergovernmental Oceanographic Commission (IOC) of Unesco for the United Nations Environment Programme (UNEP). It was presented by the writer to the UNEP Level One Advisory Group Meeting held in Nairobi, Kenya, 10-14 November 1975. The comments of participants at this meeting, and the secretariats of the United Nations Specialized Agencies, were reflected in a revision of the document which was resubmitted to UNEP in December 1975. A highly abbreviated and modified version was used as background documentation for the fourth session of the UNEP Governing Council which met in Nairobi during March 1976. The present report incorporates further updating and revision, based on new developments in this field and on further comments since 1975. While an effort has been made to accommodate all criticisms, the final views expressed are those of the author and are not necessarily endorsed by either Unesco or UNEP. In view of the document's considerable length, I have included an abstract for those readers who wish merely to have an overview of the Overview.

The initial draft of the report was prepared while the writer was at the Friday Harbor Laboratories of the University of Washington, Friday Harbor, Washington, during the Summer of 1975. It is a pleasure to extend thanks to UNEP for their support in preparation of this report and their approval for publication. Mrs. Loretta P. Beck typed the various drafts of this report, and her patience and good nature in making the many alternations have been much appreciated.

M. Waldichuk

Abstract

The problems of global marine pollution are examined in terms of both short-term, acute, local effects and long-term, chronic, cumulative, world-wide effects of pollutants in the world's oceans. The present pollution problems are most serious in coastal waters, which constitute only 10 per cent of the area of the oceans yet, together with the upwelling areas of the world, produce 99 per cent of the world fish catch. However, the long-term consequences of persistent, cumulative substances pose the greatest concern. The critical marine pollutants can be conveniently classified into five categories: (1) metals; (2) synthetic chemicals; (3) petroleum hydrocarbons; (4) radionuclides; and (5) solid wastes. Pollutants may enter the sea through rivers, atmospheric transport, ocean outfalls, ocean dumping, ships and such marine activities as mining. Atmospheric transport of pollutants and entry into the sea through fallout, rainout and washout have been considered an important rapid route for certain pollutants from man's activities on land to the world oceans. This particularly applies to the radionuclides and the polyhalogenated hydrocarbons, e.g. DDT and PCB's, but may also be important to world-wide dispersion of metals and petroleum hydrocarbons.

Problems of marine pollution from ships, especially by oil, and from ocean dumping, are rapidly coming under control through national legislation and international conventions, such as the International Convention for the Prevention of Pollution from Ships, 1973, and the International Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972. Control of atmospheric testing of nuclear weapons among the major nuclear powers, under the Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space and Underwater, 1963, has largely stopped entry of radionuclides into the sea from fallout. There are stringent controls on nuclear power reactors, and other peaceful uses of atomic energy, so that in the absence of accidents, there is minimal entry of radionuclides into the sea from these sources.

The remaining sources of marine pollution that must be controlled globally are those that are land-based and those that stem from exploitation of mineral resources (including oil) in the sea bed. The greatest contributions of pollutants from land-based sources enter the sea via the atmosphere (winds) and rivers. The Third United Nations Law of the Sea Conference is examining the possible international control of at least some of these marine pollution sources.

Many scientific conferences on the marine environment are identifying the major pollution problems, examining the critical issues and determining ways in which a meaningful base-line survey can be conducted and a useful monitoring programme established. All the United Nations Specialized Agencies concerned with the marine environment continue to review certain pollution problems within their areas of responsibility. The IMCO/FAO/Unesco/WMO/WHO/IAEA/United Nations/UNEP(1) Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) examines some of the problems on an interdisciplinary basis in annual meetings, and in intersessional working groups. It advises member agencies and/or member governments, through the agencies, on marine pollution matters. The IOC/WMO IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring commenced in January 1975, with a review of the first year's results in May and June 1976, and another review is planned for an indefinite date after 1977. The IOC International Co-ordination Group (ICG) for the Global Investigation of Pollution in the Marine Environment (GIPME) met for its third and last session at Unesco, Paris, in July 1975 and prepared a comprehensive plan for the global investigation of pollution in the marine environment and baseline study guidelines. The working committee for GIPME, which replaced ICG, met for its first session in Hamburg, from 18 to 22 October 1976. Progress is being made on scientific data exchange in marine pollution. Training

(1) A list of acronyms and abbreviations is included at the end of this report (Appendix II).

courses and workshops are providing a means of educating technical people in developing countries on techniques of measuring and assessing marine pollution and in initiating regional projects investigating problems of marine pollution.

A proposed programme for monitoring marine pollution at about 250 strategically located stations in oceanic, nearshore and estuarine waters and at 50 air-sampling stations is presented. Trends in concentrations of certain critical contaminants in water, organisms and sediments, and changes in water characteristics, should provide an early warning system, which will allow control measures to be taken before serious long-term damage is done to the global marine environment. Some projects on marine pollution research are proposed to meet the certain needs for information for pollution control.

Introduction

The oceans cover 71 per cent of the world's surface. The predominance of water on the surface of the earth is clearly evident in some of the relatively cloud-free satellite photos taken in the recent APOLLO moon missions. From the large proportion of ocean covering the earth, one can validly say that ocean is the rule rather than the exception. Earth is indeed the water planet. In volume, the enormity of the vast amount of water can only be visualized if we consider that it represents a mantle 2.7 kilometres thick spread evenly over the whole earth's surface, a total of 1.4 billion cubic kilometres. It would take 0.22 million years for a river the size of the Amazon to drain the world oceans.

This vastness has largely contributed to the myth that the oceans have an infinite diluting capacity, and that therefore they can be considered as one huge garbage dump for all of man's wastes. To some extent, this early concept of infinite dilution capacity might have been borne out, if wastes introduced into the oceans could be instantaneously dispersed and diluted into the full volume of the oceans. However, physical processes do not work that rapidly in the sea, and accumulations of waste and their unfavourable environmental consequences occur in some local areas. This may, in fact, be a fortunate thing, because the alarm has been sounded from many quarters about marine pollution. Also, we have suddenly become aware of global problems. DDT has been found in the fat tissue of marine animals everywhere, far removed from its sources. Oil slicks and tar balls are widely distributed over the oceans, and this was a startling revelation to Thor Heyerdahl (1972) in his "RA" expeditions across the Atlantic during 1969 and 1970. Tarry residues and litter can be found on beaches around the world, from Indonesia to Florida, U.S.A. The south east coast of Africa receives oil and tar balls from oily discharges on tanker routes in the Indian Ocean; Spain and Portugal in the east and the West Indies in the west are inadvertent and displeased recipients of oily residues swept ashore by prevailing winds and currents of the Atlantic.

Suddenly, the realization is upon us that the oceans cannot be regarded as a sink of unlimited capacity for all man's refuse. Sewage pollution has been causing coastal oyster beds to be closed because of high bacterial count and the threat of transmitting such diseases as infectious hepatitis. The dread Minamata disease in Japan was linked to consumption of fish and shellfish contaminated by methyl mercury from a chemical plant. Although the impact of pollution on global fisheries is still inconsequential in terms of total world output, there are already signs of serious damage to local fishery resources which could eventually multiply to significant proportions. "Red herrings" dying in Placentia Bay, Newfoundland, were found to be caused by elemental phosphorus present in colloidal form from a phosphorus plant in Long Habour. The finer and more sensitive species of fish, such as Atlantic salmon, have been declining in numbers in many areas. Clearly, the full volume of the world oceans cannot be utilized for dilution purposes, because of the nature of the sea, the character of the substances man introduces into the sea and the way in which he does it. It is by virtue of the processes which concentrate materials in the sea, and prevent total dispersion and dilution, that we may have received ample warning to do something about man's wastes before the trends show a dangerous degree of pollution developing in the open sea. We can now regard the oceans as our last defence against a global catastrophe resulting from the onslaught of man who, with an ever advancing technology and burgeoning production, seeks to satisfy his growing needs. The ocean does have a finite capacity to assimilate introduced materials, although we do not yet know what the safe limit is for that capacity.

The oceans must be viewed as a resource available for the benefit of mankind. If properly husbanded, this resource will continue to serve the many demands placed on it for all time. Satisfying an interim need at least, whether intentional or inadvertent, the ocean can serve to assimilate a limited amount of man's domestic and industrial wastes. Over the course of time, no doubt, the amount of polluting substance introduced into the sea will be diminished through deliberate national and international control. In the meantime, it is essential that irreversible damage not be done to the marine environment and its resources.

A major problem at the present time is assessing the effects on the marine environment of pollution which is superimposed on a host of natural environmental fluctuations, in addition to such effects of man as over-fishing. It might be stated that the "background noise" is often greater than the "signal". A real challenge to scientists lies in separating out the various fisheries exploration and natural environmental effects so that the changes wrought by marine pollution and other man-made disturbances can be clearly discerned. World fisheries production (FAO, 1974a) has been steadily increasing since 1946, except for a period in the early 1970s when the Peruvian anchovy fishery collapsed, because new fisheries continue to be exploited. When all new resources have been found and are exploited at an optimum sustained yield, then it may be possible to recognize declines due to pollution by man (FAO, 1971d).

Coastal versus Open Ocean Pollution

The oceans must be viewed spatially and temporally rather specifically according to the kinds of pollution to be considered. In this respect, one should examine short-term problems separately from the long-term ones. Similarly, local or inshore problems should be treated differently from the global ones. The local problems can certainly affect a resource, but it is the global ones that have serious long-term consequences. It is estimated that coastal waters to the edge of the continental shelf constitute 10 per cent of the area of the world's oceans. But 99 per cent of the world fish catch originates from these coastal waters and from the relatively small (0.1 per cent) upwelling areas. Most of the open ocean, lacking in nutrients to sustain life, is a biological desert. Table 1 illustrates the significance of the different ocean regions, from the point of view of effects on marine resources and their duration.

In terms of protection of living marine resources, and this is a rather vital consideration in pollution control, it is obvious that one would have to give prime attention to the coastal region. Controlling pollution in these waters may also relieve, or at least delay, pollution of the global oceans. However, a different type of pollution is more important in coastal waters than in the open ocean. Sewage can cause a whole host of problems in inshore waters, but may be inconsequential in the open sea, unless there are high concentrations of metals and other non-biodegradable substances. Pulpmill waste may lead to anoxic conditions in poorly flushed inshore waters, and may be quite toxic to some of the intertidal fauna. However, it may contribute little to global marine pollution in the long term, unless it contains mercurial slimicides or other such toxic and industrctible substances. On the other hand, mercury, cadmium and radionuclides, for example, released near shore can be toxic and bioaccumulated by intertidal invertebrates, but at the same time they contribute to the burden of these elements in the global ocean.

The serious problems of coastal pollution first became apparent in those heavily industrialized nations where there are concentrations of people and industry along the coast. The estuaries are some of the first aquatic areas to succumb to the abuses of man. Anadromous species of fish, which are particularly sensitive to pollution, are often the first fisheries resources to disappear. This has happened in various estuaries on both sides of the North Atlantic, where domestic sewage and industrial wastes have poured in large quanitites, for a century or more, into the rivers upstream. While the productivity of the estuaries, as measured in biomass, appears to have been undiminished, the community structure of the flora and fauna has substantially changed. "Weed" species tend to increase, while the species useful as forage by higher organisms and as food for man tend to diminish.

Although some of the highly industrialized countries would rather not have the dubious honour of serving as the early warning system for the world on marine pollution, this in fact has been the case. We have looked to Japan, for example, to provide warning on the problems that can arise with metal pollution in the tragedy of Minamata disease from mercury poisoning and the painful _Itai itai_ disease from high cadmium ingestion. The accidental contamination of food by PCB's in Japan led, as early as 1968, to a chloracne-type skin disorder complicated by palsy, fatigue, muscular pain, visual disturbance and vomiting among some 5,000 victims. The fatal consequences to bird life of mercury contamination of the environment were first noted in Sweden. Consequences of industrial waste to aquatic populations were exhibited in various ways in the Rhine River. The effect of domestic sewage in removing oxygen from waters into which it was released were clearly demonstrated in the Thames River and in the Inner Oslo Fjord, where large amounts of human wastes have been released for a long time from the cities of London and Oslo, respectively.

Table 1

Categories of ocean areas and types of pollution, with effects on uses and their duration

Ocean area	Types of pollution	Effects on uses and pollution trends	Duration of effects
Coastal waters (10% of total area; 99% of total fish production, including that from upwelling areas)	Sewage; industrial wastes; litter; petroleum hydrocarbons	Living resources destroyed or rendered unusable; industrial uses of sea water adversely influenced; amenities reduced; recreational values diminished	Short-term; mainly during period of discharge
	Synthetic organic chemicals; metals; radioactivity	Living resources decreased or rendered unusable	Long-term; metals and synthetic organic chemicals deposited in sediments may be released for a long time through normal leaching and/or dredging disturbance
Open ocean (90% of total area; 1% of total fish production, excluding that from upwelling areas)	Synthetic organic chemicals; metals; petroleum hydrocarbons; radioactivity	Increasing concentrations in water and organisms may indicate dangerous trends	Long-term; duration depends on the residence time of pollutant

It could be stated that long before the open ocean exhibits a dangerous degree of pollution, the coastal environment in many places will have become intolerably polluted. This might be generally regarded as true, unless the practices of sea disposal of waste now exercised are substantially altered. However, the coastal environment is a highly variable one, being affected by local marine characteristics and strongly influenced by processes on land. The changes which take place there seasonally, and from year to year, vary greatly from one place to another. Coastal waters especially in estuaries, can also be considered as a "filter" for fresh water entering the sea from the land. A significant proportion of dissolved and suspended substances is removed through biogeochemical activity and ultimately deposited in the sediments.

Since most of the marine pollution originates on land, and usually passes through the coastal zone first, it can be argued that control of pollution in the global marine environment can be best achieved through control of pollution in coastal waters by the coastal state. While this may be a valid approach, if there were uniformity of control among all the coastal states, there are still various uncontrollable sources of pollution, e.g. urban and rural runoffs. The ultimate net effect on the world ocean can, however, only be determined in the open sea well removed from the spurious effects of land. The trends in the open sea must determine the action needed to control global input of pollutants. Conditions in coastal waters, because they change so drastically, seasonally and from region to region, could seldom be used as an index of changing conditions in the marine environment as a whole.

The problem of global marine pollution is where international concern must be particularly expressed, although it is recognized that regional activities to assess coastal pollution problems can be also co-ordinated best by international agencies. It is in the open ocean, regarded now and probably for some time into the future as international waters, that problems of long-term consequences can become apparent. It is here, that man-made substances such as DDT and PCB's, which are alien to the natural marine environment, will first indicate that undesirable concentrations are arising on a world-wide scale. It is here too that certain constituents, such as the heavy metals, already present in the sea in very low concentrations, may exhibit dangerous global trends.

Perhaps the first form of global marine pollution was radioactivity. It initially rose from the early post-World War II nuclear weapons tests by the United States of America in the South Pacific. Transported by stratospheric air currents, the fission products from a sub-aerial nuclear explosion were distributed through the earth's atmosphere and deposited on the earth's surface mainly in temperate zones.

Radioactivity from nuclear fallout was soon identified everywhere in the oceans. The longer-lived fission products, strontium-90 (half-life 28 years) and cesium-137 (half-life 30 years) could be identified in sea water and marine biota almost everywhere, although usually in quite low concentrations. It was perhaps because of the availability of sensitive analytical techniques for measuring low concentrations of radionuclides that we learned early so much about the world distribution of fission products from nuclear weapons' tests. Using the radionuclides released in the tests as tracers, we were able to learn a great deal about the circulation and mixing processes in the oceans. We were able also to study the uptake of radionuclides by various species of marine life (Lowman, 1960). The startling concentration factor (ratio of concentration in the organism to that in ambient water) of zinc-65 in oysters (100,000 to 200,000) demonstrated some of the dangers of bioaccumulation of toxic contaminants in marine organisms.

Undoubtedly, the greatest concern about radioactive contamination was expressed not by marine ecologists but by human geneticists. It was generally acknowledged that radiation can cause mutations, and that excessive radiation can be genetically harmful. There was believed to be no lower threshold for genetic and somatic radiation injury. It was estimated by some highly qualified scientists that 50,000 more cases of leukemia would develop per year in the United States of America alone, if the level of atmospheric nuclear tests in the late 1950's was maintained.

This situation was aggravated by Soviet atmospheric nuclear tests by this time. It finally led to international negotiation on control of atmospheric nuclear testing, and the Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space and Underwater, 1963.

It has since been recognized that other substances can gain world-wide dispersal rapidly through atmospheric transport, e.g. DDT and fluorochlorocarbons, the aerosol propellants. Automobile emissions of lead from the lead tetra-ethyl used in anti-knock gasolines has resulted in significant increases in lead concentrations in the upper layers of some ocean areas.

Societal and Environmental Response Times to Pollutant Input

The troubling question of whether rising trends in concentrations of anthropogenic substances in the sea are irreversible arises. There are a number of important concepts that must be borne in mind when considering trends in marine pollutants. It should be understood that every system, no matter how large, has the capability of restoring itself to its normal state, given the proper environmental conditions and sufficient time.

Let us consider DDT, for example. It is a pollutant well known for its persistence and tendency to accumulate in the fatty tissue of all animals. However, it does undergo some degradation even though this is low. In the marine environment, it may be removed from the water by aquatic organisms which settle out and form part of the sediments. In other words, it gradually becomes immobilized. As long as the input does not exceed the degradation and the loss to the sediments, a certain steady-state, equilibrium level of DDT will be achieved eventually in the world oceans. To lower this equilibrium level of DDT, one must decrease the input. To eliminate the oceanic burden of DDT entirely, it is essential to stop the input.

The big unknown is the time required to reduce or eliminate undesirable concentrations of pollutants. Again, with DDT as an example, how long would it require the concentration of DDT to reach zero in the marine environment, if the use of DDT were abolished the world over? This is known as the response time. The time that a substance remains in the ocean until it is totally degraded or is immobilized in the sediments is known as the residence time, the approximate value of which is given by the ratio of the total amount of the substance in the ocean to the annual input or loss from the system. This could be months, years, decades, centuries or millenia, and here is where the problem lies. Some non-reactive, persistent substances could build up to undesirable levels in the marine environment before being detected, and then they might require generations to be eliminated or even adequately reduced to acceptable levels. Moreover, a substance like DDT continues to be leached by runoff from soils and forest cover long after its initial application.

There is a need for an "early warning system" for pollutants entering the marine environment, and then rapid implementation of control measures. How does one detect the presence of dangerous concentrations of a particular substance? Preferably, it would be best not to introduce the offending substance into the marine environment in the first place. But, in the event that this introduction cannot be prevented, it is highly desirable to be able to take necessary corrective action once a danger signal is noted.

Often in the past, it has taken a long time first to relate cause and effect, and then to enforce preventive measures. For example, in the late 1930's, the Chisso Corporation of Japan commenced discharging mercury wastes into Minamata Bay from its production of formaldehyde and vinyl chlorides, wherein mercuric oxide was used as a catalyst. The neurological disorder, known as Minamata disease, caused by consumption of fish and shellfish containing methyl mercuric chloride, was not identified until 1956, and it was about 1960, with already more than 80 cases reported, when the disease was widely described in medical journals giving the circumstances under which it developed. But it was not until 1963, seven years after the diagnosis of the first case and some 23 years after the first discharges of mercury into the sea, that the disease was proved to be caused by high concentrations of methyl mercuric chloride. Soon after this, action was taken to control the discharge of mercury into coastal waters of Japan, and restrictions were placed on levels of mercury in fish products entering the market. By this time, there had been some 44 mortalities and over 110 victims made helpless for life by the tragic neurological disorder.

Delay in control of pollution is partly related to our slow perception of cause/effect relationships and of environmental and ecological responses, coupled with slow development and enforcement of regulations for pollution control.

Effects of Environmental Contaminants

1. Human health hazards

Protection of human life takes precedence over everything else in our society. If mortality, or mental or physical disorders can be clearly identified with a drug, food or environmental contaminant (except perhaps with long-used substances having a traditional place in our society, such as alcohol and tobacco), that material will be quickly removed from the market or prevented from entering the environment by food and drug and public health authorities. The human deformities caused by the drug thalidomide, taken by women to prevent nausea during pregnancy, were responsible for immediate withdrawal of that substance from the pharmaceutical trade. Municipal drinking water, shown to have high bacterial counts, will be banned instantly by public health authorities in most countries. The spectre of a cholera or typhoid epidemic always lurks in the background, when a widely consumed substance like drinking water is involved.

When Minamata disease was related to the presence of methyl mercury in fish and shellfish, controls were imposed in most countries on excessive concentrations of mercury in these products before they reached the market. Radiation is known to present both somatic and genetic hazards to man. The genetic effects are not too clearly defined, but there is sufficient evidence for genetic damage by radiation to maintain radioactivity in the environment at a minimum.

There are other risks to human health which are not as clearly defined by cause/effect relationships as the Minamata disease and thalidomide incidents. It is difficult to ban a substance believed to have undesirable health consequences, if its harmful effects on humans or suitable test organisms have not been clearly substantiated. For example, the relationship of sewage pollution to the transmittal of disease by sea bathing provides little conclusive epidemiological evidence of a health risk. Consequently, protection of bathing waters against sewage pollution in some parts of the world is still maintained by so-called "standards of convenience", which are basically easily attainable standards in a given body of water.

2. Ecological impact

Perhaps the most important effect of pollutants in the marine environment is ecological disruption, i.e. the imbalance created between organisms and their environment, and between communities of organisms of different species. This is often an insidious, long-term effect which can lead to large changes in populations of commercially important fishes. The net result of pollution in inland bodies of water, such as Lake Erie, where fine fishes have been replaced by coarse fishes, is only too well known. It occurs by complex processes in the ecosystem which are poorly understood. From the point of view of protection of living resources in the marine environment, the ecological effects of pollution are of the most vital concern.

Substances with unfavourable ecological effects, but without proven human health hazard, meet with considerable resistance when attempts are made to curtail or ban their use. DDT is a case in point. The Montrose Company in the United States of America commenced production of DDT in southern California during 1944, discharging its wastes into the sewer systems which ultimately led to the sea. By 1952, the first analyses showing the presence of DDT in sediments off the coast of southern California were made. The DDT concentrations in sediments progressively increased until 1969, when production declined and waste was controlled. Between 1969 and 1972, egg-shell thinning was recognized in the brown pelican colony on Anacapa Island, which led to serious reproductive failure because of egg breakage during hatching. Other fish-eating birds showed similar trends in egg-shell thinness and resulting reproductive failure. This was attributed to DDE, a degradation product of DDT, which interferes with calcium metabolism.

The transplanted coho salmon in the Great Lakes was also experiencing reproduction difficulties, and this was alleged to be due to concentration of DDT in the gonads of the females with acute toxicity to the alevins caused by the DDT in the oil of the yolk sac as it was absorbed. DDT is also known to be toxic to young salmonids, as experienced with the Atlantic salmon in the Miramichi and other rivers of New Brunswick during extensive spraying of the forests against the spruce budworm. It has penetrated deeply into the food chain and has been found in penguins, polar bears and seals at great distances from any apparent source of DDT. Because of these ecological problems, which were quite well substantiated by scientific evidence, DDT was banned in many western countries by 1970.

However, DDT has its redeeming features. It has prevented untold misery in many tropical and semi-tropical countries through control of the mosquito which spreads malaria. Its contribution to increased agricultural production through control of insect pests cannot be denied. It is certainly still being used extensively in the developing countries. DDT will probably continue to be applied for some time in certain areas against mosquitoes for malaria control and against plant pests in agriculture. There is a trend, however, even in developing countries, toward the use of pesticides that are more biodegradable and less ecologically damaging.

Other chlorinated hydrocarbons inadvertently entering the environment, such as the PCB's, do not have the virtues of the pesticides. Their total elimination from the environment could be achieved by their replacement with ecologically less damaging substances. Better control of the use and accidental releases of PCB's would minimize their entry into the environment. Thus the ecological damage and human health risks that PCB's pose could be eliminated or substantially reduced.

There is a host of ecological effects due to the discharge of pollutants into coastal waters. Habitats of marine organisms may be adversely affected by solids settling on the bottom and by materials leached from them. Sedimentation from coastal mining operations may alter tropical waters unfavourably, especially coral reefs, where the light that is vital for photosynthesis is reduced (Wood and Johannes, 1975). Erosion from improper land management may affect coastal spawning grounds as well as those in rivers. Organic substances in both dissolved and solid form decompose and remove oxygen from the water. This can be a serious problem in partially confined areas, such as embayments and fjords, in which the water is not frequently replaced. It may even occur in basins on the exposed continental shelf where there is little or no flushing action by bottom currents. In areas where the volume waste is very large compared to the amount of water available to dilute it, even the salt composition of the sea water may be significantly changed. Normally, this is not a problem in most coastal waters if there is adequate flushing action. Such problems as pH change, due to the input of highly alkaline or acidic wastes, which can be a serious complication in fresh waters, do not commonly occur in the sea because of the buffering action of sea water.

The inflow of fresh water over coastal sea water causes a stratification to take place in the absence of tidal and wind mixing. This in effect, reduces vertical mixing, and such processes as aeration of deeper water tend to be minimized. Moreover, the comparatively fresh surface layer may have low buffering capacity and can be affected by a pollutant in much the same way as a river or a lake.

Pollutants all exhibit toxicity to aquatic organisms in various degrees. Some may be acutely toxic even in low concentrations and kill aquatic organisms over a short period of exposure. Others may have a debilitating effect. It is perhaps the latter which is most important from a long-term ecological point of view. The sub-lethal, chronic effects of pollutants may include retardation of growth, alteration of chemoreception in food-finding and mating, aberrant behaviour, physiological stresses affecting the vigour of organisms, and reproductive failure. The impact of pollutants on coastal fisheries has been reviewed by Waldichuk (1974a).

Although there often appears to be no apparent mortality due to a pollutant, the chronic effects may eliminate a population of organisms in the long-term. Fish populations have been eliminated by acid precipitation (Schofield, 1976) in lakes of the Scandinavian countries and in Canada (Beamish, 1974). Salmon have been wiped out or severely reduced in numbers running up certain streams on both sides of the Atlantic by a combination of over-fishing, pollution and other anthropogenic effects. Marine mammals (seals and porpoises) in the Baltic Sea have exhibited reproductive failure associated with high DDT and PCB concentrations in their tissues (Helle, et al., 1976). So far, there has been no conclusive evidence that populations of marine fish have been seriously affected by pollution alone. However, this may be related in part to our inability to clearly identify cause and effect in certain fisheries problems. A whole ecosystem may be modified by input of a particular pollutant, because certain species are reduced in number or eliminated. Other hardier species may fill an ecological niche vacated by a sensitive species eliminated by the pollutant.

There are pollutional effects of substances introduced into the environment which are not necessarily characterized by toxicity to aquatic organisms. For example, coloured and suspended particulate materials may retard the penetration of sunlight and thereby inhibit photosynthesis. An excess of nutrients may cause dense algal growths that adversely affect higher forms of life such as fish and shellfish. The input of heat with cooling waters may not necessarily destroy organisms in the water, but again, the conditions in which they live may be adversely altered. One species may be encouraged at the expense of another. The migrating behaviour of certain fish species may be altered by temperature gradients introduced by cooling waters.

Ecological effects provide the most compelling arguments for pollution control, but have received perhaps the least attention from pollution control agencies. The problem of criteria for protection of the ecosystem hinges on adequate quantification of cause/effect relationships. Certainly the acutely toxic effects of pollutants are recognized in drafting regulations. Preservation of endangered species now merits legislation for enforcement in some countries. Diversity of species is accepted as a desirable objective in the preservation of the ecosystem for the benefit of mankind. But the full effects of pollutants and environmental restructuring on the marine ecosystem still require detailed exposition.

3. Aesthetic impairment

We come to a third kind of effect which is more closely related to amenity, aesthetics and the "good life" than it is to ecology and undesirable trends in the marine environment. This involves those effects which primarily offend the senses of sight, smell and feel. A particularly well-known example of this kind of pollutant is oil. It forms a sheen on the water surface and fouls the beaches, which makes it unpleasant to look at, and it often imparts an offensive odour to the atmosphere, to say nothing of the unpleasant consequences for bathers who often get their feet soiled by tarry residues in beach sand. That is not to say that oil pollution is without human health and ecological consequences. However, the long-term hazards to human health and to the ecosystem have yet to be unequivocally demonstrated.

It is true that a large-scale oil spill can wipe out a fishery for a time because of unfavourable effects on fish quality in the form of tainting, fouling of fishing gear and oil coverage of shellfish beds, causing some destruction of burrowing shellfish. This can impose an economic burden on the fishing industry, through tainting of fish and market unacceptability of fisheries products. There may be a real or imaginary effect on human health through consumption of such tainted products. Wildlife can suffer the greatest damage, and oiled birds may number in the tens of thousands or even hundreds of thousands. Again, it is true that birds are a renewable living resource in that they serve also as a source of food for some human populations, particularly in the north. However, water fowl are more often considered an amenity, valuable as a recreational resource.

Perhaps we should look to the more sensitive marine ecosystems, such as coral reefs and the Arctic, for major ecological impact of oil spills. Over the long run, we must not only learn to control oil spills in the sea better, but also learn the effects of petroleum hydrocarbons on all forms of life in the marine environment. However, at the present time the main effect identified so far in major oil spills is aesthetic and the net result is economic. The costs to the fishing and tourist industries can be enormous. Moreover, the oil-cleanup bill can reach astronomical proportions. People are sensitive now to the visual effects of pollutants on the marine environment, including the presence of oil slicks and tar balls in the mid-Atlantic or mid-Pacific, even as they journey across the ocean on vacation in a cruise ship.

This concern about the aesthetics in the marine environment goes beyond the effects of oil on our beaches. It involves such visual manifestations as foam caused by detergents and pulpmill effluents and floatables arising from sewage and other wastewaters. Turbidity introduced by mine tailings and brown-coloured wastewater from pulp and paper mills, sugar refineries and distilleries all tend to discolour and render an unpleasant appearance to the ocean waters into which they discharge. In the same way, plastics and other discards of our modern society are repugnant to the visual senses. Discolouration, turbidity and plastics are not without ecological consequences. They reduce the penetration of sunlight, for example, and thereby inhibit photosynthesis and production by phytoplankton; and plastic sheets affect the substrate for settlement of larvae of benthic organisms. However, this effect may be a secondary one, exceeded in importance by aesthetic considerations.

Critical Pollutants

There is a wide range of pollutants entering the marine environment, spanning a broad spectrum of effects, from the highly visual ones, such as plastics, wood debris and foam, to the very subtle and insidious effects of bioaccumulation of metals and chlorinated hydrocarbons. Pollutants of broad international significance were identified in preparation for the United Nations Conference on the Human Environment (UNGA, MS, 1972). A Review of Harmful Substances is annually updated by GESAMP; the last revised review, arising from the VIth Session of GESAMP held in Geneva, 22-28 March 1974, was recently published (GESAMP, 1976c). We can generally classify the known pollutants into five distinct categories, which would serve a useful means of examining the problems they pose.

1. Metals

Virtually all metals are found in the marine environment (Table 2), some in moderate concentrations, e.g. calcium and magnesium, and others in very low concentrations, e.g. gold and silver. Almost all metals are bioaccumulated in one or more components of the marine food chain. They are the most persistent of substances in the environment. They can be neither transmuted nor destroyed, although they can be combined in various compounds and complexes. A point to note here is that certain metals can combine with organic substances to form highly toxic metallo-organic complexes, e.g. methyl mercuric chloride, and that some of these transformations can

TABLE 2

Metals in seawater and their effects on fish life and/or the food chain

(from Waldichuk, 1974b)

Metal	Natural Concentration in Seawater[a] µg/1 (ppb)	Bioaccumulation, Concentration Factor[b]				Stimulatory[c] Concentrations for Algae µg/1	Inhibitory[c] Concentrations for Algae µg/1
		Plankton Pp	Plankton Zp	Macro-invertebrates	Fish		
Aluminum	1	745	1,150				1,500-2,000
Antimony	0.33			300 423-810[d]	77-4, 100[d]		
Arsenic	2.6			3,300			
Barium	20	62(31)	110				34,000
Beryllium	0.0006						
Bismuth	0.02			1,000			
Cadmium	0.11	1,694	9,440	82,000-182,000[d]	180-730[d]	0	100-140,000
Chromium	0.2	<34	<65				
Cobalt	0.05	<190	<365			0.04	500
Copper	2	38	437	24,000-35,000[d]	50-250[d] 130-660[e]	6-200	6.4-1,000
Iron	3.4	2,400	5,430			0.006-10	
Lead	0.03	2,087	15,500	7,000-100,000[d]	<6,000-10,000[d]		
Manganese	1.9	158	290		16-26[d]	0.05-50	
Mercury	0.15	180	172		530-12,300		30-50
Molybdenum	10	<10	<20		o	0.01-10	54,000
Nickel	2	41	149				
Rubidium	120						
Silver	0.28	98	117				50
Thallium	<0.01						
Thorium	<0.0005						400-800

Table 2 (continued)

Metal	Natural Concentration in Seawater[a] µg/l (ppb)	Plankton Pp	Plankton Zp	Bioaccumulation, Concentration Factor[b] Macro-invertebrates	Fish	Stimulatory[c] Concentrations for Algae µg/l	Inhibitory[c] Concentrations for Algae µg/l
Titanium	1	<290	<550				2,000
Uranium	3.3						
Vanadium	1.9	<100	<200			100	10,000-20,000
Zinc	2	113	1,800	148,000[f] 172,000-290,000[d]	1,600-2,100	6.5	500-5,000

[a] From Skinner and Turekian (1973).

[b] Concentration factor (CF) is the ratio of the concentration of the element in the organism to that in ambient water. Data are mainly from Lowman et al. (1971) and are based in some cases on the bioaccumulation of the radioactive species. Pp = phytoplankton; Zp = zooplankton.

[c] Wide ranges in concentrations arise from use of different algal species in the tests. For species tested, see North et al. (1972).

[d] CF values for macroinvertebrates (mainly Pacific oysters, Crassostrea gigas) and fish (mainly Pacific halibut, Hippoglossus stenolepis) were taken from tissue analyses of the Fish Inspection Laboratory, Fisheries and Marine Service, Vancouver, British Columbia, assuming average ambient seawater concentrations.

[e] Analyses for copper in plaice Pleuronectes platessa (Vink, 1972) were used for CF values, assuming average concentrations of copper (2 µg/l) in ambient seawater, and a factor of five for conversion of dry weight values in fish to wet weight.

[f] For oysters from Pringle et al. (1968).

be carried out by bacteria in nature. Some metals, e.g. mercury, copper and silver, are extremely toxic to marine organisms, whereas others, e.g. calcium, magnesium and sodium, are comparatively innocuous. Moreover, many metals such as sodium, calcium, iron, magnesium and even zinc are vital for nutrition in marine organisms. Certain organisms have a high affinity for particular elements, e.g. zinc is concentrated to very high levels in oysters, and vanadium reaches a high concentration in the blood of tunicates. The mechanism and cause of this bioaccumulation are still not understood, but there is little evidence of apparent serious direct harm to the organisms containing the high concentrations of these elements. The early life stages of the organisms may be more acutely affected than the adults, but there is inadequate research information on the effects of metals on eggs and larvae of aquatic organisms to fully appreciate the significance of metals in the embryonic stages of marine organisms.

The order of toxicity of common heavier metals to marine organisms, based on the best available information with respect to the most sensitive life stages, is as follows (valence state is given in brackets): mercury (Hg^{2+}) > silver (Ag^{+}) > copper (Cu^{2+}) > zinc (Zn^{2+}) > nickel (Ni^{2+}) > lead (Pb^{2+}) > cadmium (Cd^{2+}) > arsenic (As^{3+}) > chromium (Cr^{3+}) > tin (Sn^{2+}) > iron (Fe^{3+}) > manganese (Mn^{2+}) > aluminum (Al^{3+}) > beryllium (Be^{2+}) > lithium (Li^{+}). However, the fact that bioaccumulation of some of the metals, e.g. cadmium, poses a threat to human consumers, means that the order of overall hazard of the metals in the marine environment can be substantially changed. The concentration of metals in the marine environment, bioaccumulation levels and some effects on marine organisms are given in Table 2.

A significant increase in the concentration of metals in seawater in open ocean areas may present an early warning signal which should be heeded. At the present time, it appears that lead is the only stable element that has exhibited increased concentrations in oceanic areas, clearly attributable to man through emission of lead from automobiles using lead tetra-ethyl and anti-knock gasolines. Although mercury has received a great deal of attention through the Minamata Bay tragedy, there is little evidence to show that man's activities are significantly increasing the amount of this metal in the global marine environment. The introduction of metals into the ocean by natural processes compared to that induced by man through mining is shown in Table 3. Toxicities of some selected metals to aquatic organisms in terms of the median lethal concentration (LC50), which is the concentration required to kill one-half of the test organisms in a specified time, are given in Table 4.

TABLE 3

Man-induced mobilization of metals exceeding natural rates by geological processes, as estimated from annual river discharges to the oceans (from MIT, 1970)

Element	Geological Rate (in Rivers)	Man-induced Rate (Mining)
	10^3 Metric Tons Per Year	
Iron	25,000	319,000
Manganese	440	1,600
Copper	375	4,460
Zinc	370	3,930
Nickel	300	358
Lead	180	2,330
Molybdenum	13	57
Silver	5	7
Mercury	3	7
Tin	1.5	166
Antimony	1.3	40

TABLE 4

Median lethal concentrations (LC50) of a number of selected metals for marine and some freshwater organisms (from Waldichuk, 1974b)

Substance	Description	48-Hr[a] LC50 in ppm[b] Brown Shrimp (Crangon crangon) except as noted	48-Hr[a] LC50 in ppm[b] European Cockle (Cardium edule) except as noted	Fish[c]	Reference
Inorganic Ions					
Aluminum	3+[d]			0.27(1)	McKee & Wolf, 1963
Arsenic	4+			8.4(2)	McKee & Wolf, 1963
Beryllium	2+			31.0(3)	Jackim et al., 1970
Cadmium	2+			27.0(3)	Jackim et al., 1970
Chromium	6+	100	100-300	33-100(4); 17.8(5)	McKee & Wolf, 1963; Portmann, 1972
Copper	2+	10-33	1	1-3.3(6); 3.2(3)	Jackim et al., 1970; Portmann, 1972
Iron	3+	33-100	100-300	5(7)	McKee & Wolf, 1963; Portmann, 1972
Lead	2+		2.45[e]	0.34[f]; 188.0(3)	Jackim et al., 1970; McKee & Wolf, 1973
Mercury	2+	3.3-10	3.3-10	3.3(6); 0.23(3)	Jackim et al., 1970; Portmann, 1972
Nickel	2+	100-330	> 330; 1.54[e]	0.8(8)[g]	Portmann, 1972
Silver	1+		0.006[e]	0.01(9)[h]; 0.04(3)	Jackim et al., 1970; McKee & Wolf, 1963
Zinc	2+	100-330	100-330	3.3(10)[i]	McKee & Wolf, 1963; Portmann, 1972

[a] Concentrations underlined are very close to the actual LC50 values. LC50 data taken from Jackim et al. (1970) are for 96-hr exposure.

[b] In most cases, concentrations are in mg/1 (weight/volume).

[c] Species: (1) young eels, *Anguilla* sp.; (2) chum salmon fry, *Oncorhynchus keta*; (3) killifish, *Fundulus heteroclitus*; (4) sea-poacher, *Agonus cataphractus*; (5) coho salmon, *Oncorhynchus kisutch*; (6) flat fish, *Pleuronectes flesus*; (7) dogfish, *Squalus* sp.; (8) stickleback, *Gasterosteus aculeatus*; (9) goldfish, *Carassius auratus*; (10) rainbow trout, *Salmo gairdneri*.

[d] Valence state of elements tested.

[e] Studies were conducted on eggs of the oyster *Crassotrea virginica* (Calabrese et al., 1973).

[f] Tests were conducted on sticklebacks, *Eucatia inconstans*, and coho salmon, *Oncorhynchus kisutch*, in fresh water with 1,000-3,000 mg/1 of dissolved solids.

[g] Concentration given as the lethal limit of nickel nitrate as nickel for sticklebacks, *Gasterosteus aculeatus*.

[h] Given as the concentration for which there was a 96-hr average survival time for sticklebacks, *Gasterosteus aculeatus*.

[i] Tests were conducted in hard fresh water with about 320 mg/1 $CaCO_3$ (Edwards and Brown, 1967).

2. Synthetic chemicals

Modern society has the technical capability to synthesize a whole host of compounds. Some of these substances are produced in the laboratory to replace natural sources, which yield only small quantities with high extractive costs, e.g. dyes, vitamins and food flavouring compounds. It is said that 20,000 new organic chemicals are synthesized every year, and that 10,000 of these may reach the developmental stage where they could be produced commercially. About 1,000 new synthetic chemicals reach the market annually. Very few, if any, of these compounds can be found free in nature, and there are few analogues of these substances in the marine environment. They are virtually all foreign to the sea, so that all observed concentrations in the water and in aquatic organisms can be attributed to man.

The chlorinated hydrocarbons have received particular attention, because of the ecological damage caused by the use of DDT, i.e. reproductive failure in birds due to egg-shell thinning, inhibition of photosynthesis by phytoplankton, toxicity to fish, reproductive failure in fish and destruction of useful insect organisms in streams; all these effects have been documented. The polychlorinated biphenyls (PCB's) have been a focal point among substances inadvertently released into the environment through leakage, breakage of containers and emissions from combustion. In a large-scale leakage in Japan, with contamination of rice oil by PCB's from leaking heat exchangers, there was evidence of serious illness leading to death in severe cases, and with a chloracne-type skin eruption in milder cases among human consumers. PCB's were found also to be highly toxic to marine crustaceans when an accidental discharge of this material in Escambia Bay, Florida, led to a large-scale mortality of shrimps. Toxicities of a number of pesticides and PCB's to selected aquatic organisms are given in Table 5.

Both DDT, including its degradation products, and the PCB's are ubiquitous, being found in marine organisms almost everywhere in the world oceans. Both are bioaccumulated in the fats of marine animals found at long distances from any apparent points of injection of DDT and PCB's (Table 6). They have set an example for us on how widespread substances, released into the environment, can become. Therefore, they have given us a cause for concern about other similar, and possibly even more ecologically damaging, materials that may be deliberately or inadvertently leaked into the environment.

The use of hexachlorobenzene (HCB) as a fungicidal agent in many parts of the world has raised some questions of possible long-term environmental harm. It is highly persistent and has been found in terrestrial and aquatic organisms. Victims in south east Turkey, who accidently ate wheat treated with HCB for planting, suffered from a porphyria-type disease.

Mirex, another organochlorine, has been used largely as an insecticide against the fire ant in the southeastern United States and as an additive in polymer formulations, because of its flame retardant properties. It is highly toxic to some species of marine organisms, 0.1 ppb causing death in juvenile crayfish in laboratory experiments. Phytoplankton showed a 42 per cent decrease in carbon fixation when exposed to 1 ppm Mirex for four hours. However, surveys of concentrations of Mirex in coastal organisms of the Gulf of Mexico and along the south east coast of the United States showed that it is neither as widespread nor present in as high concentrations as DDT in marine organisms.

Low molecular weight halocarbons are now gaining prominence in respect of their environmental impact. The chloro-fluorocarbons, used as propellant solvents in aerosol dispensers, are almost entirely dispersed to the atmosphere. They achieved some notoriety because of their suspected eroding effects on the ozone layer in the troposphere. It is estimated that the annual world production of trichlorofluoromethane is 0.3 million metric tons, and that 2 per cent of this (6,000 tons) enter the sea. Its direct ecological effects on the marine environment are unknown.

Vinyl chloride has been implicated as a powerful carcinogen for humans when present in the atmosphere. The production of the plastic, polyvinyl chloride (PVC), has also led to pollution of coastal waters, e.g. the North Sea, by certain waste products. Vinyl chloride is produced by first chlorination of ethylene to 1,2-dichloroethane (EDC), then coversion to vinyl chloride, and finally polymerization to the PVC. The wastes consist of "EDC tars" and have been implicated with "fish in bad condition" in the North Sea (Jensen, et al., 1972). Moreover, concentration factors for these residues in marine organisms ranged from 15 to 3,000.

TABLE 5

Toxicities (LC50 values) of a number of selected pesticides to aquatic organisms

(from Portmann, 1972(A) and McKee and Wolf, 1963(B))

Substance	Description	48-hour*1 LC50 (p.p.m.)*2 Brown Shrimp (Crangon crangon) except as noted	European cockle (Cardium edule) except as noted	Fish*3	Reference
Insecticides (I) and Herbicides (H)					
Aminotriazole	H	1,000-3,300			A
Atrazine	H	10-33	>100		A
Azinphosmethyl	I	0.00033-0.001	>100	0.01-0.03(1)	A
γ-BHC	H	0.001-0.0033	10		
Carbyne	H	3.3-10	100	3.3-10(2)	A
Dalapon	H	>100	>100	100(3)	A
DDT	I	0.0033-0.01	>10	0.3-1(4)	A
Dieldrin	I	0.01-0.033	>10		
Endosulfan	I	0.01	>10	0.033-0.1(2)	A
Malathion	I	0.33-1.0	3.3-10		A
Maneb	H	3.3-10	100-330	0.33-1(2)	A
Parathion	I	0.0033-0.01	3.3-10		A
Simazine	H	>100	>100	6.6-7.7(5)	A;B
Polychlorinated biphenyls (PCB's)					
Aroclor 1248		0.3-1	>10	>10(2)	A
Aroclor 1254		3-10	>10	>10(2)	A
Aroclor 1260		>10	>10	>10(2)	A
Clophen A30		0.3-1	3	>10(2)	A
Clophen A60		>10	>10	>10(2)	A

*1 Concentrations in italics are very close to the actual LC50 values.

*2 In most cases, concentrations are in mg/1 (weight/volume), but where the raw material was available in liquid form only, as in the case of oil dispersants, concentrations are in ml/1 (volume/volume).

*3 Species: (1) Pleuronectes limanda; (2) Agonus cataphractus; (3) Pleuronectes flesus; (4) Pleuronectes platessa; (5) chinook salmon, Oncorhynchus tschawytcha.

TABLE 6

Mean concentrations of chlorinated hydrocarbons in organisms from Swedish waters, 1965-1968

(from Jensen *et al.*, 1969)

Location and organism[*1]	mg/kg (p.p.m.) in fat			mg/kg (p.p.m.) in fresh tissue			Per cent fat
	Σ DDT[*2]	DDT	PCB	Σ DDT[*2]	DDT	PCB	
Swedish west coast:							
Mussels	1	0.6	2	0.02	0.007	0.084	1.3
Plaice	1	—[*4]	5	0.006	0.004	0.021	0.5
Cod	1	—	7.3	0.005	0.003	0.019	0.30
Picked dogfish	1.5	0.91	1.5	0.15	0.091	0.15	9.6
Fish oil	2.1	1.2	0.74				100
Baltic Sea proper:							
Mussels	6	1.8	4.3	0.03	0.02	0.03	0.92
Herring	17	9.7	6.8	0.68	0.40	0.27	4.4
Plaice	2.7	2.1	2.7	0.018	0.013	0.017	0.65
Cod	19	9.8	11	0.063	0.032	0.033	0.32
Salmon[*3]	31	14	2.9	3.4	1.5	0.30	11.0
Fish oil	16	7.3	3.5				100
Seal (grey) liver	96	41	44	3.9	1.7	1.8	4.1
Seal (common and grey)	130	62	30	66	32	15	52
Eggs from Guillemot	570	20	250	40	1.2	16	7.0
The Archipelago of Stockholm:							
Mussels	3	1	5.2	0.04	0.02	0.37	1.1
Herring	7.7	3.9	5.1	0.23	0.11	0.17	2.6
Seal (grey)[*3]	170	17	30	36	4.2	6.1	27.1
White-tailed eagle,							
pectoral muscle	25,000	n.d.[*5]	14,000	330	n.d.	190	1.5
brain	1,900	n.d.	910	100	n.d.	47	5.4
eggs	1,000	n.d.	540	—	—	—	5.6
Heron	14,000	n.d.	9,400	71	n.d.	48	0.5
Gulf of Bothnia:							
Herring	6.2	3.5	1.5	0.26	0.14	0.065	4.4
Seal (ringed)	120	56	13	63	30	6.8	54
Gulf of Finland:							
Seal pups (ringed)	42	23	6.5	25	14	3.9	60
Seal milk	36	21	4.5	11	6.5	1.4	31

*1 Species analysed: mussel, *Mytilus edulis*; herring, *Clupea harengus* (also for fish oil); plaice, *Pleuronectes platessa*; picked dogfish, *Squalus acanthias*; cod, *Gadus morhua*; salmon, *Salmo salar*; grey seal, *Halichoerus grypus*; common seal, *Phoca vitulina*; ring seal, *Pusa hispida*; guillemot, *Uria aalge*; white-tailed eagle, *Haliaeetus albicilla*; heron, *Ardea cinerea*; Norway pout, *Boreogadus esmarki* (for fish oil).

*2 Σ DDT = DDT + DDE + DDD.

*3 For salmon and seal, the percentage DDD in Σ DDT was 41 per cent; the average was 17 per cent.

*4 — = not estimated.

*5 n.d. = not detected.

It has been suggested that low-molecular-weight halogenated hydrocarbons may have an environmental impact of widespread and rather devastating proportions. They could interfere with the methyl transfer processes through reactions with vitamin B_{12}. Fermentation might be seriously impeded if these substances reach critical concentrations in the environment (Goldberg, 1976b).

3. Petroleum hydrocarbons

It has been estimated that about six million tons of petroleum hydrocarbons are released annually, through man's various activities, into the marine environment. Much of this enters the sea comparatively unobtrusively in small quantities scattered over a large area. The highly noticeable part of the input is in the large oil spills from capsized tankers. Major sources of oil in the sea are given in Table 7.

TABLE 7

NAS estimates of inputs and fates of petroleum in the marine environment

(from NAS, 1975b)

	Metric tons per year
Tankers, oil terminals and other transportation related sources	2,100,000
River and urban runoff	1,900,000
Atmospheric fallout	600,000
Natural seeps	600,000
Industrial wastes	300,000
Municipal wastes	300,000
Coastal refineries	200,000
Offshore production	100,000
Total	6,100,000

Certain fractions of petroleum hydrocarbons are quite toxic to marine organisms, and some crude oils are more toxic than others (Table 8), because of differences in basic composition. Oil has a certain immediate ecological impact on the marine environment, but the main problems associated with oil spills, and demanding immediate action, have been usually related to amenities. An oil film on the water is unsightly and unpleasant. Oil residues on the beach interfere with the amenities of seaside living, strolling, bathing and other recreation. Many water fowl can be destroyed by an oil spill, commercial and recreational fishing can be disrupted, and shellfish beds may be covered by tarry oil residues. However, these effects are usually of relatively short-term duration. Bird populations are eventually restored, fishing is resumed and shellfish beds are cleansed by the flushing action of runoff, waves and tides. Permanent damage by oil to an ecosystem has still to be demonstrated, and a health hazard to man through exposure to oil or consumption of oil-contaminated sea food has not been unequivocally documented.

TABLE 8

Per cent mortality of cod eggs at various ages of transfer, subjected for 100 hours to different concentrations of oil film extracts*1 of three crude oils

(from Kühnhold, 1972)

Egg age at transfer, days	Per cent mortality concentration of oil film (p.p.m.) 10^4	10^3	10^2	0 (control)
Venezuela (Tia Juana):				
0.6	63	35	31	21
3.6	47	57	43	28
10	11	3	1	2
Iran (Agha Jari):				
1.3	42	33	—	8
4	34	27	14	15
10	7	10	4	—
Libya (Sarir):				
0.2	3	1.5	2	3*2
4	2	2	2	—
10	5	8	7	9

*1 Oil at different concentrations (10^2, 10^3, and 10^4 p.p.m.) was poured into 30-1 plastic containers and left for 2 days. Slow water circulation was maintained by means of small pumps to ensure a maximum saturation of soluble compounds. The clear oil extract was transferred into test jars and renewed every 2 days. Preliminary analysis showed that the amount of dissolved hydrocarbons obtained in this way from 10^4 p.p.m. of crude oils is of the order of 10 p.p.m.

*2 Since the data were taken from histograms in the original paper, there is some uncertainty about per cent mortality in controls of the tests for Libya crude.

The clean-up of oil spills is a costly and time-consuming business. Hence, the problems of oil spills are generally reduced to one common denominator - economics. For this reason, concerted efforts have been made in attaching the responsibility for costs of clean-up to the carriers of the oil. One of the earliest attempts at formulating an international convention on oil pollution prevention dates back to 1926, when the United States of America took the initiative to host a conference for such a convention. That attempt failed to develop an international agreement, and it was not until the International Convention for the Prevention of Pollution of the Sea by Oil, 1954, that some international regulations for control of oil pollution from ships were established. The more recent conference on this subject, convened by IMCO in October-November 1973, led to a new convention (IMCO, 1973a), which was broadened to include other noxious substances, as well as ship-generated sewage and garbage.

The biological impact of oil is being examined by a number of national bodies through research and conferences. So far, the various concerns about ecological impact have not been clearly supported by good scientific evidence, so that fully defensible conclusions cannot be drawn. A working group in GESAMP reviewed available data and drew some basic conclusions on the biological effects of oil in the marine environment for the 8th session of GESAMP in Rome, 21-27 April 1976 (GESAMP, 1976a-1977a). The ecological problems of oil pollution may be most acute in sensitive marine ecosystems, such as coral reefs (Wood and Johannes, 1975) and cold Arctic waters (Milne and Smiley, 1976).

It has been said that while populations can be rehabilitated from natural environmental extremes, if such extremes are combined with a devastating pollution incident, the consequences could be irreversible. For example, large populations of eider ducks migrate to the Arctic in the spring to feed, breed, nest, rear their young and molt. Usually their migrations are timed to coincide with the opening of large cracks in the sea ice through which they feed on marine organisms. Occasionally, the appearance of these open leads in the ice is delayed because of a change in climatic conditions with an unusually late spring, as occurred in 1964, leaving solid ice throughout the area frequented by the birds (Barry, 1976). Out of a population of a million eiders, ten per cent or 100,000 birds may die of starvation. In two or three years, the population can recover from this natural decline from starvation. However, should a large oil spill occur at a time when the ice finally starts to open up, and the leads become covered with oil, then a catastrophic bird kill could result. The eider population could conceivably never recover from this double set-back.

4. Radionuclides

The problem of radioactivity in the marine environment is one that received the earliest global attention. Starting early in the latter half of the 1940's, the global inventory of radionuclides has gradually increased (Table 9). This was associated at first, of course, with atmospheric contamination by nuclear debris from U.S. weapons' tests in the South Pacific. The movement and distribution of radionuclides, throughout the global mantles of water and atmosphere, became better known than any other pollutants. Part of the reason for this was that precise methods for analysis of radionuclides with sophisticated counting devices were available even during the early post-World War II era (Lowman, 1960). The radionuclides of man-made origin detected in the marine environment are shown in Table 10. Fission products, such as strontium-90 and cesium-137, were followed through both freshwater and marine ecosystems in many parts of the world. Uptake by marine organisms of zinc-65, colbalt-60, chromium-51 and iron-55 to high concentrations in their tissues (NAS, 1971a) demonstrated the capability for bioaccumulation of certain elements by many species in the sea.

TABLE 9

Total inventory of artificial radionuclides introduced into the world oceans* (from FAO, 1971b)

	Year 1970	Year 2000
Nuclear explosions (world-wide distribution)		
Fission products (exclusive of tritium)	2-6 x 10^8 Ci	? x 10^8 Ci*
Tritium	10^9 Ci	? x 10^9 Ci*
Reactors and reprocessing of fuel (restricted local distribution)		
Fission and activation products (exclusive of tritium)	3 x 10^5 Ci	3 x 10^7 Ci
Tritium	3 x 10^5 Ci	? x 10^8 Ci
Total artificial radioactivity	10^9 Ci	10^9 Ci
Total natural ^{40}K	5 x 10^{11} Ci	5 x 10^{11} Ci

* Assumed that atmospheric nuclear testing will continue at about the rate of 1968-1970.

TABLE 10

Artificially produced radionuclides which have been detected in the marine environment (from Preston, 1972)

Mode of production					
Fission			Neutron-activation		
Radionuclide	Half-life	Type of decay	Radionuclide	Half-life	Type of decay
*^{3}H	12.26 y	β^-	*^{14}C	5.76×10^{3} y	β^-
^{89}Sr	51 d	β^-	*^{32}P	14.3 d	β^-
*^{90}Sr	28 y	β^-	^{35}S	87.2 d	β^-
*^{90}Y	64.2 h	β^-	^{45}Ca	165 d	β^-
^{91}Y	59 d	β^-	^{46}Sc	84 d	$\beta^- \gamma$
*^{95}Nb	35 d	$\beta^- \gamma$	*^{51}Cr	27.8 d	$\kappa \ \gamma$
*^{95}Zr	65 d	$\beta^- \gamma$	*^{54}Mn	314 d	$\kappa \ \gamma$
^{99}Mo	67 h	$\beta^- \gamma$	*^{55}Fe	2.7 y	κ
^{99}Tc	2.1×10^{5} y	β^-	^{59}Fe	45 d	$\beta^- \gamma$
*^{103}Ru	40 d	$\beta^- \gamma$	^{57}Co	270 d	$\kappa \ \gamma$
*^{106}Ru/^{106}Rh	1.0 y	$\beta^- \gamma$	^{58}Co	71 d	$\kappa \ \beta^+ \ \gamma$
^{125}Sb	2.7 y	$\beta^- \gamma$	*^{60}Co	5.26 y	$\beta^- \gamma$
^{131}I	8.04 d	$\beta^- \gamma$	*^{65}Zn	245 d	$\kappa \ \beta^+ \ \gamma$
^{132}Te	78 h	$\beta^- \gamma$	^{76}As	26.5 h	$\beta^- \gamma$
*^{137}Cs	30 y	$\beta^- \gamma$	^{108m}Ag	127 y	$\kappa \ \gamma$
^{140}Ba	12.8 d	$\beta^- \gamma$	*^{110m}Ag	253 d	$\beta^- \gamma$
^{140}La	40.2 h	$\beta^- \gamma$	^{113m}Cd	14 y	β^-
^{141}Ce	32.5 d	$\beta^- \gamma$	^{115m}Cd	43 d	$\beta^- \gamma$
*^{144}Ce/^{144}Pr	285 d	$\beta^- \gamma$	^{124}Sb	60 d	$\beta^- \gamma$
^{147}Pm	2.6 y	β^-	^{134}Cs	2.1 y	$\beta^- \gamma$
^{155}Eu	1.81 d	$\beta^- \gamma$	^{181}W	30 d	$\kappa \ \gamma$
			^{185}W	73 d	β^-
			^{187}W	24 h	β^-
			^{207}Bi	28 y	$\kappa \ \gamma$
			^{239}Np	2.35 d	$\beta \ \gamma$
			^{238}Pu	86 y	α
			*^{239}Pu	2.44×10^{4} y	α
			^{240}Pu	6.6×10^{3} y	α
			*^{241}Pu	13.2 y	β
			*^{241}Am	458 y	$\alpha \ \gamma$
			^{242}Cm	163 d	α

Half-life: y (years), d (days), h (hours).

* Major occurring radionuclides.

Three types of radioactivity are introduced by man into the marine environment: (1) nuclear fuels, such as uranium-235 and plutonium-238, which may be introduced from nuclear-powered ships, aircraft and satellites; (2) fission products from nuclear detonations and energy production, such as strontium-90, cesium-137 and barium-140; and (3) activation products, e.g. zinc-65 and iron-55, resulting from neutron bombardment of components of nuclear reactors and weapons and natural constituents in the environment.

More recent studies of radioactivity in the sea have been concerned with the impact of effluents from nuclear reactors on the coastal environment. A major study was conducted in the vicinity of the Windscale Works on the Cumberland coast of the United Kingdom, where the effects of such radionuclides as ruthenium-106, from one of the early post-World War II reactors, on beach sand, seaweed and plaice in the Irish Sea were investigated. The discharge of large volumes of effluent from the Hanford Works, another early reactor system, into the Columbia River, in eastern Washington State, led to comparatively high concentrations of the neutron-induced radionuclides, such as chromium-51 and phosphorus-32, in the river water. A great deal was learned about the fate and distribution of some of the river-borne radionuclides in the Columbia River estuary and in the adjacent part of the Pacific Ocean (Pruter and Alverson, 1972).

Modern reactors are designed to eliminate emissions as much as possible of even the lowest concentrations of radionuclides. Some still utilize large volumes of cooling water, and it is often the released cooling water with its relatively high temperature that is more ecologically damaging than the radionuclides. One common aspect of all nuclear reactors is that they must reprocess their fuel. This operation usually results in high concentrations of fission-product radionuclides, some with relatively short half-lives and others with quite long half-lives (Table 11). Most of the wastes from reprocessing nuclear fuel is retained in suitable storage on land, although some thought has been given in the last three decades to deep-sea burial. The London Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, prohibits the dumping of high-level radioactive wastes into the sea (United Kingdom, 1972).

What are some of the problems of radioactivity in the sea from peaceful uses of nuclear power? There is always a threat of an accident in a nuclear reactor with uncontrolled release of fission products, as occurred at Windscale during the mid-1950's, when iodine-131 contaminated pastures of Cumberland, and thus led to high concentrations of radioiodine in cows' milk. Nuclear reactor designers assure us that reactor accidents can be virtually eliminated with fail-safe systems in every conceivable location. Statistics now show that the probability of a nuclear reactor accident is something of the order of 1 in 10,000. Nevertheless, authorities are being pressed, particularly in the United States of America, to install even better safety devices in some components of current reactor design.

There has been some concern expressed about emissions of noble gases, e.g. krypton-85, and of tritium from modern nuclear reactors, which may be harmful to the marine environment. However, fears can be allayed quite quickly, when one considers that the maximum possible global concentration of krypton-85 would have negligible biological involvement, and its radiation field would be only a few per cent of that of natural potassium-40. Tritium has low biotoxicity, and there is no evidence for its bioaccumulation by marine organisms.

The main pollution problem associated with nuclear reactors now is the possible accidental loss or theft of plutonium for terrorist activities. Besides being the element used in nuclear explosives, plutonium is extremely carcinogenic if inhaled. An opportunity was afforded for following the movement of plutonium-238 through the atmosphere and noting its dispersion on the earth's surface, when on 21 April 1964 a rocket carrying a satellite with a SNAP-9A nuclear power package was aborted. The SNAP-9A contained about 17 kilocuries of plutonium-238, and after it had ruptured in the earth's atmosphere, it doubled the amount of plutonium in the environment, originally contributed by weapons testing. By mid-1970, 95 per cent of the Pu-238 had deposited on the earth's surface, and soil profiles showed that there were measurable concentrations of Pu-238 as far north as 70^{o}N and as far south as 44^{o}S (NAS, 1971a).

The concentration factor for plutonium in invertebrates ranges from 2 in scallops to 780 in a marine worm. The best collector for plutonium, however, is the weed Sargassum with a concentration factor of up to 18,500. It is suggested that in the Sargasso Sea, there is a standing crop of 0.2 curies of Pu-239 in the seaweed. Since the crop is regenerated annually, 0.2 curies of

TABLE 11

Examples of transuranic content of spent nuclear fuels (from NAS, 1975a)

Isotope	Activity	Light-water Reactor	Liquid-Metal Fast Breeder Reactor
^{239}Np	β	0.05	2.0
^{238}Pu	α	8.5	3.2
^{239}Pu	α	1.0*	1.0*
^{240}Pu	α	1.5	1.2
^{241}Pu	β	350.0	170.0
^{241}Am	α	0.6	0.5
^{242}Cm	α	45.0	19.0
^{244}Cm	α	7.5	0.4

* Activities relative to that of plutonium-239.

TABLE 12

Total litter estimates (from NAS, 1975a)

Source		Amount of Litter Generated (10^6 tons/year)
Passenger vessels		0.028
Merchant shipping		
Crew		0.110
Cargo[a]		5.600
Recreational boating		0.103
Commercial fishing		
Crew		0.340
Gear		0.001
Military		0.074
Oil drilling and platforms[b]		0.004
Catastrophe		0.100
	Total	6.360

a Assumed that an unknown percentage of the waste is released in harbours, ports or nearshore areas.
b From Anon., 1973.

Pu-239 can be transported by the weed to the marginal zones of the Sargasso Sea or to the seashore, where the weed dies and decomposes, thus resulting in concentration of plutonium in the coastal zone (Goldberg, 1976b).

Today, the largest reservoir of plutonium-239 is in nuclear weapons, estimated to range from 213,000 to 319,000 kilograms, deployed globally. Plutonium-238, with a half-life of 86 years, is the favoured transuranic for nuclear reactors in electrical power generation. By the year 1990, it is expected that about 50 tons of plutonium will be in the transport mode in the United States of America, and perhaps as much as 100-150 tons will be in movement on the surface of the earth (Goldberg, 1976b). There is great concern about leakage into the environment, the effective management of plutonium being considered one of the first-order essentials in the development of nuclear technologies.

The other problems of radioactivity in the marine environment are the more common ones that have already given us cause for concern. For example, strontium-90 concentrates in bones. In human beings, it can expose the bone marrow to high radiation with possible increase in leukemia. Cesium-137 concentrates in muscle tissue of contaminated fish and can be a source of radioactivity in sea food taken from areas receiving fission products from nuclear reactors or from fallout originating from atmospheric weapons' tests. Ruthenium-106 is taken up by the seaweed Porphyra and was of some concern as a source of radioactivity among Welsh consumers of laverbread, made from seaweed collected in the Irish Sea and contaminated by effluent from the Windscale Works. Zinc-65 can be concentrated to high concentrations by oysters and could give rise to problems in the vicinity of reactors with high discharges of this activation product. Cerium-144 is a fission product sorbed by phytoplankton, and although of relatively short half-life (285 days), could conceivably cause problems where commercial shellfish filter out the contaminated phytoplankton. To some extent, however, we know something about these problems and how to control them. The haunting spectre remains, however, of genetic damage by even low levels of additional radiation.

5. Solid wastes

The amount of solid materials entering the sea annually can be in the millions of tons (Table 12). While this type of pollutant is largely cosmetic in character and affects mainly the amenities, there are other uses of the sea which are also affected. For example, large polypropylene or nylon ropes, floating just below the sea surface, can become entangled in the propellors of vessels, causing damage and possibly accidents at sea. Plastic sheets can also become entangled in ships' propellers, as well as clogging seawater intake systems for engine cooling and other purposes. Fishing gear may become fouled by netting and ropes, and on large solid objects deposited on the bottom. For this reason, the London Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, prohibits the disposal into the sea of "Persistent plastics and other persistent synthetic materials, for example, netting and ropes, which may float or may remain in suspension in the sea in such a manner as to interfere materially with fishing, navigation or other legitimate uses of the sea". For this reason also, the Convention on the Prevention of Pollution from Ships, 1973, prohibits the discharge from vessels of large floating objects within a certain distance of shore.

From the ecological point of view, solids deposited on the bottom can adversely affect the benthic habitat. Plastic sheets, for example, can smother organisms beneath them, because of lack of oxygen replacement due to elimination or reduction of water exchange, and adversely affect the substrate for settlement of larvae. Plastic bags have been found on the heads of fur seals, and can cause the animals discomfort, if not outright death, due to suffocation. Plastic and rubber spherules have been found in the intestines of fishes. In the early post-larval stages of these fishes, it is conceivable that blockages could be produced in the intestinal tract by such indigestible materials. Plastic bags are occasionally mistaken for jellyfish and consumed by sea turtles with undoubtedly distressing effects.

Solid wood wastes are known to be highly destructive of habitats in coastal waters where logging activities are practised. Log-booming areas tend to be denuded of eel grass and invertebrate fauna, for example. Leachates from the wood and bark especially of certain species of trees, are quite toxic to most marine organisms, particularly in their egg and larval stages.

Floating logs also shade the waters and prevent penetration of light for photosynthesis. Again, substrate is unfavourably modified for settlement of larvae. In the case of fine, particulate wood wastes, as in the discharge from pulp mills where fibres are present, sludge beds may form. These decompose, utilizing oxygen from the sediments and overlying water, and often release gases, mainly methane, but sometimes also highly toxic hydrogen sulphide.

Pollution by solid waste disposal, particularly with floatables, is clearly a matter concerning mainly the coastal zone at the present time. It poses not only amenity problems but also navigational hazards. For example, in the harbour of Vancouver, British Columbia, Canada, large numbers of logs and vast quantities of wood debris are present every spring and early summer during the freshet of the Fraser River. Some of these float just below the surface, and pose a real hazard to small boaters. Large "dead-heads" (vertically suspended submerged logs) can do serious damage even to larger vessels passing over them.

Unless a great deal of debris accumulates in vast convergence zones on the high seas, as often noted in tidelines in the nearshore waters, floating solid wastes are not expected to become a serious navigational problem in the open ocean for some time to come. However, floating refuse is offensive to the eye, and it behoves everyone concerned to strive toward better housekeeping of our oceans for more pleasant voyages in clean waters across the seas.

Solid wastes such as building rubble, old movie sets and discarded automobile bodies, have been used in a positive way to build artificial reefs for fish on the coasts of California and Florida in the United States of America and off Italy in the Mediterranean.

Modes of Entry of Pollutants into the Marine Environment, Transfer Processes and Sinks

Aside from the importance of controlling the input of pollutants into the marine environment, an understanding of the modes of entry is essential for mass-balance calculations. The transfer processes of pollutants through different compartments of the marine environment are of considerable ecological interest and also necessary for mass-balance calculations. The ultimate fate of a pollutant, i.e. whether it becomes degraded or locked up in the sediments, or whether it becomes widely dispersed in the world oceans, must be known to complete the budget information needed on the credit and debit sides of mass-balance evaluations.

Most of the waste materials of our modern society are generated on land. There are three principal modes of transferring these substances from the land into the sea: (1) river discharge; (2) atmospheric transport, followed by washout with rain; and (3) coastal discharges through outfalls. Vessels contribute to a certain amount of pollution through discharge of sewage and garbage, but this source is rapidly coming under control through national legislation and international conventions. More and more material is being transported out to sea for dumping at designated dump sites. However, the largest amount of material will continue to be released into the sea through coastal outfalls.

It is becoming apparent that atmospheric transport of pollutants is not an insignificant part of the transfer process from land to sea. First, the movement of fission products from nuclear weapons' tests through the stratosphere, with fallout of these radionuclides on virtually all parts of the globe, demonstrated how widely dispersed substances released into the atmosphere can become. Then followed the DDT problem with virtually every marine animal found anywhere near the sea surface exhibiting measurable quantities of DDT. This widespread distribution of a substance, used mainly in certain agricultural and forested parts of the world, was shown to be a result of rapid dissemination through the atmosphere.

The entry of lead into the sea from automobile emissions is clearly an atmospheric transport and washout phenomenon. There is some evidence that other metals, such as mercury and cadmium, are transported around the globe by atmospheric currents and may be washed out into the sea with rain.

Sulphur dioxide emissions from coal-burning thermal plants and petroleum refineries in England, West Germany and other parts of western Europe have allegedly given rise to acidic rain and a low pH in the soft waters of some Scandinavian lakes and rivers. Although pH shift is not likely to become a problem in highly-buffered sea water, the acidic rain situation does demonstrate what can happen through atmospheric processes.

Rivers can also be a major source of pollutants, particularly if they pass through highly indus trialized areas. The Rhine River in western Europe, the Thames in the United Kingdom, the Hudson and Susquehanna Rivers in the United States and the Samida River in Japan are examples. Rivers passing through major agricultural areas, e.g. the Mississipi in the United States, can also introduce large amounts of pesticides from pest control and nutrients from fertilizers. On the other hand, large rivers flowing through comparatively virgin countryside and jungle, e.g. the Amazon and Congo, may contribute little overall man-made pollution to the sea.

Although rivers may inject a great deal of material into the sea, they affect mainly the coastal zone. It takes a long time for a substance introduced by the Mississipi River, say, to be evenly distributed throughout the world oceans. Oceanic dispersion processes are just not rapid enough to distribute river-borne materials globally within the kind of time frame we are accustomed to in the atmosphere. Moreover, most rivers discharge into marginal seas, or basins, where much of the particulate materials, and even some dissolved substances, are trapped. For example, the Mississipi River drains into the Gulf of Mexico, the Nile into the Mediterranean and the Yangtze into the East China Sea, where river contributions are most notable and tend to be confined there.

A perspective on the fluxes of some materials in the major sedimentary cycle is given in Table 13. There are insufficient data at the present time to provide reasonable estimates of the amounts of critical pollutants entering the world oceans through the different routes. An attempt has been made to obtain essential marine input data on DDT, as an example pollutant, by the IOC International Co-ordination Group for the Global Investigation of Pollution in the Marine Environment.

TABLE 13

Some fluxes in the major sedimentary cycle (from Goldberg, 1976b)

Material	Geosphere receiving material	Flux in 10^{14}g per year
Suspended river solids	Oceans	180
Dissolved river solids	Oceans	39
Glaciers	Oceans	30
Continental rock and soil particles	Atmosphere	1-5
Sea salt	Atmosphere	3
Volcanic debris	Stratosphere	0.036
Volcanic debris	Atmosphere	<1.5
Wastes of society (excluding fossil fuels)	Hydrosphere, lithosphere, atmosphere	30
Wastes dumped from ships	Oceans	1.4
Carbon and fly ash from fossil fuel combustion	Atmosphere	0.25
Industrial particulates total	Atmosphere	0.54
<2 μm		0.12

The transfer of pollutants through the food chain has particular interest in problems of bio-accumulation, tainting and reproduction of marine organisms. At present, there is too little known about transfer mechanisms, and it is here that intensive research is required to elucidate the effects of pollutants on ecosystems. The degradation of different pollutants, particularly the more persistent ones, and their deposition in marine sediments also require research for a better understanding of their long-term disposition and effects.

International Control of Marine Pollution

1. Present (1977) state of control

The early attack through international agreements on the control of marine pollution was pursued essentially along two fronts: (a) pollution by oil from ships; and (b) radioactivity. These were two areas where pollution problems were either highly visible, and because they were often associated with shipping could be more easily controlled, or were largely under the jurisdiction of national governments where control measures could be readily imposed. More recently, control of pollution from dumping wastes at sea has been considered in both global and regional conventions. IMCO is now responsible for providing secretariat services for the International Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, which provides global coverage for marine pollution control from ocean dumping. The First Consultative Meeting of the Contracting Parties under the Convention was held in London in September 1976. An Action Plan was drawn up with priorities for future work. The Second Consultative Meeting in September 1977 should resolve certain problems, such as guidelines for incineration of wastes at sea (IMCO, 1977).

The historical development of international conventions and treaties for the control of marine pollution, along with some of their shortcomings, and further needs under the Law of the Sea, have been reviewed (Waldichuk, 1973, 1977). The international conventions and other agreements, including their current status in the control of marine pollution, are given in Table 14. Preparations for the United Nations Conference on the Human Environment (UNGA, 1971) stimulated action on controls for certain marine activities, such as ocean dumping. In addition, a major part of the international effort on control of marine pollution has been devoted to oil and ships and to compensation for oil pollution damage (IMCO, 1962a, 1962b, 1969b, 1970, 1971, 1972a, 1972b, 1973b, 1973c).

TABLE 14

International conventions and other agreements for control of marine pollution

(modified, from Waldichuk, 1973)

Conventions, treaties, protocols, regulations and standards	Pollutant	Responsible body	Status June 1977
General Marine Pollution			
Convention on the Territorial Sea and Contiguous Zone	Various	United Nations	In force
Convention on the High Seas, 1958	Oil; wastes from exploration and exploitation of the sea bed and its subsoil; and radioactive wastes	United Nations	In force
Convention on the Continental Shelf, 1958	Any harmful agents	United Nations	In force
Convention on Fishing and Conservation of the Living Resources of the High Seas, 1958	All deleterious substances	United Nations	Not yet in force

Conventions, treaties, protocols, regulations and standards	Pollutant	Responsible body	Status June 1977
General Marine Pollution			
Antarctic Treaty	All deleterious substances	United Nations	Ratified by 12 nations and acceded to by 7 others. New treaty may be negotiated starting in September 1977
Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxic Weapons and on their Destruction, 1972	Biologically hazardous and other toxic substances	United Nations	Not yet in force
Protocol relating to Intervention on the High Seas in Cases of Marine Pollution by Substances other than Oil	Other substances than oil	IMCO	Not yet in force
Convention on the Protection of the Marine Environment of the Baltic Sea	All sources	Norwegian Government	Not yet in force
Convention for the Prevention of Marine Pollution from Land-Based Sources	Wastes from land-based sources	French Government	Not yet in force
Convention on the Protection of the Environment between Denmark, Finland, Norway and Sweden	Environmentally harmful activities	Swedish Government	Not yet in force
Convention on the Protection of the Marine Environment (Mediterranean)	All environmentally harmful substances	UNEP	Adopted by 16 of the 18 Mediterranean States in February 1976
Draft Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources	All environmentally harmful substances	UNEP	In preparation
Oil Pollution			
International Convention for the Prevention of Pollution of the Sea by Oil, 1954	Oil	United Kingdom until establishment of IMCO in 1958	In force

Conventions, treaties, protocols, regulations and standards	Pollutant	Responsible Body	Status June 1977
Oil Pollution			
Amendments to the International Convention for the Prevention of Pollution of the Sea by Oil, 1962	Oil	United Nations	In force
Amendments to the International Convention for the Prevention of Pollution of the Sea by Oil, 1969	Oil	IMCO	Ratified on 19 January 1977 by required number of Contracting Parties. Will enter into force on 20 January 1978
Amendments to the International Convention for the Prevention of Pollution of the Sea by Oil, 1971	Oil	IMCO	Not yet in force
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969	Oil	IMCO	In force
International Convention on Civil Liability for Oil Pollution Damage, 1969	Oil	IMCO	In force
International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971	Oil	IMCO	Not yet in force
International Convention for the Prevention of Pollution from Ships, 1973	Oil and other substances	IMCO	Not yet in force
Agreement concerning Co-operation in Dealing with Pollution of the North Sea by Oil, 1969	Oil	Government of the Federal Republic of Germany	In force
Agreement Concerning Co-operation in Measures to Deal with Pollution of the Sea by Oil, 1971	Oil	Danish Government	In force
Radioactivity			
Convention on Third Party Liability in the Field of Nuclear Energy, 1960	Radioactive materials	United Nations, IAEA	In force

Conventions, treaties, protocols, regulations and standards	Pollutant	Responsible Body	Status June 1977
Radioactivity			
Convention Supplementary to the Paris Convention on Third Party Liability in the Field of Nuclear Energy, 1963	Radioactive materials	United Nations, IAEA	Not yet in force
Convention on the Liability of Operators of Nuclear Ships, 1962	Radioactive materials	United Nations, IAEA, IMCO	Not yet in force
Convention on Civil Liability for Nuclear Damage, 1963	Radioactive materials	United Nations, IAEA	Not yet in force
Treaty Banning Nuclear Weapons Tests in the Atmosphere, In Outer Space and Underwater, 1963	Radioactive materials	United Nations, IAEA	In force
Treaty on the Prohibition of the Emplacement of Nuclear Weapons, and other Weapons of Mass Destruction on the Sea Bed and Ocean Floor and on the Subsoil Thereof, 1971	Radioactive materials	United Nations, IAEA	In force
Convention relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material, 1971	Radioactive materials	United Nations, IAEA	Not yet in force
Regulations for the Safe Transport of Radioactive Materials	Radioactive materials	United Nations, IAEA	Adopted
Regulations for the Safe Transport of Radioactive Materials	Radioactive materials	United Nations, IAEA	Adopted
Basic Safety Standards for Radiation Protection	Radioactive materials	United Nations, IAEA	Adopted
Standardization of Radioactive Waste Categories	Radioactive materials	United Nations, IAEA	Adopted
Regulations for the Safe Transport of Radioactive Materials	Radioactive materials	United Nations, IAEA	Adopted

Conventions, treaties, protocols, regulations and standards	Pollutant	Responsible body	Status June 1977
Ocean Dumping			
Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft	All wastes and other substances dumped at sea	Instruments placed with Norwegian Government	In force
Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	All wastes and other matter dumped at sea	IMCO	In force

2. Remaining problems and current international activities toward marine pollution control

Some of the marine pollution problems which are still uncontrolled are those related to: (a) land-based sources of pollutants; (b) exploration and exploitation of the sea bed; and (c) atmospheric emissions of marine consequence (Table 15). The Convention for the Prevention of Marine Pollution from Land-Based Sources, signed in Paris on 4 June 1974, covers the European sphere, and has not yet entered into force. There is no global international convention covering land-based sources of pollutants entering the water or the atmosphere. Pollution through coastal outfalls, rivers and from stacks is still largely untouched internationally.

Because the atmosphere and the oceans are not the property of any particular State or group of States, but are a common property of all the nations on the globe, there must be some control of contamination of these environmental resources. The atmosphere moves freely through wind currents from one nation to another. The oceans are in a steady state of flux, the permanent currents transporting materials deposited in one part of the ocean to other parts. Waste released in the coastal waters of one State may be deposited, in fact, on the doorstep of another. Noxious materials released from a ship at some distance from shore may get swept onto the shores of a coastal State by both the permanent oceanic currents and wind-induced and/or local tidal currents. For this reason, it is absolutely essential to control the disposal of waste materials into the marine environment, so that coastal States are not adversely affected. It is in these areas, among others, that the Third United Nations Conference on the Law of the Sea has endeavoured to reach some agreement. As it went into the 6th Session at the United Nations Headquarters in New York on 23 May 1977, the Third Law of the Sea Conference had before it the major issues of national jurisdiction over territorial seas and fishing zones, sea bed mining from manganese nodules, and control of marine pollution from a variety of sources. The unilateral declaration of a 200-mile fishing or economic zone by several countries in 1977 requires a further adjustment in the international deliberations.

The Committee on the Peaceful Uses of the Sea Bed and the Ocean Floor Beyond the Limits of National Jurisdiction was extremely active in its various subcommittees preparing for the Law of the Sea Conference. Subcommittee III was mainly involved with marine pollution, starting on problems associated with the exploration and exploitation of the sea bed and the ocean floor beyond the limits of national jurisdiction, and later broadening its role to cover other types of marine pollution (United Nations, 1972c).

A very important political and legal problem associated with pollution from the exploration and exploitation of the sea bed and the subsoil thereof, is the boundary which sets the limits of national jurisdiction (U.S. Senate, 1972). Be this as it may, pollution caused by any activity, even beyond the limits of national jurisdiction, can be transported into the near-shore waters of a coastal State. Oceanic waters know no political boundaries, and currents acting both vertically and horizontally can transport waste materials to points well removed from the sources. The traditional legal order for the greatest part of the high seas of the world must be reformulated on the basis of environmental consideration, the limits of national jurisdiction notwithstanding. It is quite obvious that new institutional arrangements will be required, and these will probably have to be quite sophisticated, in order to cope with the rather complex international problems of preservation of the marine environment.

TABLE 15

Aspects of marine pollution still requiring agreements for international control

(from Waldichuk, 1977)

Pollution sources	National control	International control	Comments
1. Discharges from ships	Develop national legislation and regulations for the prevention and control of pollution in coastal waters (territorial sea, economic zone, fishing zone, and in special areas within those zones).	Establish a sound basis of regulations for the prevention and control of pollution from vessels in the territorial sea, in the economic zone and in special areas within the zone, as well as in international waters.	Must be harmonized with the International Convention for the Prevention of Pollution from Ships, 1973.
2. Sea bed mining from drill rigs, drill ships and artificial islands	Activities in territorial sea, economic or fishing zone come national control.	Activities beyond the limits of national jurisdiction could be controlled by an "International Sea Bed Authority".	New set of guidelines and regulations must be developed for control internationally.
3. Discharge from ocean outfalls	Virtually all such discharges will be under national control. Coastal state standards must be uniform and based on international guidelines.	Criteria, standards and regulations must be developed to bring all effluent discharges under uniform control for marine environmental preservation.	Most such discharges are within national boundaries of the coastal zone.
4. Atmospheric emissions	All such emissions come under control of local authorities within the State. Controls could be based on international guidelines.	Criteria, standards and regulations for atmospheric emissions must be developed to provide uniformity for protection of the atmosphere and aquatic resources.	Certain atmospheric emissions, e.g. sulphur dioxide, may be controlled for protection of freshwater systems.

Table 15 (continued)

Pollution sources	National control*	International control	Comments
5. Other land-based sources	Coastal and inland States contributing to coastal pollution through run-off, rivers, spills and leakage can control these sources through legislation and technological developments for clean-up.	Develop effluent guidelines, water quality criteria and treatment technology handbooks for use by national authorities in marine pollution control.	A very difficult problem to resolve internationally, because of possible interference in national affairs.

Following the United Nations Conference on the Human Environment in Stockholm during June 1972, an Action Plan was developed giving the objectives of the United Nations Environment Programme (UNEP), the major functional tasks, and suggested action for groups of recommendations covering specific subject areas. Actions were suggested for 15 recommendations under "Oceans" and for 10 of 15 recommendations under "Pollutants". Activities related to the functional components of the Action Plan are: (1) environmental assessment (EARTHWATCH); (2) environmental management; and (3) supporting activities. EARTHWATCH has four components: (i) Global Environmental Monitoring System (GEMS); (ii) International Referral System (IRS); (iii) Review; and (iv) Evaluation. It was noted in the proposed programme of UNEP, presented to the Third Session of the Governing Council, Nairobi, 17 April-2 May 1975, that the most important activity in monitoring marine pollution under GEMS will be "the implementation of the Integrated Global Ocean Station System (IGOSS) pilot project, sponsored by IOC and WMO, for monitoring oil pollution". Under assessment of marine pollution, it was noted that "the principal ongoing activity at the international level is the development of a plan for the Global Investigation of Pollution in the Marine Environment (GIPME)".

Mr. Maurice Strong, then the Executive Director of UNEP, stressed the importance of adequately reflecting environmental interests in the new law of the sea and enunciated 16 principles in the opening session of the Third United Nations Conference on the Law of the Sea in Caracas, Venezuela, July 1974. These principles included inter alia a plea to States to protect the quality and resources of the marine environment, and to use the best practicable means to minimize the discharge of marine pollutants from all sources, including those that are land-based. UNEP was specifically requested by the Conference to prepare a report for Committee 3, describing both the international programmes and the national components of its monitoring systems.

Scientific Aspects of Marine Pollution

Legislation on such problems as marine pollution is often of little value unless it is strongly supported by scientific and technical information. Pollution affects the marine environment and its living populations in various ways. Some of the interactions are extremely complex and can only be understood after long and detailed study. It is essential, therefore, to examine carefully all available information before drawing conclusions for development of standards and regulations, some of which could be extremely costly if enforced. In ecological matters, unlike the physical sciences, the answers to certain questions cannot always be unequivocally stated precisely and with unmistakable certainty. Often, it is difficult to arrive at a black or white conclusion but rather only various shades of grey are possible. There is still so much to be learned, and the ultimate ecological impact of a particular pollutant cannot be defined until all parts of a rather large and complex picture are pieced together.

In the meantime, there is considerable scientific debate on certain aspects of pollution in the marine environment. It is essential that sound scientific opinion be brought to bear on those problems for which there is a lack of "hard data". Unfortunately, a large proportion of the marine pollution problems can be placed in this category. As a recent editorial in SCIENCE put it: "The modest influence of science in affiars today rests largely on its reputation for objectivity. To the degree that we abandon that virtue, we lose influence and are considered merely another self-serving, politically-biased, ax-grinding constituency" (Anon, 1975). Because there are so many uncertainties to scientific findings in the environmental field, the layman and the legislator often become confused by the pros and cons in scientific opinion and become influenced by the positive approach taken by environmental activists, who are generally opposed to any alteration of natural conditions. For this reason, the basis for national legislation, which can be a considerable economic burden on society, is sometimes challenged.

1. Intergovernmental activities related to marine pollution control

Because of the increasing international concern about pollution of the sea, several agencies of the United Nations family have become concerned with the scientific aspects of marine pollution within their particular areas of responsibility in the marine environment. A review of the involvement of intergovernmental bodies in scientific aspects of marine pollution, up to 1973, is given by Waldichuk (1973). Some of the earlier highlights as well as more recent developments are noted here:

(1) Formation of the IOC Working Group on Marine Pollution, which was disbanded following the 6th session of the IOC in September 1969 (IOC, 1970b).

(2) The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) met for the first time at IMCO Headquarters, London, in March 1969, and annually since then, successively at each of the headquarters of the agencies represented in GESAMP, i.e. IMCO, FAO, Unesco, WMO, WHO, IAEA, the United Nations and UNEP. Advice is provided to the agencies on specific marine pollution problems with which they are concerned.

(3) Recommendation by the IOC Group of Experts on Long-Term Scientific Policy and Planning (GELTSPAP) (IOC, 1970c) that the focal point for IOC's Long-term and Expanded Programme of Oceanic Exploration and Research (LEPOR) be a Global Investigation of Pollution in the Marine Environment (GIPME). This recommendation was later accepted by the Bureau and Consultative Council and by the 7th session of the IOC Assembly in November 1971 (IOC, 1972a).

(4) The ACMRR/SCOR/ACOMR/GESAMP Joint Working Party on Global Investigation of Pollution in the Marine Environment (GIPME), San Marco di Castellabate and Rome, Italy, 11-18 October 1971. The main objective was "to identify the lines of research that appear to be most effective in such investigations". Recommendations of the Working Party were accepted by the 1st session of the IOC Executive Council (IOC, 1971b).

(5) The third session of the Group of Experts on Oceanographic Research as it relates to IGOSS (IRES), Unesco, Paris, 25-29 September 1972, recognized IGOSS (IOC/WMO, 1973) as a potential basis for marine pollution monitoring, and recommended an oil pollution monitoring project, giving the scientific basis for it, to cover the North Atlantic and the major oil transport route around the Cape of Good Hope, between the Persian Gulf and Europe. A proposal was developed for discussion by various international groups (IOC, 1973a).

(6) The first session of the IOC's International Co-ordination Group (ICG) for the Global Investigation of Pollution in the Marine Environment (GIPME), was held in London, April 1973. Meetings of the ICG followed in New York, July 1974, when a comprehensive plan for GIPME was developed, and in Paris, June 1975 (IOC, 1974), where an implementation plan was drafted and baseline study guidelines, drawn up by an IOC/ICES Working Group, were finalized (IOC, 1976c); it was also recommended that an IOC Working Committee for GIPME be formed. The 9th session of IOC, held in Unesco, Paris, during November, 1975, accepted the report of the third session of the ICG for GIPME and adopted the recommendation to form a Working Committee for GIPME. The first session of the Working Committee for GIPME was held in Hamburg, Germany (Federal Republic of), 18-22 October 1976. GIPME responsibilities have included a review of IGOSS activities on marine pollution monitoring (IOC, 1976a).

(7) Initiation of the IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring, January 1975. The progress of this project has been guided by IOC/WMO (1976a) and was recently reviewed by the subgroup of experts on marine pollution (petroleum) monitoring of the IOC/WMO Group of Experts on IGOSS in London, 3-7 May 1976 (IOC/WMO, (1976b). Consultants

assessed the atmospheric contribution of petroleum hydrocarbons to the oceans (Garrett and Smagin, 1976). The pollution monitoring programme has been considered in the general plan and implementation programme for IGOSS during 1977-1982 (IOC/WMO, 1977).

(8) IOC/WMO/USDC Marine Pollution (Petroleum) Monitoring Symposium and Workshop at the National Bureau of Standards, Gaithersburg, Maryland, U.S.A., May 1974. The main purpose of this meeting was to define the oil pollution monitoring methods to be used in the IGOSS Pilot Project. A second IOC/WMO Workshop on Marine Pollution (Petroleum) Monitoring was held in Monaco, 14-18 June 1976. The Operational Plan for the Pilot Project was revised in the light of recommendations from the Subgroup of Experts on Marine Pollution (Petroleum) Monitoring and of experience reported by National Co-ordinators. An intercalibration exercise for standardization of measurements of dissolved petroleum hydrocarbons is being conducted in 1977. A third workshop is planned for the end of 1977, and the Pilot Project has been recommended to continue to the end of 1978.

(9) Working groups of GESAMP are established when the need arises to deal with specific topics. Several working groups have been active since the first session of GESAMP in March 1969, but it is only recently that they have been able to work effectively intersessionally, thanks to financial support from UNEP. At the VIIth session of GESAMP, held in IMCO headquarters, London, during April 1975, reports of two working groups were finalized and accepted: (a) Scientific bases for the determination of concentrations and effects of marine pollutants: Guidelines for an open ocean monitoring system; (b) Scientific criteria for the selection of sites for dumping of waste into the sea (GESAMP, 1975b). Four other working groups presented reports at the VIIIth session of GESAMP held at FAO headquarters, Rome, in April 1976 (GESAMP, 1976a); (Principles for developing coastal water quality criteria (GESAMP, 1976b); (d) Impact of oil on the marine environment (GESAMP, 1977a); (e) Scientific aspects of pollution arising from the exploration and exploitation of the sea bed; and (f) Evaluation of hazards of harmful substances in the marine environment. Five working groups are continuing intersessional activities on: (g) Evaluation of the hazards of harmful substances carried by ships; (h) Marine pollution implications of sea bed exploitation and coastal area development; (i) Updating of the review of harmful substances; (j) Biological effects of thermal discharges in the marine environment; and (k) Interchange of pollutants between the atmosphere and the oceans. At the IXth session of GESAMP held in the United Nations Headquarters, New York, 7-11 March 1977, two additional working groups were established to deal with: (1) Scientific aspects of removal of harmful substances from waste water; and (m) Monitoring biological parameters of marine pollution.

(10) Working groups of other bodies interested in the ocean environment, organized individually or jointly, have been active on specific problems of marine pollution:

(a) ACMRR (FAO) Working Party on Biological Accumulators. Sponsored by FAO and organized in 1974 to review ongoing research and operational programmes, to evaluate bioaccumulator species, to reccomend standardized working methods and to develop guidelines for pilot studies (FAO, 1975b); Portman, 1976).

(b) ACMRR/IABO Working Party on Ecological Indices of Stress to Fishery Resources (ACMRR/IABO, 1976).

(c) ACMRR/IABO Working Party on Biological Effects of Pollutants (ACMRR/IABO, 1977a), 1977b).

(d) WHO Working Group on Ecological Aspects of Water Pollution in Specific Geographical Areas: Study of sub-lethal effects on marine organisms in the Firth of Clyde, the Oslo Fjord and the Wadden Sea. This Working Group was proposed in 1972 and met in December 1974 (WHO, 1975a) to examine long-term effects on aquatic organisms of the same suite of pollutants to which man may be exposed. Study of the sub-lethal effects of pollutants on the flounder (Pleuronectes flesus) in Oslo Fjord was one of the first investigations initiated as part of this project.

(e) WHO Shellfish Hygiene Programme. WHO, in co-operation with FAO, convened an Expert Committee on Fish and Shellfish Hygiene in Geneva, 18-24 September 1973, to consider prevention of the transmission of human disease through contaminated fish and shellfish, and improvement of the hygienic production, processing and distribution of these foods (WHO, 1974). This work has been followed up by the publication of a "Guide to Shellfish Hygiene", prepared under the auspices of WHO (Wood, 1976).

(11) Medierranean Sea Pollution Studies and Control Activities. Work on various aspects of pollution in the Mediterranean has accelerated in the last five years with increasing involvement of FAO, Unesco (IOC), WHO and UNEP.

(a) GFCM (FAO) Working Party on Marine Pollution in the Mediterranean and Expert Consultations on the GFCM Co-ordinated Project on Pollution in the Mediterranean (GFCM, 1972). The FAO (GFCM) Expert Consultation on the Joint Co-ordinated Project on Pollution in the Mediterranean took place in Rome from 23 June to 4 July 1975 and prepared an operational document to serve as a framework for the co-operation of Mediterranean research centres and as a scientific outline for the projects (FAO/UNEP, 1975; FAO, 1976a, 1977a.

(b) Joint IOC/WMO/UNEP activities in the Mediterranean. The IOC has assumed a major responsibility for co-ordinating two pilot projects in the UNEP Co-ordinated Mediterranean Pollution Monitoring and Research Programme (IOC, 1975f, 1975g): (i) The Joint IOC/WMO/UNEP Pilot Project on Baseline Studies and Monitoring of Oil and Petroleum Hydrocarbons in Marine Waters (Mediterranean). The aim of this project is the eventual establishment of a regional monitoring programme, and in its present form it will contribute to the IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring. The University of Malta has been designated as a Regional Activity Centre to assist the sponsoring agencies in the execution of the project. Twenty-five national research centres have been nominated by 11 governments to participate; (ii) the Joint IOC/UNEP Pilot Project on Problems of Coastal Transport of Pollution. The main objective of this project is to provide information on the physical processes contributing to the transport of pollutants in Mediterranean surface waters, by investigating water circulation in coastal areas and exchange of water between coastal and offshore regions. The operational plan of a Driftcard Experiment (DRIFTEX) was developed as part of a pilot project, at an ad hoc meeting associated with the 25th Congress and Plenary Assembly of ICSEM in Split, Yugoslavia, 27 October 1976.

(c) WHO Environmental Sanitation Plan for the Mediterranean. WHO has continued its interest in developing an environmental sanitation plan for the Mediterranean seaboard with publication (Brisou, 1976) of a revised version of the text originally presented by Professor J. Brisou to the Interparliamentary Conference of Coastal States on the Control of Pollution in the Mediterranean Sea, organized jointly by the Interparliamentary Union, Italian Parliamentary authorities and the United Nations Environment Programme, in Rome, 29 March-3 April 1974.

(d) Convention on the Protection of the Marine Environment (often referred to as the Barcelona Convention). After two intergovernmental meetings held in Barcelona, Spain, the first in January-February 1975 and the second in February 1976, 16 of the 18 Mediterranean States adopted a Convention on the Protection of the Marine Environment, together with two protocols, one dealing with dumping by ships and aircraft, and the other with co-operation in combating pollution.

(e) IMCO/UNEP Regional Oil-Combating Centre for the Mediterranean (IMCO/UNEP, 1976). The Mediterranean is very important to many countries of Europe, Africa and Asia as a source of living resources, and an area popular for recreation and tourism. The Mediterranean is a major route for maritime transportation of a variety of ships, including oil tankers since the reopening of the Suez Canal. Therefore, it was proposed at an intergovernmental meeting, held in Barcelona in January 1975 that among other items, a Regional Centre be established to plan and co-ordinate measures in the event of a major oil pollution disaster. The second Barcelona Conference of Plenipotentiaries of Coastal States of the Mediterranean Region on the Protection of the Mediterranean Sea, held in February 1976, decided that such an anti-pollution centre should be established. The Government of Malta offered to host the Centre.

UNEP, after consultation with IMCO, agreed to help establish the Centre, initially covering the expenses, with the understanding that costs will be later defrayed by voluntary contributions from Mediterranean governments. The Centre was opened in December 1976 on Manoel Island in Valetta harbour. Its basic objectives are to facilitate co-operation among the Mediterranean States in the event of a massive oil spill and to help them develop their own anti-pollution capabilities. The centre will compile inventories of experts and equipment in each coastal state and act as a pool for plans for combating oil pollution. These plans can be used by other States for developing their own contingency plans. Special attention will be paid to parts of the Mediterranean, which are most vulnerable to oil pollution, clean-up methods being specified to minimize environmental damage.

(f) IAEA International Laboratory of Marine Radioactivity, Monaco, Programme of Research in the Mediterranean. With joint UNEP-Unesco-IAEA funding, the Monaco Laboratory is conducting research on the heavy metals, chlorinated hydrocarbons and radionuclides in sea water, biota, sediments and in the case of chlorinated hydrocarbons, also in air samples. It is continuing its intercalibration programme, providing environmental samples with known amounts of radionuclides, chlorinated hydrocarbons and heavy metals to participating laboratories.

(12) The International Council for the Exploration of the Sea (ICES) is an intergovernmental body which has been active in marine scientific problems of the North East Atlantic Ocean and marginal seas of north-western Europe since 1901. In the last decade, it has become quite active in marine pollution studies.

(a) North Sea Pollution Studies. In 1967, ICES formed a working group to collect factual information concerning substances considered to be harmful or potentially harmful to living resources in the North Sea. A report was issued in 1969 (ICES, 1969), covering legislation on pollution control in each country, bordering the North Sea, as well as input data on sewage, industrial wastes, pesticides and oil. The report formed the basis for more detailed studies in the North Sea, with a series of _ad hoc_ meetings during 1970 and 1971. A new Working Group for the International Study of Pollution of the North Sea and its Effects on Living Resources and their Exploitation was subsequently formed and a programme developed.

It was agreed that the initial phase of the programme would be a baseline survey, with priority given to investigation of pollutant levels in fish, followed by measurements of the same pollutants in water and sediments. The pollutants chosen included petroleum, chlorinated aromatic hydrocarbons (e.g. DDT and PCB's), halogenated hydrocarbons in general and metals (mainly mercury, lead, copper, zinc and cadmium). The rate of input of these pollutants was determined by questionnaire in order that mass balance calculations could be performed and a true understanding of the fate of the pollutants achieved. An intercalibration of analytical methods was carried out among the participating laboratories. The results of the baseline survey and of the input study were published in 1974 (ICES, 1974a). A monitoring programme which followed indicated that no change had occurred in pollutant levels between the baseline study of 1972 and the first year of monitoring in 1974 (ICES, 1977a). An ICES intercalibration exercise on metals in sea water, involving other analytical laboratories beyond North Sea countries, may form the basis for an extended international baseline study.

(b) Baltic Sea Pollution Studies. An ICES Working Group on pollution in the Baltic with co-operation of the Conferences of Baltic Oceanographers, was established in 1968. Much of the work of this Group concentrated on information about input of pollutants to the Baltic Sea area from land-based sources (ICES, 1970a).

In 1971, a joint SCOR/ICES Working Group for the Study of the Pollution of the Baltic and its Effects on Living Resources was established. A three-pronged programme was developed: (i) an extended study of the input of pollutants to the Baltic; (ii) baseline survey of the levels of contaminating substances in living resources of the Baltic, combined with intercalibrations of the analytical techniques; and (iii) a co-ordinated scientific investigation, aimed at an understanding of the processes governing the distribution and fate of pollutants in the Baltic. Organisms used in the baseline study are cod, herring, flounder and mussel (_Mytilus_ sp.) and the contaminants being analysed are mercury, lead, cadmium (with zinc and copper as a second priority), γBHC, dieldrin, DDT and PCB's. The programme, drafted by a subgroup, followed by a thorough review and revision by the Working Group, has been published (ICES, 1974b).

"BOSEX-77" (Baltic Open Sea Experiment, 1977), a large-scale multidisciplinary open-sea experiment in September 1977, designed to improve knowledge of the processes that govern the distribution and fate of pollutants in the Baltic Sea, with participation by scientists from all countries bordering the Baltic, climaxes the Baltic Sea pollution studies.

(c) Supporting ICES activities: (i) The International Diffusion Experiment RHENO involved the use of rhodamine dye in the North Sea to trace water movements (ICES, 1973a); (ii) a symposium was held under the auspices of ICES in Aarhus, Denmark, July 1972, on "Physical Processes Responsible for the Dispersal of Pollutants in the Sea, with Special Reference to the Near-Shore Zone" (Kullenberg and Talbot, 1974); (iii) a workshop was organized in 1975 on "Hydrocarbons in the Marine Environment" (ICES, _in press_); (iv) Working Group on Red Tides and Eutrophication.

The Council established this Working Group in 1975 after two task teams had collected information on possible eutrophication on the Southern Bight of the North Sea and the Kattegat area. The task of the Working Group inter alia is to initiate theoretical, observational and experimental studies of eutrophication processes in the North Sea; (v) Working Group on Effects on Fisheries of Marine Sand and Gravel Extraction. Because of the conflict of extraction of sand and gravel from the sea bed with fisheries' interests, particularly as regards the destruction of spawning grounds, the Council established in 1973 a Working Group on Effects on Fisheries of Marine Sand and Gravel Extraction. The Working Group proposed a code of practice for such extraction (ICES, 1975a), and noted that there are important pollution aspects of these activities; (vi) ICES Working Group on Pollution Baseline and Monitoring Studies in the Oslo Commission and ICNAF Areas. This Working Group has discussed the possibilities for monitoring the effects of pollutants on living organisms and on their ecosystems. A report is expected to be issued in 1977 (ICES, 1977b).

(13) River Inputs to Ocean Systems (RIOS). One of the recommendations of the ACMRR/ SCOR/ACOMR/GESAMP Joint Working Party on Global Investigation of Pollution in the Marine Environment (GIPME) (FAO, 1971c) was that ... "IOC consider the desirability and method of organizing an international multidisciplinary study of River Inputs to Ocean Systems (RIOS) and that as an initial step the IOC secretariat compile an inventory of present national and international programmes of river discharge study and measurement, including the monitoring of river-borne pollutants". Subsequently, the SCOR/ACMRR/ECOR/IAHS/Unesco Working Group on River Inputs to Ocean Systems was formed. A number of proposals have been made by this Working Group and action on some is now under way while others await funding: (i) identification of ongoing research on subjects directly relevant to RIOS, development of a pilot training programme, and planning of a RIOS Workshop; (ii) convening of the Workshop and two contemporaneous meetings of the RIOS Working Group; and (iii) execution of demonstration projects on a small number of specified rivers, including the establishment of field stations, training programmes and exchange of scientists between local institutions and co-operating institutions overseas.

(14) Biogeochemistry of Marine Sediments. A seminar on this subject was convened jointly by the Unesco Division of Marine Sciences with SCOR in Melreux, Belgium, 29 November-3 December 1976. The main purpose of the seminar was the critical evaluation of the procedures for characterizing the nature of, and reactions in, marine sediments. Because of the importance of sedimentary processes in estuaries, relative to the fate of pollutants in estuarine systems, the proceedings of the seminar (Unesco/SCOR, 1977) will be extremely relevant to marine pollution investigations.

(15) Marine Environment Protection Committee (MEPC). Following the International Conference on Marine Pollution, convened by IMCO in October-November 1973, to develop the International Convention for the Prevention of Pollution from Ships, 1973 (IMCO, 1973a), the Marine Environment Protection Committee was formed by IMCO to continue the work of the Subcommittee on Marine Pollution of the Maritime Safety Committee. Convening its Seventh Session at IMCO headquarters, London, 20-24 June 1977, the MEPC directs its efforts toward resolving some of the issues raised by the 1973 Convention and implementing the resolutions adopted by the International Conference on Marine Pollution, 1973. A Symposium on Prevention of Marine Pollution from Ships was held in Acapulco, Mexico, 21-31 March 1976 (IMCO, 1976; NTIS, 1976).

(16) Joint IOC/WMO/UNEP Programme for Monitoring Background Levels of Selected Pollutants in Open Ocean Waters. Three consultants appointed by UNEP, WMO and IOC undertook a feasibility study for such a programme, starting with recommendations of GESAMP-VII (GESAMP, 1975a). A Proposed Programme for Monitoring Background Levels of Selected Pollutants in Open Ocean Waters, based on the consultants' study, was developed by the three secretariats and reviewed by a WMO/IOC/UNEP Preparatory Meeting of Experts, held in WMO, Geneva, 23-25 March 1976. This was followed with a review by a UNEP Group of Governmental Experts held in Geneva, 26 March 1976, which approved an amended form of the programme and recommended that the Executive Heads of IOC, WMO and UNEP seek approval in principle of the proposed programme, and that an ad hoc group be formed to rewrite the programme in accordance with amendments suggested at the Preparatory Meeting of Experts. The programme received approval in principle from the Executive Committee of WMO by its Resolution 16 (EC-XXVIII) and from the Executive Council of IOC by Resolution EC-VII.11. The ad hoc group, composed of experts nominated by IOC, WMO and UNEP and representatives of their secretariats, revised the proposed programme and prepared its final version at a meeting in WMO, Geneva, 6-8 October 1976. It has been circulated to member governments for comment.

(17) FAO Inventory of Contaminants in Aquatic Organisms. FAO has developed an inventory system on contaminants in aquatic organisms and can provide a service to the world community undertaking research in this field (FAO, 1976b).

(18) IAEA activities related to the London Dumping Convention. A consultants' meeting to review future programmes related to IAEA's responsibilities under the London Convention on Prevention of Marine Pollution by Dumping of Wastes and Other Matter (United Kingdom, 1972), was held in Vienna, 1-3 September 1976. A consultants' meeting on oceanographic modelling for the London Convention was held in Woods Hole, Mass., U.S.A., 13-17 December 1976.

(19) The International Commission on Radiological Protection (ICRP). This Commission sets standards on maximum permissible radiation dose and body burden of radionuclides for humans. Forms the basis of the Critical Path approach to evaluating permissible discharges of radioactive wastes into the marine environment (ICRP, 1958).

(20) The Global Atmospheric Research Programme (GARP) could involve research components related to marine pollution, including numerical methods for prediction (Döös, 1970). It was recommended for example, in the report of the Joint Working Party on GIPME held in Castellabate and Rome in 1971 (FAO, 1971c) that sampling of atmospheric pollutants be conducted in the GARP Atlantic Tropical Experiment (GATE), carried out in 1974 as part of the series of GARP Tropical Experiments (WMO-ICSU, 1970). Moreover, it was recommended in the above-mentioned GIPME report that "SCOR and ACOMR in collaboration with the Commission on Atmospheric Chemistry and Radioactivity (of IAMAP)[1] evaluate the problems involved in studying the transport of pollutants through the atmosphere and their transfer to the ocean, including the development of suitable sampling methods, ..." The first Global GARP Experiment (FGGE) is scheduled to take place between January and June 1979, but it is unknown how much direct application the results of this experiment will have for marine pollution studies.

2. Non-governmental marine pollution investigations

The International Council of Scientific Unions (ICSU) has adherent bodies interested in the scientific issues related to marine pollution. The Scientific Committee on Problems of the Environment (SCOPE) reviewed all aspects of global monitoring, including the marine environment, and presented its report to the United Nations Conference on the Human Environment (ICSU/SCOPE, 1971).

(1) The Scientific Committee on Oceanic Research (SCOR). Another ICSU body, SCOR has among its many working groups (WG) several dealing with matters related to pollution of the marine environment:

(a) WG39 - The ACMRR/SCOR/ACOMR/GESAMP Working Party on GIPME. [See 1 (4)]. Met only once, in October 1971.

(b) WG45 - The ACMRR/ACOMR/ECOR/ICES/SCOR Working Group on Marine Pollution Research met for the first time with GESAMP representation in March 1973 (SCOR, 1973b). At the second meeting in November 1973, it was decided that the group should be known henceforth as the SCOR/ACMRR/ACOMR/ECOR/ICES/GESAMP Liaison Panel on Marine Research related to Pollution. No plan of work for this Panel was developed at that time, and it has since been disbanded.

(c) WG24 - Estimation of Primary Production under Special Conditions (with IBP/PM) (SCOR, 1973a). This Working Group considers waters, among others, which are heavily polluted and heavily eutrophic.

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(1) The correct name of this Commission is "International Commission on Atmospheric Chemistry and Global Pollution".

(d) WG29 - Monitoring in Biological Oceanography (with ACMRR, Unesco and IBP/PM).

(e) WG42 - Working Group for the Study of the Pollution of the Baltic /See (12)(b)/. A possible "International Baltic Pollution Study Year" has been considered.

(f) WG44 - Tropospheric Transport of Pollutants (with IAPSO, ACOMR, IAMAP). The terms of reference and name of this Working Group were modified at the 13th General Meeting of SCOR on 13 and 16 September 1976 during the Joint Oceanographic Assembly in Edinburgh, Scotland. The new proposed name is "Tropospheric Transport of Pollutants and Interfaxe Studies". The terms of reference include: (i) Reviewing the current knowledge in this area and organizing a symposium; (ii) Defining proper methods of observations; (iii) Planning a co-operative experiment at sea; (iv) Providing suitable means to study and evaluate the results.

(g) WG46 - River Inputs to Ocean Systems (with ECOR, IAHS, ACMRR and Unesco) /See 1 (13)/. Workshop planned for May 1978 at FAO Headquarters, Rome, if funding can be obtained.

(2) The Scientific Committee on Antarctic Research (SCAR). Another adherent body of ICSU, SCAR has a working group on the impact of exploration and exploitation on the marine environment in the Antarctic, which met in Dallas, Texas, U.S.A., in February 1977. A first report of this working group is scheduled to be released in September 1977.

(3) The International Biological Programme. During its most active period, 1965-1972, was involved with problems of pollution in the sea, among other environments. Its marine productivity section (IBP/PM) co-ordinated studies in different types of marine environments, including those affected by man. Results of many of these studies have been published.

(4) The Man and the Biosphere (MAB). This programme is co-ordinating projects, some of which are similar to those conducted under the IBP; but its role in the marine environment is somewhat peripheral, with emphasis primarily on estuaries and other coastal areas, where the activities of man have their greatest impact.

Within the general objective of the MAB programme (MAB/Unesco, 1971), a few projects have been developed, including those designed to: "(i) identify and assess the changes in the biosphere resulting from man's activities and the effects of these changes on man"; and "(ii) study and compare the structure, functioning and dynamics of natural, modified and managed ecosystems".

Within the component of the MAB programme devoted to the aquatic ecosystem, emphasis is being placed on those areas of the marine environment on which man has the greatest direct impact and vice versa, e.g. estuaries, deltas and coastal zones (MAB/Unesco, 1972a). Advances in remote sensing and ecosystem modelling are being given much attention under the MAB programme (MAB/Unesco, 1972b). Island ecosystems which are rather unique and have a great marine influence are one of the special types of areas being examined in the MAB programme (MAB/Unesco, 1973).

(5) Study of Critical Environmental Problems (SCEP). Several international and national studies have been conducted in the past few years on man's impact on the global environment. One of these projects, sponsored by the U.S.A.'s Massachusetts Institute of Technology, was held in Williamstown, Massachusetts, during July 1970. It was designated as the Study of Critical Environmental Problems (SCEP). The SCEP Report (MIT, 1970) gave an assessment of the problems and recommendations for action. The atmospheric, as well as the shore-based and other inputs of man-made waste products into the marine environment, were considered in terms of the ecological effects on water pollution. The climatic effects of atmospheric pollution were also examined.

(6) Study of Man's Impact on Climate (SMIC). Recognizing that a great number of atmospheric problems remained unresolved, the Massachusetts Institute of Technology, the Royal Swedish Academy of Sciences and the Royal Swedish Academy of Engineering Sciences, organized a study on inadvertent climate modification, in Stockholm, during July 1971. A group of some 50 scientists in atmospheric and associated physical and chemical disciplines deliberated for about a month on the vital issues concerning effects on climate from man's activities. This critical examination of atmospheric problems resulted in the report of the Study of Man's Impact on Climate (SMIC) (MIT, 1971), which defined the changes occurring in the atmosphere, and identified those changes which are clearly associated with man's activities.

(7) The Changing Chemistry of the Oceans - Nobel Symposium 20. During August 1971, the Nobel Foundation hosted the Nobel Symposium 20, on the Changing Chemistry of the Oceans, which dealt largely with man's impact on the atmospheric and marine environments (Dyrssen and Jagner, 1972). It became clear from deliberations at this Symposium, as well as at other similar gatherings, that man has a certain influence on the atmosphere and on the marine environment, although this has not yet reached a critical level. Some of man's impact is masked by "background noise" from normal fluctuations in the environment. Moreover, there are certain natural changes which still exceed those from the impact of man. In so far as effects on the atmosphere are concerned, it is quite clear that man's input of air pollutants from burning of fossil fuels has steadily increased the atmospheric carbon dioxide during the past century. Whether this will ultimately have a marked effect on climate is still a subject of debate. In the marine environment, the input of chlorinated hydrocarbons has led to high concentrations of these compounds in marine organisms the world over, often a long distance from the point of entry. It appears that much of the global transport and dispersion of these compounds is carried on initially by the atmosphere and then by currents and other dispersive processes in the sea. An estimate was made of man's role in the major global sedimentary cycle (Goldberg, 1972a).

(8) Critical Problems of the Coastal Zone. In May-June 1972, a Workshop on the Critical Problems of the Coastal Zone was held at the Woods Hole Oceanographic Institution, Woods Hole, Mass., U.S.A. (Ketchum, 1972). Recommendations were made for research and control of pollution to prevent further degradation of the coastal zone ecosystem.

(9) Dahlem Workshops on the Nature of Seawater and on Global Chemical Cycles. To examine in detail the nature of seawater and the effects of man on the chemistry of the oceans, a Dahlem Workshop was held in Berlin, Federal Republic of Germany, in March 1975 (Goldberg, 1975). The intervention of man in the atmosphere and the effects on climate were reviewed at the Dahlem Workshop on Global Chemical Cycles and their Alteration by Man, held in Berlin during November 1976. The modification of the global carbon cycle appears to be closely related to the combustion of fossil fuels which has led to an increase in atmospheric carbon dioxide of 16 ppm (parts per million), from 311 ppm in 1957 to 327 ppm in 1975 (Bolin, 1977).

(10) International Association on Water Pollution Research (IAWPR). On a continuing basis, the International Association on Water Pollution Research (IAWPR) conducts international conferences biennially on water pollution research, the first having been held in London, England, in 1962 (Pearson, 1964). Because it covers a wide range of activities in water pollution research, the IAWPR devotes only a limited amount of attention to the marine problems (Jenkins, 1971). The Seventh IAWPR Conference was held in Paris during September 1974 and the Eighth Conference was held in Sydney, Australia, during October 1976. The Ninth Conference of IAWPR is scheduled for Sweden in 1978. Papers presented at these conferences are published in the Advances in Water Pollution Research series. From time to time specialized conferences are sponsored by the IAWPR, such as the Conference on Phosphorus in Fresh Water and the Marine Environment held in London in 1972, the Conference on Nitrogen as a Water Pollutant, held in Copenhagen, Denmark, 18-20 August 1975, and the Specialized Conference on River Basin Management, Essen, Federal Republic of Germany, 12-16 September 1977. Papers from these specialized conferences are published in Progress in Water Technology and in Water Research.

(11) International Colloquia on Ocean Hydrodynamics. International colloquia are held periodically on ocean hydrodynamics in Liège, Belgium. The 9th International Liège Colloquium on Ocean Hydrodynamics, dealing with Estuaries, was held at the University of Liège, 2-11 May 1977 (Nihoul, 1977). While these colloquia are essentially discussions of applied mathematics in hydrodynamics, they provide much of the theoretical basis for the complex problems of dilution, dispersion and transport of pollutants in the sea.

(12) Symposia of the International Association for the Physical Sciences of the Ocean (IAPSO). IAPSO organized, with the International Association of Meteorological and Atmospheric Physics (IAMAP) and the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), an interdisciplinary symposium on Marine Pollution at the XVIth General Assembly of the International Union of Geodesy and Geophysics (IUGG), held in Grenoble, France, 25 August-6 September 1975 (Anon, 1976). The IAPSO Scientific Advisory Committee on "Physical and Chemical Aspects of the Dispersion of Natural and Artificial Substances and Heat in the Oceans and Seas", formed at the XVIth General Assembly, is planning a symposium on pollutant transfer processes in the surface and bottom layers of the oceans at the XVIIth General Assembly of IUGG in Canberra, Australia, December 1979.

(13) International Symposia on Aquatic Pollutants. The First International Symposium on Transformation and Identification of Aquatic Pollutants was organized by the U.S. Environmental Protection Agency and held in Athens, Georgia, U.S.A., 8-10 April 1974. The Second International Symposium on Aquatic Pollutants, sponsored by several government agencies and universities, will be held at Noordwijkerhout (Amsterdam), the Netherlands, 26-28 September 1977. The identification and measurement of various types of pollutants, the transfer of pollutants through different components of the ecosystem, and transformation and effects of contaminants on the aquatic environment and biota are reviewed in detail through presentation of laboratory and field research findings.

3. Regional activities

A number of regional studies have been made of marine pollution problems, including those in the Mediterranean and Baltic and North Seas /See Sections 1(11) and 1(12)/.

The Fourth Inter-Secretariat Meeting on Environmental Problems in the European Region was convened by the secretariats of UNEP and ECE (Economic Commission for Europe) in Geneva, 1-2 July 1976. In the marine pollution section of this report, it was noted that there was general agreement to have an inter-secretariat meeting on the marine environment. It was agreed that IOC should plan, in consultation with ICES, to organize such a meeting in 1977.

(a) Baltic Sea, North Sea and Eastern North Atlantic Ocean. Under the auspices of the International Council for the Exploration of the Sea (ICES), reviews of the pollution situation in the Baltic and North Seas have been prepared (ICES, 1969, 1970a). Annual meetings of ICES often have symposia on various subjects concerning the marine environment, and particularly on the effects of man's numerous activities on the fisheries resources of the Baltic and North Seas. A Symposium on the Physical Processes Responsible for the Dispersal of Pollutants in the Sea with Special Reference to the Near-Shore Zone was held in Aarhus, Denmark, during July 1972, under the auspices of ICES (Kullenberg and Talbot, 1974). Scientific research programmes are sometimes co-ordinated through ICES, such as the large 1965 dye-release experiment (RHENO) in the North Sea for diffusion studies (ICES, 1973a).

A Working Group for the International Study of the Pollution of the North Sea and its Effects on Living Resources and their Exploitation, has been active for some time and has recently issued Co-operative Research Report No. 39 on its work (ICES, 1973b, 1974a). Intercalibration of analytical techniques for measuring pollutants in the sea, along with a baseline survey, have been co-ordinated by the Working Group in national laboratories. The Working Group recommended (ICES, 1973b) inter alia: (i) a detailed study of pollutant inputs into the sea to establish the flux of pollutants from estuaries, fjords, outfalls, etc., under normal and abnormal hydrographic conditions; (ii) continued national monitoring programmes; (iii) studies of all aspects of the biological significance of pollutant levels in fish and shellfish and in the marine environment; and (iv) in view of the high level of activity in oil exploration and exploitation in the North Sea, intensified studies of the effects of oil on the marine environment. A pollutant input study related to the year 1972, and a study of the level of contaminating substances in living resources of the area, with 1973 as the sampling year, have been completed (ICES, 1974a). Monitoring of the same substances was conducted for the years 1973-1976 and is likely to continue. The Working Group acts also in an advisory capacity to the Oslo Commission Working Party on Monitoring which is involved with providing background information for administration of the Oslo Convention on Dumping Wastes at Sea (Norway, 1972).

Because of the responsibility of the Oslo Commission for the Eastern North Atlantic, the North Sea studies were extended to cover the whole of the Commission's area and gained co-operation from ICES member countries on the western side of the Atlantic. Extended studies of input and of the level of contaminating substances in marine resources have been completed. Intercalibration for a survey of "dissolved" heavy metals in sea water has been conducted with involvement of laboratories in North America. A study of available methods for assessing the biological effects of pollutants by a Subgroup on the Feasibility of Effects Monitoring in the ICES Working Group on Pollution Baseline and Monitoring Studies in the Oslo Commission and ICNAF Areas, should be published in 1977. A Workshop on Hydrocarbons in the Marine Environment was held in Aberdeen, Scotland, during 1975. A Norwegian-American plan for intercalibration of hydrocarbons in sea water has been developed, with the aim of future monitoring. The possibilities of monitoring pollutants in sediments were explored at a meeting of specialists in August 1976.

The Baltic has been studied by the "Baltic Oceanographers" since 1957, in a programme where there has been participation by scientists from all countries bordering the Baltic Sea (Fonselius, 1970). The "Baltic Marine Biologists", a similar group of international biologists formed some years ago, has studied the biological characteristics of the Baltic Sea. More local groups, such as the Committee on Pollution of the Oresund (Denmark and Sweden) and the Committee on Pollution of the Gulf of Finland (Finland and USSR), have concentrated on specific sectors of the Baltic. As noted earlier, there is also an ICES/SCOR Working Group on Baltic Pollution (IOC, 1973b).

Under the Scientific Affairs Division of the North Atlantic Treaty Organization, conferences have been held on the problems of pollution in the North Sea (Goldberg, 1973), as well as in other parts of coastal Europe. Recommendations have been made for conducting intensive studies in these regions and for preparing mathematical models which would provide a predictive capability (NATO, 1973). A Continental Seas Pilot Study Workshop (formerly called NATO/CCMS Coastal Pollution Workshop) was held in Ostend, Belgium, during June 1975 and dealt with various effects of man in the coastal zone (NATO, in press).

(b) Mediterranean. Regional studies are also being carried out in the Mediterranean Sea, where the threat of pollution in some areas is considered to be acute (Ritchie-Calder, 1972). The Co-operative Investigations in the Mediterranean (CIM) (Joseph, 1970), initiated by the IOC, the International Commission for Scientific Exploration of the Mediterranean (ICSEM) and FAO's General Fisheries Council for the Mediterranean (GFCM/FAO) are now co-ordinated by the Joint IOC/ICSEM/GFCM Group for Technical Co-ordination (GTC). The GFCM formed, in 1969, an ad hoc Working Party on Marine Pollution in the Mediterranean and its Effects on Living Resources and Fisheries, which, with the ICSEM, prepared a review, "The State of Marine Pollution in the Mediterranean and Legislative Controls" (GFCM, 1972). The GFCM ad hoc Working Party noted above became a permanent one, and after completing the review, prepared plans for baseline studies on pollutants in commercial species and on ecological effects of pollution in the Mediterranean.

Various meetings and consultations have been held recently on protection of living resources and fisheries from pollution in the Mediterranean (FAO, 1974c). An International Workshop on Marine Pollution in the Mediterranean was convened in Monaco during September 1974 by IOC, GFCM and ICSEM, with the financial support of UNEP (IOC, 1975f). A Mediterranean marine pollution research and monitoring programme was proposed.

An intergovernmental meeting on the protection of the Mediterranean, sponsored by UNEP, was held in Barcelona from 28 January to 4 February 1975 (UNEP, 1975), at which time a draft convention for the protection of the Mediterranean was developed. The Action Plan approved in that meeting included a scientific component which has now become the UNEP Joint Co-ordinated Mediterranean Pollution Monitoring and Research Programme. A conference of plenipotentiaries of the coastal States of the Mediterranean region was held in Barcelona, 2-16 February 1976 at which the above-mentioned convention was adopted.

A meeting held in Msida, Malta in September 1975, sponsored by IOC, WMO and UNEP, drew up operational plans for two pilot projects: one on baseline studies and monitoring of oil and petroleum hydrocarbons in marine waters and another on problems of coastal transport of pollution. The FAO (GFCM)/UNEP Expert Consultation on the Joint Co-ordinated Project on Pollution in the Mediterranean was held from 23 June to 4 July 1975 in Rome, and was followed by the WHO/UNEP Expert Consultation on the Coastal Water Quality Control Programme in the Mediterranean, held in Geneva from 15 to 19 December 1975. The purpose of these meetings was to develop operational plans for four projects to be co-ordinated by FAO and one to be co-ordinated by WHO. The projects in the FAO/UNEP Joint Co-ordinated Project on Pollution in the Mediterranean were: (1) Baseline Studies and Monitoring of Metals, particularly Mercury and Cadmium, in Marine Organisms; (2) Baseline Studies and Monitoring of DDT, PCB's and other Chlorinated Hydrocarbons in Marine Organisms; (3) Research on the Effects of Pollutants on Marine Organisms and their Populations; and (4) Research on the Effects of Pollutants on Marine Communities and Ecosystems. The WHO/UNEP project was entitled: Coastal Water Quality Control.

The pilot projects are being conducted primarily by national laboratories nominated by national authorities. Intercalibration exercises are being conducted and technical guidelines are being issued.

Mid-term reviews of these projects were made at the following meetings: (1) the IOC/WMO/UNEP mid-term review and expert consultation, held in Barcelona from 23 to 27 May 1977; (2) the WHO/UNEP mid-term review and expert consultation, held in Rome, 30 May to 3 June 1977; and (3) the mid-term expert consultation of the Joint Co-ordinated Project on Pollution in the Mediterranean, held under the FAO (GFCM)/UNEP auspices in Dubrovnik, Yugoslavia from 2 to 14 May 1977.

Four other pilot projects have subsequently been added to the Joint Co-ordinated Mediterranean Pollution Monitoring and Research Programme. IAEA and UNEP are co-operating on: (1) Intercalibration of Analytical Techniques; (2) Maintenance Services for Analytical Instruments; and (3) Biogeocycle of Pollutants in Open Waters of the Mediterranean (with IOC); while WHO, IAEA, Unesco and ECE are co-operating on (4) Pollutants from Land-Based Sources.

(c) Caribbean. Most of the studies for this area have been conducted in the Gulf of Mexico and consist of physical and chemical oceanography and fisheries management research. Many of the international marine investigations have been co-ordinated by IOC within the Co-operative Investigations of the Caribbean and Adjacent Regions (CICAR), and it is anticipated that these will be continued under its successor, the IOC Association for the Caribbean and Adjacent Regions (IOCARIBE). A major baseline study in the Gulf of Mexico is focusing on the concentration and distribution of selected metals and petroleum hydrocarbons in the marine biota and sediments. This project arose out of the concern about the potential impact of oil and gas development on coastal waters in the Gulf of Mexico.

The IOC with the co-operation of FAO (Western Central Atlantic Fisheries Commission (WECAFC)) and UNEP, organized the International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, held in Port of Spain, Trinidad and Tobago, 13-17 December 1976 (IOC, 1976f). Seven pilot projects were proposed, including baseline and monitoring studies and a project on effects of pollutants, especially those from domestic and industrial sewage, on tropical ecosystems of economic importance. It is expected that these will become incorporated in a UNEP regional action plan along the lines of the Mediterranean Action Plan.

(d) Indo-Pacific. The FAO/UNDP Fisheries Development and Co-ordination Project for the South China Sea and certain activities under the Economic and Social Commission for Asia and the Pacific (ESCAP) have marine pollution components. However, there is no large, internationally co-ordinated programme of marine pollution research and monitoring in the region. The International Workshop on Marine Pollution in East Asian Waters was convened by IOC jointly with FAO (Indo-Pacific Fisheries Council (IPFC)) and UNEP, in Penang, Malaysia, 7-13 April 1976 (IOC, 1976d). The state of knowledge of marine pollution was reviewed and four regional projects were proposed, along with three or four subregional projects in each of six subareas. The report of this Workshop is expected to be part of the input into a proposed intergovernmental meeting, following the pattern basically set for the Mediterranean.

An ad hoc Meeting of the Group of Experts on Future Programmes and Co-operation in the Western Pacific Area was held in Noumea, New Caledonia, in July 1977 under the auspices of the IOC.

An International Workshop on Marine Pollution in the South East Pacific is being organized by the Permanent Commission for the South Pacific (CPPS), with the support of IOC and FAO, and possibly of UNEP. The dates of this Workshop have not yet been fixed.

(e) Red Sea and the Gulf of Aden. An Intergovernmental Group of Experts from the Arab States bordering the Red Sea and Ethiopia was convened by the Arab League Educational, Cultural and Scientific Organization (ALECSO), with the support of UNEP, at Jeddah, Saudi Arabia, November-December 1975. A plan of action for protection of the environment of the Red Sea was prepared, and the general outline for a "Regional programme for the study of the environment of the Red Sea and the Gulf of Aden" was adopted. A draft convention and two protocols for the protection of the Red Sea and the Gulf of Aden environment were prepared at the second Jeddah meeting, convened by ALECSO and UNEP, 12-18 January 1976. A Regional Scientific Programme for Environmental Studies, including pollution research and monitoring, was also approved at this time. The short-term plan in this Programme includes two pilot projects: (i) baseline studies and monitoring of oil in seawater; and (ii) effects of oil on marine organisms and their ecosystems. It is proposed also to monitor radioactive pollution in the Red Sea and the Gulf of Aden, covering seawater, the atmosphere, rain, soil and the marine food chain. The long-term plan in the Regional Scientific Programme aims at monitoring pollutants and their effects on marine organisms and their eco-systems, following the guidelines set out for the Mediterranean pilot projects.

A regional oceanographic centre will be established at Jeddah to co-ordinate the activities of the Programme. There will also be a Regional Data Centre and a Marine Biological Reference Collection Centre.

(f) The Persian Gulf and the Gulf of Oman. The state of marine sciences in the Gulf region was reviewed by a Unesco meeting of experts held in Paris, 11-14 November 1975. All countries bordering the Persian Gulf were visited by an inter-agency fact-finding mission during the period 26 March-19 May 1976 to study the impact of coastal development. An Action Plan for the Protection and Development of the Persian Gulf is in preparation. UNEP convened a Regional Expert Consultation in Bahrain, January 1977, and an Experts Meeting in Nairobi, June 1977, to review and advise on further development of the Action Plan. A regional intergovernmental meeting will be convened in Kuwait in January 1978 to discuss and reach agreement on an action plan. An inter-agency task force in October 1976 prepared guidelines for a draft regional agreement for co-operation on protection of the marine environment.

(g) Other Regional Studies. Other regional studies, co-ordinated by the IOC, could become involved in certain aspects of marine pollution monitoring and research, e.g. Co-operative Studies of the Kuroshio and Adjacent Regions (CSK) and Co-operative Investigations of the Northern Part of the Eastern Central Atlantic (CINECA). The IOC's Working Committee for GIPME has asked the IOC Scientific Advisory Bodies and the ICSU Scientific Committee on Antarctic Research to determine whether there is interest in, and a need for, a marine pollution workshop on the southern oceans. Arctic and Antarctic studies have been conducted collaboratively by nations having common interests in cold water and ice problems. Some of these joint programmes are being extended to include environmental problems, particularly with the advent of oil and gas exploitation in the Arctic.

In the sub-Arctic Pacific, studies have been conducted since 1954 on the marine environment of commercial species of fish, particularly Pacific salmon, by the United States of America, Canada and Japan, under terms of the International North Pacific Fisheries Commission. However, these have not taken marine pollution *per se* into consideration.

4. National studies of global significance

There have been several national programmes on marine pollution considered to have global significance. First of all, the U.S. studies of distribution of fallout radionuclides from nuclear weapons' tests in the Pacific during the 1940's, 50's and 60's provided an early picture of the global dispersion of radioactive debris through the stratosphere (NAS, 1971a). This was followed by studies of the entry and dispersion of radionuclides into the aquatic environment from nuclear reactors in the U.S.A., where radioactive effluents were discharged from the Hanford Works in Washington State into the Columbia River draining into the North East Pacific (Pruter and Alverson, 1972), and in the United Kingdom, where the Windscale Works on the Cumberland coast release their effluents into the Irish Sea (Preston, 1974).

More recently, the Minamata tragedy of mercury poisoning of humans led to extensive studies of mercury pollution in coastal waters of Japan, along with other environmental investigations (Japan Environmental Agency, 1975). These problems have had a global impact, in that they have raised sufficient concern for pollution by metals to be examined in both the atmosphere and the oceans in many parts of the world.

The findings of DDT in marine organisms, and the reproductive failure in birds off the coast of California led to world-wide investigations of this organochlorine pesticide. Its global distribution suggested a more rapid dispersion than possible through river runoff and sewer outfalls. The mechanism of atmospheric transport was finally singled out as the mode of rapid world-wide dispersion.

The discovery in Sweden that PCB's are as widely distributed in the environment as DDT and its degradation products stimulated investigation of this organochlorine industrial chemical in many parts of the world oceans. The fact that it is persistent, bioaccumulated in marine organisms and is highly toxic were sufficient causes for concern. Its presence in the various components of the marine food web has been investigated in coastal and oceanic waters of both the Atlantic and Pacific.

In the U.S.A., several conferences and workshops have been conducted under the auspices of the National Academy of Sciences - National Research Council and National Academy of Engineering to examine the marine pollution problem. During the late 1950's and early 1960's, working group studies were conducted on both the east and west coasts of the U.S.A. concerning the problem of low-level radioactive waste disposal from land (NAS-NRC, 1959a, 1962) and nuclear submarines (NAS-NRC, 1959b) into the sea. These studies led to some measure of national control in the U.S.A. over ocean dumping of radioactive wastes, and to a better understanding of radioactive pollution in the marine environment (NAS, 1971a).

The Committee on Oceanography of the National Academy of Sciences established in the spring of 1970 a panel on monitoring persistent pesticides in the marine environment, in order to study the impact of DDT and other chlorinated hydrocarbons on the marine environment to suggest courses of action based upon its findings. The panel was convened in Williamstown, Massachusetts, in July 1970, and a report was prepared (NAS, 1971b). Recommendations for research included studies of rates of entry of each chlorinated hydrocarbon pollutant into the marine environment, and baseline determinations of the distribution of the pollutants among the components of that environment followed by a programme of monitoring long-term trends.

Although the International Decade of Ocean Exploration (IDOE) has been largely an initiative of the U.S.A., it has been accepted as an important element of IOC's Long-term and Expanded Programme of Oceanic Exploration and Research. An IDOE Office was established under the U.S. National Science Foundation (NSF), and six goals were prescribed, the first of which was: "Preserve the ocean environment by accelerating scientific observations of the natural state of the ocean and its interactions with the coastal margin - to provide a basis for (a) assessing and predicting man-induced and natural modifications of the character of the oceans; (b) identifying damaging or irreversible effects of waste disposal at sea; and (c) comprehending the interaction of various levels of marine life to permit steps to prevent depletion or extinction of valuable species as a result of man's activities". At the request of the IDOE Office of NSF, a special study was held under the auspices of the Ocean Science Committee of the National Academy of Sciences - National Research Council, Ocean Affairs Board, during August 1971 at Durham, New Hampshire, U.S.A. A report was issued on this study (NAS-NRC, 1971), in which five major problem areas were reviewed: (1) the identification of major recognized and unrecognized pollutants, their sources and rates of input; (2) delineation of processes affecting the dispersal of these pollutants; (3) understanding the geochemical and biological transfer of critical elements or compounds in the ocean; (4) establishing the effects of pollutants on organisms including man; and (5) identification of the sites of final deposition of specific elements and compounds in the ocean environment. The report aimed to highlight areas of investigation that the group believed were important for further study.

It was evident from the reviews conducted that not enough data were available on which to formulate long-term research on problems in marine environmental pollution. To fill this gap in knowledge, the National Science Foundation's Office for IDOE supported a Baseline Data Acquisition Programme. There was participation from scientists in the United States and abroad in this one-year study, with measurements on a broad selection of marine organisms, sediments and sea-surface samples. The results of measurements of heavy metals, halogenated hydrocarbons and petroleum hydrocarbons obtained during the baseline investigations were summarized in a pre-conference volume (Goldberg, 1972b), which was used as a basis for study by the participants at the IDOE Baseline Conference held in New York during May 1972. Their report (Goldberg, 1972c) gave an assessment of the problems as they were identified during the 1970-1972 period. They concluded that "the readily identifiable contamination in the open ocean by synthetic halogenated hydrocarbons (such as PCB and DDT and its metabolites) and petroleum hydrocarbons potentially constitute a problem of global concern". Among recommendations presented were:

> "that a continuing research programme to determine inputs, dispersal paths and present levels of the synthetic halogenated hydrocarbons and of petroleum hydrocarbons in representative plants and animals of coastal and open ocean zones be immediately initiated with the objectives of evaluating hazards to living processes and of defining sources of these materials.

Simultaneously and with high priority, research should be expanded in biological laboratories to evaluate the impacts of existing levels of these substances upon living organisms".

The Pollutant Transfer Programme, starting in 1972, followed the Baseline Data Acquisition Programme and set up as its goals: (1) to identify important transfer pathways and mechanisms; (2) to evaluate the major environmental factors which affect transfer processes; and (3) to develop principles governing transfer of pollutants. A Pollutant Transfer Workshop was held in Port Aransas, Texas, 11-12 January 1974, to assess the accomplishments of the first two years (1972-1974) of the investigators in the Transfer Programme. Detailed information was obtained on the transport of trace metals, PCB's, DDT and petroleum hydrocarbons, but workshop participants recognized that the programme was in a rather early stage to draw many significant conclusions (Duce, et al., 1974).

Out of the Durham meeting arose a number of monitoring programmes, as well as the proposal for the Controlled Ecosystem Pollution Experiment (CEPEX), which started in the summer of 1973 in Saanich Inlet, British Columbia (NSF, 1973). This is an interdisciplinary programme of investigation in large inverted plastic silos, or underwater "greenhouses", by chemists, zoologists, botanists, microbiologists and mathematical modellers on heavy metals and hydrocarbons in the food chain of the sea under controlled experimental conditions, maintained in situ, as similar as possible to the natural environment. It involves several United States, Canadian and United Kingdom institutions, and is supported by the National Science Foundation's IDOE Office in Washington, D. C.

A primary goal of the experiment is to determine whether deep-sea forms are more sensitive to pollutants than inshore forms, and therefore whether the former require greater protection from pollution. It is hoped with this experiment to gain a fuller understanding of the effects of metals and other pollutants on different trophic levels and of their movement through the food chain in the sea, under experimental conditions fashioned to resemble as closely as possible those occurring in nature. A better appreciation of the weak links in the food chain, which are affected more than others by specific pollutants, will allow better management of waste disposal and protection of renewable resources in the sea.

The U. S. A. passed legislation to control ocean dumping with the Marine Protection, Research and Sanctuaries Act of 1972. In order to study the ecological implications of ocean dumping, an ad hoc panel of the Ocean Science Committee in the Ocean Affairs Board of the Commission on Natural Resources of the U. S. National Research Council organized a workshop in Woods Hole, Massachusetts, during 9-13 September 1974. The workshop reviewed and integrated scientific and technical information on ocean disposal to develop concepts for monitoring and regulating this practice (NAS, 1976). Gaps in information on such aspects as marine dispersion and sea-to-air transfer of contaminants were identified.

Recognizing the need for standardized analytical techniques for measuring pollutants in the environment, the National Research Council of Canada, with support from a number of interested scientific organizations, held an International Symposium on Identification and Measurement of Environmental Pollutants in Ottawa, Canada, during June 1971 (Hoffman, 1971). A few analytical problems of pollutants in the sea were considered.

A workshop, sponsored by the National Oceanic and Atmospheric Administration of the U. S. Department of Commerce, was held in California during October 1972 to consider a national marine pollution monitoring programme (Goldberg, 1972d). It paid particular attention to selection of sampling sites and techniques of sampling. Analyses by standardized sensitive methods of both water and organisms for inorganic and organic constitutents, considered as critical pollutants received detailed examination. This study has been expanded and updated for contemporary needs in marine monitoring (Goldberg, 1976a).

The problem of oil pollution looms larger than ever on the horizon, with the burgeoning oil industry on the continental shelves of the world and ocean transport of oil with tankers of ever-increasing size. The TORREY CANYON disaster is still a vivid memory, with the contamination and devastation along the beaches of southern England and the north coast of France by oil and clean-up chemicals. Some of the studies there and in the Santa Barbara, California oil spill, provided valuable information on the ecological impact of oil pollution and dispersants (Smith, 1968; Holme, 1969). The ecological problems of oil pollution have been studied by a number of investigators in the U.S.A., including, among others, North (1967), Ketchum (1972), Blumer (1969, 1971), Erhardt and Blumer (1972) and Blumer et al (1973). Recent symposia, seminars and conferences in both Europe and North America have dealt with oil pollution as a matter of some urgency (Hoult, 1969; NATO, 1970; API, 1970, 1975; Cowell, 1971; FAO, 1971b; Peters, 1974; NAS, 1975a, 1975b).

Problems of environmental pollution by metals have received a great deal of attention since the Minamata episode, as reflected by international conferences held recently on the subject (Krenkel, 1975; Ward, 1975). Some of the biological concerns in marine pollution by heavy metals were reviewed by Waldichuk (1974b) in a symposium on the effects of pollution on the physiological ecology of estuarine and coastal water organisms, held at the University of South Carolina, Georgetown, S.C., U.S.A., 14-17 November 1973 (Vernberg and Vernberg, 1974). The foregoing symposium was followed by another which dealt with physiological responses of marine biota to pollutants including metals (Vernberg et al, 1977). Scientists at the Fisheries Radiobiological Laboratory at Lowestoft, England, have monitored for over a decade selected heavy metals in coastal waters around the British Isles (Preston et al., 1972). It is of some significance that these studies showed that there has been little change from 1960 to 1970 in the number of areas contaminated and in the extent of contamination by heavy metals (Preston, 1973). Toxicity studies on marine organisms in polluted estuaries of the United Kingdom have shown a development of tolerance to metals among certain species (Bryan, 1974).

The atmosphere has been recognized as one of the important routes for transfer of certain pollutants from the land to the sea. This was identified in the IDOE Pollutant Transfer Programme (Duce, et al., 1974). The U.S. National Academy of Sciences supported a Workshop on Tropospheric Transport of Pollutants to the Ocean, held in Miami, Florida, 8-12 December 1975 (NAS, 1977).

The Biologische Anstalt Helgoland, Federal Republic of Germany, has sponsored approximately biennially since 1963 International Helgoland Symposia dealing with some aspects of the marine ecosystem. Recent symposia have taken into account the effects of man. The Fifth Symposium, held in September 1972, was entitled "Man in the sea - in situ studies on life in oceans and coastal waters". The Sixth International Helgoland Symposium on the subject "Ecosystem research" was held in Helgoland, 26 September-1 October 1976. The two major topics reviewed in the formal programme were: (i) Ecosystems in the sea and in small natural water bodies; (ii) Multispecies cultures and artificial microcosms. Informal sessions discussed other special topics in depth. The proceedings of these symposia are published in the journal "Helgoländer wissenschaftliche Meeresuntersuchungen", with the Fifth Symposium published in Volume 24 (1973).

In the U.S.A., the MESA (Marine Ecosystem Analysis) Programme of the National Oceanic and Atmospheric Administration in the U.S. Department of Commerce is designed to develop an in-depth understanding of the marine ecosystem and the effects of man's activities on it. Three areas of concern are being investigated in this programme: (1) The New York Bight; (2) Puget Sound; and (3) North East Pacific Ocean. Studies in the New York Bight are investigating the ecological effects of many decades of dumping of various types of wastes. The Puget Sound area has been chosen for study as a relatively pristine area. In the North East Pacific, the Deep Ocean Mining Environmental Study (DOMES) is addressing potential environmental effects of the deep ocean mining of manganese nodules. The MESA programmes are scheduled to continue to 1985.

In the United Kingdom, the Natural Environment Research Council has conducted research on pollution of the natural environment (NERC, 1976), and has emphasized estuaries in particular (NERC, 1975). The various ecological problems associated with waste disposal into rivers and the estuarine environment are being examined in some 30 estuarine systems of Great Britain.

Table 16 summarizes scientific activities of international significance in the study of marine pollution.

TABLE 16

Significant international organizations, conferences and other activities dealing with marine pollution (given roughly in chronological sequence with an attempt to group related activities)

(modified, from Waldichuk, 1973)

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
IOC Working Group on Marine Pollution	IOC(Unesco)	Met only once in August 1967, then disbanded.	IOC, 1967
Joint Group of Experts on Scientific Aspects of Marine Pollution (GESAMP)	IMCO/FAO/Unesco/ WMO/WHO/IAEA/ UN/UNEP	Met for first time March 1969 and annually since to review marine pollution problems of international significance on an interdisciplinary basis. There are GESAMP Working Groups on: (a) Evaluation of the Hazards of Harmful Substances in the Marine Environment; (b) Principles for developing Coastal Water Quality Criteria; (c) Scientific Bases for the Determination of Concentrations and Effects of Marine Pollutants; (d) Scientific Basis for Disposal of Waste into the Sea; (e) Impact of Oil in the Marine Environment; and (f) Scientific Aspects of Pollution Arising from the Exploration and Exploitation of the Sea Bed.	GESAMP, 1969, 1970, 1971, 1972b, 1973a, 1973b, 1974a, 1974b, 1976a, 1976b, 1976c, 1977a, 1977b
Joint Working Party of the Advisory Committee on Marine Resources Research, the Scientific Committee on Oceanic Research and the World Meteorological Organization	FAO(ACMRR)/ SCOR/WMO (AGOR)	Met in Ponza and Rome, Italy, 29 April-7 May 1969. Identified problems of marine pollution, among others, requiring investigation.	ACMRR/SCOR/ WMO(AGOR) 1969
Special Working Group of the IOC on the Long-term and Expanded Programme	IOC (Unesco)	Met in Unesco, Paris, 16-21 June 1969, to prepare a Draft Comprehensive Outline of the Scope of the Long-term and Expanded Programme of Oceanic Exploration and Research, including a section on marine pollution.	IOC, 1969, 1970a

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
Group of Experts on Long-term Scientific Policy and Planning (GELTSPAP)	IOC (Unesco)	Met for the first and only session in Monaco, 16-25 September 1970. Developed details for the Long-term and Expanded Programme of Oceanic Exploration and Research including a focal point for a Global Investigation of Pollution in the Marine Environment (GIPME).	IOC, 1970c
International Decade of Oceanic Exploration (IDOE)	IOC (Unesco). Funded by national science funding agencies such as NSF's Office of IDOE in the U.S.A.	A programme spearheading U.S. bilateral or multilateral co-operative marine environmental studies. It is an important element of IOC's LEPOR.	NAS-NAE, 1969; NAS-NRC, 1971; Goldberg, 1972b, c; NACOA, 1975
Seminar on Methods of Detection, Measurement and Monitoring of Pollutants in the Marine Environment, FAO, Rome, 4-10 December 1970	FAO/Unesco/IAEA/SCOR/WMO	Report prepared on the best available techniques for measurement of various pollutants in the sea.	FAO, 1971b
Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, FAO, Rome, 9-18 December 1970	FAO	A major international conference on the state of pollution in the sea and its effects on the living marine resources.	FAO, 1971a; Ruivo, 1972
ACMRR/SCOR/ACOMR/GESAMP Joint Working Party on Global Investigation of Pollution in the Marine Environment (GIPME)	FAO/SCOR/WMO/Unesco/IMCO/IAEA/WHO/UN	Met in San Marco di Castellabate and Rome, Italy, 11-18 October 1971, and prepared a definitive report. Identified research needs in marine pollution and developed an outline for GIPME.	FAO, 1971c
ACMRR/IABO Working Party on Ecological Indices for Measuring the State of Living Resources as Affected by Environmental Stresses	ACMRR (FAO)/IABO	Designated by parent bodies (FAO) and other affiliated groups (ICG for GIPME, SCOR) for this function in 1973. Report published in 1976.	FAO, 1971c; SCOR, 1973; IOC, 1973b; ACMRR/IABO, 1976
ACMRR/ACOMR/ECOR/ICES/SCOR Working Group on Marine Pollution Research (SCOR Working Group 45)	ACMRR (FAO)/ACOMR/ECOR/ICES/SCOR	Met for the first time in London on 30 March 1973 to develop terms of reference and a plan of activities	SCOR, 1973b

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
		with a principal objective to advise the ICG for GIPME on needs for coordination of marine pollution research. At its second meeting in November 1973, decided to be known as the SCOR/ACMRR/ECOR/ICES/GESAMP Liaison Panel on Marine Research Related to Pollution. Disbanded later.	
ACMRR/IABO Working Party on Biological Effects of Pollutants	ACMRR (FAO)/IABO	Organized in 1973 to undertake reviews of bioassays and other aspects of biological effects of marine pollution. Work completed in 1976 and reports issued.	FAO, 1971c; SCOR, 1973; GESAMP, 1973a; ACMRR/IABO, 1977a, 1977b
ACMRR Working Party on Biological Accumulators	ACMRR (FAO)	Organized in 1974 to review ongoing research and operational programmes, to evaluate bioaccumulator species, to recommend standardized working methods and to develop guidelines for pilot studies. Work was completed and reports issued in 1976.	FAO, 1975b; Portmann, 1976; Bernhard, 1976
WHO Group on Sublethal Effects of Pollutants on Marine Organisms	WHO	Proposed in 1972 to examine long-term effects on aquatic organisms of the same suite of pollutants to which man may be exposed. Study on flounders in Oslo Fjord is one of first such investigations.	ICES, 1973b; WHO, 1975a
Intergovernmental Working Group on Marine Pollution	United Nations	One of the working groups of the Preparatory Committee for the United Nations Conference on the Human Environment. First session in London, 14-18 June 1971; second session in Ottawa, 8-12 November 1971. Responsible for developing 23 principles for preservation of the marine environment and a draft convention on control of pollution by ocean dumping.	United Nations, 1971a, 1971c

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
Commission on Monitoring of the Scientific Committee on Problems of the Environment (SCOPE)	ICSU/SCOPE	Prepared a report on global environmental monitoring for the United Nations Conference on the Human Environment. Third General Assembly of SCOPE held in Vancouver, Canada, 11-15 August 1975.	ICSU/SCOPE, 1971
United Nations Conference on the Human Environment, Stockholm, Sweden, 5-16 June 1972	United Nations	Endorsed 23 principles for protection of the marine environment. Adopted 26 principles and 109 recommendations for environmental action.	United Nations, 1972a, 1973a; UNGA, 1972
United Nations Environment Programme (UNEP)	Member States provide contributions to the Environment Fund. Administered by the United Nations Environmental Secretariat under the Governing Council	Arose out of the United Nations Conference on the Human Environment. Funds are allocated for environmental projects proposed by United Nations agencies, fulfilling functional components of the Action Plan, consisting of: (1) environmental assessment (EARTHWATCH); (2) environmental management; and (3) supporting activities. EARTHWATCH includes: (a) Global Environmental Monitoring System (GEMS); (b) International Referral System (IRS); (c) Review; and (d) Evaluation.	United Nations, 1972a; UNEP, 1973; United Nations, 1973
Intergovernmental Meeting on Ocean Dumping, Reykjavik, Iceland, 10-15 April 1972	Government of Iceland	Developed Draft Articles of a Convention for the Prevention of Marine Pollution by Dumping.	Iceland, 1972a, 1972b
Intergovernmental Conference on the Convention on the Dumping of Wastes at Sea, London, England, 30 October-10 November 1972	United Kingdom Government, participating States	Convention adopted on 13 November 1972. Instruments of ratification deposited with U.K. Government until other arrangements formulated. Ratified by requisite number of countries in December 1975 and brought into force. IMCO now administers it.	United Kingdom, 1972; UNGA, 1973

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
International Conference on Marine Pollution, London, England, 8 October-2 November 1973	IMCO	New convention developed on control of pollution by oil and other noxious substances from ships, including ship-generated garbage and sewage.	IMCO, 1973a, 1973b, 1973c
International Co-ordination Group (ICG) for the Global Investigation of Pollution in the Marine Environment (GIPME)	IOC (Unesco)	Met for the first time in London, April 1973, to co-ordinate marine pollution investigations globally. Initiated a study on the "state of the health of the ocean". Developed a comprehensive plan for GIPME at the second session in New York, July 1974, and an implementation plan at the third session in Paris, June 1975. Recommended formation of an IOC Working Committee on GIPME which met for its first session in Hamburg, 18-22 October 1976.	IOC, 1973b, 1974, 1975a, 1976a, 1976b
Joint IOC/WMO Planning Group for IGOSS (IPLAN)	IOC (Unesco), WMO	First session held in Unesco, Paris, 26-30 June 1972. Developed a preliminary plan for a co-ordinated pollution monitoring programme in the framework of IGOSS.	IOC/WMO, 1972a
Group of Experts on Oceanographic Research as it Relates to IGOSS (IRES)	IOC (Unesco), WMO	Third session held in Unesco, Paris, 25-29 September 1972. Developed the scientific basis and outlined a plan for a pilot oil pollution monitoring project in the North Atlantic.	IOC, 1972c
IRES Ad Hoc Group on Oil and Dissolved Constituents of Sea Water, Kiel, Federal Republic of Germany, 12-16 March 1973	IOC (Unesco), WMO	Reviewed available methodology on sampling and analysis for oil in sea water. Recommended standardized procedures for the IGOSS Pilot Project on Marine Pollution Monitoring (Oil).	IOC, 1973c
Workshop on Inputs, Fates, and the Effects of Petroleum in the Marine Environment, Airlie, Virginia, U.S.A., 21-25 May 1973	Ocean Affairs Board, Commission on National Resources, National Research Council, Washington, D.C.	Reviewed all aspects of oil in the marine environment and drew several conclusions, one of which was that "the most damaging indisputable	NAS, 1975b

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
		adverse effects of petroleum are oiling and tarring of beaches, the endangering of seabird species and the modification of benthic communities along polluted coastlines where petroleum is heavily incorporated in the sediments".	
Symposium and Workshop on Marine Pollution Monitoring (Petroleum), Gaithersburg, Maryland, U.S.A., 13-17 May 1974	IOC (Unesco), WMO, U.S. Dept. Commerce	Reviewed methodology for sampling and analysis of oil in the sea, in aid of the IGOSS Pilot Project on Marine Pollution Monitoring (Oil).	NBS, 1974
Joint IOC/WMO Task Team II on Marine Pollution Monitoring Rockville, Maryland, U.S.A., 20-22 May 1974	IOC (Unesco), WMO	Developed an "Operational Plan for the Pilot Project on Marine Pollution Monitoring under the Framework of IGOSS".	IOC/WMO, 1974
Ad Hoc Meeting of the Joint IOC/WMO Subgroup of Experts on IGOSS Marine Pollution (Petroleum) Monitoring Pilot Project, Kiel, Federal Republic of Germany, 15-19 September 1975	IOC (Unesco), WMO	Reviewed methodology for the collection and analysis of petroleum hydrocarbon samples at greater depths in the sea, and recommended methods and reference standards.	IOC/WMO, 1975
Annual Conference on Prevention and Control of Oil Pollution	American Petroleum Institute, U.S. Environmental Protection Agency and U.S. Coast Guard	The 1975 Conference was held in San Francisco, California, U.S.A., 25-27 March 1975, and the Proceedings have been published. The 1977 Conference was held in New Orleans, Lousiana, 8-10 March 1977. Wide range of topics are covered, including effects of oil on the marine environment and biota.	API, 1975
Co-operative Investigations in the Mediterranean (CIM)	Co-ordinated by the Joint IOC/ICSEM/GFCM Group for Technical Co-ordination of CIM	Marine pollution interests are only peripheral. Emphasis is on oceanography and renewable aquatic resources.	Joseph, 1970; Ritchie-Calder, 1972

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
GFCM Working Party on Marine Pollution in the Mediterranean and Expert Consultations on the GFCM Co-ordinated Projects on Pollution in the Mediterranean	GFCM (FAO)	Set up as an Ad Hoc Working Party in 1969 to prepare a review, and then as a permanent working party to develop plans for baseline studies on pollutants in commercial species and on ecological effects of pollution in the Mediterranean, as part of UNEP's "Mediterranean Action Plan".	GFCM, 1972; FAO, 1974c
Intergovernmental Meeting on the Protection of the Mediterranean, Barcelona, 28 January-4 February 1975	UNEP	Major objective of the meeting was adoption of an action plan to protect the Mediterranean. Considered a co-ordinated programme for research, monitoring and assessment of the state of pollution in the Mediterranean, along with protective measures.	UNEP, 1975
Expert Consultation on the Joint Co-ordinated Project on Pollution in the Mediterranean, Msida, Malta, 8-13 September 1975	IOC (Unesco), WMO, UNEP	Consultation was charged with developing the operational documents for two pilot projects: (a) baseline studies, and monitoring of oil and petroleum hydrocarbons in marine waters; (b) coastal transport problems of pollutants.	IOC, 1975g
Expert Consultation on the Joint Co-ordinated Project on Pollution in the Mediterranean, Rome, 23 June-4 July 1975	FAO (GFCM)/UNEP	Purpose of meetings was to develop operational plans for four projects: (a) research on the effects of pollutants on marine communities and ecosystems; (b) baseline studies and monitoring of metals, particularly mercury, in marine organisms; (c) baseline studies and monitoring of DDT, PCB's and other chlorinated hydrocarbons in marine organisms; and (d) research on the effects of pollutants on marine organisms and their populations.	FAO/UNEP, 1975

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
Expert Consultation on the Coastal Water Quality Control Programme in the Mediterranean, Geneva, 15-19 December 1975	WHO/UNEP	Objective was to develop international plans for the project of coastal water quality control.	WHO, 1975b
IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte-Carlo, 9-14 September 1974	IOC (Unesco), GFCM (FAO)	Critical marine pollution problems in the Mediterranean were reviewed and pilot projects on baseline studies, monitoring and research were outlined.	IOC, 1975c
Conference of Plenipotentiaries on Protection of the Marine Environment against Pollution in the Mediterranean, Barcelona, Spain, 2-16 February 1976	UNEP/United Nations system agencies	Convened to adopt a draft Framework Convention for the Protection of the Marine Environment against Pollution in the Mediterranean.	UNEP, 1976
International Symposium on Discharge of Sewage from Sea Outfalls, London, England, 27 August-6 September 1974	United Kingdom Department of Environment	Covered many aspects of sewage disposal into the sea, including regional problems, indicators of sewage pollution, microbial standards, effects of non-microbial pollutants, sewage treatment, microbial mortality, dispersion in the sea and predictive modelling.	Gameson, 1975; Waldichuk, 1974-1975
NATO/CCMS Coastal Pollution Workshop, Ostend, Belgium, 8-13 June 1975	Committee on the Challenges of Modern Society (CCMS) of NATO	Belgium hosted the Workshop, having been the pilot country on the CCMS coastal pollution project. Physical, chemical and biological aspects of coastal pollution were examined, and models to provide a predictive capability were proposed.	NATO, in press
Seminar on the Protection of Coastal Waters against Pollution from Land-based Sources, Lisbon, Portugal, 17-22 November 1975	Economic Commission for Europe (ECE)	Reviewed problems of coastal pollution and some protective measures, pertinent to the European Economic Community.	ECE, 1976

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
International Council for the Exploration of the Sea (ICES)	Member States	Highly effective organization, started in 1901, to deal mainly with hydrography and fisheries in the North Sea, Baltic Sea and North East Atlantic. Has a North Sea Pollution Working Group which is co-ordinating pollution investigations in the North Sea.	ICES, 1969, 1970a, 1970b, 1973b; 1973b, 1974a, 1974b, 1975a, 1975b, 1977a, 1977b, in press; Fonselius, 1970; Kullenberg and Talbot, 1974
Global Atmospheric Research Programme (GARP)	WMO/ICSU Organizing Committee	Transport of pollutants through the atmosphere and transfer to the sea have been considered. The GARP Atlantic Tropical Experiment (GATE) was conducted in 1974, and the First Global GARP Experiment (FGGE) is planned for 1979.	Döös, 1970; WMO-ICSU, 1970
Third United Nations Conference on the Law of the Sea, Caracas, Venezuela, June-August 1974; Geneva, March-April 1975; New York, 15 March-7 May 1976; New York, 2 August-17 September 1976; New York, 23 May-15 July 1977	United Nations	New conventions being negotiated on: territorial seas; fishing zones; pollution control; and exploration and exploitation of the seabed and ocean floor beyond the limits of national jurisdiction.	United Nations, 1972b, United Nations, 1976
International Biological Programme - Marine Productivity (IBP/PM)	Co-ordinated by an International IBP Committee. Supported by national science funding agencies, such as National Science Foundation in the U.S.A. and the National Research Council in Canada	Organized as a five-year programme, 1965-1970, but was extended in some cases to 1974. Perturbation of the marine environment by activities of man were considered in some of the studies of this programme.	SCOR, 1973
Man and the Biosphere (MAB) Programme	Unesco co-ordination; supported by national science funding agencies	Only peripheral interest in the marine environment, i.e. estuaries and coastal zones, 4th session of the International Co-ordinating Council of MAB held in Paris, 18-28 November 1975.	MAB/Unesco, 1972a, 1972b, 1973

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
International Association on Water Pollution Research (IAWPR)	Organized and coordinated by an international governing body	First International Conference on Water Pollution Research, held in London, England, during 1962. Conferences held every two years with the 7th Conference held in Paris, France in September 1974 and the 8th in Sydney, Australia, October 1976. The 9th will be held in Sweden in 1978. Proceedings of conferences are published in series "Advances in Water Pollution Research". IAWPR also publishes Water Research, an international journal covering the field of water pollution research. Marine pollution research is one of three main interest areas covered. Conferences on specialized topics are convened from time to time.	Pearson, 1964; Berger, 1965; Jenkins, 1971; SCOR, 1973
Study of Critical Environmental Problems (SCEP), Williamstown, Massachusetts, 1-29 July 1970	Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts, U.S.A.	Reviewed man's impact on the global environment. Made an assessment and gave recommendations for action.	MIT, 1970
Study of Man's Impact on Climate (SMIC), Wijk, Stockholm, Sweden, 28 June-16 July 1971	MIT, Royal Swedish Academy of Sciences and Royal Swedish Academy of Engineering Sciences	Reviewed man's impact on climate and examined inadvertent climate modification through such processes as pollutant emissions into the atmosphere.	MIT, 1971
Twentieth Nobel Symposium, "The Changing Chemistry of the Oceans", Aspenåsgarden, Lerum, and Chalmers University of Technology, Göterborg, Sweden, 16-20 August 1971	Nobel Foundation	Reviewed through formal presentations and discussions, characteristics of the marine environment and the atmosphere and changes brought about by man.	Dyrssen and Jagner, 1972

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
Second International Congress on Marine Pollution and Marine Waste Disposal, San Remo, Italy, 17-21 December 1975	Various	Specifically dealt with domestic sewage and industrial waste-water disposal in the marine environment.	Pearson and De Fraja Frangipane, 1975
International Conference on Heavy Metals in the Environment, Toronto, Ontario, Canada, 27 October-31 October 1975	Canada National Research Council, U.S. Environmental Protection Agency, WHO and others	Many scientific matters concerning heavy metals in the environment including marine waters, were presented and discussed.	Ward, 1975
National Conference on Polychlorinated Biphenyls, Chicago, Illinois, U.S.A., November 1975	U.S. Environmental Protection Agency	Problems of polychlorinated byphenyls, in lakes, rivers, estuaries and other coastal marine environments were reviewed, with respect to effects on aquatic organisms and humans.	Ayer, 1976
Symposia, conferences, panels, workshops and working group meetings on radioactivity, held as required	IAEA, with occasional co-operation of FAO, WHO and IMCO, along with regional and national atomic energy authorities	These gatherings are convened to deal with problems of radio-active waste disposal, safety practices in transport and handling of radioisotopes, identification of environmental issues associated with nuclear reactors, and to develop manuals, standards, guidelines and regulations.	IAEA, 1960, 1961a, 1961b, 1965, 1966, 1967a, 1967b, 1969, 1970, 1971a, 1971b, 1971c, 1973a, 1973b, 1975a, 1975b, 1975c, 1975d, 1975e, 1976
IAPSO (International Association for the Physical Sciences of the Ocean) Symposium on Marine Pollution, International Union of Geodesy and Geophysics, XVI General Assembly, Grenoble, France, 25 August-6 September 1975	IAPSO, with IAMAP and IAVCEI	An interdisciplinary symposium on marine pollution, involving the physical oceanographic aspects, as well as marine chemical aspects of water and air pollution.	Anon, 1976

Organization and/or Conference	Sponsoring international agencies and/or other bodies	Remarks	References
ECE (Economic Commission for Europe) Seminar on the Protection of Coastal Waters from Land-based Sources, Lisbon, Portugal, 17-22 November 1975	ECE	Reviewed the problems and proposed measures for control of pollution of coastal waters from land-based sources.	ECE, 1976
NATO Science Committee Conference on Ecological Toxicology Research: Effects of Heavy Metal and Organohalogen Compounds, Mont Gabriel, P.Q., Canada, 1974	NATO Scientific Affairs Division	Discussed: (a) the entry, distribution, and fate of heavy metals and organohalogen pollutants in the physical environment; (b) the uptake, metabolic fate, and mechanism of action of these materials in living organisms; and (c) movement of heavy metals and organohalogens through food chains and the resultant effects.	McIntyre and Mills, 1976
Working Group of Experts on Liability and Responsibility for Pollution and other Environmental Damage, UNEP, Nairobi, 23 February-4 March 1977	UNEP, with participation of experts from governments and international organizations, including IMCO	Convened by UNEP pursuant to Principle 21 of the Stockholm Conference Declaration and Decision 66 (IV) of the UNEP Governing Council. Considered liability mechanisms with respect to specific types of environment damage. Suggested areas of study: (a) marine pollution from offshore mining; (b) marine pollution from land-based sources; (c) air pollution; and (d) pollution of rivers.	
UNEP Industrial Sector Seminar on Environmental Conservation in the Petroleum Industry, Unesco Headquarters, Paris, 29 March-1 April 1977	UNEP, with participation from governments, international organizations, and the International Petroleum Industry Environmental Conservation Association (IPIECA)	Purpose of the Seminar was to exchange information and views amongst governments, the oil industry and international institutions in relation to environmental conservation in the petroleum industry. Among others, conclusions reached were: (a) the early implementation of the 1973 Convention for the Prevention of Pollution from Ships; (b) need for long-term research on the environmental impact of oil spills; (c) promotion of assistance to developing countries to enable them to effectively respond to oil pollution emergencies.	

Data Exchange

Oceanography has a comparatively long and successful history on the archiving and retrieval of data. Machine processing and sorting of data have greatly facilitated physical and chemical oceanographic research. National oceanographic data centres were established in a number of countries active in oceanography during the 1950's. The U.S. National Oceanographic Data Centre in Washington, D.C., was one of the first to be established. As a result of the need for oceanographic data exchange, arising out of programmes in the International Geophysical Year, 1957, World Data Centre A was established in Washington, D.C., and World Data Centre B in Moscow, USSR, to be managed by the International Council of Scientific Unions and operated by the national academies of science.

The IOC, almost from its inception in 1960, formed a Working Committee for International Oceanographic Data Exchange (IODE). The problems of archiving marine pollution data in some standard format were recognized early in the deliberations of GESAMP. The Chairman of the Working Committee for IODE was approached by correspondence on one or two occasions by the Chairman of GESAMP to explore the possibilities of archiving marine pollution data. Partly as a result of such requests, and partly as a result of needs of IGOSS in its Pilot Project, an ad hoc Group on Marine Pollution Data was formed and presented its first report to the Working Committee for IODE at its seventh session in New York, during July 1973.

Recommendations from an enlarged ad hoc Group on Marine Pollution Data were presented at the eighth session of the Working Committee for IODE held in Rome, during May 1975 (IOC, 1975b). These dealt largely with reporting, archiving, retrieval and exchange of petroleum hydrocarbon data from the IGOSS Pilot Project, and of other chemical data which may be available in national laboratory archives. As a result of the first session of the Working Committee for GIPME (IOC, 1976b), a proposal on GIPME data and information exchange will be addressed to the Working Committee on IODE. Also, the Second IOC/WMO Workshop on Marine Pollution (Petroleum) Monitoring (IOC, 1976e) stimulated action for improvement of exchange of marine pollution data. The IODE ad hoc Group on Marine Pollution Data met in Paris, May 1977; it drafted a number of guidelines on this subject.

A centralized international data referral system has been developed by the IODE ad hoc Group on Marine Pollution Data and the Joint Task Team (IOC, ICES, IAEA, FAO, IHO, WMO, WHO, IMCO, UNEP) on Interdisciplinary and Interorganizational Data and Information Management and Referral (IMAR). It is known as the Marine Environmental Data Information Referral System (MEDI).

To assist scientists in locating sources of environmental data, the IMAR Task Team has issued the "Guide to International Marine Environmental Data Services" (Unesco, 1975), which lists marine data centres holding relevant data records. For example, the FAO Fishery Data Centre (FDC) holds data on levels of pollutants in marine organisms, as well as on fish-stock assessment and catch monitoring. FAO has prepared a Directory of Institutions Engaged in Pollution Investigations (FAO, 1974b), and an Inventory of Data on Contaminants in Aquatic Organisms (FAO, 1976b). The Directory includes about 200 institutions and gives details of project activities, with indexes by country of project, by geographic area covered, by contaminant and by host organism. An additional 1,200 institutions have been canvassed, and an enlarged edition of the inventory will be published (as requested by the Working Committee for GIPME), with information on the funding of projects, staff implementating such projects and a list of publications issued on the projects.

The Codex Alimentarius Commission develops, with the assistance of FAO and WHO, international standards governing pollutant levels in food, including that obtained from the sea, and a code of ethics for the international food trade.

The FAO/IOC Aquatic Sciences and Fisheries Information System (ASFIS) was conceived in 1959, and the major component, the journal entitled Aquatic Sciences and Fisheries Abstracts (ASFA) is being enlarged to give better coverage of the physical sciences. National institutions in Canada, France, Federal Republic of Germany, United Kingdom, USSR and U.S.A. are collaborating in the system, and others are expected to join. It is expected that the system will be fully computerized by 1978, and tapes will be available to input centres to meet regional and national needs for retrospective searches of bibliographic information. Pollution aspects of the aquatic sciences, including the non-conventional literature, are being covered in part by the Marine

Biological Association of the United Kingdom (MBA, UK), Plymouth. Established in 1970, the Marine Pollution Information Centre at MBA, UK contains at present the world's most comprehensive collection of literature on both marine and estuarine pollution, with some 15,000 entries. The Marine Science Content Tables, a monthly periodical reproducing the tables of contents of core journals in marine sciences and technology, was initiated in 1965. It continues to provide rapid dissemination of information on key literature in the marine sciences and technology, and provides a schedule of future marine science and fishery meetings (FAO, 1977b).

The International Nuclear Information System (INIS), of the International Atomic Energy Agency, in partnership with some 50 nations, provides documentation on the world's significant literature related to the IAEA missions, through an automated, world-wide co-operative bibliographic collection of nuclear science and technology information. The World Health Organization advocates the use of automated bibliographic systems, such as MEDLINE and TOXLINE (both in U.S.A.) for matters relating to the physical and health sciences. The World Meteorological Organization co-ordinates the International Maritime Meteorological Punch Card (IMMPC) system for storage of marine meteorological observations for national use, as well as for international exchange. Within the World Weather Watch plan of WMO, marine meteorological data are preserved by world meteorological centres and by certain regional meteorological centres, as part of their entire meteorological data decks.

The International Council for the Exploration of the Sea has a Service Hydrographique, which has prepared in printed form and on magnetic tape, practically all physical and chemical oceanographic data collected during 1902-1962 in the ICES region by ICES member countries. The "Inventory of Oceanographic Investigations at North Atlantic Ocean Weather Stations", issued annually, now covers the whole period of observations of these weatherships. ICES publishes sea surface temperature anomalies in 14 regions of the northern North Atlantic in its "Annales Biologiques". The Service Hydrographique issues "Monthly Means of Surface Temperature and Salinity for Areas of the North Sea and the North-Eastern North Atlantic".

The United Nations Environment Programme recently organized an International Referral System (IRS) for sources of environmental information. IRS will be the normal access point for other UNEP information and data systems, such as the World Register of Rivers Discharging to the Oceans, the Global Environmental Monitoring System, and the International Register of Potentially Toxic Chemicals, as these systems are developed.

Training Programmes and Training Needs

Sampling and analysis of pollutants in the marine environment and in the biota requires skills that are available in relatively few laboratories of the world. Research on the effects of contaminants on marine organisms and ecosystems is being carried out in even fewer laboratories. It demands a high degree not only of skill in conducting laboratory and field experiments, but also of basic understanding of physiological processes. For any kind of global investigation of marine pollution, there is a need for training of scientists and technicians in many laboratories, particularly of developing countries.

Regional workshops, such as those conducted on the Mediterranean in Monaco during September 1974 (IOC, 1975f), on East Asian waters in April 1976 (IOC, 1976d) and on the Caribbean and adjacent regions (IOC, 1976f), can be a good first step toward establishing regional training programmes. Moreover, regional pollution investigation projects can be initiated on the marine environment. For example, in the Caribbean Workshop (IOC, 1976f), six pilot projects were proposed for study: (1) sources, effects and fates of petroleum and petroleum products in the Caribbean, Gulf of Mexico and adjacent regions; (2) health aspects of the disposal of human wastes into the marine environment; (3) investigation of the hydrological regime as it affects the transport and fate of pollutants in coastal lagoons and estuaries; (4) the effect of medium-scale eddies on the transfer and mixing of pollutants; (5) effects of pollutants, especially those from domestic and industrial sewage, on tropical ecosystems of economic importance; (6) baseline and monitoring studies of persistent chemicals in the Caribbean, Gulf of Mexico and adjacent regions; and (7) controlled experiments on the effects of pollutants on tropical marine organisms and ecological communities. The World Health Organization, with the co-operation of the Danish International Development Agency (DANIDA), has conducted successful training courses related to protection of human health, on marine pollution sampling, analysis and control, since 1970 (WHO/DANIDA, 1976). FAO, with co-operation of the Swedish International Development Agency (SIDA), has conducted annual training courses in marine pollution, oriented to protection of living resources, since 1972 (FAO/SIDA, 1974a). One of these courses has been held in Lima, Peru, 10 February-22 March 1975 (FAO/SIDA, 1975) as a regional training exercise (in Spanish) for Latin American countries. The Fourth Training Course, a special session on bioassays and toxicity testing, was held in Kristineberg, Sweden, 30 October-29 November 1975 (FAO/SIDA, 1976a). The Fifth Workshop on Marine Pollution in Relation to Living Resources was held in Manila, Philippines, from 17 January to 27 February 1977, when 25 participants from eleven developing countries of the East Asian region attended. The Sixth FAO/SIDA Workshop will be held in eastern Africa in early 1978. The course lectures have been published in a series of reports covering different aspects of marine pollution measurement and assessment (FAO/SIDA, 1974b, 1976b). Regional training is further envisaged, as part of the Programme for Regional Laboratories on Aquatic Pollution, being planned by FAO in various parts of the developing world. The first such laboratory in Mombasa, Kenya, is in the initial planning stage with financial support from SIDA.

The IOC has co-ordinated a number of oceanographic training programmes in the Caribbean, Africa and South East Asia through its Working Committee for Training, Education and Mutual Assistance in the Marine Sciences (TEMA) (IOC, 1975c, 1975d). The training programmes proposed through the ICG for GIPME, as recommended by its ad hoc Task Team on Training and Technical Assistance Needs, could be co-ordinated through the IOC Working Committee for TEMA. Some groundwork was conducted during early 1975 by Dr. T. Hirano of the Ocean Research Institute, University of Tokyo, on preparations for the IOC/FAO/UNEP International Workshop on Marine Pollution in East Asian Seas (IOC, 1975a). As a follow-up to the Second IOC/WMO Workshop on Marine Pollution (Petroleum) Monitoring (IOC, 1976e), a Training Course of Marine Pollution (Petroleum) Monitoring was held at Duke University's Marine Laboratory at Beaufort, North Carolina, U.S.A., in November-December 1976. This course was attended by 22 participants from 19 member countries. Co-operative Investigations of the Kuroshio and Adjacent Regions, co-ordinated through the IOC, have provided great stimulus for Japanese oceanographic work in recent years, and some of these studies may have relevance to marine pollution studies in the western Pacific.

There are other miscellaneous training activities, such as the SCOPE-UNEP Programme with the Chelsea College of Technology, which could serve a useful means of training technical personnel for marine pollution laboratories. A training course on the marine environment has been sponsored by the Government of Japan in collaboration with Unesco at the Faculty of Fisheries, Hokkaido University, Hokadate, Hokkaido (Sugawara, 1974). A study course in chemical oceanography was arranged in 1969 by ICES with the support of Unesco (ICES, 1970b). Unesco, with the assistance of IOC and United Kingdom funds-in-trust, is organizing a course in marine chemistry related to pollution studies with emphasis on specialized techniques, scheduled to commence in January 1978. Another co-operative course, involving Unesco's Division of Marine Sciences, is one in marine sciences planned for 1978 at the Open University in the United Kingdom, designed to help foster marine science in developing countries.

Training for technicians can be provided through intensive courses of two months' to two years' duration. But scientific expertise can only be gained through graduate training at a reputable centre of higher learning. There is a need for financial aid in the form of fellowships for promising students, so that the essential scientific expertise can be imparted to a sufficient number of personnel for work in the marine pollution field. Scientists already trained to high levels of performance in particular disciplines, who exhibit an interest in marine pollution studies should be encouraged with post-doctoral fellowships to pursue research on marine pollution problems at national and international centres acknowledged for their excellence in certain aspects of the marine environment. The Monaco International Laboratory of Marine Radioactivity, for example, could train specialists in radioactivity, metals and chlorinated hydrocarbon analysis, provided training candidates could be assigned to individual scientists there for at least six months.

Several universities and technological institutes have now established study programmes on environmental problems including marine pollution. An inventory is required on the availability of such facilities throughout the world so that guidance can be given to students interested in entering this field. Where there is a lack of such formal training facilities, encouragement should be given to appropriate universities and colleges to establish environmental centres and institutes.

Various United Nations agencies and their working groups are developing guidelines and handbooks on methods in marine studies. These are often specialized (FAO, 1975a; Portmann, 1976; Bernhard, 1976; WHO/DANIDA, 1976) and are supplementary to standard texts on methods in marine chemistry (Strickland and Parsons, 1972; Grasshoff, 1976).

Gaps in Marine Pollution Control Activities and Priorities for Future Action

If one examines closely the state of environmental knowledge concerning the world oceans, one can soon identify many gaps. The effects of the critical pollutants on the marine environment and its living resources are not at all well understood so that one can only speculate on the long-term consequences of such pollution. To embark on a programme of investigation to learn about all aspects of marine pollution would be very costly indeed. It is essential, therefore, to be quite selective in choosing priority topics for marine pollution research, so that the knowledge can be applied in the most effective way for pollution control. International conventions are being developed for control of marine pollution from specific sources. To be effective these conventions require backing by sound scientific information.

1. Legislation

International conventions have been developed quite expeditiously for control of pollution from ships and as a result of dumping wastes at sea. However, there are major gaps that must be bridged before control of marine pollution can be dealt with fully. Some of these gaps are filled by national legislation (U.S. House of Representatives, 1970), but this is not universally the case. Since winds and water currents know no national boundaries, the wastes of one nation can readily affect the coastal waters of another. These sources of pollution (Table 16, page 55) are not covered in existing conventions and require urgent international action. They can be grouped as follows:

(a) Shore-based pollution sources, including river discharges;

(b) Atmospheric emissions; and

(c) Pollution from exploration and exploitation of the sea bed and the subsoil thereof.

It is presumed that some of these problems will be resolved by the Third Law of the Sea Conference, where (c) and control of pollution by ships have been particularly examined in detail. But in the absence of international agreement through this forum, some other mechanism will be required to bring about control of these sources, which have been estimated to account for about 90 per cent of the oceans' pollution.

2. State of the health of the ocean

Examination of all available information on pollution in the marine environment shows that there is a dearth of reliable data on existing levels of the critical pollutants from various parts of the world ocean. It is true that most of these substances are still present only in very low concentrations, and few experts are available who can measure accurately these materials in the water, the sediments or the living resources. However, sampling and analytical methods have advanced sufficiently in recent years so that a reliable global picture of critical pollutant concentrations and distributions in the marine environment should be attainable, provided there is good prior standardization and intercalibration of methods.

A first requirement, therefore, is to procure baseline data of high quality at a number of significant points in the world oceans. A second requirement is to determine inputs of these substances through: (1) the atmosphere; (2) rivers; (3) coastal outfalls; and (4) ships.

A strategy should be developed to obtain the co-operation of the world experts and the most advanced laboratories in obtaining the required data. The following sequence of steps is proposed as a way of acquiring such information:

(a) organize a workshop of world experts on the various critical pollutants in the marine environment, i.e.: (i) metals; (ii) synthetic chemicals, such as DDT, PCB's and chlorofluorocarbons; (iii) petroleum hydrocarbons; (iv) radioactive elements; (v) solid wastes. The objective should be to establish what is now known about levels of these groups of pollutants in the marine environment, and to determine the best (simplest, most reliable, and most sensitive) methods of analysis;

(b) select a network of about 100 well-chosen stations in the world oceans, where all the critical pollutants will be measured in the water at a number of depths within a specified period (of perhaps 2 months) by comparable methods, as a baseline survey;

(c) select about 100 coastal stations, removed from direct river influence, where similar pollutants will be measured in the water at the same depths during the same period as a baseline survey;

(d) at 50 major estuaries in the world, chosen for good geographical distribution, measure the concentrations of the critical pollutants in the river water at monthly intervals over the span of a year, bracketing the period of oceanographic observations;

(e) at the oceanic and coastal stations, collect plankton in vertical hauls for analysis of critical pollutants during the period of oceanographic observations;

(f) at the oceanic and coastal stations, moor in rafts attached to buoys suitable biological accumulators (e.g. mussels) for at least two months for uptake analyses of the critical pollutants;

(g) at established air sampling stations (about 50 covering all critical areas of the earth, particularly where there are large industrial emissions into the atmosphere), measure concentrations of the critical pollutants at selected elevations on a monthly basis over the span of a year, bracketing the period of oceanographic observations.

3. Marine pollution research

It has sometimes been said that environmental legislation is only as good as the information available to support it. There are many areas of environmental/ecological understanding that can be readily identified as lacking in basic knowledge. Some of the more obvious needs are listed as follows:

(a) Marine ecosystem alteration due to input of pollutants or restructuring of the environment. Quantitative information is particularly needed on estuarine ecosystems which often support juvenile stages of commercially important anadromous species or even pelagic species, which may use estuaries for spawning and rearing. Ecosystem models verified by field data are required to provide a predictive capability in the assessment of the environmental impact of development.

(b) Sub-lethal effects of individual pollutants and mixtures of pollutants on marine organisms. Simple techniques are especially required, such as rate of growth of hydroids or rate of regeneration of byssal threads in mussels. Effects of pollutants, particularly of large-volume effluents, such as cooling waters, on behaviour of coastal and anadromous fisheries, need to be known, since migration runs and reproduction may be affected.

(c) Interaction of sub-lethal effects of pollutants with environmental effects on marine organisms. All species have an optimum range of temperature, salinity and dissolved oxygen in which the effect of a pollutant is minimized. Outside this range, there is a synergistic effect of the pollutant and unfavourable environmental conditions, which causes organisms to succumb more quickly than under the preferred environmental conditions. This type of information is required for improved management and control of waste disposal in widely varying coastal environmental conditions.

(d) Effects of pollutants on populations. Techniques must be developed for studying the effect of pollutants on populations of marine species, separate from other man-made effects such as fishing. Adverse pollution effects on populations have been identified with respect to stocks of fish in lakes. So far, population dynamics usually takes into account such factors as spawning, recruitment to a year class, fishing activity and natural mortality. The effect of environmental changes often does not have a place in a population dynamics equation. The information from a bioassay laboratory has little value except in extreme situations. Field information on pollutant effects, combined with laboratory data, is required for a better understanding of the impact of pollution on the population of a species.

(e) Effects of pollutants on different life stages. The effect of a pollutant at sub-lethal concentrations on marine, anadromous and catadromous species may manifest itself in many ways. For example, exposure of the juveniles of species of Pacific salmon to low concentrations of copper can adversely affect their ability through osmo-regulation to adapt to salinity changes as they go from a freshwater environment to the sea. This could seriously reduce a run of salmon. A better understanding is needed of the effects of various pollutants on the different life stages of organisms, and not just on the stage that is most conveniently held in the laboratory.

(f) Coastal water quality criteria for marine organisms. There are few good marine bioassay data on which to base water quality criteria for protecting living marine resources. In many instances, reliance has to be placed on freshwater data for evaluation of the maximum permissible concentrations of particular waste substances discharged into coastal waters. There is a need for toxicity data using the sensitive stages of marine organisms which are to be protected, under controlled environmental conditions. The 96-hr LC50 (the concentration of a substance lethal to 50 per cent of the test organisms over a 96-hr exposure period) is no longer adequate for developing valid water quality criteria. The threshold concentration at which a response is elicited is required, and this may take weeks or months of exposure, if there is a long-term cumulative effect.

With the large number of substances now being carried in bulk by ships, and with the discharge of many of these materials through coastal outfalls, the information is urgently needed for proper controls in management of waste disposal.

(g) Coastal water quality criteria for sea bathing and protection of human health. The increasing use of beaches for recreation by tourism in many countries demands that a full-scale study be conducted on health risks of sewage pollution and industrial wastes in bathing areas. The few epidemiological data obtained so far on the health effects of bathing in sewage-polluted waters have been quite inconclusive for the development of acceptable water quality criteria for bathing waters.

(h) Eutrophication in the sea. Some coastal areas receiving domestic sewage, or other high-nutrient wastewaters, are leading to highly eutrophic conditions, even in normally low-nutrient waters, e.g. the Adriatic Sea, with large algal blooms leading to "red tide" conditions and fish kills. Fisheries and recreational uses of beaches can be adversely affected. A better understanding is required of factors leading to over-enrichment with nutrients and the unfavourable consequences of red tides, so that improved control by wastewater treatment and/or mode of effluent discharge into the sea can be achieved.

(i) Effects of bioaccumulation on living marine resources. Many fisheries resources have been banned by food and health authorities because of high levels of contaminants, or have been unacceptable to the consumer owing to tainting, as a result of bioaccumulation of foreign substances present in the water, e.g. metals, petroleum hydrocarbons and certain phenolic substances. The mechanisms of bioaccumulation are poorly understood, and research is required if effective prevention or remedial measures are to be introduced. Moreover, the effect of the bioaccumulated substance on the organism itself is unknown, except with certain well-studied compounds such as DDT and mercury. Harmful effects of bioaccumulated material to the organism itself could impose further restrictions on permissible concentrations in the marine environment when water quality criteria are developed.

(j) Adaptation of organisms to pollutants. Some organisms develop a tolerance, either by acclimatization or by genetic adaptation, to comparatively high levels of pollutants. The mechanism by which this is achieved, and its long-term significance to the ecosystem and to harvesting of the living resources, would be valuable in developing management strategies for waste treatment and disposal into the sea.

(k) Detoxification mechanisms in marine organisms acting on such substances as metals. Certain proteins, such as metallothionein, are known to combine with metals, e.g. cadmium, and detoxify them. It is unknown whether some organisms can tolerate high metal concentrations because of the presence of these detoxifying proteins, and whether there is a mechanism for increasing production of the proteins in the presence of higher metal concentrations. A better understanding of the detoxification mechanisms would allow for better development of water quality criteria, and ultimately of standards for disposal of metal-containing effluents into the marine environment.

(l) Bio-transformation of metals and metalloids. The organic complex, methyl mercury, has been recognized as being the highly toxic form of mercury. Moreover, it has been shown that bacteria found in nature can transform the relatively innocuous forms of inorganic mercury into the toxic organic form. How many other metals and metalloids can be converted bacteriologically into the metallo-organic form? How many are rendered more toxic, in this way, and how many become harmless complexes? There may be a need to take precautions, because of bio-transformation to highly toxic end-products of other metallic substances, besides mercury, in the environment.

(m) Degradation processes of certain substances such as oil by marine micro-organisms, including phytoplankton. There have been reports of isolation of strains of micro-organisms that can rapidly degrade oil. The possibility of seeding oil spills with these micro-organisms always has a certain appeal to those charged with the responsibility of oil-spill clean-up. (In fact, there are products now on the market which allegedly lead to microbial degradation of oil.) There is a need for research on microbiological degradation of oil, among other organic pollutants, so that there can be better management of oil-spill clean-up activities. Such investigations are required particularly for low-temperature climes, e.g. the Arctic, where microbiological action is especially slow most of the year.

(n) Pathways of persistent materials through the marine ecosystem. The transfer through the marine food web of most persistent substances is poorly known. The bio-accumulation by individual species and bio-magnification up the food chain are of particular concern, where the top predator happens to be man or the food of man. The ultimate fate of a pollutant, i.e. whether it degrades, is taken up by the biota or ultimately deposited in the sediments, is important in mass-balance evaluations in determining the long-term impact of a pollutant on the marine environment.

(o) The transfer of pollutants to the ocean through estuaries. It is speculated that many pollutants in rivers do not actually reach the open ocean but are abstracted from the water by such processes as flocculation, sorption and co-precipitation and are deposited in the sediments. Studies are needed to gain a better understanding of the geochemical processes in estuaries responsible for removal of contaminants from the water and to identify substances that are deposited in the sediments in this way. The mobilization of such substances through dredging is also of vital concern for protection of the living resources.

(p) Transfer of pollutants to the ocean via the atmosphere. There is little quantitative information on the transport of pollutants from the land to the sea by way of the atmosphere, even though this is considered to be an important route for some substances. This type of information is vital for mass balance evaluations. Some properly designed experiments are required for the determination of input of critical pollutants from land to sea through the atmosphere.

(q) Environmental factors in pollutant decay. The natural degradation of certain pollutants when exposed to the environment is an important factor to consider in any long-term studies of the impact of pollutants and in mass balance evaluations. Experiments on degradation of critical pollutants by water, oxygen, high temperature, sunlight and desiccation are required.

(r) Assimilative capacities for pollutants in different marine areas. The pollutant load that can be safely assimilated or dispersed varies from one area of the ocean to another, depending on such factors as currents, tidal exchange, mixing, winds, runoff, exposure to the open sea, temperature and plant and animal life. Quantitative assessments of the assimilative capacities of a number of diverse systems are needed as a guide for management of waste disposal.

(s) Ecosystem modelling. Simple and realistic models of ecosystems are required to allow management to proceed on a firm basis. A trophodynamic model, taking into account the flow of energy from basic producers to the top predators, could identify a point in the food chain where a pollutant might have its greatest impact. Thus attention can be focused on a particular trophic level or species, which is most vulnerable to a pollutant or other man-made change in the environment. In this way, the capability for predicting the impact of a pollutant on the ecosystem is enhanced.

Model development must pass through the necessary stages, with logical mathematical formulation based on sound ecological data. Then the critical parameters in the model must be tested with suitable data that would evaluate the reliability of the model.

Conclusions

A great deal has been said about the pollution of our last bastion of defence, the world's oceans, against the onslaught of man with his increasing population, advancing technology and growing demands for the products of his technology and innovation for a better life. The critical ocean pollutants can be classified in five categories: (1) metals; (2) synthetic chemicals; (3) petroleum hydrocarbons; (4) radionuclides; and (5) solid wastes. However, except for some constituents which could be precisely measured for a long time, e.g. certain radionuclides, little is known about the world-wide distribution and ocean inventory of the critical pollutants.

A baseline survey of the present level, accurately measured, of critical pollutants in the water, biota and sediments of the oceans and in the principal entry routes (rivers, coastal outfalls and atmosphere) is required before trends can be recognized. The effects of pollutants on marine organisms and ecosystems, particularly at sub-acute concentrations over long periods, must be better understood. Better knowledge of marine processes which affect transfer of pollutants through the different compartments of the marine environment and food web will enable us to better manage and control waste disposal and pollution in the sea.

International conventions have been adopted for control of marine pollution from ships and from dumping waste at sea. International global agreements are still needed for the control of shore-based sources of marine pollution, particularly through rivers, from coastal outfalls and through the atmosphere. Much research on the local, regional and global impact of various classes of pollutants is required for better management and control of waste disposal into the marine environment under both national legislation and international conventions.

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APPENDIX I

List of tables

APPENDIX II

List of Acronyms

ACC	Administrative Co-ordination Committee
ACMRR (of FAO)	Advisory Committee on Marine Resources Research
ACOMR (of WMO)	Advisory Committee on Oceanic Meteorological Research
ALECSO	Arab Educational, Cultural and Scientific Organization
API	American Petroleum Institute
ASFA (of ASFIS)	Aquatic Sciences and Fisheries Abstracts
ASFIS (of FAO/IOC)	Aquatic Sciences and Fisheries Information System
BHC (gamma)	Benzene hexachloride (lindane)
BOSEX-77	Baltic Open Sea Experiment, 1977
CCMS	Committee on the Challenges of Modern Society
CEPEX	Controlled Ecosystem Pollution Experiment
CICAR	Co-operative Investigations of the Caribbean and Adjacent Regions
CIM	Co-operative Investigation of the Mediterranean
CINECA	Co-operative Investigations of the North part of the Eastern Central Atlantic
CMG	Commission on Marine Geology
CPPS	Permanent Commission for the South Pacific
CSK	Co-operative Investigations of the Kuroshio and Adjacent Regions
DANIDA	Danish International Development Agency
DOMES	Deep Ocean Mining Environment Study
DRIFTEX	Driftcard Experiment of IOC/WMO/UNEP
DDD	Dichloro-diphynyl-ethane
DDE	Dichloro-diphenyl-ethylene
DDT	Dichloro-diphenyl-trichloro-ethane
ECE	Economic Commission for Europe
ECOR	Engineering Committee on Oceanic Resources
EDC	1, 2-dichloroethane

ESA	Department of Economic and Social Affairs of the United Nations Secretariat
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FDC (of FAO)	Fishery Data Centre
FGGE	First Global GARP Experiment
GARP (of ICSU and WMO)	Global Atmospheric Research Programme
GATE	GARP Atlantic Tropical Experiment
GELTSPAP	Group of Experts on Long-Term Scientific Policy and Planning
GEMS	Global Environment Monitoring System
GESAMP	IMCO/FAO/Unesco/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution
GFCM (of FAO)	General Fisheries Council for the Mediterranean (of the Food and Agriculture Organization)
GIPME	Global Investigation of Pollution in the Marine Environment
GTC (of CIM)	Joint IOC/ICSEM/GFCM Group for Technical Co-ordination of the Co-operative Investigation of the Mediterranean
IABO (of IUBS)	International Association of Biological Oceanography (of the International Union of Biological Sciences)
IAEA	International Atomic Energy Agency
IAHS	International Association of Hydrological Sciences
IAMAP	International Association of Meteorology and Atmospheric Physics
IAPSO	International Association for the Physical Sciences of the Ocean
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
IAWPR	International Association on Water Pollution Research
IBP/PM	International Biological Program/Productivity - Marine Section
ICES	International Council for the Exploration of the Sea
ICG (for GIPME)	International Co-ordination Group
ICITA	International Co-operative Investigations of the Tropical Atlantic
ICNAF	International Commission for the Northwest Atlantic Fisheries
ICRP	International Commission on Radiological Protection
ICSEM	International Commission for Scientific Exploration of the Mediterranean Sea

ICSU	International Council of Scientific Unions
IDOE	International Decade of Ocean Exploration
IGOSS	Integrated Global Ocean Station System
IHB	International Hydrographic Bureau
IHO	International Hydrographic Organization
IIOE	International Indian Ocean Expedition
IJC	International Joint Commission
IMAR	Interdisciplinary and Inter-organizational Data and Information Management and Referral
IMCO	Inter-Governmental Maritime Consultative Organization
IMMPC	International Maritime Meteorological Punch Card system
INIS (of IAEA)	International Nuclear Information System
IOC	Intergovernmental Oceanographic Commission
IOCARIBE	IOC Association for the Caribbean and Adjacent Regions
IODE	International Oceanographic Data Exchange
IPFC	Indo-Pacific Fisheries Council
IPIECA	International Petroleum Industry Environmental Conservation Association
IPLAN	Joint IOC/WMO Planning Group for IGOSS
IRES	Group of Experts on Oceanographic Research as it Relates to IGOSS
IRS	International Referral System
IUGG	International Union for Geodesy and Geophysics
IWGMP (of PC for UNCHE)	Intergovernmental Working Group on Marine Pollution (of the Preparatory Committee for the United Nations Conference on the Human Environment)
IWGMS (of PC for UNCHE)	Intergovernmental Working Group on Monitoring or Surveillance (of the Preparatory Committee for the United Nations Conference on the Human Environment)
LEPOR	Long-term and Expanded Programme of Oceanic exploration and Research
MAB	Man and the Biosphere
MBA UK	Marine Biological Association of the United Kingdom
MEDI	Marine Environment Data and Information referral system
MEPC	Marine Environment Protection Committee

MESA	Marine Ecosystem Analysis (U.S.A., National Oceanic and Atmospheric Administration)
MIT	Massachusetts Institute of Technology (Cambridge, Mass., U.S.A.)
NACOA (of the U.S.A.)	National Advisory Committee on Oceans and Atmosphere
NAS-NAE (of the U.S.A.)	National Academy of Sciences - National Academy of Engineering
NAS-NRC (of the U.S.A.)	National Academy of Sciences - National Research Council
NATO	North Atlantic Treaty Organization
NBS (of the U.S.A.)	National Bureau of Standards
NERC (of the U.K.)	National Environment Research Council of the United Kingdom
NSF (of the U.S.A.)	Natural Science Foundation
NTIS (of the U.S.A.)	National Technical Information Service
PCB	Polychlorinated-byphenyl
PVC	Polyvinyl chloride
SCAR (of ICSU)	Scientific Committee on Antarctic Research
SCEP	Study of Critical Environmental Problems
SCOPE	Scientific Committee on Problems of the Environment
SCOR (of ICSU)	Scientific Committee on Oceanic Research
SIDA	Swedish International Development Agency
SMIC	Study of Man's Impact on Climate
TEMA (of IOC)	Training, Education and Mutual Assistance in the marine sciences
UNCHE	United Nations Conference on the Human Environment, Stockholm, Sweden, June 1972
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNGA	United Nations General Assembly
USDC	United States Department of Commerce
WECAFC	Western Central Atlantic Fisheries Commission
WHO	World Health Organization
WMO	World Meteorological Organization

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