REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

Management and conservatio
of renewable marine resources i
the Indian Ocean region: Overvie

UNEP Regional Seas Reports and Studies No. 60

Prepared in co-operation with

IUCN

UNEP 1985

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PREFACE

Thirteen years ago the United Nations Conference on the Human Environment (Stockholm, 5-16 June 1972) adopted the Action Plan for the Human Environment, including the General Principles for Assessment and Control of Marine Pollution. In the light of the results of the Stockholm Conference, the United Nations General Assembly decided to establish the United Nations Environment Programme (UNEP) to "serve as a focal point for environmental action and co-ordination within the United Nations system" (General Assembly resolution 2997(XXVII) of 15 December 1972). The organizations of the United Nations system were invited "to adopt the measures that may be required to undertake concerted and co-ordinated programmes with regard to international environmental problems", and the "intergovernmental and non-governmental organizations that have an interest in the field of the environment" were also invited "to lend their full support and collaboration to the United Nations with a view to achieving the largest possible degree of co-operation and co-ordination". Subsequently, the Governing council of UNEP chose "Oceans" as one of the priority areas in which it would focus efforts to fulfil its catalytic and co-ordinating role.

The Regional Seas Programme was initiated by UNEP in 1974. At present, it includes eleven regions 1/ and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to controlling environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-orientated programme activities 2/.

The Regional Seas Programme has always been recognized as a global programme implemented through regional components. Inter-regional co-operation among the various sea areas on common problems is an important element in assuming the compatibility of the different regional components.

As a contribution to the development of the five Action Plans supported by UNEP in the framework of the Regional Seas Programme in the Indian Ocean region, the International Union for Conservation of Nature and Natural Resources (IUCN), in co-operation with UNEP has prepared this document.

1/ Mediterranean, Kuwait Action Plan region, West and Central Africa, Wider Caribbean, East Asian Seas, South-East Pacific, South-West Pacific, Red Sea and Gulf of Aden, Eastern Africa and South-West Atlantic.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports

This document is based on more detailed reviews prepared for each of the five regions 3/4/5/6/7/ in the wider Indian Ocean area. They review the past and ongoing conservation activities relevant to the Indian Ocean on the global, regional and national levels; identify priority concerns of the Governments bordering the region; and contain recommendations for inter-regional and regional projects to be undertaken to address those concerns.

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3/ IUCN/UNEP: Management and conservation of renewable marine resources in the South Asian Seas region. UNEP Regional Seas Reports and Studies No. 62. UNEP, 1985.

4/ IUCN/UNEP: Management and conservation of renewable marine resources in the Kuwait Action Plan region. UNEP Regional Seas Reports and Studies No. 63. UNEP, 1985.

5/ IUCN/UNEP: Management and conservation of renewable marine resources in the Red Sea and Gulf of Aden region. UNEP Regional Seas Reports and Studies No. 64. UNEP, 1985.

6/ IUCN/UNEP: Management and conservation of renewable marine resources in the East Asian Seas region. UNEP Regional Seas Reports and Studies No. 65. UNEP, 1985.

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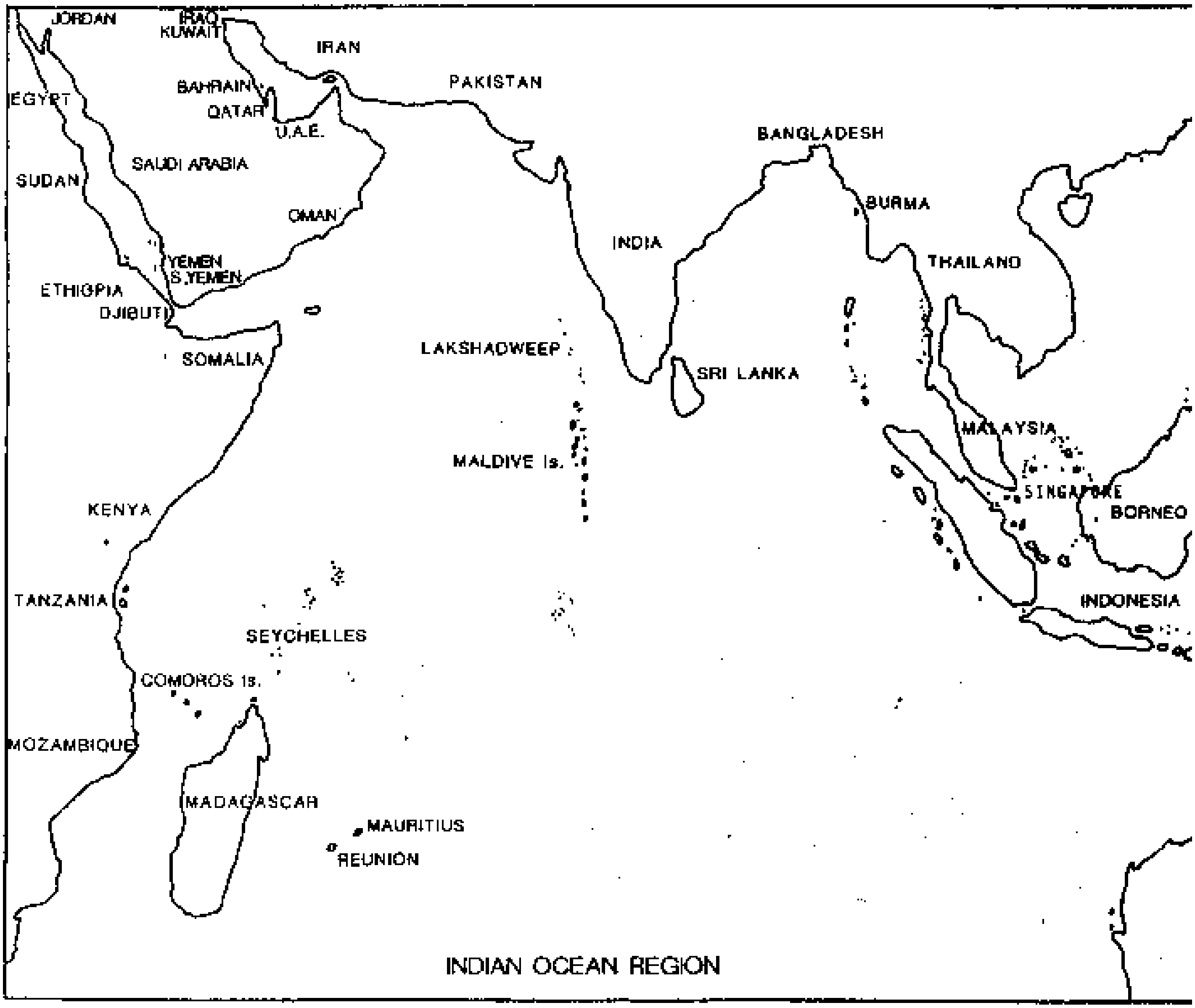
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MAURITIUS
REUNION
INDIAN OCEAN REGION

INTRODUCTION

Introductory Comments

This paper provides a summary of the status of different biological marine resources, habitats, species groups and species of economic value and/or scientific interest within the Indian Ocean Region (IOR). It also gives an overview of the degradation of these resources that is becoming apparent through much of this region. The extent of national and international activities directed towards managing and conserving these resources is also indicated.

Further details concerning the topics covered by this overview may be found within the five supporting reports, each of which deals with one of the five 'regional seas' areas lying within the wider Indian Ocean region.

Joint consideration of the status of the marine environment within these five areas makes sense, both from scientific and practical points of view. The areas together constitute the greater portion of a single major marine biogeographic province (the Tropical Indo-West Pacific). Within this province all areas have most habitats and species in common. Thus within any one smaller area up to 80% of the species of marine animal and plant are likely to be ones occurring through much or all of the Indian Ocean. Likewise, the conditions and problems affecting the marine environment are for the most part similar throughout this region. And, in addition, the social and economic conditions are comparable in many of the countries concerned so that they face similar problems in developing the effective conservation and management of their marine resources.

Area Covered

The five Regional Seas areas covered by this report are (from north-west to south-east): the Red Sea and Gulf of Aden region; the Kuwait Action Plan region; the Eastern African region; the South Asian Seas region and the East Asian Seas region.

The area covered by this report therefore has its northernmost limits at 30°25'N in the Red Sea, and at 30°30'N at the head of the Kuwait Action Plan (KAP) region, while the southerly limit is marked by latitude 25°S, at the Mozambique border. The western boundary runs along almost the entire East African coast, thus encompassing the continental island of Madagascar, and the smaller oceanic island groups of the Seychelles, Mauritius, Reunion, Comoros, Lakshadweep and Maldives. And the eastern boundary lies at approximately 40°E on a line which virtually divides the Island of Irian (New Guinea) in two.

It is worth noting that within this region the islands of Indonesia and the Philippines have much the longest coastlines: Indonesia comprises approximately 13,677 islands, with a coastline length of 81,000 km. (Soegiarto & Polunin, 1982); the Philippines encompasses 7,107 islands and has a coastline length of approximately 17,500 km (de Celis, 1981). This fact is of regional significance since, if the total coastline of some of the mainland areas is computed, it is much smaller than that of either of these two island groups (see Table 1). Hence the potential for coastal and shallow-water marine habitats (mangrove, seagrasses, coral reefs, etc.) is somewhat greater in the East Asian Seas region than in other parts of the IOR. It, and the KAP and Red Sea and Gulf of Aden regions, must also be considered more vulnerable to pollution because of their semi-enclosed nature.

Table 1

Region	Length of Coastline (km)
Eastern Africa region	11,950
Red Sea and Gulf of Aden	9,571
Indonesia	81,000
Philippines	17,500

Climate

The climate within the Indian Ocean region varies both seasonally and according to location. In general it is dominated by the monsoonal cycle. Annual rainfall, for example, increases moving southwards and, outside the incidental precipitation frequently associated with the coast and the islands, its seasonal occurrence is closely tied to that of the monsoon winds. The seasonality of the monsoons is, in turn, linked to the position and movement of the Intertropical Convergence Zone (ITCZ).

At the beginning of the year the ITCZ lies south of the equator. In the south, the south-east trades blow, while in the north the north-east monsoon is fully developed, but is dry over much of the Indian Ocean. In the second quarter, the ITCZ moves north, reaching southern India in late April. The south-east trades occupy the whole of the southern ocean, while in the north rain systems become frequent in the Bay of Bengal and in the south-east Arabian Sea, a few developing into cyclones. In the third quarter the south-west monsoon holds sway over the Arabian Sea, India, the Bay of Bengal, the western part of the East Asian Seas region, and the Eastern Africa region, where mean wind speeds and rainfall reach their maximum. In the southern ocean, the south-east trades reach a mean speed of 9 $m.sec^{-1}$ - the world's most vigorous tradewinds. In the fourth quarter, winds change to north-easterly over the north, the tradewinds in the south diminish, and the ITCZ migrates south again. The south-west monsoon diminishes but there is still heavy rainfall in some northern areas such as the Bay of Bengal (Couper, 1983; UNEP, 1982), and in the central and eastern parts of the East Asian Seas region. Rainfall is highest throughout the East Asian Seas region (see Table 2 below) with West Malaysia, for example, having an annual rainfall of between 2,000 and 4,000 mm. (Chua & Charles, 1980).

The KAP region and the Red Sea and Gulf of Aden region, with the exception of those areas bordering the Arabian Sea, fall outside the Indian Ocean monsoonal gyre. Instead, these two near-enclosed seas have climates which are essentially continental rather than maritime, and this results in generally high temperatures and limited freshwater input, although in the KAP region and northern Red Sea temperatures fall drastically in winter. The net result is a typically arid coastline. Similar semi-desert to desert areas exist in most of Somalia, in northern Kenya and in south-western Madagascar.

The annual rainfall pattern has a direct effect on the occurrence of some critical habitats (e.g. mangrove). In addition, it is significant in influencing other environmental factors such as the extent in coastal waters of sedimentation, of nutrient enrichment, and of reduced salinity, all of which in turn help determine the types of shallow water habitat which are prevalent in an area.

Table 2

Region	Mean Annual Rainfall (mm)
Red Sea and Gulf of Aden	100-300
Kuwait Action Plan region	100-300
EasternAfrica region	1,000-2,000 (much less in north)
South Asian Seas region	1,000-3,000
East Asian Seas region	above 3,000

(after Couper, 1983)

Oceanography

It is not appropriate that the oceanography of the Indian Ocean should be reviewed in detail here, since the subject is relevant only as background, and in so far as oceanographic conditions influence the distribution and occurrence of habitats and resources. Moreover a convenient synopsis has recently been provided by UNEP (UNEP, 1982). However a few key points will be briefly summarised.

The surface currents of the Indian Ocean proper are essentially dominated by a large anticyclonic subtropical gyre in the southern part, and a reversing current system in the northern hemisphere. The southern subtropical gyre forms the westward-flowing equatorial current in lower latitudes and the eastward-flowing westwind drift in higher latitudes. Part of the south equatorial current flows around the north of Madagascar and then south as the Mozambique current between Madagascar and East Africa.

The most universal feature of the current pattern is, however, the effective reversal of the northern subtropical system under the seasonal influence of the monsoons. During the north-east monsoon (November to April) a well-developed north-east monsoon drift or north equatorial current flows west and produces the south-west flowing Somali current off the coast of Somalia. During the south-west monsoon (May to October) the monsoon drift flows eastward with branches flowing clockwise in both the Bay of Bengal and the Arabian Sea, where the action of the monsoon wind generates major upwelling of deep nutrient-rich water off the coasts of Somalia and southern Oman.

The movement of water masses modifies the effect of climate on the temperature and salinity of the ocean. Over most of the Indian Ocean surface temperatures vary between 25°C and 30°C, but because of the direction of circulation, the western parts of the ocean are generally warmer than eastern parts at the same latitude. Annual variation is relatively small, only 2-3°C, through much of the East Asian Seas region, but increases to 4-6°C in the Eastern African region, where temperatures drop during the south-westerly monsoon period. However, the most dramatic drop in temperature occurs in the Arabian Sea off the coasts of Somalia and Oman where the annual upwelling brings clear, cold, nutrient-rich water to the surface, and locally temperatures fall to less than 18°C (Currie et al, 1973). The Somali and South Arabian upwellings account for the highest levels of productivity found within the Indian Ocean (Fagoonee, 1983).

The temperature regimes of the Red Sea and KAP region are slightly different from those of the rest of the IOR. In the Red Sea average annual surface water temperatures decrease uniformly up the Red Sea from 28°C in the south to 22°C in the north (Morcos, 1970). Similarly in the KAP region temperatures decrease to the north falling to a minimum of 15°C in late winter. Mean annual variation is approximately 7°C both in the northern and southern Red Sea and in the Gulf of Aqaba. However both the Gulf of Suez and KAP region are much shallower, and surface and coastal waters are subject to wide temperature changes in response to daily and seasonal climatic variations, mean annual temperature variations being about 11°C and 17°C respectively.

Surface salinity over about two thirds of the IOR, is between 35 and 36ppt, but in the north-eastern quarter of the Ocean salinity is depressed as a result of high rainfall and input of freshwater from the land, especially during the (south-west) monsoon. Through much of the East Asian Seas region, and also in the northern Bay of Bengal, salinity averages between 30 and 33ppt. Similarly, in the coastal zone of the South Asian Seas and East African regions salinity is slightly depressed by rainfall to less than 35ppt.

By contrast, both the Red Sea and the KAP region have elevated salinities. In the Red Sea salinity increases to more than 41ppt in the north. In the KAP region, open water salinity is about 40ppt but increases to 70ppt and more within semi-enclosed areas such as the Gulf of Salwah (in the south-west). Salinities are also slightly elevated in the Arabian Sea, being in the region of 36-37ppt.

This pattern of circulation and the prevailing temperatures and salinities are, in part, responsible for considerable and highly significant regional differences in the levels of key nutrients within surface waters. Concentrations of nitrate and phosphate are very low in the well-stratified oligotrophic waters contained within the southern and northern subtropical gyres ($<0.2 \times 10^{-3}$ mg-at l^{-1} PO_4-P; $<1.0 \times 10^{-3}$ mg-at l^{-1} NO_3-N). They are generally higher in coastal areas, especially near river mouths, as a result of coastal upwelling and entrainment. They are higher in parts of the East Asian Seas region, especially to the north of Sumatra, off the south Java coastline, and at the eastern end of the Indonesian archipelago, in the Arafira Sea (Soegiarto & Polunin, 1982). And they are particularly high during the south-west monsoon within the areas of the Arabian upwelling, off the coasts of Somalia and Oman ($>1.0 \times 10^{-3}$ mg-at l^{-1} PO_4-P; $>1.5 \times 10^{-2}$ mg-at l^{-1} NO_3-N) (see e.g. McGill, 1973).

Nutrient concentrations in the Red Sea are generally lower than those in Indian Ocean waters, while by contrast, nutrient levels in the KAP region tend to be higher. The nutrient conditions in different parts of the IOR are a major factor influencing not only the productivity of each area, and hence the extent of its renewable resources, but also the occurrence and distribution of many of the different key habitats which are considered in the following sections.

CONSERVATION AND MANAGEMENT ACTIVITIES

International

The general extent of conservation and management activities within the IOR is most easily considered under three headings - international, regional and national. At the wider international level many of the IOR countries are signatories to international laws and conventions covering aspects of the prevention of marine pollution in the open ocean and the protection of endangered species.

-Amongst the most important and universally accepted of these conventions are those which involve the control of pollution from shipping activities. The MARPOL Convention of 1973 extended an earlier oil pollution convention to include all types of pollution from ships and to restrict operational oil discharge; this was followed in 1978 by a protocol on tanker safety and pollution prevention (MARPOL, 1973/1978). However the effectiveness of these conventions lies in the establishment of the necessary reception facilities in operational countries (IMO, 1983) and on adequate patrolling.

International conventions which primarily concern endangered or protected species and which are ascribed to throughout the regions include the BONN convention, concerning the protection of migratory species, and CITES, concerning the international trade in endangered species.

A fuller list of significant international conventions would include the following:

International Convention for the Prevention of Pollution of the Sea by Oil. London.

International Convention for the Prevention of Pollution from Ships, London (MARPOL). International Regulations for Preventing Collisions at Sea, London.

Convention on the High Seas, Geneva.

Convention on the Continental Shelf, Geneva.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, London.

African Convention on the Conservation of Nature and Natural Resources, Algiers.

Convention on the Conservation of Migratory Species of Wild Animals (BONN Convention) Bonn.

Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), Washington.

United Nations Convention on the Law of the Sea, (UNCLOS) Kingston.

Indian Ocean Commission 1982.

World Heritage Convention.

Ramsar Convention (Wetlands).

Man and the Biosphere Programme, (UNESCO).

Details of nations which have ratified these conventions are included in some of the companion reports dealing with individual Regional Seas areas.

In addition to the promotion of such legislative activities the UN and other international agencies, in particular the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the International Maritime Organisation (IMO), the World Health Organisation (WHO), the International Union for Conservation of Nature and Natural Resources (IUCN), and the World Wildlife Fund (WWF), have assisted in marine conservation and management activities at global and international (as well as regional and national) levels by sponsoring and assisting in various relevant projects and programmes. At this wider level a Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) involving the UN bodies was established in 1969 and provides advice in relation to marine pollution; it completed the first global report on the health of the oceans (UNEP, 1981). And in 1972 the Stockholm Conference defined Earthwatch (the global environmental assessment programme) as one of the three basic components of the Action Plan for the Human Environment. The Global Environmental Monitoring System (GEMS) is one of the four components of Earthwatch and the assessment of the state of ocean pollution and its impact on marine ecosystems was adopted as a GEMS task by the Governing Council of UNEP. The implementation of GEMS is seen by UNEP as a joint undertaking of the relevant UN bodies. The monitoring of the quality of the marine environment as a component of GEMS is now carried out through the UNEP Oceans and Coastal Areas Programme, regional aspects of which are discussed further below.

The IOR itself was, from 1959 to 1965, the subject of the International Indian Ocean Expedition, which was initiated by the Scientific Committee on Oceanic Research (SCOR), but which involved several agencies, including the newly formed Intergovernmental Oceanographic Commission (IOC).

The Division of Marine Sciences of UNESCO has also been responsible for aiding aspects of marine and coastal science through its Coastal and Marine Project (COMAR), the principal element of which is aimed at promoting research and training on aspects of coastal systems with emphasis on their ecological structure and function and their interaction with other systems. The project also collaborates in the collection and evaluation of traditional knowledge and practices in coastal ecosystems, with a view to incorporating this knowledge into present day research and management (UNESCO, 1985a). UNESCO has also been especially involved in training activities (workshops, training courses, etc.) related to research on and management of coastal habitats, its regional programmes assisting in the development of groups of scientists and managers, in particular in relation to the management of mangrove resources. Of particular relevance to the IOR, as well as other tropical regions, have been workshops on monitoring, assessment and management of coral reef communities (UNESCO, 1983; 1984b), and manuals on research methods in coral reefs (UNESCO, 1978), mangroves (UNESCO, 1984a) and seagrasses (UNESCO, in prep.).

IUCN, in addition to assisting marine conservation projects within individual countries of the IOR, has developed international programmes of research, in particular on threatened species (e.g. turtles, cetaceans), promoted awareness of management problems, especially in relation to critical habitats such as mangroves (e.g. IUCN, 1983) and sponsored conferences and publications related to the establishment and management of protected marine areas (e.g. McNeely & Miller, 1984; Salm & Clark, 1984). In conjunction with UNEP, a meeting was convened in 1979 which led to the establishment of the Indian Ocean Whale Sanctuary; this in turn led to a WWF/IUCN research programme on Indian Ocean Cetaceans, focusing on the sperm whale.

Regional

Action plans for the protection and development of the marine and coastal areas of each of the regions are incorporated in UNEP's Regional Seas Programme. As an initial procedure, reports for each of the countries within a region were called for, allowing the existing environmental status to be evaluated.

Co-ordination of all Red Sea and Gulf of Aden activities is the responsibility of the Arab League Educational Cultural and Scientific Organisation (ALECSO), which, with support from UNEP, provides the interim secretariat for PERSGA (the Red Sea and Gulf of Aden Environment Programme) in Jeddah, Saudi Arabia. Eight countries in the region are members of PERSGA. Since 1976, a number of symposia, training courses and workshops have been held with support from UNEP and UNESCO, and PERSGA has provided support to member countries in the establishment of national marine science institutions, and in surveys and planning for the conservation of management of coastal and marine habitats.

The KAP (Kuwait Action Plan) region encompasses all the states of the Gulf and Iran, and has a secretariat, the Regional Organisation for the Protection of the Marine Environment (ROPME), in Kuwait. The action plan is directed in particular towards combating pollution and establishing related research and monitoring programmes. With support from UNEP and UNESCO a series of workshops and training schemes have been held, and two region-wide monitoring programmes initiated for oil and non-oil pollutants respectively. ROPME has also supported a series of ecological studies in countries of the region, carried out in part with the assistance of IUCN, and has established the Marine Emergency Mutual Aid Centre (MEMAC) based in Bahrain, designed to give rapid response to oil disasters.

In 1981 the five member states of ASEAN (the Association of South-East Asian Nations - Indonesia, Malaysia, the Philippines, Singapore and Thailand) adopted a cooperative programme to ensure that environmental considerations are incorporated into all aspects of economic development within the region. The Action Plan for the Protection and Development of the Marine and Coastal Areas of the East Asian Region is incorporated in the UNEP-sponsored Regional Seas Programme. The foundation for the development of the Action Plan was laid at the International Workshop on Marine Pollution in East Asian waters, held in Penang, Malaysia in 1976, since when a series of workshops, seminars and conferences have been held.

Although the Eastern African Action Plan has not yet been finally adopted by the states of the region, it has been adopted in draft form along with its guidelines and objectives, and progress has been made through workshops and projects. The convention, protocols and plan of action for the Eastern African region are due to be concluded during 1985.

The South Asian Seas region was established by UNEP Governing Council decision 11/7 in 1983. It includes the marine and coastal areas of Bangladesh, India, the Maldives, Pakistan and Sri Lanka, although the precise geographical coverage of the region has not yet been defined. In March 1984 a meeting of step, national reports discussing the environmental condition of each of the countries involved in the region should be prepared.

At the wider regional level several countries of the IOR are pledged to the Indian Ocean Alliance. In 1980, the Alliance approved various recommendations concerned with the conservation and management of the marine environment, including recommendations concerned with the study and protection of turtles and marine mammals, and with the prevention of oil pollution.

National

The extent of particular national conservation and management activities in relation to the coastal and marine environment, is summarised, in so far as this information is generally published, within the companion reports dealing with the particular regions.

Here it may be noted that there is a general pattern in the development of such management activities within the nations of the IOR. Although the degree of development of an infrastructure for coastal and marine environmental protection and management varies considerably between countries, moves towards the prevention of marine pollution and the conservation of marine habitats and species have been made throughout the Region. However, in all but a few countries in the IOR the actual enforcement of regulations concerning the emission of pollutants, the protection of species and the establishment of marine parks or protected areas remains a major problem.

The early fisheries legislation of many IOR countries made provisions relating to general pollution or general damage to marine life. However, these provisions are almost invariably too imprecise for dealing with the wide variety of emissions and wastes that may now be discharged into the marine environment or the many indirect ways in which marine life may be harmed.

Within the countries of the IOR responsibility for the protection of the marine environment was, until recently, frequently unclear or poorly defined, and may have been nominally or partially assigned to diverse governmental departments within, for example, Ministries of Agriculture, Housing, Education and Science, Health, Defence, or Transport, or within the National Research organisation. More recently some countries have moved to establishing National Environmental Agencies, sometimes operating either in relation to an interministerial committee or council (e.g. Saudi Arabia, Oman, Tanzania), or within a Ministry of the Environment (e.g. Kenya, La Reunion). Well-established national environmental agencies assuming responsibility for the marine environment are now operating in, for example, Bahrain, Indonesia, Kenya, Sri Lanka and Saudi Arabia. Other countries which are just establishing or have recently established such an agency or national plan include Egypt, Malaysia and the Philippines. A priority task for these agencies has in most cases been the development and enactment of a comprehensive and up-to-date set of standards controlling emissions, discharges and impacts in the marine environment (such as recently, for example, has been promolgated in Saudi Arabia).

Protection of the marine environment also requires the prevention of damage or destruction to important areas of coastal and marine habitat, and the conservation of rare or endangered species, or of economically significant stocks of fish and invertebrates. The establishment of marine parks or protected areas is one measure which may assist with these objectives and with the promotion and safeguarding of recreation and tourism. Approximately half of been established (e.g. Djibouti, Egypt, India, Iran, Kenya, Mozambique, Oman, Sri Lanka); in a second group of countries a rather larger number of marine protected areas has been declared (e.g. Indonesia, Malaysia, Philippines, Seychelles). Some other countries are in the process of establishing their first marine parks or reserves (e.g. Commoros, Jordan, Kuwait, Sudan, Tanzania).

However, it is considered that as industrial and urban development gathers pace it is essential to move in the direction of establishing comprehensive coastal zone management plans. These should include a coastal zoning scheme incorporating a full network of marine and coastal protected areas (including resource reserves and nature reserves as well as multiple use marine parks). Countries developing such a policy include Indonesia, Philippines and Saudi Arabia. In some countries national conservation strategies for terrestrial and marine environments are being developed; these include India, Indonesia, Madagascar, Malaysia and Oman.

In addition some countries have been able to establish specific long-term marine conservation projects concerned with the study and protection of particular habitats or species. These include: Indonesia - mangroves; Oman - turtles; Philippines - coral reefs; Sri Lanka - cetaceans. Further reference to such studies or projects is included within the sections dealing with particular habitats, species and resources, either in this report or in the companion reports dealing with the individual Regional Seas areas.

RESOURCES, HABITATS AND SPECIES

Open Sea

The pattern of moderate differences in oceanographic conditions between different parts of the IOR results in significant differences in the planktonic and pelagic flora and fauna characteristic of each area. In particular, large differences arise between different areas in the levels of primary and secondary productivity.

Krey (1973) recognised six plankton-geographic regions within the area covered by this report, different regions tending to be dominated by different groups of phytoplankton as follows:-

Coastal upwelling areas (southern Arabia and Indonesia/Australia)	Diatoms
Central Arabian Sea and Bay of Bengal	Dinoflagellates, blue-green algae
Somali current region	Diatoms
Mozambique current region	Diatoms
Equatorial current region	Dinoflagellates, coccolithophores
Southern subtropical gyre	Dinoflagellates

In addition, the enclosed seas of the Red Sea and KAP region might be considered as separate areas since in each, as indicated above, oceanographic conditions do differ distinctly from those of the Indian Ocean proper.

Such comparisons indicate that, in general, diatoms tend to predominate in the more productive regions. For example, Subrahmanyan and Sarma (1960) described that 70-80% of the phytoplanktonic biomass in Indian waters could be accounted for by 29 species of diatom (including 10 species of Chaetoceros), 7 flagellates and the blue-green alga, Trichodesmium erythraeum. The spatial pattern of predominance of different phytoplanktonic groups principally differs from that of other oceans in the frequent dominance or sub-dominance in many areas of this blue-green alga, which blooms in the surface layer and often gives rise to characteristic red tides. The species is endemic to the Indian Ocean, and its prevalence may be related, since it is able to fix nitrogen, to the very low levels of nitrate present in oligotrophic Indian Ocean waters.

The pattern of regional variation in the primary productivity of the phytoplankton varies with the season; in particular, and as might be expected, major differences occur between the periods of the north-east and south-west monsoons, associated with the reversing character of the northern subtropical gyre. In addition, slightly different assessments result from different approaches to estimating actual planktonic production (see e.g. Krey, 1973). Nevertheless, the general pattern is well established, largely as a result of the work of the International Indian Ocean Expedition (Kabanova, 1968; Moiseev, 1969; Krey, 1973; Cushing, 1973). During the south-west monsoon primary productivity is much the highest within the broad arc of the northern Arabian Sea, stretching from Somalia to Western India with, off the south-east coast of moderately high primary production (over 500mg.C.m^{-2}day^{-1}) occur to the south of the Indonesian archipelago and within the equatorial current. During the north-eastern monsoon primary production is somewhat lower in most areas, productivity in the Arabian Sea in particular falling off markedly with the seasonal cessation of the Arabian upwelling. However, moderate levels of productivity (over 500mgCm^{-2}day^{-1}) occur at this time to the north-west and north-east of Madagascar, in inshore areas through much of the East Asian Seas region, and also in some areas off the south-east coast of Arabia. During both seasons the lowest productivities (around 100mg.C.m^{-2}day^{-1}) occur within the 'desert regions' of the northern and southern subtropical gyres.

In the Red Sea, because of the well-stratified and nutrient-poor conditions, the open sea generally shows a very low primary production, though this increases markedly in the south. Within the enclosed areas of the KAP region nutrient concentrations are much higher, but in inshore waters planktonic productivity is often limited by elevated salinity. Since the sea is so shallow, with an average depth of only about 30m, benthic productivity is frequently much more significant than planktonic productivity even in the open sea, a fact reflected in the predominantly benthic and demersal nature of the fishery.

Elsewhere in the Indian Ocean the major open ocean fishery is for tuna, using long-lines or purse seines; this is largely operated by international fishing concerns the majority of which are based outside the region. Also, in many areas and especially within coastal and oceanic upwellings, the oil sardine comprises a considerable portion of the catch. And in the Eastern African region, around the offshore banks of Mozambique, the Seychelles and the Mascarenes, sailfishes and billfishes are caught in particularly large numbers. These pelagic fisheries are discussed in further detail in a later section.

Also associated with productive open sea areas of the Indian Ocean are a group of animals of particular social and scientific significance, the whales. These too are considered in a separate section below, though here it is relevant that the major conservation achievement affecting the open sea habitat of the region has been agreement in 1979 to the Indian Ocean Whale Sanctuary, which extends from 20^{o}E to 130^{o}E and south to 55^{o}S.

The principal threat to the open sea environment clearly arises from pollution, although recent assessments have generally concluded (UNEP, 1982; GESAMP, 1982) that, linked to the comparatively low levels of industrial activity around the region, concentrations of most pollutants in the open ocean are not yet approaching levels where they are likely to have a major impact on marine life.

Oil pollution, however, is becoming increasingly evident through many parts of the region, and in addition to impacts on coastal habitats, the observed incidences of oil spills and tar balls, and the levels of dissolved hydrocarbons in surface waters, appear to have been increasing. This pollution is related, in the KAP region and the Gulf of Suez, to production from offshore oilfields and, throughout the Indian Ocean, to the shipping of considerable quantities of oil from the Middle East. In the Indian Ocean proper oil pollution is most conspicuous along and in regions adjacent to the main tanker routes, which run either eastwards off western India to Australia and the Far East, or westwards past southern Arabia and around the coast of Africa. Thus over 12 years 21 individual spills of more than 160 tonnes were recorded in the Eastern Africa region (see UNEP, 1982), and tar balls, previously unnoticed, are now abundant along the coasts of India, Somalia and Oman (see, for example, Dhargalkar et al, 1977). It has been estimated that 33,440 tonnes/year are now discharged into

In recent studies mean concentrations of dissolved petroleum residues in surface waters of the Red Sea, the KAP region, and in areas of the Indian Ocean around the tanker routes have generally been found to lie between 25 and 50 g/l (see, for example, Sen Gupta & Kureishy, 1981) that is, at levels distinctly above what are presumed to be normal background levels, but at concentrations below those which are yet known to affect any organisms. However, in some areas concentrations of over 250 g/l have been recorded and these are approaching levels that have been reported to affect more sensitive organisms, including some fish and invertebrate larvae. Moreover, it should be noted that there is evidence that low level chronic oil pollution may have more serious long-term environmental consequences than do very occasional large oil spills (Loya & Rinkevitch, 1980).

Major oil spills, however, in addition to causing extensive contamination, can cause direct impact, not only to the littoral zone in areas where they may come ashore, but also to seabirds and air-breathing marine vertebrates present in the open sea. With an estimated loss rate of 4000-5000 barrels a day, the spill from the Nowruz oil field off the coast of Iran, which began in early 1983 following damage to three oil platforms, was the largest spill to have occurred in the Indian Ocean region, and the second largest globally, being exceeded only by the IXTOC 1 release. During the Nowruz spill considerable mortality of dugong, turtle, sea snakes and seabirds was reported from the eastern coastline of Saudi Arabia, though some uncertainty remains as to whether the spill itself was the cause (see UNESCO, 1985b).

Whatever the extent to date of damage to marine life and resources in the open ocean, caused by oil and non-oil pollution, it is evident that, given the rapid pace of industrialisation, a regular and standardised monitoring of levels of oceanic pollution must be sustained throughout the region. It is even more vital that controls to regulate and minimise release of pollutants be enforced at both national and international level.

Deep Sea

Relatively little is known of the deep sea fauna of the IOR, although deep sea habitat is widespread except within the enclosed KAP region. The distribution of abyssal substrates may be summarised as follows. Lava and ash accumulations occur in the mid-ocean volcanic areas. Red clay predominates on the floor of the eastern Indian Ocean south of 10°N, and also occurs in some areas east of Madagascar, and west of India. Globingerina ooze predominates in the western and north-eastern Indian Ocean. And terrigenous sediments, mainly kaolinite, occur close to land around the margins of the Ocean although in more arid areas carbonaceous sediment derived from corals and other benthic organisms may predominate.

Knowledge of the deep benthos of the region has been summarised by Neyman et al. (1973). In general the benthos of the Indian Ocean is far less rich than that of temperate regions and coastal zones. Its biomass mirrors the productivity of the overlying surface waters and is lowest, $<0.05g.m^{-2}$, between Madagascar and Western Australia, beneath the southern subtropical gyre, and also beneath the northern subtropical gyres between western India and Eastern Africa, and in the Andaman Sea ($0.05-0.1g.m^{-2}$). Apparently mean biomass is less than $2.75g.m^{-2}$ at all depths below 1000m (Beljaev & Vinogradova, 1961). Benthic productivity is greater in shallower nearshore regions, the higher mean values ($10-50g.m^{-2}$) of biomass being found, as might be expected, on shelf areas in the northern Arabian Sea, around Java and Sumatra, and in small areas off the mouths

Red Sea the bathypelagic zone is desert-like (Weikart, 1962), a reflection of the very low open ocean productivity in this area.

The deep fauna of the IOR is apparently dominated by polychaetes, principally suspension feeders (e.g. Serpulidae), especially at greater depths. Arthropods (amphipods, isopods, decapods and cirripedes) and sponges are also important, more so in less deep water, while molluscs and echinoderms are relatively scarce (Neyman et al., 1973).

While benthic productivity may be very low, some areas of the IOR possess extensive and largely unexploited stocks of mesopelagic fish, occurring at depths between 100–350m. Notably the north-west Indian Ocean includes the greatest abundance of mesopelagic fish anywhere in the world, with estimated biomasses of between 60 and 150 million tonnes in the northern and western Arabian Sea and between 6 and 20 million tonnes in the Gulf of Oman (see Gjøsaeter, 1984). The dominant species in many of the catches appears to be Benthosema pterota, but other members of the families Gonostomidae, Myctophidae and Bragmacertoides are also well represented. However, the small size of these species presents a difficulty for the economic exploitation of the fishery.

A second exploitable deep sea stock is represented by the deep sea lobster Peurulus sewelli, and related species, which occur at 200 to 600m off Yemen, Somalia, Kenya and the west coast of India. The predicted sustainable yield off Yemen, for example, is reported to be 200 tonnes of tails per annum (see Venema, 1984).

At present no deep sea areas are managed or protected but significant impacts requiring regulation may arise in the future from deep sea mining of minerals as nodules or as metaliferous brines, or from deep sea disposal of highly toxic wastes or of radioactive materials. The most pertinent example of a threat of this type is provided by the planned exploitation of the mineralised muds present within some 15 deeps in the centre of the Red Sea. A pre-pilot mining test conducted in 1979 appeared to confirm the feasibility of such a process, and a pilot mining operation is expected to be initiated in the near future (see Lange et al., 1980; Nawab, 1984). The principal impacts anticipated from fullscale mining are likely to be elevated heavy metal concentrations and increased turbidity, both as a result of the mid-ocean disposal of the mining tailings. The Saudi-Sudanese Red Sea Joint Commission have supported a major research effort directed at minimising the impact of the mining (Abu Gideiri, 1984).

Open Soft-Bottomed Habitats

Open soft-bottomed habitats include both nearshore seabed areas dominated by sand and silt, and also sand and sand-mud beaches on open coasts, where typically wave action restricts the settlement of finer particles or of detritus. Two common categories of soft-substrate material may also be distinguished. Terrigenous sands and clays predominate in the South Asian Seas region, on coastlines influenced by input from rivers in the Eastern African and East Asian Seas regions, and also in the northernmost part of the KAP region. Generally coarser calcareous sediments predominate in the Red Sea and KAP regions, and in the reef forming areas of the Eastern African and East Asian Seas regions.

In shallow soft-bottomed seabed areas plant and animal communities are richer in species and have greater total biomass than they do in deeper waters offshore. Biomass values may reach several hundred g.m^{-2} (Neyman et al., 1973).

levels between 80 and 150m attributed to the effect on the oxygen minimum layer (Elizarov, 1968).

In shallow seabed areas molluscs, especially gastropods, and to a lesser extent echinoderms become predominant along with crustacea. Where there is an admixture of coarser materials or occasional stones and boulders, sponges, barnacles, bryozoans, anemones and ahermatypic and even hermatypic coral may also form a significant component. Where however sedimentation is heavy, epibenthic organisms seem scarce save for a sometimes increased occurrence of ophiuroids (see, for example, Seibold, 1973). In the immediate sublittoral zone on sand-silt bottoms there is frequently a characteristic invertebrate assemblage dominated by bivalves such as Macoma, sand dollars such as Clypeaster humilis and Echinodiscus spp., detritivorous holothurians, Holothuria spp., and predatory gastropods such as Nassarius coronatus and Oliva bulbosa (IUCN, 1985).

Intertidal coarse sandy beaches, such as occur on coasts exposed to the full swell of the Indian Ocean, have a very limited flora and fauna, this because of the high mobility of the substrate and the absence of detrital material which is kept in suspension by high wave energy. Nevertheless, a modest meiofauna is probably present, certain diatoms colonise patches of sand in some areas, and some specialised macrofauna also survive, such as the species of Bullia, a predatory whelk which use its foot as a sail to be moved up and down shore by the surf. Sandy shores also provide vital nesting grounds for marine turtles (see below).

The primary productivity of nearshore shallow water soft-bottomed habitats in the IOR appears rarely to have been estimated, but is certainly relatively low. Scattered macroalgae may occur attached to rocks and larger pebbles, especially in depths of less than 30m. Secondary productivity depends in part on detritus derived from planktonic productivity or imported from adjacent areas. Nevertheless these soft-bottomed habitats frequently provide significant fishing grounds since they are suitable for trawling, and there are moderate stocks of a wide variety of fish species, both detritivores, such as the goatfishes (Mullidae), and predators of benthic invertebrates, such as the emperors (Lethrinidae). Trawl fisheries are particularly significant in such areas when stocks of commercial penaeid shrimps are present, as in the KAP region, off the west coast of Madagascar, the west coast of India and in the north eastern Bay of Bengal. These fisheries are considered in further detail below.

Intertidal coarse sediments (i.e. sandy beaches) are principally and increasingly important for their recreational and general environmental value, but at the same time they are increasingly subject to a series of impacts. They are exploited for construction material such as sand and gravel, and for minerals (in Thailand, for example, for tin). Coastäl construction work can result in downshore beach erosion. And pollution by oil tar and other rubbish detracts considerably from any recreational potential. In the IOR even beaches remote from the tanker lanes, for example in the Seychelles (Ferrari, 1983), are receiving increasing quantities of tar.

Open coast soft-bottomed habitats have also been affected by inland soil erosion, particularly in the Eastern African and East Asian Seas regions. In Madagascar for example as much as 250 tonnes of soil per hectare is being washed away every year (Randrianarijaona, 1983). Rivers carry greatly increased sediment loads to the sea where deltas have been expanded and down-current coastal areas subjected to increased sediment loads. At Malindi, a major Kenyan tourist centre, such sediment brought to the coast by the Sabaki river, has been deposited on previously sandy beaches resulting in considerable beach accretion, reportedly as much as 500m in the last 10-15 years (Finn, 1983).

A further impact, prevalent in the KAP region, arises from coastal infilling and land reclamation, which becomes especially serious when more productive habitats, considered below, are damaged or destroyed.

Sandy areas are not generally protected areas per se, but are often included as a major part of a reserve area which has been established to protect some other part of the environment, or an endangered species or a breeding ground, e.g. turtle beaches.

Enclosed Soft-Bottomed Habitats

Enclosed soft-bottomed habitats include coastal lagoons, mudflats and shallow mud-silt bottoms in protected bays and estuaries, and lagoons associated with coral reefs. In the IOR comparatively few studies have yet concentrated on these habitats, and in particular, there is little comprehensive information available on their occurrence, extent and significance in different areas. It is evident however, that such habitats are widespread in the region, that their significance can vary considerably depending on exact environmental conditions, and also that such areas are especially susceptible to damage and destruction resulting from industrial and residential development.

Enclosed soft-bottomed substrates are most productive and most significant when they support mangrove and seagrass communities; these are considered in detail in the next sections. But even where the substrate lacks macrophyte cover, there may be a well-developed and diverse flora and fauna. For example, on intertidal flats on the east coast of Saudi Arabia, Basson et al (1977) distinguish three zones: an algal mat zone inhabited by many small gastropods, ostracods, nematodes, flatworms, copepods and oligochaetes; a Macrophthalmus zone, in which the most conspicuous invertebrate is the crab M.depressus, but in which many others are also present; and a Cerithid zone, dominated by sometimes very high densities (>2000 m^{-2}) of Cerithidea cingulatum.

Such an abundant macrofauna can be associated with a high secondary productivity as is well-known from studies in temperate estuaries (e.g. Warwick et al., 1979) where detrital material provides food for huge numbers of crustaceans, molluscs, and annelids. These in turn support large populations of fish and/or overwintering wading birds (see e.g. Prater, 1981).

However, mudflats may also have a significant primary productivity due to a surface film of microalgae; in temperate regions this may be of the order of $100g.C.m^{-2}$ (e.g. Cadée & Hegeman, 1974), but evidence suggests that such productivity may be larger moving into the tropics, and that it may make a greater contribution to local secondary productivity. Thus Day et al. (1973) estimated that the productivity of benthic microflora in a shallow water bay in Louisiana (USA) was $244g.C.m^{-2}$ and accounted for a third of the primary productivity input into the system. And in a recent study in Bahrain (IUCN, 1983b) it was noted that an intertidal mudflat has a chlorophyll concentration due to the epibenthic film of $0.16-0.24g.m^{-2}$, a value approaching that typical of upwelling areas (about $0.3g.m^{-2}$) and much higher than that of oligotrophic tropical oceanic waters. In fact the primary productivity per unit area of mud flat was estimated to be approximately fifty times higher than that of the surrounding sea.

Irrespective of their primary productivity such intertidal flat and mud bottoms provide critical areas in which much of the primary production from adjacent mangrove and seagrass beds is converted into valuable secondary production, and thus supports stocks of many important commercial fish such as rabbitfish (Siganus spp.), goatfish (Mullidae) and emperors (Lethrinidae). In the East Asian Seas region in particular, major fisheries are developed in estuarine areas. Such estuaries and bays also provide crucial nursery grounds for other fish, for example, various species of snapper (Lutjanidae), and especially for commercial shrimp, notably Penaeus semisulcatus in the KAP region, and Metapenaeus kutchensis in the South Asian Seas region.

Coastal lagoons, behind bars and barrier islands, and to a lesser extent fringing reef lagoons, may also be relatively productive. However, the primary and secondary productivity of coastal lagoons and enclosed bays is, throughout the Indian Ocean, extremely variable. This is so because of the extremes of salinity which may occur along many more enclosed shorelines. Especially within the KAP region and the Red Sea, many semi-enclosed bays and creeks have elevated salinities and temperatures as a result of the hot climate and high rates of thermo-evaporation.

Thus in a recent study of the long creeks (known locally as sharms and mersas) which occur on both sides of the Red Sea (IUCN, 1984a) it was found than in moderately shallow water (1-3m deep) to the sides of broader mersas, salinities may be increased to 45-48ppt, while enclosed areas at the innermost parts of mersas salinities of up to 50-70ppt were recorded. The most saline lagoon areas were completely devoid of marine life but in more equitable areas a variety of fish and invertebrates were common. The invertebrates included most significantly juveniles of three species of commercial shrimp, of which the most abundant was Penaeus semisulcatus. Such bays and mersas are known to serve as nursery areas for these species of shrimp (Branford, 1981), and probably do so in many areas of the IOR. Also present were various commercial fish species including especially mojarra (Gerridae), silversides (Atherinidae), grey mullet (Mugilidae) and juvenile emperors (Lethrinidae). As concluded by Barnes (1980) many of the most abundant lagoonal species, both of fish and invertebrates, appear to be generalist consumers of detritus, benthic algae and epiphytes.

Experience indicates that in the IOR as elsewhere enclosed soft-bottomed habitats, occurring in lagoons, estuaries, creeks and small bays, are especially susceptible to a wide variety of impacts. Such enclosed or partially enclosed areas are particularly liable to be affected by construction work, because they are either potential harbours and boat channels, or are easily infilled; and they are attractive locations for the siting of private residences or commercial buildings, and serve as a natural focus for recreational developments. They are also especially susceptible to pollution because of their reduced water circulation, so that pollutants discharged into them tend to concentrate there. Besides industrial discharges, private houses clustered around a creek tend to be built, in the absence of any regulations, so as to discharge their sewage and waste into the creek, a practice which can easily result in local eutrophication. In the KAP region in particular, coastal infilling on a large scale (tens of km^2) has been responsible for the destruction of large areas of productive soft-bottomed habitat. While in the East Asian Seas region, especially in North Java, South Sulawesi and Sumatra, coastal lagoons have been widely converted for aquaculture of milkfish (Chanos chanos), Tilapia and catfish (Puntias javanicus).

Estuarine areas are also affected by pollutants being brought down river, especially since many of the region's main cities, in which industrial activity tends to concentrate, are located on major rivers. Thus, for example, it is estimated that as a result of pollution only 10% of the cockle farms on the Petchaburi River, Thailand, now produce yields within the normal range (Piyakarnchana, 1980). Also in the Eastern African region, important estuaries may be threatened by construction of upstream dams, which result in a decrease in sedimentation and erosion of the river delta (see Finn, 1983).

Enclosed soft-bottomed habitats are often included in coastal reserves where the major element is mangrove, but only a few are protected in their own right. They should be given special status in any coastal zone management plan. While it may be most beneficial for some such areas to be used for industrial or residential purposes, of for aquaculture, enclosed bays and creeks represent a limited and valuable resource in their own right, and alternative use should only be determined upon after national or regional studies have assessed the full extent of the resource, and determined which areas are most critical for fisheries and wildlife.

Mangroves

The extent and development of mangrove stands and forests varies considerably across the region. They reach their fullest extent within the East Asian Seas region. Indonesia possess 3,806,119 hectares (although 77% of this is in Irian Jaya) (Salm & Halim, 1984), Malaysia 652,219 hectares (most of this in Eastern Malaysia) (Saseskumar, 1980), Thailand 312,714 hectares (Piyakarnchana, 1980), and Philippines, 146,139 hectares (NEPC, 1983).

Mangrove is moderately well-developed in more restricted areas of the South Asian Seas and Eastern African regions. In the northern Bay of Bengal, the Sunderbans, in the southern Gangetic delta, support over 500,000 hectares (Mukherjee, 1984), and in Pakistan and western India the Indus delta supports 250,000 hectares (Snedaker, 1984). Mangrove is less developed in Sri Lanka and patchy or thin in the island nations and groups of the Indian Ocean, although mangroves in the Andaman and Nicobar Islands appear to be among the least disturbed.

In the KAP region relatively few stands of mangrove survive except in Iran, but in the Red Sea patches of mangrove are scattered along both coasts, being more abundant in the south, but petering out in the north. The Saudi Arabian Red Sea coast for example, is thought to support approximately 10000 hectares of mangrove (IUCN, 1984a, 1985).

The character and development of the mangal changes across the region in a similar way. In the east many species contribute to the mangal, for example, 38 in Indonesia (Soegiarto & Polunin, 1982), and well-developed forests incorporate four or more zones dominated by different genera, particularly Avicennia, Sonneratia, Rhizophora and Bruguiera (Gong et al., 1980). The mangroves of eastern Bangladesh are essentially similar to those of Malaysia (Snedaker, 1984), whereas on the west coast of India the mangrove areas are dominated by Avicennia marina and Rhizophora mucronata, although a total of about twenty genera have been found in the Gulfs of Cambay and Kutch, which are reputed to be the best developed mangals on that coast (Untawale, 1984). In Pakistan the Indus river delta is dominated by Avicennia officinalis, often in poor stands, with only occasional trees of Ceriops (Salm, 1975).

Avicennia marina is the only mangrove recorded from the KAP region and Gulf of Oman (Basson et al., 1977) and this is also the principal species in the Red Sea, although very occasional stands of Rhizophora mucronata also occur (Zahran, 1967; IUCN, 1984a), mainly towards the south, and Bruguiera gymnorhiza has also been reported from a single location in North Yemen (Draz, 1956).

As their extent, development and high productivity might suggest, mangroves are a reserve of considerable value and have been increasingly heavily utilised in many parts of the area, especially in the East Asian Seas and South Asian Seas regions. Coastal people have used the wood for fuel, fishing stakes and fodder and in the past the bark of Indian mangals has been used for tannin production. One or two species produce edible leaves or fruit. IUCN's review (1983a) on the global status of mangrove ecosystems lists nearly 50 products in all that are obtained from mangrove forest. Most recently mangals have been heavily used for chipboard production. In Indonesia, for example, the combined export and domestic value of all mangrove forestry products was estimated in 1978 at about US$26 million.

Besides their direct value, mangrove areas are increasingly understood to be of immense value because of the other natural resources, in particular fisheries for fish, crustacea and shellfish, that they may provide or sustain. Apart from fish or crustacea obtained from within the mangrove (for example, the sergestid shrimp, Acetes spp.), mangroves are essential nursery areas for other commercial fish and shrimp species (MacNae, 1974). The productivity of the marine prawns Penaeus merguiensis, Metapenaeus monoceros and Metapenaeus brevicornis has clearly been related to existing mangrove areas (Unar & Naamin, 1984). Mangroves also directly support much nearshore fish production, leaf fall from mangals being exported to sustain a large population of invertebrate detritovores and their predators, including many commercial fish species. In the Philippines the major fishing grounds are generally located near areas bordered by mangrove (Gomez, 1980), and by way of comparison, it was estimated in 1970 (Robas, cited Walsh, 1977) that one acre (0.405 ha) of undisturbed mangal estuary in Florida yields US$7,980 worth of commercial fish products in 20 years. In Indonesia, the combined exports and domestic value of mangrove-linked fisheries products in 1978 was at least US$194 million (Salm & Halim, 1984).

Mangroves also support many species of non-commercial plants and wildlife. For example IUCN (1983a) indicate that over 300 species of plant and over a thousand species of marine invertebrates and vertebrates have been recorded from south-east asian mangrove areas. In addition, 177 birds and 36 species of mammals have been reported in association with mangroves in this area. More conspicuous species of scientific interest and conservational value include estuarine crocodiles, many water birds and the rare Royal Bengal Tiger, found in the Sundarban mangroves of Bangladesh and India.

As rapidly as the enormous direct and indirect value of mangroves, in sustaining a wide variety of renewable resources, has come to be appreciated and understood in recent years, the loss and destruction of mangroves appears to have proceeded faster and at an accelerating pace. Mangroves have been lost from increased pressure of cutting for fuel and timber, related to the rapid growth of human populations. Mangroves are cleared, drained and/or felled for agriculture, residential or commercial development. They are cleared for conversion into fishponds. And in particular in recent years large areas of mangrove forest have been felled for conversion to chipboard or paper, generally for export to industrial nations outside the region (MacNae, 1974; Soegiarto, 1980). In the past, forest managers have frequently cropped mangrove on a 16 to 30 year silvicultural cycle, but increasingly timber companies, (particularly Japanese), appear to be felling large areas with no regard for either traditional or recommended silvicultural practices.

Thus in the Philippines the area of mangrove has decreased from 418,990 hectares in 1967 to approximately 146,139 hectares in 1978 (NEPC, 1983). In Indonesia an estimated 700,000 hectares was converted to agricultural land between 1969 and 1979 (Soegiarto, 1980). In Singapore 10-12% of total land used to be mangrove, but only 3% now remains (MNS, 1984). In India, Blasco (1977) estimated that only 365,000 hectares remained, roughly half the official estimate for 1963. Total destruction is even reported over large areas of massive and relatively inaccessible stands in the Bay of Bengal (Mukherjee &

Tiwari, 1984). In Western and Southern India, much of the originally extensive mangrove has been removed (Untawale, 1984; Krishnamurthy & Jeyaseelan, 1984).

Even where mangroves represent a scarce resource they are being lost without regard to their value. Over half of the mangrove stands on the Saudi Arabian north east coast have been infilled for housing or industrial development in the past ten to fifteen years (IUCN, 1982).

Mangroves have also been subject to other impacts. Tin mining, followed by conversion for salt production, appears to have been responsible for most mangrove loss in Thailand (Piyakarnchana, 1980). The Sundarbans mangrove ecosystem has been severely affected by the Farakka Barrage, which has diverted waters of the Ganges; as a result floods, soil toxification, land instability and pest infestations have increased, while fertility, water quality, forests and fisheries have declined (IUCN, 1983a). Oil spills from the sea, or other pollutants brought down river have also resulted in extensive defoliation and death of mangroves (Soegiarto & Polunin, 1982).

Management policies have been developed in many countries of the region in response to this rapid loss of natural resources. In Indonesia a 50-200 m. green belt should be retained along the coast (Soegiarto, 1980). Similarly in the Philippines a belt of not less than 100 metres facing the sea must be excluded from fish pond construction (NEPC, 1983). Reserves, either strict reserves or forestry reserves, have been established in Indonesia, Brunei, Malaysia, Thailand, Bangladesh and India, either specifically to protect or manage mangrove areas, or in which mangroves are an important element.

However these reserves cover only a small proportion of mangrove areas and felling or other impacts are making inroads into these areas. The Klias National Park in Sabah was actually degazetted in 1980 for timber exploitation. And in general, even where management policies have been formulated they have frequently not yet been fully implemented; this may be partly because of 'rampant violations' by commercial operators (NEPC, 1983) and partly because of the difficulties of restricting access to mangrove areas and preventing unauthorised use or damage. Even within the best managed forest reserves there may have been a decline in productivity and timber production (Gomez, 1980; Gong et al., 1980) although the reasons for this are not really understood.

The continuing decimation of mangrove resources has already stimulated concern and activity internationally and regionally. In 1978 SCOR, in collaboration with UNESCO's Division of Marine Sciences, established a working group on Mangrove Ecology. In 1980 IUCN also established a working group on Mangrove Ecosystems to collate existing information for use in guiding the management and conservation of this natural resource. Cooperation of these two groups was partly funded by UNEP and WWF.

Within the ASEAN region detailed national reports and an overall regional report on 'The Present Status of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution' were published by FAO/UNEP in 1980.

UNESCO especially continue to be active in promoting activities related to mangrove research and management, including mangrove mapping by remote sensing, a UNEP/UNESCO regional project on sedimentology in mangrove areas, and the development of a network of mangrove managers and scientists in the Indian Ocean.

The major concern for mangroves, both within and beyond the region, must be for the extremely rapid direct destruction of mangrove areas that is now the present rate, by the turn of the century mangroves will be restricted to a modest number of generally small reserves and to degraded or poorly developed stands in remote areas. The long-term environmental and socio-economic repercussions are predicted to be considerable, but are not given due consideration because of powerful economic forces favouring immediate destructive utilisation of mangrove areas.

The ASEAN reports included recommendations which may be taken as summarising the urgent action required through almost the entire Indian Ocean region. These were that national governments should:-

1. Take immediate steps to radically reduce the amount of mangrove being released for development, until more is known about the stage of mangrove resources and the environmental impact of destroying this ecosystem.

2. Seek to establish more fully protected mangrove areas and develop management plans for them.

3. Identify priority degraded areas for re-afforestation.

4. Ensure that existing policies and legislation relating to the mangrove environment are more strictly enforced.

The IUCN (1983a) report on the 'Global Status of Mangrove Ecosystems' details recommendations for the action necessary to underpin the decision-making and enforcement required by national authorities. These include:-

1. The development of a database of the extent of mangrove for use by national and international planners;

2. The development of National Mangrove Resource Management Plans by National Mangrove Committees;

3. The development of an extensive programme to create awareness of the value of mangrove resources and conservation among decision-makers, managers and users;

4. The promotion of national and international collaboration on research to provide the information required for the effective protection and management of mangrove resources.

Seagrasses

In all, about 15 species of seagrass of 7 genera are believed to occur within the whole IOR. In many areas their variety and occurrence has not yet been well studied, but it is known that while some areas support extensive dense beds of seagrass, in others seagrasses are relatively sparsely distributed. The species most abundant in the region appear to be Halophila stipulacea, Halophila ovalis, Halodule uninervis, Thalassia hemprichii, Cymodocea serrulata, Enhalus acoroides and Syringodium isoetifolium.

13 species, of which Thalassia hemprichii is the most widespread, have been recorded in Indonesia (Soegiarto & Polunin, 1982). At the other end of the region 9 species have been recorded from Eastern Africa (Aleem, 1984) and ten along the Red Sea coast of Saudi Arabia (Aleem, 1979; IUCN, 1984a). Fewer

Mauritius, although some of these are nevertheless abundant around parts of many of the higher granitic islands (i.e. the Seychelles, the Mascarenes, the Andamans and the Nicobar Islands). There are also large seagrass beds in southern India and in the numerous estuaries and embayments of Sri Lanka. Around the periphery of the region, under cooler or more saline conditions, the number of species may be reduced. Only three species, Halophila stipulacea, H. ovalis and Halodule uninervis, occur within the KAP region, but there they nevertheless form an extensive and economically significant habitat.

In some other areas dense seagrass beds are uncommon or not extensive. This seems to be true of at least some of the coast of Pakistan and of much of the coast of western India, probably because the coastal waters are exposed and turbid so that seagrasses can not easily find a foothold or grow well.

Seagrasses are not exploited directly except that the seeds of Enhalus acoroides are eaten by some coastal people (Soegiarto & Polunin, 1982), but seagrass beds are of major economic importance both because they provide critical nursery grounds for many commercial species of fish and shrimp, and more especially because their very high primary productivity may support abundant invertebrate and fish stocks in surrounding areas.

Tropical seagrass beds are among the most productive of natural ecosystems. Productivities of 0.5-16 $g.C.m^{-2}day^{-1}$ and 500-3,000 $g.C.m^{-2}yr^{-1}$ have been recorded (Drew, 1971; Patriquin, 1973; McRoy, 1974; Buesa, 1975; Zieman, 1975) and standing stocks may reach several $kg.m^{-2}$ (Aleem, 1984). A recent review of the topic is provided by Zieman and Wetzel (1980), although few estimates have been made for any seagrass beds within the IOR.

It has generally been concluded that most of this productivity enters the decomposer food chain (Wood et al., 1969; Wahbeh, 1980). The senescent blades break off and decompose, either within the grassbed or after being carried to adjacent areas. The resulting detritus and bacteria (see Fenchal, 1970) are consumed by an abundant meiofauna, by sponges, sessile polychaetes, bivalves (including pearl oysters), a wide variety of crustacea (including commercial shrimp species) and some fish such as mojarra (Gerres spp.) and some mullet (Mugilidae). Many other fish feed in turn on the invertebrate infauna. In some parts of the region, for example in Sri Lanka (see maps in Salm, 1978), seagrasses cover an area far in excess of that covered by mangroves and coral reefs, and probably make the largest contribution to the primary production of inshore waters.

Species thus directly dependent on seagrass beds either as juveniles or adults include the important commercial shrimp, Penaeus semisulcatus, which provides valuable catches in the KAP region (Price, 1982) and in the Gulf of Mannar (Southern India) (Manisseri, 1982), pearl oysters within the KAP region (Basson et al., 1977), and various commercial fish species of the genera Lutjanus (snappers), Lethrinus (emperors), Siganus (rabbitfish), Upeneus and Mulloidicthys (goatfish) (e.g. Soegiarto & Polunin, 1982). The fish are often caught incidentally during shrimp fishing and may even form the major part of the catch (Manisseri, 1982; IUCN, 1983b).

In addition to their importance to the more usual fisheries, seagrasses provide the major food source for two species of considerable scientific and conservational interest and resource value, the Dugong (Lipkin, 1975), and the Green turtle (Carr, 1952; Hirth et al., 1973; Ross, 1979); juvenile Hawksbill turtles also feed on seagrasses (Phillips & McRoy, 1980).

Given their significance to the various fisheries, seagrass beds are approximate economic value of the fishery generated by a seagrass dominated bay in Saudi Arabia (Tarut Bay) has been estimated by Basson et al. (1977). If seagrass in the bay were incorporated into food chains, the estimated value of the fish yield would be US$8 million. If instead, grass was converted at the same efficiency (1% overall) into shrimps, the calculated value would be nearly US$12 million. On the other hand, if the seagrass was grazed directly by green turtles, at an efficiency of 10%, the turtle yield was estimated to be US$46 million. The value of these natural resources is based on 1977 prices, and the calculations are very approximate and largely theoretical. Nevertheless, they demonstrate the considerable value of local biological resources which, if managed correctly, are renewable.

Despite such estimates of economic value, the need for protection and management of major seagrass bed areas has been little considered. Because of the relatively inconspicuous nature of this habitat, impacts to seagrass beds have been much less well documented than those to other major marine ecosystems. Nevertheless, local impacts have been reported. For example, estuarine disturbances such as industrial and agricultural runoff have damaged seagrass beds in Sri Lanka (Salm, 1975), and industrial wastes, sewage discharges and overfishing have been reported to have led to changes which included the destruction of a seagrass bed in Mauritius (Procter & Salm, 1974).

Damage to and loss of seagrass beds has perhaps been most serious within the KAP region. Here extensive seagrass beds occur in water 2-10 m. deep and support very valuable shrimp and fish resources. But in nearshore waters, especially in Saudi Arabia (IUCN, 1982), Kuwait and Bahrain (IUCN, 1983b) large areas of this habitat have been lost by extensive land reclamation and infilling, by dredging to form shipping and boat channels and by excessive sedimentation resulting from upcurrent infilling or dredging activities. Heavy sediment loads may suffocate or completely cover the plants, while increased turbidity alone reduces light levels in the water column and on the seagrass, thus reducing or preventing photosynthesis or growth. The collapse of the shrimp fishery in the northern part of the Gulf has been largely attributed to the loss of critical seagrass habitat (Jones, pers. comm.).

In view of the increasing amount of coastal engineering and construction work, infilling and dredging taking place throughout the IOR, it seems likely that similar damage must often be occurring elsewhere but be unappreciated. Unfortunately it seems likely that where dredging has once been carried out there is often fairly permanent alteration in the nature of the seabed, resulting in a much less productive and less diverse habitat. Dredging alters the substrate composition in areas of seagrass bed loss to produce a matrix of much finer materials. These finer materials are very difficult for plants to recolonise and are much more easily resuspended than coarser sediments, so perpetuating the problems of turbidity. In Florida, for example, recolonisation was still negligible ten years after the disturbance of a bay bottom by dredging (Taylor & Saloman, 1968). Even when the seagrass rhizomes themselves survive superficial dredging, it may take a year or more for them to recommence growth.

Seagrass beds are also being affected by other impacts. Damage occurs where demersal trawling takes place (e.g. Basson et al., 1977), and may become non-reversible as trawling is intensified in the face of overfishing and declining stocks. Eutrophication consequent upon waste discharge promotes overgrowth by epiphytic algae. Destruction of seagrass beds as a result of overgrazing by epidemic populations of sea urchins has been reported from the Gulf of Aqaba (Red Sea) (Mastaller, 1979; Wahbeh, 1980) as well as from outside the region, the population outbreaks of these urchins very possibly occurring as a result of the overfishing of the fish species which are their predators

Seagrass beds may also be susceptible to impacts from oil pollution. In addition to direct effects on the seagrass, more serious and possibly longer-term damage may occur through interaction between the oil and the sediments in which the seagrass is growing. Much of the oil and tar from oil spills eventually sinks as appears to have happened to most of that resulting from the recent major 'Nowruz' oil spill in the KAP region. On the seabed, oil and sediment can agglomerate into more buoyant lumps and pellets which, in relatively shallow water, can be removed by wave and current action. (Diaz-Piferrer (1962), for example, recorded the loss of 3,000m^3 of sand from a Puerto Rican beach in less than a week due to this effect.) Thus where oil settles over seagrass beds, loss of sediment may lead to uprooting of the grass and damage to or destruction of the bed.

There appear to be few management policies specifically related to the protection of seagrass beds and resources. Seagrass beds are a significant element within some reserves or proposed reserves, but no protected area is known to have been established specifically to protect this habitat. In Bahrain infilling and dredging activities now require a licence, a move intended especially to protect important seagrass areas, and similar restrictions may operate or are being introduced in some other countries. There is an urgent need to assess the extent of damage to seagrass beds throughout the region and to encourage more careful regulation of infilling, dredging and other coastal engineering projects, for example by more general use of environmental impact assessment procedures.

A recent regional symposium convened by the Indian Marine Biological Association has emphasised the importance of seagrass beds and recommended research on their status and ecology, and UNESCO/IABO are shortly to publish a volume on methods for seagrass research.

Rocky Shores and Substrates

Rocky shores varying from limestones to hard volcanic rocks are widespread through the East Asian Seas region; they also occur in India between the Ganges and Godavari, between Krishna and Cape Comorin, and in Karnataka and Maharashtra, in Pakistan west of the Indus delta, on the Andamans and Nicobars, in the Seychelles and on Mauritius, and in outcrops and rocky islets along the coast of East Africa. Along the southern coast of Arabia a variety of exposed rocky habitats occur - boulder beaches, sedimentary rocky shores, and metamorphic and limestone cliffs.

In the Red Sea much of the coastline consists of raised reef rock forming a low 1-2 metre high cliff, although this is frequently separated from the water by a narrow belt of sand, and where this is absent the intertidal zone is very narrow. In the KAP region rocky shores occur most commonly in Iran; Saudi Arabian shores are generally very flat but may be formed of intertidal rock flats which may be very productive (Basson et al., 1977).

Information on the extent and character of rocky shore communities throughout the area is generally incomplete. Frequently rocky sublittoral zones are fringed or dominated by corals. In the Red Sea and Gulf of Aden, where the intertidal zone is narrow and air temperatures high, rocky littoral zones are dominated by grazing and predatory gastropods, such as *Nerita* spp. Where wave action is more regular Indian Ocean shores are frequently dominated by rock oysters, *Saccostrea* spp. In a few areas, for example in parts of Kenya and Tanzania, algae dominate the intertidal. This may be where nutrient levels are luxuriant growth of Ulva fasciata, Ecklonia radiata and Sargassum spp. (IUCN, 1983c).

Trawling is difficult over rocky ground and fishing off rocky shores is generally limited to use of line, especially for groupers (Serranidae) and snappers (Lutjanidae), and pots, especially for rock lobsters (e.g. Mohan, 1983). An endemic abalone (Haliotis mariae) occurs in the kelp beds in southern Oman (IUCN, 1983c). The main significance of intertidal and subtidal rocky shores dominated by algae lies, however, in their high productivity, which in some Indian Ocean areas may be a significant factor in the elevated production of inshore coastal waters, as it is in parts of Europe and America (Platt & Irwin, 1971). Green algae may be consumed directly by some species such as Siganus (rabbitfish) or Diplodus (pinfish). Most brown algae eventually become torn or broken and decompose to detritus which supports rock oysters, shrimp and numerous meiofaunal and macrofaunal invertebrates. These in turn become the food of a wide variety of commercial fish species, especially snappers (Lutjanidae), emperors (Lethrinidae) and bream (Sparidae), which may then be caught in surrounding waters (e.g. IUCN, 1983c).

In general rocky shores and coasts in the region appear less impacted than other important habitats. Locally they have been lost through coastal engineering and construction work, including the removal, in parts of the area, of beach rock ("Faroush") for building (Basson et al., 1977). Also, rocky shore communities are especially sensitive to oil pollution (Nelson-Smith, 1972; Baker, 1983). Despite the frequent occurrence of oil spills in some areas (KAP region, Gulf of Suez) there seems to have been no specific study of their impact on rocky shores within the region. The effects elsewhere have, however, been well documented. In general, fresh crude or light oil products tend to penetrate well and have toxic internal effects, whereas weathered or heavy oils tend to cause external mechanical effects through smothering.

A number of protected areas within the IOR have rocky shores and substrates as a significant element though this may not have been the primary reason for establishment of such reserves. It may particularly be noted that rocky shores and high cliffs often have considerable landscape value, and may form an important component of the coastline within recreational and touristic areas. Unconsidered development and construction work in the coastal zone may greatly reduce or destroy the aesthetic value of such coastline, lending to a depreciation in the economic value of the tourist industry and a loss in the quality of the environment enjoyed by local people. There is probably an increasing need throughout the region for such shores to be protected specifically for their landscape value.

Coral Reefs

Coral reefs (fringing reefs, platform (bank) reefs, patch reefs, barrier reefs and atolls) form perhaps the most conspicuous of marine habitats within much of the IOR; they are certainly as important as any in terms of productivity, diversity and the provision of livelihood for inhabitants of coastal settlements. Their complexity and productivity support numerous and abundant fish species, which may account for as much as half of the catch within some areas; in many countries they are a major feature of a valuable and expanding tourist industry, and they constitute habitats of enormous scientific and educational interest and social and cultural value. However, as described in further detail below, in most if not all countries of the region, degradation and loss of reef habitats is occurring to varying degrees, often at a rapid pace.

In the East Asian Seas region the most extensive reefs occur in Indonesia and the Philippines. In Indonesia the most prolific reef development is towards the eastern end of the archipelago, but reefs also occur off Sumatra and Java. And in the Philippines fringing reefs are associated with many of the 7,000 or so islands in the area, Negros and Palawan having particularly good reef development. In Malaysia, Thailand and Burma most of the reefs occur as fringing and patch reefs associated with offshore islands, there being relatively little development along the mainland coastline, presumably because of the sometimes heavy runoff of freshwater of which corals are intolerant.

In the South Asian Seas region, Bangladesh and Pakistan have no coral reefs due to the high turbidity and soft substrate, except that corals are found on rocky substrata west of the Indus. India has two widely separated areas containing reefs, the Gulf of Kutch in the north-west, and Palk Bay and the Gulf of Mannar in the south-east. Sri Lanka has shallow reefs especially on its south and east coasts. The Indian islands of Lakshadweep (Laccadives) are entirely composed of atolls and therefore have extensive sublittoral reefs, as do the Nicobars and Andamans.

In the East African region well-developed fringing reefs and patch reef complexes occur along major sections of the coasts of Somalia, Kenya and Tanzania, and around their offshore islands, and Madagascar has well-developed reefs on parts of both coasts. The Seychelles have varying reef development. Reefs are generally absent from the west coast of Mahé, but those of Aldabra atoll have been especially well studied. In the Mascarenes, reef development generally diminishes from east to west, Rodriguez and Mauritius having well-developed fringing reefs although these are located far offshore.

Coral reef habitats are particularly dominant in the Red Sea. Although for zoogeographic reasons species diversity is lower than in the Indian Ocean proper, the lack of freshwater input along most of the coastline results in vigorous inshore coral growth and formation of well-developed fringing reefs around almost the whole of the northern two-thirds of the sea. In addition, around much of the Red Sea, extensive groups of reefs, including patch reefs, platform reefs, submerged reef banks and ring reefs, occur 5-15km from the shore and in some areas complexes of reefs and islands extend as far as 50km offshore (see e.g. Mergner, 1984; IUCN, 1984). However, there is a decrease in quality and extent of coastal coral communities moving south of about 20°N (Wainwright, 1965; IUCN, 1985), largely because of the shallower bathymetry and higher turbidity of this region.

In the KAP region, reefs are less well-developed, but they are nevertheless more extensive and spectacular than generally acknowledged (Basson et al., 1977). Particularly well-developed fringing reefs surround Karan, Jana, Jurayd and three other offshore islands in the Saudi Gulf, Kubbar Island (Kuwait) and several islands between the Straits of Hormuz and Bandar Asalu (Iran). Coral reefs are also present in the coastal waters of the United Arab Emirates (UAE) and along the eastern coasts of Bahrain and Qatar, as well as in Oman.

In general, the reefs of the IOR are formed and/or dominated by a variety of species of the genera Porites, Acropora, Goniastrea, Favia, Pocillopora, Stylophora, Millepora and Platygyra. However many other species and genera occur. The East Asian Seas region is generally considered as the faunistic centre of the Indo-Pacific region and over 400 species of hard coral are thought to occur in Philippine waters. Moving westwards and northwards the diversity of the coral fauna gradually declines. 174 species are recorded from the east coast of the Malaysian peninsula (De Silva et al., 1980), about 60 from the Gulf of Thailand, 117 from south-east India, about 200 from Madagascar and from

Chagos (Sheppard et al., 1984), over 150 from the northern and central Red Sea (Sheppard, 1983), and about 40 from the KAP region (Burchard, 1979).

The diversity of fishes and of the different floral and invertebrate groups is equally high and shows comparable trends, although the extent of available information varies considerably from group to group and country to country.

The high productivity of corals and coral reefs is now well documented. Generally gross productivity appears to fall within the range 2,000-5,000 $g.C.m^{-2}yr^{-1}$ (see Lewis, 1977). As a result of the food thus generated and the cover available on reefs, their major value is in terms of the artisanal and commercial fisheries which they support. It has been estimated that the standing stock of fish on reefs may reach 5-15 times that per unit area found in productive North Atlantic fishing grounds, and twice that for managed temperate lakes (Stevenson & Marshall, 1974). It is suggested that maximum fish harvests that can be sustained from coral reefs are probably 10-20 mt/km^2 (Munro, 1984). Because of the patchy nature of the reef habitat and its tight recycling of nutrients total catches may not be as high as in major fisheries in temperate and upwelling regions of the world's oceans, but they are frequently of considerable local significance through the IOR and, as pointed out by Gomez (1980), the importance of coral reefs as providers of fish and shellfish for home consumption and local markets is probably underestimated. Commercial fish associated with reefs include many species of snapper (Lutjanidae), grouper (Serranidae), emperor (Lethrinidae), jack (Carangidae), grunt (Pomadasyidae) and goatfish (Mullidae).

In addition to providing edible fish, and also some shellfish (such as spider conch, Lambis spp.), reefs provide many ornamental products including shells, corals and aquarium fish, and attract visitors and tourists (sometimes in very large numbers), hence providing employment for local people. They also provide a growing list of medicinal products, are of immense scientific and educational value, and act as a wave buffer, protecting coastlines from erosion and storm damage.

In appreciation of the importance of coral reef resources, marine parks and other protected areas incorporating coral reefs have now been established in a number of countries within the IOR. In Indonesia coral reefs are an important element in at least seven National or Marine Parks and Reserves. In the Philippines coral reefs are included within 6 established parks and reserves; additional marine parks and reserves have been declared by Presidential decree, although they have not yet been incorporated within the National Park System, and their present status is a little unclear (Wells, 1982). In Malaysia, two National Parks on the west coast of Sabah incorporate reef areas, as does the Tarutao National Park in Thailand.

There are fewer marine parks or reserves in the Western Indian Ocean. There are three marine parks in Kenya, that at Malindi being especially well-known.

In the South Asian Seas region there are as yet only a few protected reef areas. In India there are corals within the country's first operating marine National Park in the Gulf of Kutch, and the Krusadi Island reefs are included within the area of the Gulf of Mannar proposed as another marine park. In Sri Lanka there is little formal protection for reefs, although at the southwest tip of the island lies the Rocky Islets Sanctuary covering 1.5 hectares.

In the Red Sea and Gulf of Aden region protection for coral reefs was only the establishment of Marine Parks and Reserves have taken place in Egypt, Jordan, Sudan and Saudi Arabia. Towards the end of 1984, Ras Mohammed was designated as Egypt's first National Park in the Red Sea. In both Jordan and Sudan marine conservation legislation has been upgraded and proposals are in hand for establishment of National Parks at Aqaba (Jordan) and Sanganeb (Sudan). In Saudi Arabia there are no coral dominated reefs within the stretch of coastline encompassed by the established Asir National Park in the southwest corner of the country, but along the rest of the coast interim protection is being given to some 70 candidate sites for protectorate status, a majority of which include coral reefs.

Within the KAP region, Sheedvar Island (off the western end of Lavan Island, Iran), has excellent coral reefs and has been protected since 1972. In Saudi Arabia designation of the six offshore islands as marine protectorates is also imminent.

Despite the establishment of these reserves and parks only a tiny per cent of the region's coral reefs fall within protected areas, and despite the increased pace of introduction of environmental legislation, degradation of coral reef communities is taking place at an accelerating rate in an increasing number of areas as a result of a variety of impacts. The threats to coral reefs throughout the world are numerous and have been reviewed in general terms by Johannes (1975), and Kenchington and Salvat (1984). Here it is proposed to concentrate on the four or five impacts which are causing considerable damage within the IOR, some of which are omitted by these authors.

Sedimentation

Sedimentation occurs as a result of land infill and other coastal construction work, as a result of dredging, and as a result of an enormously increased sediment load being carried to the sea by rivers following upstream land and soil erosion. Increased sedimentation is probably the single most destructive influence on coral reefs in the Indian Ocean region.

Corals are generally intolerant of very heavy sediment loads; not only are the low light levels in turbid waters insufficient for adequate photosynthesis and growth, but the excessive sediment eventually clogs or smothers the coral polyps, preventing feeding and interfering with respiration (Marshall & Orr, 1931; Marszalek, 1981).

Corals are able to free themselves of some sediment, by secretion of mucus and the action of cilia, and some coral assemblages are characteristic of turbid waters (Crossland, 1907; Maragos, 1972). But they are able to survive only so long as sediment particles are small and relatively easy to remove, and under such conditions, because of the energy requirements and loss involved in freeing themselves of sediment, growth and net productivity are low. As sediment loads increase the corals die, and in extreme cases may be completely buried (Hubbard & Pocock, 1972; Marsh & Gordon, 1974).

Examples of reef damage and loss as a result of sedimentation occur within every regional seas area in the IOR. Large scale siltation following inland deforestation is believed to be responsible for reef deterioration in much of the ASEAN region (Gomez, 1980). Sedimentation as a result of coastal and marine tin mining is the major cause of damage to reefs in Thailand (Chansang et al, 1981). Reef damage off the east coast of Peninsular Malaysia is especially noticeable in bays adjacent to agricultural development (De Silva et al, 1980).

mortality has occurred on Minicoy atoll, the largest in Lakshadweep, as a result of dredging of the main shipping channel (Pillai, 1981). In the Comoros, siltation of reefs and lagoons is lowering fishery productivity (World Bank, 1979). Sedimentation from inland deforestation is reported to be causing damage in the Andaman islands (Whitaker, 1984). In Kenya coral in the northern part of the Malindi Marine National Park has been severely affected as a result of the great increase in sediment input to the sea by the Sabaki river, following upriver soil erosion (Finn, 1983). In Bahrain a quarter or more of the main coral area has been lost, and much of the remainder noticeably impacted as a result of sedimentation caused by dredging of shipping channels and by infilling (IUCN, 1983b). And in the Red Sea off Saudi Arabia, fringing reefs along 30km of coastline have been impacted by sedimentation following infill operations to construct the Jeddah corniche road (IUCN, 1984b).

Damage by echinoderms: sea urchins and Crown-of-Thorns starfish

There appears to be an increasing incidence within the region of damage to reefs by endemic populations of sea urchins (echinoids) and of Crown-of-Thorns starfish (Acanthaster planci). Crown-of Thorns starfish feeds directly on coral colonies, digesting in situ patches of the tissue layer, and became notorious in the late 1960s and early 1970s because of the widespread destruction caused to coral communities on the Great Barrier Reef and in some other parts of the western Pacific Ocean (e.g. Guam) by infestations of this species. More recently within the Indian Ocean region large populations of A. planci appear to have caused high coral mortality in Minicoy atoll (Lakshadweep) (Pillai, 1981), in Sri Lanka, in Mauritius, at locations in Peninsula Malaysia (De Silva et al., 1980), Eastern Malaysia (Wood et al., 1977) and Indonesia (Aziz & Sukarno, 1977).

Reef urchins normally feed by grazing on the algal turf that colonises rocky surfaces of the reef. However, when the urchins Diadema setosum or Echinometra mathaei are present in large numbers the rasping action of their teeth erodes the reef surface and the bases and branches of corals under which they shelter, causing the corals to collapse and die. In some cases the urchins appear to erode the living coral tissue or attack it directly. Extensive damage of this type, first reported from the Caribbean (Lewis, 1977; Kristensen, 1978), has now been observed in the Red Sea off Egypt (Ormond, 1980) in Bahrain (Barratt & Ormond, 1985), in Kuwait (Downing, pers.comm.) and in Kenya (Kendall, pers.comm.).

Whether such population explosions of reef echinoderms are an entirely natural phenomenon or are at least in part attributable to man's impact on the environment is as yet uncertain (see Endean (1976) and Frankel (1977) for opposing views). However there is now good evidence that in the Red Sea at least high populations of urchins or Crown-of-Thorns are associated with reduced numbers of their principal predators, the large triggerfishes (e.g. Balistoides viridescens), the large pufferfishes (e.g. Arothron hispidus), and some of the emperors (Lethrinus spp.) (IUCN, 1984a). It seems very probable that throughout the Western Indo-Pacific increased frequency and size of echinoid and A. planci population outbreaks may be largely attributable to the considerable intensification of artisanal and recreational fishing which has greatly reduced the numbers of these key predators.

Mining of Reef Rock

Mining of reef rock from active reefs for road building, construction and lime production has caused extensive damage to reefs, especially in India, Lakshadweep, Sri Lanka, Indonesia, and to a lesser extent in other countries of the reef in Palk Bay, and by 1973 much of the reef had already been destroyed (Pillai, 1973); and extensive quarrying has occurred at many sites in the Gulf of Mannar where at one site 30 boats were removing 30,000m^3 of reef per year (Venkataramanujam et al., 1981). Equally in Indonesia there were reported to be more than 80 limekilns in operation in 1979 in East Java alone, burning at least 800 m^3 per month (UNDP/FAO, 1979).

Dynamiting and other destructive fishing methods

The use of dynamite to kill and collect reef fish seems to be not uncommon in a series of countries from Egypt to Kenya and Tanzania to Sri Lanka and to Indonesia. For example damage to vast areas of coral on the Taka Bona atoll in Indonesia (UNDP/FAO, 1982a), to the Tarutai National Park in Thailand (Alexander, 1983) and to reefs in East Malaysia (Wood, 1977), is attributed in part to fish blasting. Of course, this technique not only kills numerous non-commercial fish and invertebrates which are the food of commercial species, but destroys the corals which provide food and shelter for the fish, thus reducing or eliminating the possibility of subsequent catches.

Almost as destructive are Muroami fishing techniques, used in the East Asian Seas region, which involve driving fish into nets by banging on and smashing the coral. Corals may also be broken off to disguise traps or act as bait. And the increased extent of trawling within coral areas is also destructive of corals and reefs and is reported, for example, to have caused considerable damage in the Tarutao National Park (Sudara, 1981).

Other impacts

Various other impacts generally of more local significance have also been reported affecting reefs in the region. These include extensive collection of aquarium fish (Sri Lanka, Indonesia), trampling by reef fishermen and visitors (Kenya, Sri Lanka, Philippines), collection of corals for the curio trade (Philippines, Kenya, Egypt), and damage caused by boats and their anchors (Egypt, Sri Lanka, Malaysia). In general impacts on corals within the region due to either oil pollution or to waste discharge appear to have been less frequent than might have been supposed, and have generally affected only relatively small areas of reef.

In response to the evident destruction of valuable reef communities there have been some moves by national governments to prevent destructive practices and to establish effective management both outside and within marine parks and reserves. However progress in this direction has not yet been sufficient to halt or even slow the general decline and degradation of reef habitats. Dynamiting is illegal in almost every country of the region, yet fish bombers continue to operate without being apprehended, particularly in the Philippines, Indonesia and Malaysia. In the last two countries removal of live coral from the sea is restricted whilst in the Philippines a recent decree (1980) makes it illegal for anyone to possess stony corals for any purpose. Yet mining and curio collection continues. In India and Sri Lanka there appear to be even fewer mechanisms for reef protection. Misunderstanding and tradition have allowed destructive practices to continue. The recent introduction of environmental agencies in Sri Lanka has yet to have an effect on the reef environment (Hoffmann, 1983).

Protection and management is proving difficult even within reef conservation areas, especially in remoter parts where itinerant fishermen and fishing vessels operate. For example, at the Tarutao National Park in Thailand the reefs continue to be degraded by trawling and dynamite fishing. Day-to-day number, inadequately equipped, and have had to face physical violence on a number of occasions (Alexander, 1983). Similar problems have occurred in the Moluccas reserves where activities such as walking and poling over the reefs, dragging traps over reefs, collecting molluscs and spearfishing have continued. (UNDP/FAO, 1982b). Even in Kenya where the Marine Parks are a major tourist attraction, illegal fishing and damaging of corals apparently continues within the Marine Park areas.

Management plans for protected reef areas are, however, being developed in some countries. Plans have been produced for protected areas in Indonesia. One of the aims of the National Parks and Reserves Development Programme in the Philippines is to formulate management plans for pilot sites. In the Maldives, management policies are currently being formulated following a UNESCO visit to advise on the matter (Kenchington, 1983). And work towards the development of management plans for reef reserves in the Red Sea is also in hand in both Saudi Arabia and Egypt. Further, in some cases, management is proving successful. At Sumilon National Fish Sanctuary in the Philippines, the protected area serves as a valuable reservoir of fish, and local fishermen's catches have increased since the reserve was established (Ross, 1984).

Research and management activities in relation to coral reefs within the Indian Ocean are being encouraged and assisted by international cooperation and initiatives both at regional and global levels. A 'Status Report on Research and Degradation of Coral Reefs in the East Asian Seas was produced in 1980 (Gomez, 1980) as part of a cooperative FAO/UNEP project which recommended research in four areas - the effects of sedimentation, the effects of reef blasting, the productivity of stressed reefs and determination of the sustainable yields of coral reefs. Following on from this two projects have been funded as part of the UNEP regional seas programme:-

a) A survey of the state of coral resources.

b) A study of the effects of pollutants and destructive factors on coral communities and related fisheries.

The South Asian Seas programme is less advanced but recently the symposium on Endangered Marine Animals and Marine Parks hosted by the Marine Biological Association of India included among its recommendations that each nation provide protection to its coral reefs.

Within the Red Sea and Gulf of Aden, the Regional Seas organisation (PERSGA) has given support to marine conservation projects involving habitat surveys and proposals for the establishment of Marine Parks and Reserves, principally protecting coral reef areas, in Egypt, Jordan, Saudi Arabia, Sudan, and North Yemen.

At the wider international level, IUCN has drafted a Coral Reef Directory of the region (Sheppard & Wells, 1985) based on information available in the literature and supplied by numerous specialists; UNESCO (1984b) has recommended that programmes on coral reefs should be extended and expanded, and followed up its workshop on the assessment of reefs (UNESCO, 1983) with a workshop on monitoring of reef communities, held in Indonesia in April 1985. And UNEP in considering Marine and Coastal Conservation in the Eastern African region (IUCN/UNEP, 1984) has emphasised the need for assessment of the status and distribution of each type of habitat, including coral reefs.

Tunas and Billfishes

In looking at the overall picture of Indian Ocean fisheries, it is convenient to distinguish those resources that are of ocean-wide significance (tunas, billfishes and marine mammals), and those which are individually confined to the waters of a particular country, even if there are considerable similarities in the situations in different countries. Tunas and billfishes will be considered in this present section and other fisheries together in the next. Marine mammals will be considered separately.

Tunas are distributed throughout the Indian Ocean. The highest concentration of the larger species of tuna (Yellowfin (Thunnus albacaves), Bigeye (T. obesus), Albacore (T. alalunga), and Southern bluefin (T. maccoyii)] as well as of billfishes and marlin occur in the offshore areas, and except for a few of the smaller more coastal species, are scarce in the shallower areas and in enclosed waters such as the Red Sea, the northern part of the KAP region and the upper Bay of Bengal. All tuna species are very active, and some migrate over long distances. The southern bluefin in the southern Indian Ocean forms a single stock, which moves westward into the Atlantic and eastward into the southern Pacific at least as far as New Zealand. The albacore may also form a single Indian Ocean stock, but the other species may not move quite so far, and may thus form more than one stock within the Indian Ocean. The Pacific also has large tuna stocks, and some of these are exploited by the Philippines and Indonesia, and therefore come within the scope of this review. The movements of these fish can take them well to the east, and a proper analysis of the dynamics of these resources and the problems of their management, would require consideration of the area east of the region under review. Since this is beyond the scope of this report, the comments which follow concentrate on the Indian Ocean, but are generally relevant also to the tuna fisheries in the Philippines and eastern Indonesia.

The tuna resources in the Indian Ocean, though not known accurately, and probably significantly less than those in the Pacific, are clearly substantial. With the exception of the southern bluefin and the larger individuals of the other big species (Yellowfin, Albacore and Bigeye) which are exploited fairly heavily by long-liners, recent catches have been much smaller than their sustainable potential.

Tunas are among the most favoured species in world trade, and, as stated above, tuna vessels (long-liners and, more recently, purse-seiners) are among the relatively few long-range vessels operating in the Indian Ocean from outside the area. Most of the large tuna caught in the Indian Ocean are exported to Japan, the United States or Europe, but most of the smaller species are consumed locally. Potentially, therefore, Indian Ocean states can benefit from the tuna resources in a number of ways - export of locally caught fish, payments for fishing rights and use of harbour facilities by non-local fleets, employment ashore and afloat in both local and long range fleets, and food for local consumption. Under the present intensity and pattern of fishing the benefits currently obtained are less than might be possible.

Tuna fishing falls into three main groups, long-lining for the large fish, industrial scale fishing using purse-seines or live bait (pole and line) for surface schools of Skipjack (Katruwonus pelamis) and Yellowfin, and local fisheries using a variety of gears (gill-nets, trolling, etc), for small species of tunas as well as smaller sizes of the larger species. In the Indian Ocean industrial fishing by large vessels was, until recently, confined to long-liners from eastern Asia (Japan, Republic of Korea and Taiwan), whose activities have continued without real change (except in the balance between countries) for some available to them which includes bill-fishes and marlin in addition to the larger tuna (FAO, 1979). Until 1983 only a few trials had been made with purse-seining, but then experimental voyages by a couple of French vessels proved highly successful. Effort increased in 1984 and it seems that in 1985 all the large French tuna-seiners normally operating in the Atlantic will be in the Indian Ocean, as well as a number of Spanish vessels. Total catches of Yellowfin and Skipjack are increasing sharply, but the effect on the stocks are unknown.

Local tuna fisheries are patchy. The Maldives and Sri Lanka have important fisheries. India has significant catches on the south west coast and around the Laccadives, and Indonesia has fisheries based in western Sumatra and Bali (as well as in eastern Indonesia), but elsewhere catches are small.

However, a number of countries including India, following the changes in the Law of the Sea and the increased interest in fishery potential, are thinking about greatly increasing their direct participation in the tuna fisheries.

Billfishes, and to a lesser extent, some of the tunas, are prized sportsfish. Big game fishing is less well-developed as a tourist attraction in the Indian Ocean than elsewhere, but some fishing is done from Kenya. It does not have a significant impact on the stocks, but the desire to maintain or develop a tourist industry based on game fishing and thus to maintain a good stock of large fish, can be a significant factor in forming national policies towards the management of these species.

Because the distances over which most species move exceed the dimensions of most zones of national jurisdiction, effective management of these resources requires international agreement on the general objectives of management and on the specific measures to be taken. So far the necessary agreement does not exist. Unlike the situation in the Atlantic and the eastern Pacific, in the Indian Ocean there exists no independent commission charged with the conservation and management of tuna which can review management policy, as well as assemble and examine the scientific resource data on which management decisions need to be based. Possible management of the larger species of tuna, heavily exploited by the long-line fleets, was discussed at the first session of the tuna management committee of FAO's Indian Ocean Fishery Commission in October 1970, but no consensus emerged and possible measures do not seem to have been seriously discussed since 1970. Countries operating the long-range fleets were not anxious to accept restrictions on their existing operations, while most coastal states were equally reluctant to consider measures that might restrict their opportunities for possibly increasing the participation in the fishery in the future.

Due to the lack of a generally agreed ocean-wide policy, there is little opportunity for putting any management into practice. Some countries, notably the Seychelles, with wide Exclusive Economic Zones (EEZs)and good tuna resources, have set controls on foreign fishing in their EEZs. These controls, which mostly set out arrangements for payment of licence fees, are more concerned with realising some benefits from the foreign fishery than with conservation of the resource.

Up to the present there has been little concern (with the important exception of southern bluefin) for the status of the resource and for its conservation, and the lack of rapid change in either the amount of fishing or the abundance of the fish made this lack of concern fairly reasonable, even though the larger Yellowfin, and possibly other large species have been heavily fished for a couple of decades.

The very rapid expansion of purse-seining by France and Spain in the last couple of years, and the possibility, especially if the world tuna market recovers, of increased fishing by both coastal and landlocked countries, raises the need to pay more attention to the issues of conservation and management. Purse-seining takes a wider range of sizes of fish than long-liners, which take very few if any small juvenile fish, so that the former would therefore be expected to offer a more serious threat to the resource. There is so far no evidence that the amount of fishing has reached an undesirable level, and the most immediate concern is to have up-to-date scientific information on the status of the resource. The most recent review was that carried out at a workshop held in Shimizu, Japan, in June 1979 (Anon, 1980), though FAO is planning to hold a similar workshop in December 1985.

The success of these scientific studies depends critically on the quality of statistical data that is available. Efforts have been made in the last couple of years by the FAO/UNDP project in Colombo, to improve the supply of data, but what is available still leaves much to be desired. This makes it more difficult for coastal countries to plan the orderly development of their national fisheries, as well as for assessing the possible need for conservation and management.

While FAO is currently arranging for data collection and for analysis, a matter of serious concern must be the ability of FAO to maintain the essential long-term commitment to these activities. The data centre in Colombo is funded by UNDP, which as a matter of principle continues to fund projects for only a limited number of years. Attention needs to be paid to possible alternative arrangements, which might well include the establishment of an independent international commission responsible for the research on, and management of, tuna in the Indian Ocean. A special concern (not discussed in this report which concentrates on the Indian Ocean) is the very small size range of Yellowfin and Skipjack taken in the Philippines. In terms of numbers of fish, this is probably much the largest tuna fishery in the world, and may have a serious effect on fisheries of larger tuna.

The recommendation of immediate concern is that support should be given to the on-going collection of statistical data and to carry out the scientific work needed to assess the resource. This will require a commitment by countries of the region to the collection of national statistics to submit to the regional data centre, as well as encouragement of any associated scientific research. It will also require a commitment by FAO and UNDP to compile regional statistics and to co-ordinate, on an ocean-wide basis, an assessment of the resources. It is further recommended that there should be a review, perhaps at a workshop or similar meeting of national experts, of the possible long-term arrangements for scientific study and management of tuna (including compilation of regional statistics). A project for such a workshop is given below.

Other pelagic and demersal fish; shrimps and other crustaceans

The problem of these groups are similar, and in some cases, the fisheries are not distinct - in many parts of the area shrimp make up an important part of the catches in the demersal fisheries, and it is the presence of the high-priced shrimp that makes demersal fishing worthwhile. For this reason it is more convenient to look at fisheries (except tuna) as a whole.

In general, the Indian Ocean proper is not rich in commercial fish. It lacks the major upwelling areas, or the wide continental shelves which produce the rich fishery grounds elsewhere (Gulland, 1983). Within this general picture the coasts of East Africa (south of Somalia) and the Red Sea, are particularly poor in commercial fish resources (although there is a fairly rich fishery on the west coast of Madagascar) while with the monsoons there is seasonal upwelling along an arc from Somalia, past the coasts of Arabia to Pakistan and the west coast of India, which produces relatively high quantities of fish, particularly the small shoaling pelagic fish (sardines, anchovies, etc) typical of upwelling areas elsewhere. To the east there are wide shelves, particularly in the Java Sea and the Gulf of Thailand, which support good stocks of demersal fish.

Faunistically the whole area belongs to the Indo-Pacific region, so that in a given type of habitat the same species occur throughout the area. The number of species is very high, particularly on coral reefs where they are significant as tourist attractions or aquarium fish as well as direct sources of food. In the demersal fisheries up to a hundred species contribute significantly to the catch.

Because of the scarcity of large concentrations of a few species of fish this region has seen few of the rapid build-ups of industrial scale fishing, and hence few sudden and obvious collapses of over-fished stocks. This does not mean, though, that all the fish stocks are in a healthy state. In fact, the high populations in south and south-east Asia cause very heavy pressure at least on the coastal resources by sheer numbers of fishermen, even when the technology used is very simple. Further off-shore, the growth of trawling, especially around Thailand, has caused a very great decline in the total density, and a change in species composition (Pauly, 1979). The species that have declined by the greatest extent, mostly the larger and longer-lived species (e.g. snappers (Lutjanidae), and sharks and rays), are now at extremely low densities in these heavily trawled areas.

Other stocks that appear to be severely affected by fishing include a number of valuable penaeid shrimp stocks - in the KAP region, off the west coast of India, and in western Australia. Pelagic species do not appear to have been affected much, but these stocks have shown themselves elsewhere to be unstable, and the Indian oil sardine does seem to go through periods of low abundance, most recently about half a century ago.

Over much of south and south-east Asia, as well as in the Indian Ocean islands, fish is extremely important, and is the major source of protein for many communities. In the western Indian Ocean fish is generally less important, and for Kenya and Tanzania freshwater fish is more important than marine fish.

The larger penaeid shrimp are highly prized, and frozen shrimp are a major item in the export trade of India and several other countries (Gulland & Rothschild, 1984). Some other species (e.g. squids,) are also exported for food (usually frozen), and a few countries (e.g. Sri Lanka) export particularly large numbers of live reef fish for the aquarium trade.

In all parts of the area fishing, and the ancillary trades associated with fishing, are important, and in some places the only significant, sources of employment in coastal communities.

Fishing has always been important throughout the region, and a great variety of traditional gears have been developed. Despite the introduction of modern types of gear and the importance of these gears in some areas, e.g. trawling in Thailand, and for shrimp in India, traditional gears still account for a high proportion of the total catch in most parts of the area.

Altogether according to FAO statistics, about four million tons of fish are taken from the Indian Ocean, and about six million tons in the western central Pacific, mostly by the countries discussed here (Philippines, Indonesia, Malaysia and Thailand). In terms of economic value the most important single group of species are the shrimp (approaching half a million tons). In terms of weight some of the groups of small pelagic fish (sardines, scads and mackerels), are rather more important, though despite improvements in national statistical systems, a great deal of the catch is not identified to species or even species groups.

Few fish are caught or killed other than in directed fishing operations, but many species are caught incidentally in fisheries directed primarily at other species. Large quantities of demersal fish are caught by trawlers which are mainly interested in shrimp, though in this region (unlike the Gulf of Mexico and some other regions), most of this by-catch is brough ashore, - fresh, iced, or dried - and sold. This incidental catch can raise conservation problems when the by-catch species is particularly vulnerable to over-exploitation. Short of a drastic reduction in the total amount of trawling (which is probably unacceptable), it may, for example, be very difficult to rebuild some of the most severely depleted species in the Gulf of Thailand.

The dominant consideration in government fishery policies has been that of increasing catches; where conflicts between different groups of fisherman have been serious, resolution of these conflicts have also been given attention. In contrast, the need to manage and conserve the resource, though not in principle omitted, has seldom received much attention in practice. Most countries have legislativeprovision for introducing the normal range of management measures (closed areas or seasons, size limits, and some control of the amount of fishing), but few have administrative arrangements for a regular review of the state of the resources, the trends in the fisheries, and consideration of the effectiveness of any current management measures, and the need for new or varied measures.

The most widespread measures currently in force are those aimed at reducing conflicts. Most countries in south and south-east Asia prohibit trawling, and sometimes other forms of mechanized fishing, within a fixed distance of the coasts in order to reduce competition with artisanal fishermen, though enforcement is not always fully effective.

Resource management measures are less common. A closed season has been applied in the shrimp fisheries of the KAP region. Several countries prohibit (not always successfully) the use of explosives, and other destructive gears. Regulations setting the minimum mesh size of trawls or other nets, or the minimum size of fish that can be landed, are in existence in several countries, but are not fully enforced.

A basic concern throughout the region is with the high level of exploitation on many of the stocks, especially in the shallow coastal zones, and with the social conflicts arising from competition for this limited resource. An associated concern is the inadequacy of the basic infrastructure required to manage these resources, i.e. the arrangements for compilation of catch and effort statistics, scientific assessment of the stocks, and administrative review of these assessment and current management practices. Most countries do collect some statistics and do some research, but in few is the work co-ordinated to give adequate support to the formulation and implementation of a sound management policy. In some cases the scientific work is relatively straightforward, but there is a lack of full understanding of the dynamics of the demersal stocks, and of the changes in species composition that have occurred. Better knowledge is also needed about the response of coral reef communities to exploitation, and how to manage them for a high sustained yield. Destruction of mangroves, and the loss through land-reclamation etc of lagoons and other nursery areas for shrimp and fish, is of high concern in many areas.

There is not sufficient information to make specific recommendations for measures to manage and conserve the fish resources. It is however strongly recommended that all fishery development plans included an adequate review of the information on the resource, and that the plans are not funded and implemented unless this review shows that the resource can sustain the planned development, i.e. the burden of proof should be with the development planner to show that the resource base is adequate, rather than the present practice of assuming that all will be well unless there is clear evidence of resource limitations.

It is also strongly recommended that countries strengthen the scientific and administrative structures so as to ensure collection of adequate catch and effort statistics, assessments and regular monitoring of the resources, and regular administrative review of these scientific results. This is essentially a matter for each country individually, but this work will be helped by regional collaboration, and by assistance from the international community, particularly in training in general stock assessment techniques, and in certain specific studies, including assessing coral reef resources, and in examining the implications of species changes in the demersal communities. Proposals for this international support are made among the suggested projects.

Marine Mammals

The Indian Ocean, and waters of south-east Asia have a marine mammal fauna similar to that of other tropical and sub-tropical areas. Antarctic stocks of baleen whales move north into the Indian Ocean in the Antarctic winter, but there may be small independent stocks in the northern Indian Ocean. There are a large variety of small cetaceans, some of which are not well known. The distribution of Dugong extends over most of the region, but appreciable numbers are now found only in eastern Indonesia, Paqua, New Guinea and northern Australia.

The baleen whales, except Minke whales, have been severely depleted by hunting in the Antarctic. Sperm whales, especially the larger males, have also been reduced, though possibly not to quite the extent of baleen whales. Dugongs are now extremely scarce over much of their range. The Indus river dolphin is now very scarce, possibly through dam construction and other changes in river systems, though the Ganges river dolphin still seems common. There is little information about the status of small cetaceans though it is possible that the large incidental catches around Sri Lanka could have affected some species.

The large baleen whales and sperm whales did support large industries; American and British whalers operated in the region (Wright & Martin, 1983). Also, for decades a major land-based whaling station operated from Durban, which took Blue, Fin, Humpback and Sperm whales on their migrations between the Antarctic and the Indian Ocean. However, the International Whaling Commission has declared the Indian Ocean a sanctuary. Therefore there is now no hunting of baleen whales and, although it is not clear what species of small cetaceans are covered by the declaration (or by other decisions of the IWC), there is in fact no directed hunting of any cetacean in the central Indian Ocean at present. However, in the three seasons prior to the establishment of the Whale Sanctuary, 225 Bryde's whales were taken from the Philippines area by Japanese whalers (see Ohsumi, 1980). Except for Dugong in eastern Indonesia no small species of marine mammal is taken in significant quantities for food. Possibilities exist for whale watching to become a significant part of the tourist industry in Sri Lanka and elsewhere, but these have not been realised yet.

Dugongs are very vulnerable to being caught incidentally in a variety of nets along the coast, and although there is little information on the actual numbers killed, or on the proportion these numbers are of the existing stock, it is believed that incidental catches have had, and are having, a serious effect on the stocks.

Incidental catches of small cetaceans occur on a significant scale in the gill-net and other fisheries around Sri Lanka and southern India. Several thousand animals of a number of species are believed to be killed annually, but the effect on the stocks is unknown.

The two major priorities concern firstly the low abundance of Dugongs throughout most of the area, and secondly the possible impact of incidental catches on some populations of small cetaceans. In both cases the lack of good information about the present distribution and abundance of Dugongs, and about the magnitude of the incidental catches of small cetaceans (in actual numbers, and in relation to the size of the populations of the species concerned) is an obstacle to effective action. It would also be desirable to set up a programme to assess and monitor the stocks of whales and other animals within the IWC's Whale Sanctuary.

For these reasons, it is recommended that action should be taken to determine the present abundance and distribution of Dugongs, especially in the western Indian Ocean where the numbers are particularly low. More precise assessment of the numbers and species of small cetaceans taken in gill-net and other fisheries should be strongly encouraged and countries are also urged to take action to minimise the numbers of both Dugongs and cetaceans caught incidentally during fishing operations. Support should be given to a programme of research to assess and monitor stocks of marine mammals in the Indian Ocean Sanctuary.

Turtles

There are seven species of marine turtle of which five are found in the IOR; the Green (Chelonia mydas), the Hawksbill (Eretmochelys imbricata), the Loggerhead (Caretta caretta), the Leatherback (Dermochelys coriacea), and the Olive Ridley (Lepidochelys olivacea). As is well known, sea turtles are threatened worldwide, and four of the above species, the Green, Hawksbill, Olive Ridley and Leatherback, are listed in the IUCN Red Data Book as endangered. The fifth, the Loggerhead, is considered to be vulnerable.

The distribution of significant breeding grounds for the five species is indicated in Table 3. Green and Hawksbill are the most widespread species and are the only ones breeding in the Red Sea, in the KAP region (apart from some Leatherbacks nesting in Lakshadweep), and on the island groups of the Western and Central Indian Ocean. The Loggerhead has, in fact, the most restricted distribution of nesting grounds, preferring to next in rookeries on large sandy beaches. The world's largest Loggerhead rookery is on Masirah Island in Oman; other rookeries occur in Somalia, Mozambique and Sri Lanka, and a few Loggerheads nest in Tanzania, Malaysia and Indonesia.

As is increasingly appreciated, the region's turtle population represents a valuable resource. For example, the value of turtle products exported from Indonesia in 1980 was US$928,539 and in 1981 US$407,542 (Salm & Halim, 1984). Given adequate management and regulation many of the populations could be used

Almost everywhere in the region, however, all species of turtle appear to be in marked decline.

In many areas eggs are collected from breeding grounds, often in very high numbers. Over 90% of eggs are thought to be taken at some sites in India and Malaysia and, for example, egg production at Trengguna on the east coast of Malaysia was estimated to be around two million in the 1950's but has since fallen to under a million. At many sites the situation is exacerbated by general human disturbance and by an increased number of dogs also digging up nests.

In other areas the adults are hunted, by net or by harpoon, for their meat or their fat, and in particular, in the case of the Hawksbill, for their shell (tortoiseshell). In the Philippines and parts of Indonesia the Green turtle has been hunted almost to extinction (de Celis, 1981; Soegiarto & Polunin, 1982). In Bengal an illegal fishery for Olive Ridleys was recorded landing over 20,000 turtles in just 4 months (Biswas, 1979). Between 1974 and 1978 an estimated annual average of 22,000kg. of tortoiseshell was exported from the Philippines, and an estimated 150 tonnes a year is being exported from Indonesia. Export of shell from these and other countries of the region continues in apparent contravention of CITES. Large scale slaughter of turtles by foreign fishing vessels, many from outside the region, is described as taking place just outside East Malaysian waters (de Silva, 1980).

In addition, nesting beaches are increasingly disturbed by residential developments and by visitors, and adults are often taken incidentally in the nets of trawlers and rarely released.

Turtles have been afforded some protection in the East Asian Seas region, notably in Indonesia where Loggerhead, Leatherback and Olive Ridley are, in theory, completely protected by Ministerial Decree; it is intended to formulate plans to achieve a sustainable harvest of Greens and Hawksbills (Suwelo et al., 1981) but for the present over-exploitation of these two species appears to be continuing. Turtle nesting beaches are included within 21 protected areas (Salm, 1984). In Malaysia some states have prohibited the hunting of the turtles and Green, Leathery and Olive Ridley turtles are actively conserved by hatchery programmes run by the Fisheries Department (Tow & Moll, 1981).

In the South Asian Seas region all turtles are theoretically protected in Pakistan, India and Sri Lanka. However, law enforcement is difficult and in both India and Pakistan there is continued consumption, while in Sri Lanka laws regarding turtle capture were actually suspended, citing the large number of people thought to rely on taking them.

In the Eastern African region, harvesting of eggs and adults has continued largely uncontrolled, with the exception of the Green turtle in Reunion and both Green and Hawksbill turtle in the Seychelles, although even here control outside the main islands is apparently poor.

By contrast, in both the Red Sea and Gulf of Aden, and in the KAP region, although there has been little formal protection of turtles, exploitation has generally, until now, been fairly limited, and involved only irregular taking of adults or eggs by small numbers of fishermen. This may reflect in part Muslim prohibition on the consumption of turtle meat, and in part the dispersed distribution of breeding sites. Oman has been especially active in developing turtle conservation and research.

more regional conventions, such as the African Convention on the Conservation of Nature and Nature Resources. But these conventions seem as yet to be only partially effective. It is clear that much greater effort is required to implement protective measures and that further international cooperation is needed in view both of the patterns of migrations which take turtles across national and regional boundaries, and of the international nature of the trade in turtle products, especially tortoiseshell.

Seabirds

In all 42 species of seabird appear to breed in the IOR. Their breeding occurrence within each Regional Seas area is summarised in Table 4. Only a portion of these species breed in any one region. Recent reviews have described 16 species breeding in the Arabian region (Gallagher et al., 1984), 17 in Eastern Africa (Cooper et al., 1984), 23 among the central Indian Ocean islands (Feare, 1984) and 14 from Indonesia (de Korte, 1984).

Fourteen seabird species appear to be endemic to the region or parts of it. Of these, six are endemic just to the northwestern Indian Ocean - Jouanin's Petrel (Bulweria fallax), Socotra cormorant (Phalacrocorax nigrogularis), White-eyed gull (Larus leucophthalmus), Sooty gull (L. hemprichii), White-cheeked tern (Sterna repressa) and Saunder's tern (S. saundersi), as is also the Crab plover (Dromas ardeola), a shore bird breeding exclusively on offshore islands.

Among the islands of the central Indian Ocean three gadfly petrels exist only in isolated populations in the Mascarenes. Of these, Barau's petrel (Pterodroma baraui) and the Mascarene petrel (P. aterrima) are endemic to the area. The latter is probably the rarest seabird in the IOR, its existence this century being known only from two specimens collected in 1970 and 1974. Also Abbott's booby (Sula abbotti), and the Christmas Island frigatebird (Fregata andrewsi) occur only on Christmas Island.

Of the remaining four species, two are local species of cormorant, Indian cormorant (P. fuscicollis) and Javanese cormorant (Halietor niger), and the other two are species of tern confined to the IOR, the Lesser crested tern (Sterna bengalensis) and the Lesser noddy (Anous tenuirostris).

Seabirds breeding in the region have become increasingly impacted by man's activities, largely by general disturbance and habitat change linked to the spread of villages, holiday homes, and navigational and military installations to offshore islands, by accidental introduction of predators (e.g. cats and rats), and also by egg collection and the taking of chicks. In the past eggs have been collected in small quantities by fishermen and coastal villagers, generally in a sustainable manner; but in recent years, as a result of human population expansion and the increase in range of motorised fishing craft, the taking of eggs and chicks has been greatly intensified. Such effects appear to have been greatest in East Asia, Eastern Africa and the Kuwait Action Plan region (see de Korte, 1984; Feare, 1984; Gallagher et al., 1984, Cooper et al., 1984).

By contrast, although in other regions seabirds have been seriously affected by oil pollution and by accumulation of pesticides, neither of these yet appears to be a significant problem in the IOR.

Terns and gulls are generally more able than other seabirds to sustain serious impacts, and none is yet threatened with regional extinction. The highly palatable and adults, young and eggs are all taken; they are especially vulnerable to human disturbance because gulls take their eggs when they leave the nest; they are excluded either by the destruction of trees used for nesting, or by the planting of previously treeless islands with coconuts, and they do not readily move from their traditional nesting islands. In both Indonesia (de Korte, 1983) and among the islands of the central/western Indian Ocean (Feare, 1983), many islands known to support breeding colonies in the earlier part of this century now either lack any breeding birds, or support only greatly reduced numbers. On Christmas Island, the one surviving colony of Christmas Island frigatebirds (Fregata andrewsi) has been depleted in significant numbers (Nelson, 1972).

Seabird colonies have been established as reserves at various locations. Two major seabird nesting islands in Indonesia are protected as well as six other sites (Salm & Halim, 1984). Three island reserves are in existence in Malaysia and a bird sanctuary has recently been incorporated in the Apo Reef Island Marine Park in the Philippines. Several islands are protected in the Seychelles, and a National Park has recently been established on Christmas Island. However, protective legislation is difficult to enforce on remote islands, and numbers of major breeding sites lack even formal protection, e.g. Kiunga-tenewe Islands and Latham Island (Tanzania), Mait Island (Somalia), various islands in the Red Sea (Sudan, Saudi Arabia), and Cosmoledo Atoll (Aldabras-Seychelles).

Apart from seabirds, some other bird species breed on or are confined to small islands in the IOR, e.g. the Sooty falcon (Falco concolor) in the Red Sea and KAP region, the Crab plover (Dromas ardeola) in the north-west Indian Ocean. Various of the larger islands of the Indian Ocean, such as the Seychelles and Mauritius, also have a good number of endemic species of land bird. Most of these birds are endangered or threatened, while other endemic species are already extinct; these however are beyond the scope of this report.

Also, on many mainland coasts, mud flats and other wetland habitats provide important feeding grounds for resident or migrant shore birds. For example, large numbers of palaearctic waders migrate from Siberia and Russia via the KAP region and/or Southern Red Sea to Eastern Africa. Probably significant staging sites occur in Kuwait and the Asir.

CONCLUSIONS AND RECOMMENDATIONS

The foregoing account presents a fairly gloomy catalogue of the destruction of habitats such as mangroves and coral reefs, and the decline of species through overexploitation and habitat loss. It is not intended to imply that there are not still moderate areas of relatively unimpacted habitat or, in many areas, reasonable populations of important species, but these areas and populations are becoming fewer and fewer, and in general it is clear that in the last fifteen to twenty years there has been a major decline in the extent and condition of various marine habitats and in the populations of numerous species of marine animal and plant. We have reached and passed the point where this decline should be of concern only to conservationists. All of these habitats and many of these species represent renewable resources of almost incalculable value, resources that should and could continue to provide human populations in the IOR with food and other materials for long into the future, but which at the present rate of destruction are unlikely to do so for far into the 21st century.

Stimulated by the reports of habitat loss and species decline referred to them, the authors of this report have been interested in a preliminary estimate of the effect of this damage on the food producing potential of the Indian Ocean region as a whole. Such estimates are obviously open to considerable error, but some indication of the likely effect may be derived from considering the estimates of primary production in the Indian Ocean proposed by Moiseev (1969) (see Table 5). After crude adjustment to allow for the fact that essentially only the tropical and subtropical Indian Ocean is included within the region considered by this report, his figures suggest that up to 46% of primary production may be due to shallow water neritic habitats occupying only about 1% of the ocean's surface. Thus, if the loss in the primary production by these habitats due to their destruction or degradation was 20%, perhaps the largest figure suggested by the reports described here, this implies a loss of approaching 10% in the total primary production of the IOR.

The corresponding effect of this loss on secondary and tertiary production, and hence on the potential catch of fish, is even more difficult to estimate. It depends in particular on the effective number of trophic levels and the transfer efficiency between them. Both of these factors differ significantly between different environments (see Ryther, 1969; Cushing, 1973), and the values for these systems remain very uncertain. However, the results of some calculations suggest, as also concluded by Cushing (1973), that the bulk of the tertiary productivity within the IOR is due to primary production in coastal waters and upwellings and in shallow water and coastal benthic habitats. The latter might well account for a third of tertiary production, so that a 20% loss in primary production in these habitats might result in an overall reduction of about 7% in the available fish catch of the IOR.

At the same time there appear, from local reports, to be indications of increasing overfishing in some parts of the IOR, in particular in the East Asian Seas region, in the northern KAP region, and in nearshore areas close to centres of population in the Eastern African and Southern Asian regions. A summary of the data for fish catches by different countries in the IOR in recent years (see Tables 6 & 7) shows that on the whole, for most areas, the catch has remained surprisingly consistent. However, the suspicion is that this has only occurred as a result of a very considerable increase in fishing effort, particularly when measured in terms of investment of other resources (fuel, materials). As more accessible stocks become overfished, other stocks become more heavily exploited. The principal region where there remain large, relatively unexploited stocks of modest demersal and inshore stocks are underexploited, largely through infrastructural problems (Ardill, 1983).

The present evidence is consistent with the following overall picture of the effect of man's activities on the exploitable fish stocks of the IOR. Actual fish catch has remained more or less constant in recent years because whereas some fifteen years ago man was taking perhaps only 60-75% of the total optimum sustainable yield of the IOR, now it seems likely that he may be taking on average 80 or 90% of optimum sustainable yield of a production which, as a result of habitat damage and overfishing, is now 10 to 20% smaller. If the present trend continues it seems likely that even if for some years, as a result of increased exploitation of less exploited stocks, fish catch in the IOR as a whole can be sustained, sooner or later habitat damage and overfishing will reduce the food producing potential of the region below the present level of catch.

Irrespective of the details of these conclusions, the greatest concerns for the environment of the Indian Ocean region may be summarised under several headings. They are:-

1. Habitat loss. Specifically the loss of critical marine primary production in the IOR. In particular:-

i) approximately 50% of mangrove forest has been lost in the last 15-20 years, largely by clearing and felling for fuel and timber;

ii) perhaps 20% of coral reefs have been damaged or noticeably affected by impact, mainly by sedimentation and mining;

iii) perhaps 10-20% or more of productive mud flat habitats have been lost, largely through infilling and reclamation or pollution;

iv) perhaps 5% or more of seagrass beds have been destroyed, either from dredging or infilling.

2 Overfishing. The enormous intensification of fisheries in some areas has almost certainly resulted in a reduction in stocks of fish, shrimp, and other crustacea and shellfish to below the stock size required to support maximum sustainable yield. Overfishing is or is becoming especially prevalent with regards to:-

i) coral reef and nearshore fisheries for grouper, snapper, etc., particularly in the East Asian Seas region; overfishing also results in indirect damage to the reef;

ii) inshore trawling fisheries, for finfish and shrimp, particularly in the Gulf of Thailand and the northern KAP region;

iii) in addition it seems that, in view of the lack of any controls or management, overfishing of offshore pelagic fisheries for tuna, etc., is likely to occur within the next few years.

3. Endangered Species. Several groups of larger vertebrate, which are not only of special conservational interest, but are also of potential resource value, are threatened, especially by overexploitation but also by habitat loss:

i) Turtles, of five species;

ii) Dugong and other marine mammals;

iii) Seabirds, especially the Pelicaniformes (boobies and frigate birds).

Other concerns seem, to the authors of the report and within the context of the IOR, to be relatively minor. The great diversity of invertebrates will and can only be adequately protected if the habitats within which they occur are protected, either within marine reserves or parks, or within regions zoned for controlled exploitation.

The management and conservation of species also requires the maintenance of adequate water quality. The occurrence and extent of marine pollution within the IOR is certainly increasing, and in some local areas, especially near large cities, has damaged or destroyed marine habitats and resources. However, it should be emphasised that, as also concluded in previous reports (UNEP, 1982; GESAMP, 1982), neither oil-pollution nor non-oil pollution has so far been a major factor in causing widespread decline and loss of marine habitats and species stocks in the IOR. The causes of this are simpler - they are the direct or indirect physical destruction of the habitat, and the overexploitation of the species.

This conclusion, in our view, would argue against too much concentration on major projects designed to assess the distribution and effects of particular pollutants. Such projects, in view of the costs of many of the laboratory analyses involved, can be particularly expensive, and are more so if lengthy oceanographic cruises are also involved. This is not to say that action should not be taken. Baseline data sets from around the region are essential if later impacts are to be demonstrated, and, in particular, environmental standards and regulations must be established (where not already established) and enforced throughout the IOR. However, we would urge that priority should be given to developing and introducing mechanisms, at the national and international level, which will slow or halt the current rush of habitat destruction, species decline and resource loss.

Much of the action required, and many of the projects that are desirable, are relatively easily determined, and they have, for the most part, already been proposed: sometimes at the global level by international conferences or workshops, often supported by the international agencies; sometimes at the regional level within individual Regional Seas programmes; and sometimes at the national level by the environmental protection departments of particular countries. It is undesirable to duplicate or confuse the more specific recommendations or proposals of these organisations, which have considered in more detail problems relating to particular countries, regions or habitats. In the present context, therefore, a brief set of general recommendations is suggested and, in the light of these and of the on-going marine environmental and conservation activities of the region, a series of proposals are developed for projects which may may serve either:

i) to assist the speed with which nations and regions can act to strengthen or introduce effective management of the marine environment, or

ii) to increase, through international cooperation, the effectiveness with which research and development can be undertaken, related to critical and urgent environmental problems common to all or much of the IOR.

General Recommendations

1. Habitat Loss. In view of the extent and speed of the loss of highly productive critical habitats, which provide the productivity base for indispensable fisheries and renewable resources, the nations of the IOR should co-operate and act to survey, protect, manage and conserve, through the control of exploitation and the further establishment of marine parks and reserves, their

mangrove forests
coral reefs
seagrass beds
and productive mud flats.

2. Overfishing. In view of the rapidly increasing incidence of overfishing of stocks of demersal and pelagic fish, crustacea and shellfish, and of the vital significance of these stocks as a source of food for the coastal peoples of the regions, national authorities should cooperate and act to regulate to their own long-term advantage, their

coral reef fisheries
inshore demersal fisheries
and oceanic pelagic fisheries.

3. Endangered Species. In view of the rapid decline in numbers of various marine vertebrates which not only present a potentially valuable resource, but which are of major scientific, educational and conservational interest, the nations of the IOR should co-operate and act to enforce and extend the protection given to

marine turtles
Dugong, whales and other marine mammals
seabirds, especially the Pelicaniformes (boobies and frigate birds).

Table 3

Distribution of Significant Turtle Breeding Grounds
in the Indian Ocean Region

Country/Area	Green	Hawksbill	Loggerhead	Leatherback	Olive Ridley
	Turtle Species				
Mozambique	+	+	+		+
Madagascar	+	+	+		
Tanzania	+	+			+
Kenya	+	+			
Somalia	+	+			
Ethiopia	+	+			
Sudan	+	+			
Egypt	+	+			
Saudi Arabia	+	+			
North Yemen		+			
PDR Yemen	+	+			
Oman	+	+	+		+
Northern KAP region	+	+			
Iran	+	+			
Pakistan	+				+
India	+	+			+
Sri Lanka	+	+	+	+	+
Bangladesh					+
Lakshadweep	+	+		+	
Maldives/	+	+			
Seychelles	+	+			
Mascarenes	+	+			
Andaman	+	+		+	+
Nicobar	+	+		+	+
Burma	+	+		+	+
Thailand	+	+		+	+
Malaysia	+	+		+	+
Indonesia	+	+		+	+
Philippines	+	+			

Note: + indicates the recorded presence of significant breeding populations of the species concerned.

Table 4

Breeding Distribution of Seabirds in the Indian Ocean Region

		Red Sea	KAP	East Africa	Ind. Ocean	South Asia	East Asia
Wedge-tail shearwater	C			+	+		
Audubon's shearwater	C		+	+		+	
Trinidad petrel					*		
Mascarene petrel	E				*		
Barau's petrel	E				*		
Jouanin's petrel	E		*				
Red-billed tropic bird			+			+	
Red-tailed tropic bird	C			+	+		
White-tailed tropic bird	C			+	+	+	+
Pink backed pelican		+		+			
Masked booby	C		+	+	+	+	+
Red-footed booby	C			+	+	+	+
Brown booby	C	+			+	+	+
Abbot's booby	E				*		
Common cormorant						+	
Indian cormorant	E					+	
Socotra cormorant	E		+				
Little pied cormorant							+
Javanese cormorant	E					+	+
Great frigate bird	C			+	+	+	+
Lesser frigate bird	C			+	+	+	+
Christmas Is.frigate bird	E				*		
White-eyed gull	E	+					
Sooty gull	E	+	+	+			
Grey-headed gull				+			
Slender-billed gull			+				
Whiskered tern				+		+	+
Gull-billed tern							+
Caspian tern		+	+				
Indian River tern						+	+
Roseate tern	C			+	+	+	+
White-cheeked tern	E	+	+	+	+		
Black-naped tern					+	+	+
Bridled tern	C	+	+	+	+	+	+
Sooty tern	C		+	+	+	+	
Little tern						+	+
Saunders'tern	E	+	+				
Greater crested tern		+	+		+	+	+
Lesser crested tern	E	+	+			+	+
White tern	C				+	+	
Brown noddy	C	+			+	+	
White-capped noddy	C						+
Lesser noddy	E				*	+	

+ indicates significant breeding;
* indicates critical breeding sites;
C indicates circumtropical distribution;
E indicates endemic to part of the Indian Ocean Region

Table 5

Sources of Primary Production in the Indian Ocean Region

	Average Production $mgCm^{-2} day^{-1}$	Percentage of Total Indian Ocean	Total Annual Primary Production tons C
Oligotrophic Central Subtropical	70	27	0.5×10^9
Equatorial Divergence	200	14	0.7×10^9
Coastal Upwelling	340	12	1.0×10^9
Neritic (Coastal)	1000	1	1.9×10^9

(Modified from Moiseev, 1969, to exclude temperate and subpolar regions).

Table 6

Summary of Fish Catches from Indian Ocean Region, 1973-1983

	Western Indian Ocean			Central Indian Ocean			Eastern Indian Ocean		
	1973	1978	1983	1973	1978	1983	1973	1978	1983
Egypt	4.4	9.1	13.6						
Sudan	0.8	0.7	4.5						
Ethiopia	25.8a	-	0.4a						
Somalia	30.0a	8.4	15.5a						
Kenya	4.0	4.6	6.4						
Tanzania	23.0	47.3	35.5						
Mozambique	13.3	22.9	37.4						
Madagascar	21.2	12.9	12.3						
Seychelles	3.0	5.4	3.9						
Mauritius	6.4	7.1	9.5						
Reunion	2.5	2.0	3.0a						
Comoros	3.0	4.0a	4.0a						
TOTAL African C.	137.4	124.4	146.0						
Saudi Arabia	26.4	26.5	26.4a						
Yemen Arab Republic	10.0a	19.2	12.2						
Yemen People's Democratic Republic	133.5	48.0	74.1						
Oman	180.0a	73.0a	108.8						
Qatar	2.2a	2.2a	2.1						
Bahrain	1.5	4.0	6.8						
United Arab Emirates	43.0	64.4	73.1						
Kuwait	5.2	6.3	4.1						
Iraq	6.3	8.6a	8.0						
Iran	16.9a	59.3	30.0a						
Pakistan	209.1	257.8	283.0						
India	948.1	1081.0	1040.0	262.3	408.7	518.3			
Maldives	33.7	25.8	38.5						
Sri Lanka	93.7	139.8	187.9						
Burma				338.1	396.1	442.9			
Bangladesh				88.0	118.0	144.0			
Thailand				24.7	229.1	372.1	1515.5	1728.7	1728.9
Brunei							1.5	2.6	3.0
Malaysia							450.4	682.4	725.9
Singapore							17.9	15.6	19.1
Indonesia				62.3	116.3	163.9	824.1	1021.8	1428.0
Cambodia							10.8	10.8a	5.1a
Vietnam							837.2a	403.0a	505.0a
Philippines							1204.3	1199.5	1271.4
TOTAL South and West Asia	1709.6	1815.9	1895.0	775.4	1268.2	1641.2	4861.7	5064.4	5686.4

Note: a) FAO estimates

Table 7

Summary of Fish Catches from Indian Ocean Region, 1973-1983, including catches by vessels based outside the region

	Western Indian Ocean			Central Indian Ocean			Eastern Indian Ocean		
	1973	1978	1983	1973	1978	1983	1973	1978	1983
Japan c)	25.9	23.7	20.4	18.3	17.1	11.7	163.7	245.2	264.8
Korea	26.4	63.2	44.0	-	18.8	1.9	-	15.6	17.6
Taiwan	26.5	6.8	18.5	11.5	13.0	10.4	7.4	7.1	4.0
USSR	43.7	25.4	30.8	0.5	0.7	+	-	-	9.5
Bulgaria	-	0.3	-						
German Democratic Republic	-	0.9	0.6						
Romania	-	-	1.0						
France	-	-	20.5						
Italy	-	0.8	1.4						
Spain	5.3	2.1	-						
TOTAL, non-local	127.8	123.2	137.2	30.3	49.6	24.0	171.1	267.9	295.9
TOTAL, Africa	137.4	124.4	146.0						
TOTAL, South and West Asia	1709.6	1815.9	1895.0	775.4	1268.2	1641.2	4861.7	5064.4	5686.4
TOTAL FAO area b)	1977.9	2067.7	2186.1	879.8	1383.9	1774.2	5118.4	5633.7	6150.9

Notes:

a) FAO estimates

b) FAO statistical areas are rather larger than the area under review. Catches in FAO area includes catches by South Africa, Australia, PNG and in the open Pacific.

c) Includes Japanese skipjack fishery in Western Pacific, to the eastward of the area under review.

PROJECT PROPOSALS

The following outlines of project proposals have been prepared in the light of the conclusions and recommendations as have been developed in the present report.

A. REEF SEDIMENTATION

Main Interested Areas: KAP region; Eastern Africa; East Asian Seas region.

Background

Sedimentation of coral is probably the major impact leading to degradation and loss of reef communities in the IOR. Heavy sediment loads arise from dredging, infilling and other coastal construction work, and are increasingly brought down river as a result of extensive inland deforestation, land mismanagement and soil erosion. Despite this, the effects of sediment on corals have not been fully quantified and there are no precise estimates of how much sedimentation different coral species are able to tolerate. In addition, it is necessary to determine the most appropriate methods for reducing sedimentation during dredging, infilling and other coastal engineering work, and to examine the feasibility of reducing soil erosion and the increased sediment loads being carried by rivers.

The Project

The project would involve several parallel elements:-

a) A monitoring programme would be established to record rates of sedimentation on reefs in several countries where sedimentation is a major problem (e.g. Kenya, Bahrain, Malaysia), and to monitor adjacent coral assemblages. Particular attention would be paid during this work to testing and comparing the value of different types of sediment trap, and developing a simple cost-effective method of recording sedimentation.

b) A second research programme, undertaken by the same staff in parallel with the first, would review available information and undertake further desirable experimental work to quantify the sediment loads which different coral species are able to tolerate over different lengths of time.

c) A third element would involve a panel of engineering and land management consultants and specialists to draw up standard recommendations for minimising the degree of sedimentation produced by dredging, infilling, coastal and soil erosion, etc.

d) The final element would bring together scientists and engineers to develop a simply-worded and well-illustrated brochure or small booklet for distribution to relevant government departments, engineering contractors, etc., publicising and explaining the problems of sedimentation of coral communities, and the actions which should be taken to limit this.

Staff Involved

a) & b) Three scientists and one support staff for two years, to visit field sites and work in collaboration with local scientists and personnel. Operational costs.

Travel and secretarial costs.

d) Workshop. Travel and per diems for participants.

Output

- evidence establishing effects of sedimentation in reef areas under study;
- recommended procedures and methods for minimising sediment load due to dredging, infilling, soil erosion etc.;
- recommended standards and regulations to enforce use of methods minimising sediment production;
- recommended methods for measuring sediment load on reef and other areas;
- information on the tolerance limits of reef corals and the effects of sedimentation on coral communites.

B. CRITICAL RESOURCE AND HABITAT SURVEYS

Main Interested Areas: All regions.

Background

In view of the rapid degradation and destruction of productive critical habitats (mangroves, coral reefs, seagrass beds, mud flats) taking place in many parts of the region, it is essential that environmental managers and decision-makers have information on the extent and status of these habitats within their regions. Such information can assist in generating plans to manage and protect these habitats by directing residential and industrial developments elsewhere, by appropriate zoning of the coast and inshore waters, and by the establishment of marine parks and reserves and fisheries management and conservation areas.

Such broad scale critical resource and habitat surveys have or are being undertaken in some countries of the IOR (e.g. Saudi Arabia, Indonesia) and in others information regarding some, if not all, of these habitats may be relatively complete (e.g. Egypt, India, Philippines). However, there are some countries (e.g. Somalia) for which there is little or no information about the distribution of these habitats. Assistance is necessary to help some nations in carrying out this survey work, while others, it is considered, would benefit from clear recommedations on the best methods to use. It is suggested that a brochure or booklet be prepared which would present this information and provide an introduction to the more comprehensive volumes on research methods prepared by UNESCO (1978, 1984a&b, & in prep.).

The Project

The project would involve two elements:-

a) completion of a model critical habitats survey in several countries of the region (Somalia, Tanzania, Maldives, Sri Lanka, United Arab Emirates and Eastern Malaysia are possibilities);

b) development and production of an introductory manual or booklet recommending methods for organising surveys and recording and collating data;

Staff Involved

a) Two scientists and two research assistants to undertake habitat surveys. Operational costs.

c) Co-ordinator and secretary for each secretariat.

Outputs

These would be:-

- introductory manual on organisation of and methods for critical habitat surveys.

C. HABITAT DIRECTORIES AND DATABASES

Main Interested Areas: All regions.

Background

In view of the rapid degradation and destruction of productive critical habitats (mangroves, coral reefs, seagrass beds, mud flats) taking place in many parts of the region, it is essential that environmental managers and decision-makers have information on the extent and status of these habitats within their regions. Such information can assist in generating plans to manage and protect these habitats by directing residential and industrial developments elsewhere, by appropriate zoning of the coast and inshore waters, and by the establishment of marine parks and reserves and fisheries management and conservation areas.

Where possible information is required on an ocean-wide basis so the significance of particular habitat areas can be properly assessed. Moves have already been initiated to establish or develop information bases for some habitats. UNESCO has proposed an Indian Ocean Mangrove Database to incorporate information from satellite imagery, and IUCN is producing a series of Coral Reef Directories, the Indian Ocean volume of which is now in draft form. However, for these habitats the data which have been collated are still somewhat limited, and continual updating is essential in view of developing impacts to many areas. Also for other habitats no regional database has been established. For example, the Symposium hosted by the Marine Biological Association of India (1985) recommended that special attention be given to studies and surveys of seagrass beds. Thus it is recommended that priority attention be given to supporting the development of existing regional databases and habitat directories and to funding the establishment of others. Assistance is necessary to help some nations in carrying out the necessary survey work, and to standardise data collection and presentation, so that regional patterns of distribution can be appreciated and understood.

The Project

The project would involve:-

the establishment or further development of regional directories/databases for each critical habitat; the database would be serviced by a small secretariat which would also coordinate training and assistance and disburse information to national agencies; it is suggested that IUCN, UNESCO, and UNEP could assist in supplying these secretariats and database facilities.

Regional directories or databases should be established for each of the following habitats:-

- coral reefs
- mangroves
- seagrass beds
- mudflats and associated wetlands
- small islands
- kelp forests and algal communities

Staff Involved

a) Co-ordinator, research assistant and secretary for each secretariat.

Outputs

These would be:-

- IOR directories/databases for reefs, mangroves, seagrasses, mudflats, islands and algal communities;
- maps of critical habitat distribution for each region;
- supplementary databases of appropriate field data.

D. NETWORKS

Main Interested Areas: All regions

Background

Vital habitats (mangroves and coral reefs) and resources (fisheries and endangered species) are being depleted in many parts of the Indian Ocean. Local specialists and resource managers need assistance in developing management methods, introducing appropriate laws and regulations, surveying resources, and sustaining their general activities. Environmental conditions across much of the IOR are very similar and many of the same species are common to many areas. UNESCO have recently established a regional network of mangrove scientists and managers, and ICLARM (Philippines) have developed a network of Fisheries Managers in the region. It is suggested that this idea should be taken up and supported with regard to these and other areas of specialisation so that more formal IOR networks of managers and scientists are established for the following habitats and species groups:-

mangroves
coral reefs
seagrasses
fisheries
turtles
marine mammals
seabirds

with priority being given, along with supporting the existing networks, to establishing networks for turtles and for coral reefs.

The Project

Co-ordinators would be appointed for each habitat/species group and provided with secretarial and administrative support. It is suggested that, at least initially, individual international agencies could support the establishment of particular networks. The networks should not be too structured or formal but should be open to all interested persons within the region, and also to specialist scientists from outside the IOR. The networks could pursue the following activities:-

a) circulating of newsletters. It is suggested that in addition perhaps to distributing a more formal printed newsletter on an annual or semi-annual basis, the networks should emphasise the regular and rapid circulation of duplicated or photocopied informal notes and correspondence between members of the network.

b) organising exchange visits of managers and specialists between different countries of the IOR. These should, in so far as is possible, involve practical management work or investigations in the field. This would assist local scientists and resource managers in obtaining information about methods and management techniques, and generally encourage them in their work.

management and enforcement methods in the context of the IOR, and specifying a standard set of laws and regulations which should ideally be adopted by each country of the IOR where no comparable legal control already exists. However, expensive international meetings should not be a priority.

Staff Involved

Initially 5-7 part-time co-ordinators. Secretarial and administrative expenses.

Limited funds for international travel.

Output

The formal outputs would be:-

- the annual or semi-annual newsletter
- short reports by those involved in exchange visits
- booklets resulting from workshops (at a later stage)
- a set of recommended laws and regulations for adoption by member countries.

E. CORAL REEF FISHERIES ASSESSMENT AND MANAGEMENT

Main Interested Areas: Red Sea and Gulf of Aden region; Eastern Africa; East Asian Seas region.

Background

Coral reefs are important sources of fish, and are particularly important to small-scale artisanal fishermen. Though mainly traditional gears are used, many reefs are heavily fished, and some of the larger, more valuable species, eg snappers and groupers, are seriously depleted in many areas. Most traditional stock assessment methods are not directly applicable to coral reefs, and those wishing to manage coral reefs as a continuing source of food have no good source of advice on how to assess or manage reef fisheries. The aim of the project would be to examine these methods, eg the extent to which catch and effort statistics, or changes in sizes of individual species can be used in assessment, or whether closed areas or seasons, or limits on the number of vessels or fishermen operating are useful approaches to management.

The Project

The project would be carried out in four stages, the first two of which would proceed in parallel. First would be a careful literature survey to compile and analyse data on yield rates (catches/ha), changes in species composition under exploitation, population parameters of major reef species, etc. At the same time field studies would be carried out, probably in the northern Red Sea and/or Eastern Africa, to compare the characteristics (species composition, sizes of individual species, etc) on exploited and unexploited reefs in the same general area. This would be followed by a small expert working group which would meet to review the results, and possible assessment and management methods. Finally, the deliberation of the workshop would be used in preparing a manual on coral reef assessment and management.

Staff Involved and Other Costs

a) Literature search - 1 research assistant - 6 months

b) Field studies

c) Workshop:
Travel and per diems of participants   Operational costs

d) Manual - 1 Senior Research Scientist - 4 months
- 1 Research Assistant - 6 months
Typing, publication

Output

- The main output should be a manual written in a style to give practical assistance to scientists in the Indian Ocean charged with assessing coral reef fisheries, and to managers

F. SPECIES CHANGES

Main Interested Areas: East Asian Seas region; South Asian Seas region; KAP region;

Background

Following increased exploitation, eg through the introduction of trawling, there have been large changes in the species composition of a number of communities. These changes are important in themselves, especially when some species decline very greatly, and also, because of the differences in value between species, of some economic significance. The nature and causes of these changes are not well understood, and with some exceptions such as the Gulf of Thailand, are not well documented. A better understanding of these changes is essential in forming a management policy for the resources involved. Because similar changes seem to have occurred throughout much of the Indo-Pacific region it would be useful to have comparative data for the whole region.

The Project

The project will concentrate on establishing a good data base on species changes, especially in the demersal communities. It is believed that outside the published literature information also exists in unpublished records of local fishery offices, results of surveys, etc. These data can best be obtained by visits to the offices concerned. By going back to original records it may be possible to distinguish between species that are lumped together in later compilations, eg tabulation of total national catch. Such grouping is often inevitable for some tabulations since the number of species is very high (perhaps several hundreds), but for some scientific study it will be important to keep a separation.

The project will therefore have two main thrusts. First, the examination of past data, to extract what information there is on species composition, and to place it in a readily accessible data base. Second, to collaborate with the appropriate national offices so that future information will be readily accessible.

G. ASSISTANCE IN OVERFISHING STUDIES

Main Interested Areas: East Asian Seas region.

Other Interested Areas: South Asian Seas; Eastern Africa.

Background

Many stocks of fish and crustaceans are overfished, and management is needed. The scientific advice on which the necessary management actions are based comes from the fishery research institutes in the countries concerned. These institutes are, in general, doing a good job, but do need further strengthening and support. Responsibility for this lies with the national governments, but outside assistance from the international community can be effective in assisting these institutes in carrying out their tasks.

Because the problems are similar in a number of countries, one productive form of assistance is the promotion of exchange of information, and the development of techniques capable of general application.

The Project

From the great variety of possible forms of international cooperation, the project will focus on two that appear particularly significant. The first is the development of a common data base system that will facilitate the exchange of information between countries. This will take advantage of the recent developments in computing, which have put the use of computer technology, especially micro-computers, within reach of most countries in the region. The second is related and will deal with the development of computer based methods of stock assessment and analysis, particularly the methods that are not tied to temperate water conditions, and are therefore more applicable to the region.

H. TUNA MANAGEMENT WORKSHOP

Main Interested Areas: Eastern Africa (island states); South Asian Seas region.

Other Interested Areas: Red Sea and Gulf of Aden region; KAP region.

Background

For many years, up to 1983, the tuna fisheries in the Indian Ocean have changed little. There was a moderate sized longline fishery by East Asian countries on large tuna, and significant local fisheries around Sri Lanka and the Maldives. Otherwise catches were small, and except for the larger sizes of Yellowfin, Albacore, Bigeye and southern bluefin in the Southern Indian Ocean, the stocks were much less than fully exploited. In the last couple of years a large French and Spanish purse seine fishery has developed, mostly based in the Seychelles, catching Skipjack and Yellowfin. At the same time, several coastal states, partly as a result of the establishment of 200 mile EEZs, have become more aware of the tuna resources of the Indian Ocean and have felt that the coastal states around the Indian Ocean should receive a greater share of the benefit from these resources.

The rapid increase in fishing effort, and the concerns of the coastal states are raising questions on how the tuna resources should be managed. These involve difficult biological and political problems. Because several of the species migrate over large distances - more than the full width of the Indian Ocean in the case of southern bluefin tuna - these problems need to be examined on an ocean-wide basis.

Some aspects are already being handled. The FAO/UNDP project in Colombo is compiling ocean-wide statistics, though it seems to be meeting problems in obtaining sufficiently detailed statistics from some relevant countries. FAO is also planning to arrange, as part of the activities of its Indian Ocean Fisheries Commission and its Tuna Management Committee, regular meetings of tuna scientists. However these arrangements, though important preliminaries for management, do not address the management problems directly.

In the long run it may be desirable to establish, for the Indian Ocean, an independent tuna commission, such as ICCAT in the Atlantic or IATTC in the eastern Pacific in order to achieve effective management, including conservation of the stock, and adequate participation by coastal states. This would take time. In the short run, it might be timely to examine the advantages and disadvantages of this, and other possible approaches.

The Project

The project would arrange for a workshop of technical experts, to examine alternative approaches to tuna management in the Indian Ocean, including the arrangements necessary for collection, reporting and compiling of statistics, and for scientific research. The output would be a report setting out the alternatives, and the actions that would be necessary to implement them.

I. CETACEANS

Incidental Kills

Area: South Asia Seas region

The Indian Ocean sanctuary should in theory provide an ideal protection for the large cetaceans of the whole region. However, elsewhere in the world large cetaceans are killed incidentally to fisheries' operations while the scale of kill to small cetaceans in a variety of fisheries has been considerable.

This is of particular concern for small cetaceans in the South Asian Seas region. A project aimed at surveying the extent of incidental killing of cetaceans in the waters of this region would be particularly timely. A survey has been conducted in Sri Lanka and this could serve as a model for surveys in other areas. The extent of the resources required would obviously vary depending on the waters concerned. Accordingly, initially it might be appropriate to consider a feasibility study for surveying incidental catches in the entire region. This could act as a prelude to a detailed study involving all the countries of the region. The feasibility study itself could be performed by a consultant operating for 3-4 months.

Cetacean Survey

The KAP region and the Gulf of Oman are both areas where knowledge of the abundance of cetaceans is very limited. The Gulf of Oman, because of its high productivity, might be expected to support a significant number of cetaceans. The topography of the area lends itself readily to the sort of boat-based survey already conducted by the TULIP in Sri Lankan waters. Such a survey might well complement work on other marine resource problems of the area.

J. DUGONG SURVEY

Main Interested Areas: Red Sea and Gulf of Aden region; KAP region.

Other Interested Areas: Eastern Africa.

Background

The Dugong is an endangered species, and has become very rare over all of its range outside eastern Indonesia, Papua New Guinea and northern Australia. It is difficult to determine appropriate management measures because of the very poor information on how many Dugongs are left, and where the main concentrations are.

The Project

A survey will be carried out in selected areas, using a small aircraft flying according to a carefully designed grid, using standard wildlife censusing procedures. The two main priority areas will be parts of the Red Sea, because this is believed to contain the largest population of surviving Dugongs outside its eastern stronghold, and the KAP region, because the stock here seems to have been severely affected by recent oil spills. The possibility also exists of carrying out similar surveys in other regions.

Staff and Other Costs (per survey)

Hire of aircraft (including pilot) - 2 months

1 senior scientist - 2 months

1 observer/research assistant - 2 months.

Output

- Maps showing the distribution of Dugongs, and estimates of the total numbers in the survey area.

K. PUBLIC AWARENESS

Main Interested Areas: All regions.

Background

Awareness by both the general public and by governmental and organisational decision makers of the great value of renewable marine resources, and of the urgent need to protect and manage them, is fundamental to securing the preservation of the environment and the sustainable use of resource species. Environmental conditions are comparable across many parts of the IOR, and many areas have many species in common. Therefore it is suggested that there is considerable potential for cooperation and cost cutting in generating public awareness materials (posters, leaflets, booklets, slide sets) that may be used and circulated across the whole IOR.

The Project

It is proposed that a small project team be established to generate public awareness materials and to stimulate their distribution and use. The materials would be produced either without a text, or in such a way that local text can easily be added to pictures and illustrations which can be used in any country. It is suggested that the team should concentrate, at least initially, on the production of posters, post cards, stickers, framed pictures for use in governmental offices, etc., slides and perhaps a calendar. in each case text can be limited to a slogan or short paragraph.

It is suggested that attention should also be given to the design and production of a readily comprehensible and strong durable sign, indicating that an area is protected and that fishing, collection of eggs, corals, shells or damage to marine life is forbidden. These might be mass produced and distributed in large numbers to participating countries for use in protected areas, marine parks or reserves.

Staff Involved

1 scientific co-ordinator, 1 assistant/technicial, 1 secretary.

Funds for production and circulation of material.

Limited travel funds to oversee distribution and discuss use of materials.

Output

- Sets of posters
  postcards
  framed pictures
  stickers
  slides
- Calendar

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