REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

An ecological study of sites on the coast of Bahrain

UNEP Regional Seas Reports and Studies No. 72

Prepared in co-operation with

IUCN ROPME

UNEP 1985

PREFACE

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 (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. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present 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 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 regional legal agreements and of action-oriented programme activities [2/].

During its fourth session in 1976 the Governing Council of UNEP approved the preparatory work for convening a Regional Conference on the Protection of the Marine and Coastal Environment of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. Subsequently, on the basis of a fact-finding mission sponsered by UNEP and supported by several United Nations agencies, a draft action plan dealing with the sceintific and socio-economic aspects for the protection and development of the marine environment of the region was prepared and reviewed by a series of technical meetings of Government-nominated experts. In April 1978 a Regional Conference of Plenipotentiaries was convened in Kuwait for the purpose

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

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsered by other bodies. UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

of reviewing, revising and adopting the action plan and related legal instruments. The Conference, adopted on 23 April 1978,

(a) the Action Plan for the Protection and Development of the Marine Environment and the Coastal Areas of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates, 3/

(b) the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, 4/

(c) the Protocol Concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency, 4/

(d) resolutions on (i) interim secretariat, (ii) financial arrangements, (iii) steps to be taken for the establishment of the Marine Emergency Mutual Aid Centre, and (iv) co-ordination between the regional marine meteorological and environmental programmes 3/.

The Action Plan has subsequently become known as the Kuwait Action Plan.

Within this Action Plan, the Governments have approved a number of projects and assigned priority to some of them. The ecological study of sites on the coast of Bahrain was one of these priority projects.

The study was entrusted to the International Union for Conservation of Nature and Natural Resources (IUCN) under the general supervision of the Regional Orgainzation for te Protection of the Marine Environment programme (ROPME) and the United Nations Environment Programme (UNEP). IUCN has undertaken the study in co-operation with the Bahrain authorities (the National Focal Point, the Directorate of Fisheries, the Directorate of Environmental Protection, and others).

The main objective of the project was to initiate an ecological study of the intertidal and subtidal biota at selected sites around Bahrain, with special reference to the shrimp fishery and the Saudi-Bahrain causeway under construction. The study has involved quantitative sampling of the fauna and flora, and of selected oceanographic factors at 12 stations covering three sites around the northern half of Bahrain.

This publication is an Abridged Report on the study. The detailed report is contained in a volume of which only a few copies have been produce and which are available at the Secretariat of ROPME, IUCN and UNEP.

3/ UNEP: Action Plan for the protection of the marine environment and the coastal areas of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. UNEP Regional Seas Reports and Studies No. 35. UNEP 1983.

4/ Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution and Protocol Concerning Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency. UNEP 1983.

ABRIDGED REPORT: AN ECOLOGICAL STUDY OF SITES ON THE COAST OF BAHRAIN

The present project has been carried out as part of the 1982/83 programme of investigation of the Regional Organization for Protection of the Marine Environment (ROPME) into the marine environment of the Kuwait Action Plan (KAP) Region. The study has been undertaken within the framework of the United Nations Environmental Programme (UNEP) by two consultants (Dr. A.R.G. Price and Mr. D.H.P. Vousden) of the International Union for the Conservation of Nature and Natural Resources (IUCN) from the Tropical Marine Research Unit (TMRU) at the University of York, United Kingdom. The work was carried out in close co-operation with, and with assistance from, the Directorate of Environmental Protection of the Ministry of Health, Bahrain.

The main objective was to initiate an ecological study of the intertidal and subtidal biota at selected sites around Bahrain, with special reference to the shrimp fishery and the Saudi-Bahrain Causeway currently under construction. Results from oceanographic and biological sampling at six coastal and six offshore sites around Bahrain form the basis of this study. The sites selected on the east coast are located at Askar (N and S) and on the west coast at the Causeway (N and S) (i.e., on the north and south sides of the causeway respectively) and at Zallaq (N and S). Additional scientific observations and collections (e.g., of critical marine habitats, animal counts, pollution, etc.) were made at a number of other localities, including the Hawar Islands and the coral reefs on the east side of Bahrain.

The detailed results obtained from the oceanographic and biological survey are summarised below, following a review of available information on critical marine habitats and species of economic, scientific and cultural importance.

In the coastal province of Bahrain, and in the Gulf as a whole, three major critical marine habitats are recognised - mangroves, seagrass beds and coral reefs. Mangroves in the ROPME sea area are represented by a single species, Avicennia marina, though in Bahrain there are now few mangroves left. The last known stand of mangrove of any significance can be found near Sanad. This area displays the typical high productivity associated with mangrove communities with, for example, concentrations of molluscs greater than 500 m^{-2}.

Because of the physical conditions prevailing in the Gulf, coral reefs are not as widely distributed as in many tropical seas, and the growth and diversity of corals is not as great (see Basson et al. 1977). Although the variety of corals is higher than previously supposed, only 24 genera of hermatypic scleractinians have been recorded from the ROPME sea area (Burchard, 1979), compared with 36 and 55 in south-east Arabia and the Red Sea respectively (Rosen, 1971). However, Inner Gulf coral reefs are of particular interest to scientists because they manage to exist in an environment of high salinities and wide temperature variation near the limit of their tolerance. They also provide reef ecologists with an opportunity to study an otherwise highly complex community in a relatively simple form. In addition, the reefs in the Gulf are of considerable economic and social significance.

All three species of seagrass known for the Gulf occur around Bahrain: Halodule uninervis, Halophila ovalis, and Halophila stipulacea. These seagrasses are well-known for their eurythermal and euryhaline nature, but H. uninervis is probably the commonest locally. Seagrasses provide a food source for many marine animals. Turtles and dugong feed directly on the growing plant, as do some fish, notably rabbitfish (Siganus spp.). Also associated with seagrass are many animals

beside those that feed on it, including species of economic and cultural importance such as the commerical shrimp (Penaeus semisulcatus), and pearl oysters (Pinctada spp.) which rely on seagrass for larval settlement and growth. Around Bahrain seagrasses play a key role in maintaining the productivity of local fisheries, and the mapping and conservation of the seagrass beds must be considered of paramount importance.

At the present time, critical marine habitats, especially mangroves and the intertidal flats with which they are associated, are being degraded or are actually disappearing as a result of coastal in-filling and other activities associated with Bahrain's industrial development programme. The status of coral reefs and seagrass beds is also precarious in certain areas. Other renewable natural resources of special value around Bahrain include certain additional critical marine habitats (e.g. intertidal and shallow subtidal sand-mud flats), as well as organisms such as pearl oysters, turtles, birds, whales and dolphins, probably dugong and also various endemic species. The fisheries are considered separately below.

The oceanographic survey included measurements of water temperature, salinity, turbidity (suspended particulate matter, sedimentation and secci disc readings), chlorophyll and zooplankton abundance. Large seasonal variation in water temperature was recorded at both the coastal (14-35°C) and offshore sites (13-31°C), the range being greater than in comparable latitudes elsewhere because the Gulf is shallow and almost landlocked. In particular, the limited depth of the Gulf results in a relatively small thermal capacity, allowing water temperature to track air temperature much more closely than occurs in open ocean areas. Extremes in temperature (high and low) have also been reported in other parts of the Gulf (Enomoto, 1971; Basson et al., 1977; Price, 1979), and this undoubtedly limits the number of species that can survive in the area.

Salinities at the study sites were always high, but were approximately $10^{o}/_{oo}$ greater at the west coast sites (means $50-57^{o}/_{oo}$) than at the east coast sites means $43-45^{o}/_{oo}$). This is partly a result of the geographic position of Bahrain with only a shallow, relatively narrow stretch of water separating the west coast from the Arabian mainland. Also of significance is the complex pattern of water circulation in the region of the Gulf, and the effects of a large, almost stationary and highly saline body of water known as Dawhat Salwah lying to the south-west of the Bahrain Archipelago. Spot salinity measurements (coastal and offhore) were also taken around much of Bahrain, and showed that salinity generally increases from north to south on both the east and west coasts and that salinity is higher on the west than on the east coast. In the immediate vicinity of the causeway between Umm Na'san and Bahrain, salinities were $9^{o}/_{oo}$ greater on the south side of the causeway ($57-59^{o}/_{oo}$) than on the north side ($48-50^{o}/_{oo}$). This appears to have had some impact on the fauna and flora, but only in the immediate area.

Secci disc readings and measurements of suspended particulate matter (spm) made at the offshore sites suggest that the water is more turbid at the Causeway (N) site than at the other sites on the west coast, according well with visual observations. Secci disc results also indicate a progressive decrease in water turbidity (3.0-7.4 m) from Causeway (N) down the coast to Zallaq (S). The pattern is believed to be a reflection of the extensive dredging operations that have taken place around the north of the causeway. On the east coast, both secci disc readings and measurements of spm show that, for example, at Askar (N) turbidity is variable, but often very high. Again, frequent large-scale dredging to the north of Askar is the probable cause. Data from sedimentation traps are difficult to interpret (Mann, 1982), particularly since, during the present study, the traps could not be left down for the same period of time for logistical reasons. Nevertheless, very high sedimentation (5.9 ml $m^{-2}hr^{-1}$) was recorded at both Askar sites, though little was recorded on the west coast (0.13-0.52 ml m^{-2} hr^{-1}).

The overall picture obtained is that turbidity is relatively high at the Causeway (N) and Askar (N) areas, principally as a result of dredging. The adverse effects of dredging and high turbidity on biological communities are well documented and are further discussed below.

Measurements of chlorophyll in seawater samples collected around Bahrain suggest that planktonic primary productivity is low, agreeing with results obtained around Bahrain prior to construction of the causeway (unpublished data). Values obtained during this study ranged from 0.49-1.28 mg m^{-3} and it appears that phytoplankton levels may be higher on the east coast than on the west coast, an effect which might be expected in view of the salinity difference between the two sides of the island. During the present investigation chlorophyll concentrations were also measured for benthic microalgae on intertidal sediments. The results suggest that benthic primary productivity is of much greater importance than productivity in the water column by phytoplankton in shallow coastal areas. This is discussed in more detail below.

Zooplankton abundance (secondary productivity) was low during the investigation (0.0056-0.1819 ml m^{-3}), reflecting the low chlorophyll levels recorded in the water column (primary productivity). These values are lower than those recorded nearby in Saudi Arabia (Price, 1979; 1982b), largely as a result of the higher salinities prevailing around Bahrain. Equally, around Bahrain, highest values were recorded on the east coast (Askar sites), and on the west coast the mean zooplankton abundance was higher at Causeway (N) than at Causeway (S); these results confirm an inverse relationship between planktonic productivity and salinity.

Biological studies revealed the presence of a rich epibenthic (surface) fauna on the intertidal flats at Askar (N) and Causeway (N) in particular, and also to a lesser extent on the lower intertidal at Askar (S). Conspicuous elements of the surface fauna included both algal feeders (e.g., cerithid gastropods) and various scavengers or predators such as crabs (Macrophthalmus depressus, Portunus pelagicus) and even octopus and sea snakes (Hydrophis cyanocinctus/lapemoides), as well as numerous birds. The rich intertidal fauna is attributed largely to the high productivity of benthic algae - principally diatoms, blue-green and filamentous green spieces; however, partially submerged seagrass also contributes to this productivity at Askar (N). In many parts of Bahrain this benthic productivity seems to be much more important than planktonic productivity.

Intertidal infauna consisted largely of polychaetes (e.g., Ceratonereis erythraeensis). The variety of infaunal polychaetes shows the same distributional pattern observed for the surface fauna, with a greater number of species at the Askar (N) and (S) and Causeway (N) sites than at the other intertidal sites. At the Causeway (S) intertidal site both the infauna (polychaetes) and surface fauna may be relatively impoverished. However, the polychaete infauna was also limited at Zallaq (N) in terms of species (2), despite the high density of individuals (>900 m^{-2}).

Visual fish counts over a 200 m long 5 m wide transect were made at each paired (N and S) site, and at a spot survey on Fasht Adham. Dominant fish species were recorded and different trophic categories of fish could be clearly distinguished. The common species in nearly all categories are known to be commercially important and are supported by the benthic food chain; thus, they are ultimately dependent on the productivity of the benthic flora.

Beach seine studies were undertaken at four of the coastal sites - Askar (N), Causeway (N) and (S) and Zallaq (N). Large numbers of small fish were collected at Askar (N) and Causeway (N). These results, together with the visual counts made underwater, have indicated that a major portion of the dominant species (e.g. Siganus sp., Diplodus noct, Gerres oyena, Upeneus tragula) are either herbivores,

feeding directly on the algal growth, or detritivores feeding on the organic material and meiofauna derived principally from the decomposition of the plant material. Many other species (e.g. Sillago sihama, Lutjanus ehrenbergi, Lethrinus nebulosus), are predators which feed on bottom-living worms and crustaceans, or on other benthic fish. Only a few species observed inshore (e.g. Allanetta forskali, Sardinella fimbriata) are plantivores, or are predators of smaller planktivorous fish (e.g. Caranx spp.), and so rely directly or indirectly on phytoplankton productivity within the water column. These conditions correspond to the much greater importance of benthic productivity in inshore waters discussed above.

Collections made by beach seine have also revealed that the Causeway (N) and Askar (N) coastal sites are nursery areas for various penaeid shrimps, including the commercially important species, Penaeus semisulcatus, which was particularly abundant at Askar (N). Another large species, Penaeus latisulcatus, was also recorded in both areas but in greater numbers at Causeway (N). The large populations of shrimps and fish at these sites are undoubtedly supported by the rich surface fauna and infauna present. In contrast, there were relatively low beach seine catches and an impoverished invertebrate fauna at the Causeway (S) coastal site, which may well be due to the increased salinity resulting from the causeway. The catches were similarly impoverished at Zallaq (N), again probably a result of the (here naturally occurring) high salinity.

Results of biological studies at the offshore sites present a somewhat different picture. Seagrass beds were examined both at and around the study sites, and at a number of other offshore locations. Within the study site areas seagrass was wide-spread at Askar (N) and (S) with all three gulf species represented. Seagrass was also observed at the Causeway (N) site but, significantly, most was dead or dying and recently burried under 25 cm of silt. Helicopter overflights followed by spot-diving confirmed the presence of extensive beds of seagrass on the eastern coastline, and revealed additional beds as far south as the Hawar Archipelago, but only a restricted distribution on the western coastline.

The relatively high abundance of seagrass at Askar and other areas on the east coast is undoubtedly related to the less stressful salinity conditions (42-46°/$_{oo}$) there. In contrast, the more limited occurrence of seagrass at the west coast sites is partly due to the higher salinity (46-58°/$_{oo}$) prevailing on the west coast. However, differences in the nature of the seabed are also involved, the thin layer of sediment over flat rock found in some parts off the west coast being much less suitable for growth of seagrasses.

The greatest number of species of surface fauna at the offshore sites was observed at the Askar (S) and Causeway (S) sites. At the Causeway (N) site there was a complete absence of surface fauna during three successive sampling periods, clearly due to the heavy siltation mentioned above. A relatively impoverished surface fauna was also apparent at Askar (N) and again this could well be a reflection of the effects of dredging and increased turbidity.

Penaeid shrimp larvae were almost entirely absent in plankton samples collected from the offshore sites, indicating that the sites themselves may not be shrimp spawning areas. However, because of the localised nature of shrimp spawning in the Gulf (Basson et al., 1977; Price, 1979, 1982b), the possibility of spawning occuring in nearby areas cannot be precluded. Planktonic and juvenile shrimps are the most vulnerable stages of the shrimp life cycle and, for this reason, conservation of both spawning grounds (when located) and nursery areas is of vital importance to the continued welfare of the fishery.

Catch statistics and other information, as discussed in the report, indicate that the catch of shrimp declined markedly over 1977-1979, in association with a rise in the numbers of industrial trawlers, but that following the introduction in 1980 of a closed season from February to June, the catches have risen again each year from 1979-1982. The decline up to 1979 was assumed to be the result of over-fishing, particularly during the spring spawning and recruitment period. However, it is important to emphasize the role that damage to and loss of critical habitats could have in reducing catches. Loss of intertidal mud flats and mangroves by in-filling, and damage to subtidal seagrass beds from dredging and sedimentation, will greatly reduce the food and shelter available to the shrimps. Thus, this will result in reducing the size of the stock and making over-fishing of the reduced stock a more probable occurrence.

Catches of fin fish appear to have risen and then levelled off over the last few years. The rise can largely be attributed to an increased efficiency and effort of fishing. An increasing number of industrial trawlers alternate between catching shrimp and fin-fish, according to season; and much of the artisanal fishing now appears to be carried out by an increasing number of small, fast, open workboats with a greater fishing range than the old sailboats. However, the same point that has been made concerning the shrimp fisheries may be made with regard to fin fisheries. A large proportion of the species caught depend directly or indirectly for their food on the high primary productivity of seagrass beds, coral reefs, and intertidal and shallow subtidal sand-mud flats.

The extent of shallow water in-filling and sediment damage to reefs and seagrass beds is such that this cannot but have reduced the size of the fish stock available in inshore waters. Much of the intertidal habitat loss, and sedimentation of seagrass beds observed appears to be relatively recent in origin and has perhaps been occurring at an increasing rate over the last 5-10 years. The extent of loss of intertidal habitat and damage to subtidal habitats has reached the level where it is difficult not to believe that this has had an impact on the shrimp and other fisheries in Bahraini waters. It is predicted that if the loss and damage continues at the same rate for any length of time, this will result in a severe decline in local shrimp and fish catches, particularly in the artisanal section. There are already reports that the landings at some fishing villages are now declining, and the fishermen are complaining that extensive dredging is affecting their fishing grounds.

By contrast, there is no clear evidence that construction of the causeway has so far had any major effect on the shrimp or fin fish in that region. There has been some loss of seagrass beds near and just to the north (Causeway (N) site) of the embankment, but in proportion to the extent of the seagrass beds along the west coast, the area concerned is quite small. As mentioned previously, there has also been a clear increase in salinity (up to $10^{o}/_{oo}$) in a small region immediately south of the embankment, and this has probably slightly reduced productivity and species variety in that area. But to date salinity elevation has not spread more than 0.5 to 1 km down the coast, and there is no indiction that the causeway has yet impacted the marine life in the Zallaq region, either onshore or offshore. However, because the salinity along the west coast is already high, more than a small further general increase in salinity could well eliminate both seagrass beds and shrimp from that area. It is known that both P. latisulcatus (Jones et al., 1978) and P. semisulcatus (Buchard, personal communication) can tolerate salinities of up to $60^{o}/_{oo}$ at least as adults. Also, seagrasses, particularly Halodule uninervis, have been found in salinities of up to $60^{o}/_{oo}$, but they are probably not able to tolerate much higher salinities. Thus, for productivity to be maintained, general salinity along the west coast should not increase beyond this level.

Apart from increased salinity and turbidity (mentioned above), the causeway may have other environmental effects. For example, it may possibly create a barrier to migrating shrimps and fish. Also, sinking of the piles into the seabed has necessarily caused a certain amount of habitat destruction. On the other hand, the causeway may be of some ecological benefit by acting as an 'artificial reef'; some of the pilings have already become colonised by various sessile organisms (e.g., algae and barnacles), which in turn appear to be providing food or refuge for larger animals such as fish (e.g., Epinephelus tauvina). Secondary effects resulting from the causeway are likely to include a general increase in industrial development, and additional pressure on already heavily utilised coastal natural resources.

In addition to the causeway, there are other factors degrading the coastal environment of Bahrain. These include discharge of sewage and industrial effluents, as well as dredging, blasting and coastal in-filling associated with the causeway. Direct destruction by dredging comes from physical damage to the seabed or reefs. In the case of soft bottom communities, this can render the scoured sediments unsuitable for recolonisation by seagrass and associated fauna for many years. On the east coast of Bahrain near Sitra, channels have already been cut directly through the fringing reef, destroying large tracts of otherwise healthy coral. As well as the direct physical damage, secondary effects from dredging can be considerable. For example, increased turbidity can limit the production of phytoplankton (McLusky, 1981), as well as benthic communities, such as the seagrass beds (Zieman, 1975) and coral reefs (Johannes, 1975; Schumacher, 1977), by reducing light penetration and photosynthesis.

The effects of the Nowruz (Iranian) oil spill of February 1983 on the marine life of Bahrain are not clear, but these seem likely to be less significant than the considerable effects of in-filling and dredging.

A number of recommendations arise from this study. They aim, principally, at minimising environmental consequences resulting from the construction of the causeway and at reducing impacts caused by other factors. Specific recommendations include:

(a) control of impacts on critical marine habitats, principally by regulation of dredging and coastal in-filling; in this regard, several sites were considered to be in need of urgent protection; they include mangroves at Sanad, seagrass beds south-east of Bahrain, and intertidal mud flats on the north and east coasts;

(b) continued monitoring of the effects of the causeway; a limit should also be set whereby the salinity within 1 km south of the causeway would not rise to more than $60^{o}/_{oo}$, and the salinity anywhere between 2.5 and 25 km south of the causeway should not rise above $58^{o}/_{oo}$; methods are also given for reducing the salinity should the proposed limit be approached;

(c) management of the shrimp and fin fisheries, including accurate monitoring of landings, as well as continuation of beach seine studies on a regular basis to monitor juvenile populations;

(d) other recommendations, which include continued monitoring and combating of oil pollution, and other coastal impacts; such work should complement studies and activities currently being undertaken by the Directorate of Environmental Affairs; the mapping of critical marine habitats should also be considered to be of high priority.

PUBLICATIONS IN THE UNEP REGIONAL SEAS REPORTS AND STUDIES SERIES

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No. 21 CPPS/UNEP: Sources, levels and effects of marine pollution in the South-East Pacific. (1983) (In Spanish only)

No. 22 Rev. 2. UNEP: Regional Seas Programme in Latin America and Wider Caribbean. (1985)

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No. 25 UNEP: Marine pollution. (1983)

No. 26 UNEP: Action Plan for the Caribbean environment programme. (1983)

No. 27 UNEP: Action Plan for the protection and development of the marine environment and coastal areas of the West and Central African region. (1983)

No. 28 UNEP: Long-term programme for pollution monitoring and research in the Mediterranean (MED POL) - Phase II. (1983)

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