The 1991 Gulf War: Environmental Assessments of IUCN and Collaborators

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WWF - WORLD WIDE FUND FOR NATURE

WWF - World Wide Fund for Nature is the world's largest private international conservation organisation with 28 Affiliate and Associate National Organisations around the world and over 4.7 million regular supporters. WWF aims to conserve nature and ecological processes by preserving genetic, species and ecosystem diversity; by ensuring that the use of renewable natural resources is sustainable both now and in the longer term; and by promoting actions to reduce pollution and wasteful exploitation and consumption of resources.

IOC - INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

The IOC was established in 1960 as a body with functional autonomy within UNESCO to promote marine scientific investigations and related ocean services, with a view to learning more about the nature and resources of the oceans through the concerted action of its members. The IOC promotes, plans and coordinates observing and monitoring systems on the marine environment; and promotes preparation and dissemination of processed oceanographic data, information and assessment studies, and development of standards, reference materials and nomenclature for use in marine science and related ocean services.

IAEA - INTERNATIONAL ATOMIC ENERGY AGENCY

The IAEA Marine Environment Laboratory at Monaco is a Technical Division of the International Atomic Energy Agency and is the only marine laboratory within the UN system. MEL's primary aims are to help Member States understand, monitor and protect the marine environment from pollution, and to coordinate technical aspects of international marine protection, training and assistance programmes. The Laboratory's scientific and technical programmes are carried out in close cooperation with the Principality of Monaco, UNEP and the IOC.

THE MARINE AND COASTAL AREAS PROGRAMME

IUCN's Marine and Coastal Areas Programme was established in 1985 to promote activities which demonstrate how conservation and development can reinforce each other in marine and coastal environments; conserve marine and coastal species and ecosystems; enhance awareness of marine and coastal conservation issues and management; and mobilise the global conservation community to work for marine and coastal conservation. The Marine Conservation and Development Reports are designed to provide access to a broad range of policy statements, guidelines, and activity reports relating to marine issues of interest to the conservation and development community.

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Summary

This document summarises the results of environmental assessments of the 1991 Gulf War undertaken by IUCN-the World Conservation Union and collaborators during the period 1991 to 1993.

Hostilities in Kuwait in January 1991 resulted in the discharge of an estimated 6-8 million barrels of oil, making it by far the world's largest oil spill. This was followed by the conflagration of more than 600 oil wells, which had atmospheric consequences on both terrestrial and marine ecosystems. In addition to these and the more direct effects on human well-being, there were 'secondary' effects including destruction of sewage treatment plants in Kuwait.

The first section of the document provides a background and pre-war setting to the Gulf, in terms of its biological and human environments. This preview is followed by a summary of the major findings of each study. Following initial post-war assessments, studies have included broadscale assessment of coastal ecosystems, analysis of contaminants in sediments, biota and seawater, studies on coral reefs and assessment of the shrimp fisheries.

Broadscale coastal surveys were undertaken in 1991, 1992 and 1993, and comparisons made with 'baseline' data collected at the same sites before the war (1986). Not surprisingly, oil levels were significantly greater in 1991 than during 1986. On the other hand, the abundances of certain species groups halophytes, birds and fish) were significantly higher in 1991 than in 1986. Oil levels in 1992 and 1993 decreased to levels not significantly different from 1986, suggesting some recovery of at least surface substrata.

Quantitative analysis of sediments and biota revealed that the highest levels of contamination were along the heavily-impacted coast of Saudi Arabia between Ras Al Khafji and Ras Al Ghar, where concentrations of total petroleum hydrocarbons (expressed as Kuwait crude oil equivalents) ranged from 62-1400 μg^{-1} dry wt in surface sediments, 570-2600 μg^{-1} dry wt in clams and 9.6-31 μg g-l dry wt in fish muscle. Gas chromatographic analyses indicated that much of the spilled oil in at least the surface layer of the intertidal zone had substantially degraded within a few months of the spill. However, core sampling more that two years after the war revealed a very contaminated layer at many sites in the intertidal and shallow subtidal just a few centimeters below the sediment surface. This initial regional survey demonstrated that hydrocarbon contamination originating from the war-related pollution events was restricted to approximately 400 km from the source, that levels of combustion derived PAH's in the marine environment at that time (e.g. 1-450 ng g^{-1} dry wt for pyrene in sediments) were of the same order as those which have been measured in several coastal areas of the United States and northern Europe. Outside the immediate area of impact, petroleum hydrocarbon and trace metal levels in sediment and bivalves were generally as low as, or lower than, those concentrations measured at the same sites before the war.

Petroleum hydrocarbon concentrations in the nearshore sea surface of northern Saudi Arabia have decreased significantly since initial assessments in August 1991. Nevertheless, in August 1992 more than one and a half years after the Gulf War oil spill, relatively high and toxic concentrations of contaminants remained in the nearshore surface waters of Kuwait and Saudi Arabia. Toxicity tests on marine invertebrate (heart urchin) larvae indicated that the subsurface water column was not toxic, but the sea-surface microlayer at about half the sites sampled demonstrated significant toxicity. The order of toxicity was Khafji (Saudi Arabia) > Fahaheel (Kuwait) > Qaruh Island (Kuwait)> Ras al Mishab (Saudi Arabia) > Manifa (Saudi Arabia).

Studies in Kuwait and Saudi Arabia investigated possible war impact on reef and coral fish populations. This was undertaken against a background of detailed knowledge of their ecology (particularly in Kuwait) gathered in the years leading up to the Gulf War. No evidence of pollution damage was detected on the Saudi Arabian reefs, and apatchy distribution of mortality in three species of coral was found on the offshore Kuwait reefs. It is concluded that natural fluctuations in the coral reef community may have effectively masked any supposed medium-term impact of the Gulf War.

Concern also arose that the 1991 Gulf War oil slick, and/or reduced light and temperatures from the burning oil wells, may have affected coral and reef growth. Small coral colonies were therefore collected for geochemical and related analysis. Provisional results have been obtained, analysing the outer four annual rings of a Saudi Arabian Gulf coral. ‘Enrichment’ of fresh oil on the outside and higher concentrations of degraded oil within the head are evident. Preliminary analysis has also revealed relatively high levels of mercury (Hg) in the corals from Kuwait (140-230 ng g-l dry wt).

Analysis of the fisheries point towards a real and sudden decline in shrimp stocks. In 1991-92 the Saudi Gulf shrimp stock showed a decline in spawning biomass to about 1-10%, and a decline in total biomass to about 25%, of the pre-war level. This is because spawning biomass in autumn fell to zero as observed in the artisanal fleet’s landings. The CAI gives higher average values for the 1991-92 period, but in autumn 1991, crucial for autumn spawning, there were few if any adults in the population. This decline in spawning biomass by at least an order of magnitude is likely to cause a reduction in recruitment and make the stock more sensitive to recruitment over-fishing. The low spawning biomass improbably causally related to the decline stock size and condition that occurred subsequent to pollution by oil spills and oil smoke following the firing of Kuwaiti oil wells in February 1991. The statistics, although still partly tentative, are worrying because fishing ceased at the onset of the war for several months, and shrimp populations would normally be expected to rise.

Shrimp eggs and larvae are particularly susceptible to environmental stress, and severe reduction in water or habitat quality can potentially disrupt spawning and impair recruitment. During the known spawning season (April) of commercial shrimp, *Penaeus semisulcatus,* the abundance of larvae was significantly reduced at two major spawning areas (Safaniya & Ras Tanura) in 1992, compared with abundance data from the 1970's. Possible reasons for the observed patterns include natural environmental changes, ‘normal’ background impacts (e.g. coastal reclamation/dredging, pollution) and impacts arising from the 1991 Gulf War. It is suggested that interactions between these and perhaps other factors, rather than any single cause, may be involved.

The 1991 Gulf War generated much concern and interest, nationally, regionally and internationally. Whether or not environmental predictions about the 1991 Gulf War have matched reality is still under discussion. Research to date indicates that a simple answer cannot realistically be provided for several reasons. First, predictions often have differed widely, ranging from the Gulf becoming virtually lifeless to more or less trivial effects. In addition, not all areas of the Gulf suffered the same overt damage. Further, different ecosystems that were exposed to oil or smoke were not necessarily affected in the same way. The degree of environmental damage from an event such as a war depends also on the time-scale over which its effects are considered.

Extended forms of governance are advocated to address interconnections between the environmental and human domains, and to deal more effectively with transboundary problems and opportunities. In particular the need is demonstrated for greater integration of the social and natural sciences; and from this development of multidisciplinary models, to improve understanding of the Gulf and to determine its governing needs.

Whatever the eventual environmental outcome of the 1991 Gulf War, there is a growing realisation that marine renewable resources often contribute significantly to national economies and even geopolitical stability. Indeed their effective assessment and management is fundamental to sustainable development. The recent war highlighted dramatically both the importance and vulnerability of the Gulf's marine environment.

Acknowledgements

We wish to thank the organisations listed in Annex 2, for their collaboration and assistance. In particular, grateful acknowledgement is made to IUCN- the World Conservation Union, World Wide Fund for Nature (WWF-International & WWF-Japan) and the Japanese International Cooperation Agency for financial support.

1. Introduction

The military hostilities in Kuwait in January 1991 resulted in the discharge of vast quantities of oil into the Gulf's marine environment. Although the total volume of the spill is still not fully agreed upon, most estimates indicate c. 6-8 million barrels, making it by far the world's largest oil spill. By comparison, the spill from the *Ixtoc 1* was less than four million barrels, and from the Amoco *Cadiz, Torrey Canyon, Exxon Valdez* and *Braer* less than two million barrels in each case. In addition, the conflagration of more than 600 oil wells in Kuwait had produced severe atmospheric pollution (Bakan *et al.*, 1991; McCain *et al.*, *1993)* with effects on both terrestrial and marine ecosystems. 'Secondary' environmental effects of the war included destruction of sewage treatment plants in Kuwait, resulting in the discharge of over 50,000 m^3/day of raw sewage into Kuwait Bay, threatening the intertidal systems, polluting public beaches and downgrading the quality of seawater used for desalination (Gerges, 1993). There were also the more direct and serious effects on human life, health and well being.

This document summarises the results of environmental assessments of the 1991 Gulf War undertaken by IUCN - the World Conservation Union (see Annex 1 for acronyms) and major collaborating agencies, organisations and institutions (Annex 2) during the period 1991 to 1993. Several organisations and institutions not shown in Annex 2 also worked jointly with IUCN in aminor way or indirectly. Most of the collaborative studies are described more fully in a special issue of *Marine Pollution Bulletin (Price&* Robinson, 1993).

The first section of this document (following the Introduction) provides a background and pre-war setting to the Gulf, in terms of its biological and human environments. Much of this is taken directly from Sheppard *et al.* (1992). This is followed by a summary of the major findings of each study. Several of the studies have considered the impacts on a range of ecosystems, while others have focussed on particular ecosystems such as coral reefs and associated fish communities. Special emphasis has been given to the shrimp fisheries, in view of their major socioeconomic and biological importance. These studies have included stock assessment and monitoring of shrimp spawning activity via examination of eggs and larvae. Wherever possible, comparisons have been made with pre-war data available through earlier IUCN studies and other research. The final section attempts to provide a synthesis and some conclusions.

2. The Gulf: Its Setting

2.1 Historic importance

People have been attracted to the shores of the Gulf formillenia. An early maritime civilisation, Dilmun, prospered some 4,000-5,000 years ago, encompassing what is now Bahrain and the eastern coast of Saudi Arabia. Before the tenth century AD, the Arabs had established a trade network extending from the Gulf as far eastwards as China. Using stitched, lateen-rigged craft, cargoes of textiles and spices were accompanied by the exchange of new ideas, science and religion. Such voyages were made possible through the Arabs' sophisticated knowledge of astronomy and navigation. Nowadays, there is still some trade using traditional craft *(dhows)*, now motorised, between the Gulf, Pakistan and East Africa. However, the *dhow* trade has been largely replaced by more modem transport.

2.2 Present day uses, values and impacts

Coastal uses and values

The Gulf's marine environment is becoming increasingly important in fulfilling social, economic, development and strategic objectives of the region. The Gulf (together with the Red Sea) plays a particularly vital role in providing most of the population with freshwater from desalination plants. Fisheries are a multi-million dollar industry, and the artisanal fisheries in particular are also a resource of great social significance. The Gulf's coastal and marine environment harbours birds and other wildlife of international as well as national significance, including a high proportion of species unique or 'endemic' to the region. Renewable resources and an uncontaminated marine environment therefore play a pivotal role in regional prosperity and sustainable development. Discovery of oil in the Gulf during the 1930s and 1940s led to a massive increase in shipping, and was principally responsible for the immense economic wealth and strategic importance associated with the region today.

Impacts and pressures

Coastal uses and other human activities have inevitably impinged on the Gulf environment (Table 1), the extent and magnitude varying geographically. These activities and their effects on the Gulf environment are briefly analysed, together with coastal management activities (below), to understand the context of impacts from the 1991 Gulf war (see also Sheppard *et al.*, 1992; Price, 1993).

Oil, domestic, urban and industrial pollutants are a problem in several parts of the Gulf, although effects on ecosystem structure and function are generally not well known. The coastal zone is also fast becoming the repository for solid wastes. Major ecological problems have arisen from loss/degradation of productive coastal habitats, caused by coastal landfill, dredging and sedimentation. In some Gulf States (eg. Saudi Arabia) more than 40% of the coastline has now been developed. Anchor damage to coral reefs now a problem on Jurayd island and possibly elsewhere. In addition to fishing, hunting of bird eggs is intensive in some areas. Agriculture does not appear to be causing major coastal environmental problems, but further studies are needed. Possible longer-term coastal impacts in the Gulf include effects of global climate change, acid deposition and large-scale marine ecosystem instability.

Table 1.
Coastal and marine uses and major environmental pressures in the Gulf (from Sheppard *et al.*, 1992; Price, 1993).

Coastal and Marine Use	Actual or Potential Environmental Pressures
Shipping and Transport	
Shipping	Oil spills; anchor damage
Ports	Coastal reclamation and habitat loss; dredging, sedimentation; oil and other pollution
Residential and Commercial	Coastal reclamation and habitat loss; dredging, developments sedimentation; sewage, fertiliser and other effluents; eutrophication; solid waste disposal
Industrial Development	
Oil & Petrochemical Industry	Oil, refinery and other effluents containing heavy metals; drilling muds and tailings; air pollution
Mining	Sedimentation and elevated heavy metal levels
Desalination & seawater treatment plants	Effluents with elevated temperatures, salinities and sometimes heavy metals and other chemicals
Power plants	Various effluents; air pollution, increasing greenhouse gases and global warming; acid deposition
Fishing and collecting	Population decline of target and non-target species and changed species composition of fish, shrimp and other biota; habitat degradation (including anchor damage)
Recreation	Some reef degradation from anchor damage and collecting
Agriculture	Local eutrophication (eg. from fertilisers); only low levels of insecticides such as DDT, aldrin, dieldrin and lindane recorded in marine sediments and biota; saline intrusion and possible effects on coastal ecosystems

2.3 Previous environmental and biological studies

The earliest expedition to the Arabian region was that of a Danish survey team in 1762, including the zoologist Forskål. The results, giving the descriptions of many marine plants and animals subsequently found in the Gulf were published posthumously (Forskål, 1775). Niebuhr, the only surviving team member, continued the work and subsequently visited the Gulf. The first major expeditionto the Gulf was Danish Scientific Investigations in Iran (Jessen & Spårck, 1939-49). This was followed by various cruises and studies, which included oceanographic research undertaken from the German vessel *Meteor (eg.* Brettschneider *et al.*, 1970; Rabsch, 1972) and the Japanese vessel, *Umitaka Maru* (Kuronuma, 1974). There have also been biological contributions from scientists working on sedimentary processes in UAE (Purser, 1973). During the 1970s and 1980s environmental activities and fishery investigations expanded in many parts of the Gulf.

In the western Gulf, particularly Saudi Arabia, very little marine scientific information was available prior to ecological studies undertaken by SAUDI ARAMCO during the 1970s (Basson *et al.*, 1977). Thereafter research and monitoring has increased, often from environmental concern over the extraction, refining and transport of oil, and the array of other activities linked to coastal development. During the 1980s, an active enviornmental and research role was, and continues to be, taken by MEPA, SAUDI ARAMCO, KFUPM RI, NCWCD and other local institutions, often in collaboration with outside agencies and organisations.

Of particular significance has been the collaborative environmental activities of MEPA with IUCN, which included an assessment of ecosystems (biotopes) and management requirements (IUCN/MEPA, 1987a). This work, together with similar studies in the Red Sea (IUCN/MEPA, 1987b,c) culminated in a framework for a coastal zone management programme (IUCN/ MEPA, 1987d). These assessments adopted an interdisciplinary approach, and involved marine ecologists, oceanographers, ornithologists, ocean and coastal planners and environmental lawyers with specialist knowledge of islamic law, or *Sharia.*

It appears that prior to the 1970s there was greater understanding of marine ecosystems along the eastern Gulf. However, this situation has reversed and the Iranian side of the Gulf is currently among the least studied marine areas in the world.

Summarised pre-war information for the Gulf is given in a recent ecological review of the Arabian region (Sheppard *et al.*, 1992). This also includes an account of the fisheries, human uses and aspects of coastal zone management.

2.4 Coastal zone management (czm)

CZM programmes

The coastal zone management programme developed in Saudi Arabia and other Gulf States, such as Oman, has provided a framework aimed at balancing the needs of development with those of conservation.

Among the analyses undertaken in Saudi Arabia were identification of principal resource use conflict areas by map analysis (IUCN/MEPA, 1987a), as follows. A summary map was compiled of major coastal and marine uses (Figure 1) (see also 'Present day uses, values and impacts' above). Areas of concentrated key resources were identified (Figure 2), based on distribution maps of individual key resources. These include mangroves, freshwater dependent vegetation, coral reefs, seagrasses, rock/algae, feeding/breeding birds, nesting turtles, dugong and key fisheries resources. Areas of actual or potential resource use conflict (Figure 3) were identified by overlaying the summary map of coastal and marine uses (Figure 1) with the map of concentrated key resources (Figure 2). Overlapping (Figure 3) indicates areas where management may be needed most urgently (IUCN/MEPA, 1987a; Price, 1990). Non-overlapping areas indicate resource-use computabilities, indicating where there may be opportunities for future sustainable resource use and development.

The proposed coastal zone management programme (IUCN/MEPA, 1987a,d) identified a number of major tasks, in response to the various problems, opportunities and issues relating to the Gulf (and Red Sea) coasts. Among these tasks are: formulation of options for legislative and regulatory structures, including an integrating 'Umbrella Law' relating to all environmental matters, with specific consideration of the need for coastal zone management; and continued development of the coastal and marine protected area system for environmentally sensitive areas (ESAs).

Although the national coastal zone management programme as a whole has yet to be implemented, several of the above tasks are now well developed. For example, as a result of the above and earlier studies 11 ESAs plus seven recreational areas have been identified in the Gulf. Through subsequent initiatives of NCWCD, these ESAs are being incorporated into a broader system plan of protected areas for the entire country (Child & Grainger, 1990). Protected areas have been classifed according to various socio-economic and ecological criteria. It appears that multiple-use areas will assume considerable importance. The dual approach of protected area management (Jungius, 1988) in conjunction with geographically broader resource and uses policies is considered to be effective, and is also adopted elsewhere, for instance in Oman.

A particularly successful example of a coastal zone management plan in the region, both conceptually and operationally, is that of Oman. However, the Omani Gulf coastline was little, if at all, affected by marine oil pollution from the recent Gulf War. Details of coastal zone management are therefore not given here, but are available elsewhere (eg. IUCN, 1986, 1988, 1989; Salm & Dobbin, 1987, Sheppard *et al.*, 1992).

Kuwait Action Plan (KAP)

Included in the Regional Seas Programme of UNEP is the Kuwait Action Plan (KAP) region, that is, the Gulf. The Kuwait Action Plan forms part of the *broader KuwaitRegionaZ Convention on the Protection of the Marine Environmentfrom Pollution.* All Gulf countries are signatories to the convention, whose aims include to prevent and control pollution from ships and other causes, to establish national standards, and to develop national research and monitoring programmes relating to all types of pollution. The KAP operates through close cooperation with

Figure 1.
Summary map showing areas of major coastal and marine use along the Saudi Gulf coast. This is derived from individual maps showing areas associated with oil exploration and development, oil industry and facilities, other industry, ports and harbours, recreation and tourism, military/coastguards, hunting (egg collecting) and fishing (from IUCN/MEPA, 1987a).

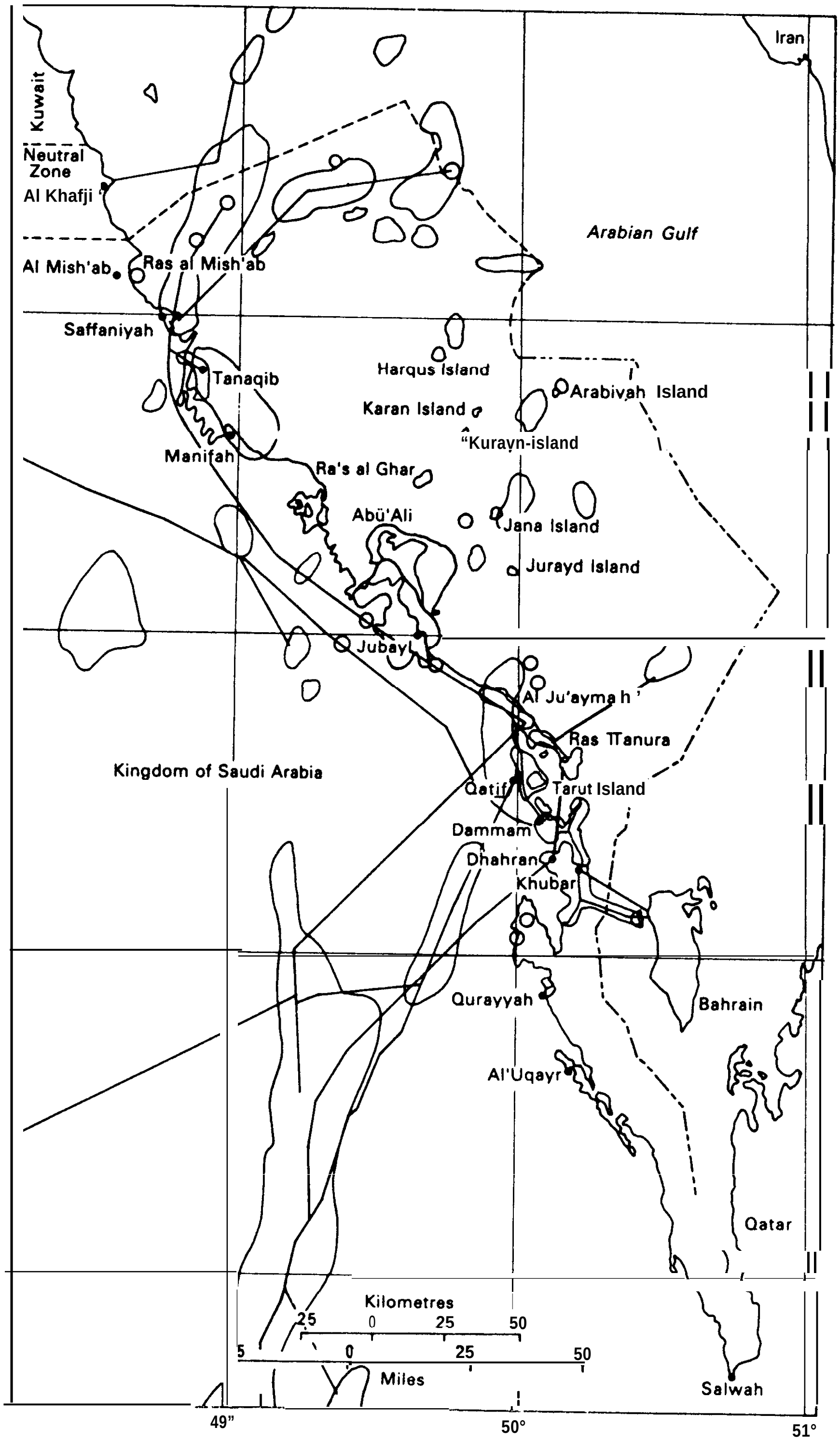


Figure 2.
Summary map of concentrated key resources areas along the Saudi Gulf coast.
This is derived from individual maps showing distribution of mangroves, fresh-water dependent vegetation, coral reefs, seagrasses, rock/algae, feeding/breeding birds, nesting turtles, dugongand key fisheries resources (from IUCN/MEPA, 1987a).

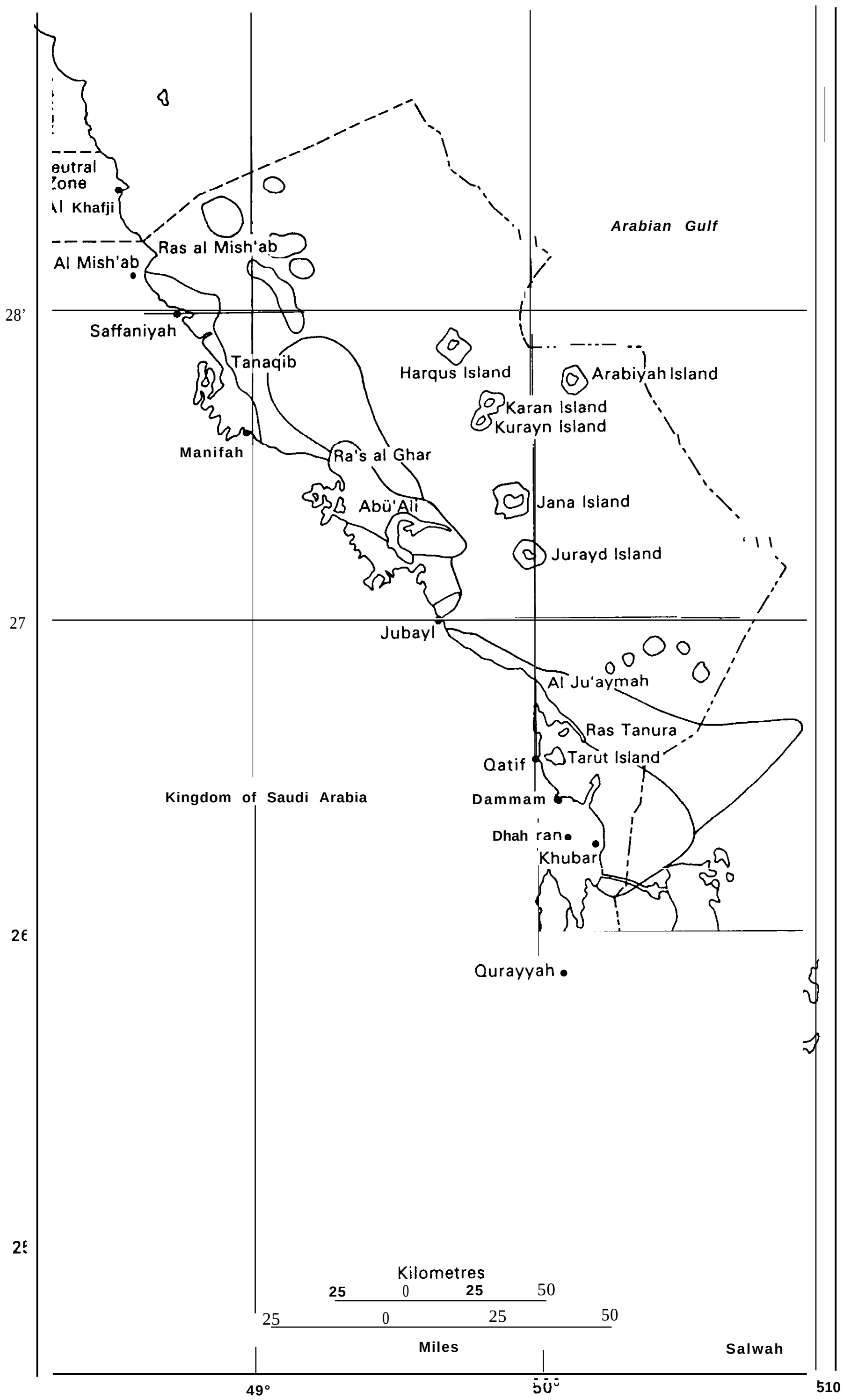
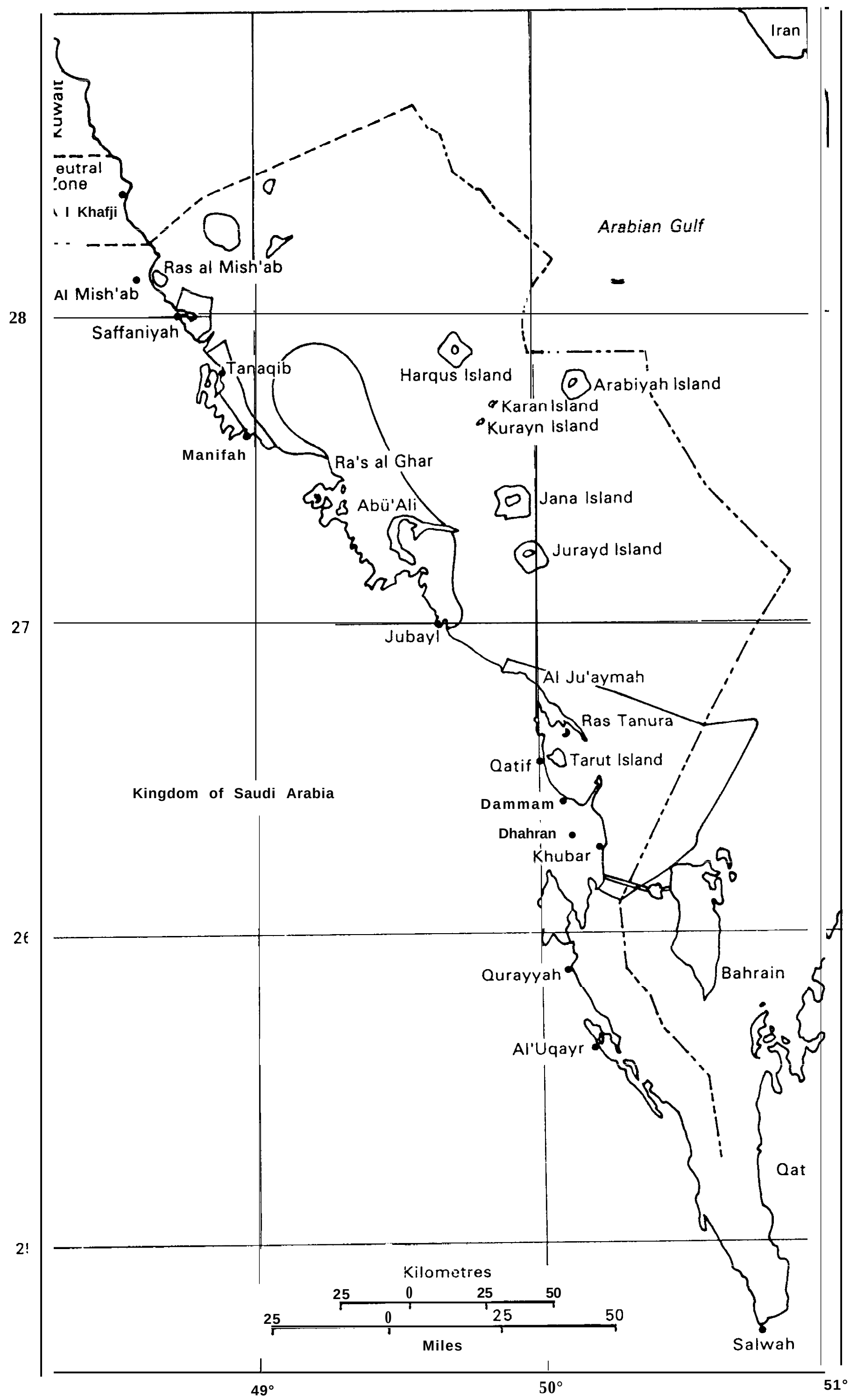


Figure 3.
Map showing areas of actual or potential resource use conflict along the Saudi Gulf coast. This is derived by overlaying the summary map of coastal and marine uses (Figure 1) with the map of concentrated key resources (Figure 2). Areas of overlap denote areas of actual or potential resource use conflicts, and non-overlapping areas indicate resource-use compatibilities (from IUCN/MEPA, 1987a).



international organisations, regional organisations (eg. ROPME), and also with many national organisations, institutions and focal points. Many of the major conservation and research initiatives in the Gulf have been part of UNEP's Regional Seas Programme.

Other regional and international agreements

Among these are the Arab Declaration on Environment and Development, the GCC, MEMAC and GAOCMAO. These and other agreements relate to environmental management and pollution control.

Important international agreements include, CITES, Ramsar (Wetlands Convention), the Bonn Convention on Migratory Species, Indian Ocean Alliance, IBP, UNESCO MAB, the World Heritage Convention, and others including parts of UNCLOS.

Hence, at the outset of the 1991 Gulf War a considerable body of scientific information existed, and management frameworks were already broadly in place. Upholding regional and international agreements is particularly important in seas like the Gulf, whose transboundary resources constitute a valuable 'commons' shared by eight countries and utilised by many more.

3. Post-war Coastal and Marine Assessments

3.1 Initial post-war assessment

Background and objectives

Following the environmental incursions in Kuwait in early 1991, an immediate priority was define the extent and magnitude of environmental impacts and priorities for protection and/or cleanup. The overall purpose of the initial mission was therefore to report on the extent of damage to the Gulf's coastal and marine environment, the extent of cleanup activities and other national and international efforts, and to identify possible assistance that might be needed.

Activities

Activities included an immediate post-war visit to Gulf (3-13 March 1991); a helicopter overflight along Gulf coast; *in situ* coastal inspections; advice to MEPA on environmental aspects of Gulf crisis, for instance on critical coastal areas and priority areas for clean-up; assistance to MEPA concerning development of medium-term and longer-term strategies for dealing with the environmental consequences of the conflict. In addition, there was involvement in radio programmes, TV documentaries and press interviews.

Results

The immediate post-war mission provided an overview of the prevailing environmental situation. A detailed scientific assessment was not intended, although a synopsis of environmental and socioeconomic features of key coastal areas was provided. Key coastal areas included: Manifa Bay complex (including Safaniya & Tanajib), the offshore coral islands (especially Karan & Jana), Abu Ali/Dawhat Dafi/Mussallamiyah complex, Tarut Bay and adjacent area, and the Gulf of Salwah. Further details are given in IUCN (1992), Price (1991), Price & Sheppard (1991) and Sheppard& Price (1991).

3.2 Ecosystems, oil and other impacts

Background and objectives

Pre-war rapid survey data on the abundance of key ecosystems, species groups and the magnitude of oil pollution and other impacts were collected in 1986 at 53 coastal sites along the Saudi Arabian Gulf coast (Figure 4). The objectives of this study were to reexamine selected sites during the post-war period (August 1991, 1992& 1993), to determine the changing status of the Gulf's coastal environment as a result of the 1991 war and other human activities.

Activities

Thirty five sites along the Saudi Arabian Gulf coast were reexamined during August 1991, ten of which were surveyed again during August 1992 and August 1993. The latter study included seven oil/war-impacted sites, one site in a transition area and two sites in a control (unimpacted) area. A rapid survey technique was employed, using ranked, (O-6) data. This provides a semi-quantitative logarithmic assessment of the abundance of ecosystems/species, and magnitude of impacts/pollution (Price, 1990, Price & Coles, 1992; Price *et al.*, 1988). Four sites were also surveyed for the first time using this technique in Kuwait during August 1992.

Results

Using the 1986/1991 data set (35 sites), oil pollution was significantly greater in 1991 (mean 3.20) than in 1986 (mean 1.77). Oiling was also significantly greater at sites north of Abu Ali than to the south in 1991, but not in 1986. Algae, bird and fish abundances were all significantly greater in 1991 than in 1986.

The mean magnitude of oil pollution was also significantly greater in 1991 compared with 1986, using the data set for 1986/ 1991/ 1992 /1993 (10 sites: Table 2). However, the mean value decreased in 1992 and 1993 to levels not significantly different from 1986. In 1992 0il pollution declined further (2.2 on scale O-6), suggesting recovery of at least surface substrata to pre-war levels (2.0). However, subsurface tar levelsof 870 gi^{m-}2 were recorded at Abu Ali, and samples have been collected here and elsewhere to determine the degree of toxicity. Of the biota surveyed, only fish showed significant change (increase) in abundance, but decreased in 1993 to a value similar to that observed in 1986. The observed ecosystem abundance patterns may be attributed as much to seasonal variability, 'background' human impacts and the semi-quantitative nature of the survey, as to war-related environmental incursions. Nevertheless, the apparent increase in certain faunal and floral elements clearly indicates that the Gulf conflict had not caused complete environmental collapse. The surveys also revealed that other pollution (e.g. plastics, metals) has increased steadily. Visual inspections indicated that coastal infilling, inparticular, remains a major environmental problem. Further details are given in IUCN (1992) and Price *et al.* (1993a).

Figure 4.
Map of Gulf showing locations of study sites for rapid coastal assessments (from Price *et al.*, 1993a). Sites *1-53* were surveyed in 1986; sites indicated by a star were resurveyed during 1991, and sites indicated by a triangle in 1992.

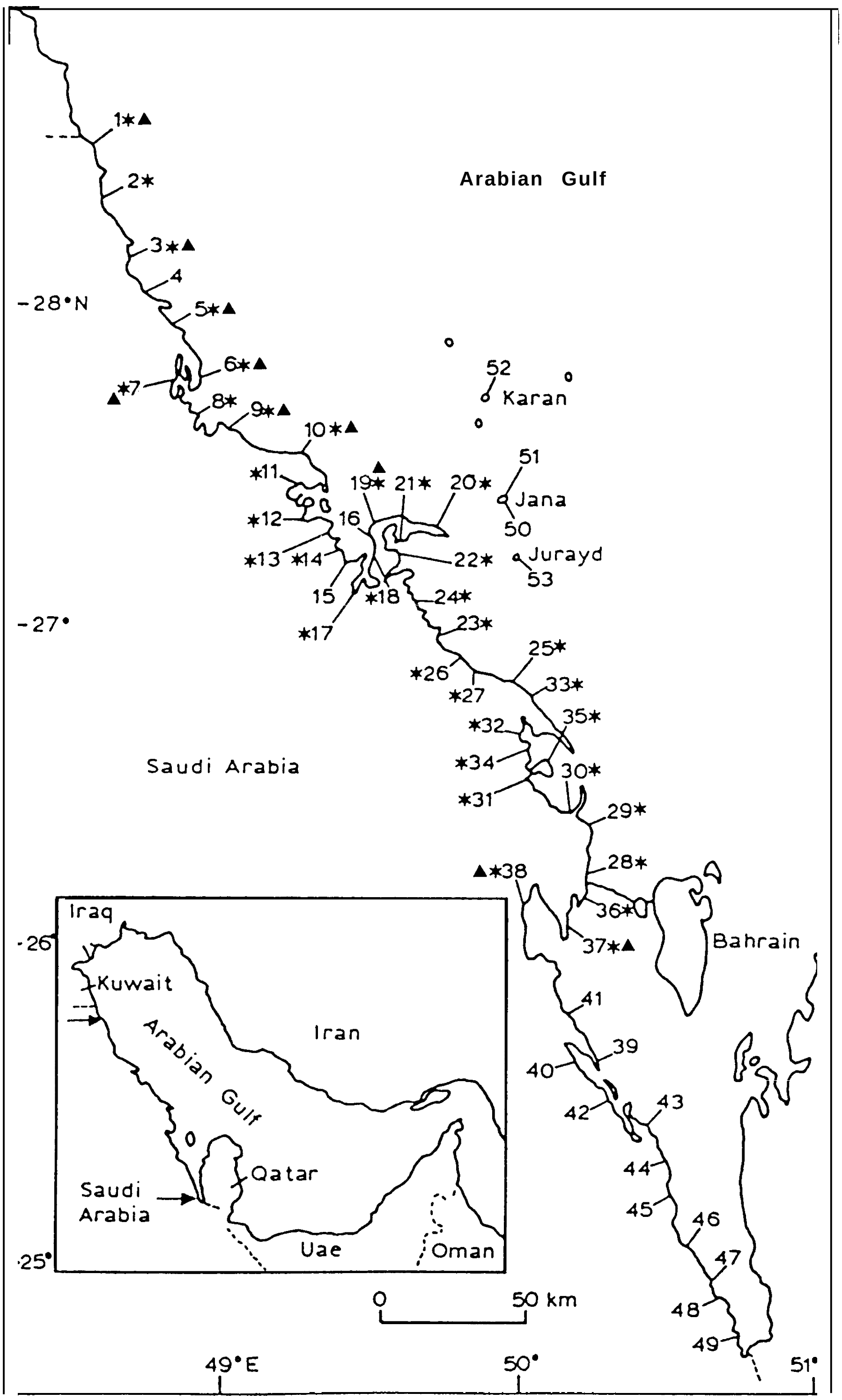


Table 2.
Changes in mean abundance of ecosystems/species and mean magnitude of impacts/ pollution based on rapid surveys at ten sites along the Saudi Arabian Gulf coast, based on a ranked O-6 scale (based on Price *et al.*, 1993a).

Ecosystem/species	1986	1991	1992	1993
Algae	3.5	4.9	4.8	3.6
Halophytes	2.7	2.1	1.8	2.6
Seagrasses	2.2	2.9	2.5	2.2
Birds	0.6	1.2	1.2	1.2
Fish	0.3	3.9	3.1	1.8
Invertebrates	5.1	5.5	5.4	5.5
Use/impact				
oil	2.0	4.0	3.0	2.2
Metals, plastics, etc.	2.3	3.4	3.4	4.1
Driftwood	2.2	2.4	3.0	2.9

3.3 Petroleum hydrocarbons and other contaminants

Background and objectives

Measurements of petroleum hydrocarbons and other contaminants such as trace metals are necessary in order to define quantitatively the extent to which pollutants have impinged upon coastal ecosystems and entered food chains. Such measurements were made in the Gulf after the war and compared with data for previous years.

Activities

Sampling of sediments and biota (fish & clams) was undertaken in several Gulf States. The locations of stations before and after the 1991 Gulf War are shown in Table 3 (see Fowler *et al.*, 1993). Post-war seawater samples were collected from sites in Kuwait and Saudi Arabia (Figure 5). Seawater samples were collected at the surface microlayer (upper 30-100 pm) and at approximately 50 cm depth ("bulkwater"). Special consideration was given to the microlayer, in view of its special environmental significance. This is the interface between the atmosphere and the ocean, and the point of entry of marine and atmospheric pollutants. Both types of inputs were undoubtedly significant during the 1991 Gulf War. The surface microlayer is distinctive physically and also very rich biologically; for example eggs of many commercial crustaceans and fish are often concentrated within it. At each coastal site duplicate microlayer and subsurface (bulk) seawater samples were collected for analysis of hydrocarbons and heavy metals.

Seawater, sediment and biota samples were analysed for hydrocarbons and trace metals. Microlayer and subsurface seawater samples also underwent laboratory toxicity tests. Sand dollar eggs *(Dendraster excentricus)* were exposed to the seawater samples, to compare the effects of microlayer and subsurface seawater on egg development. Analysis of data included comparisons between 1991 and 1992. During August 1993 sampling was undertaken, and included collection of sediment/oil samples for subsequent toxicity testing. However, the samples have not yet been analysed.

Results

(a) Marine environmental contaminants

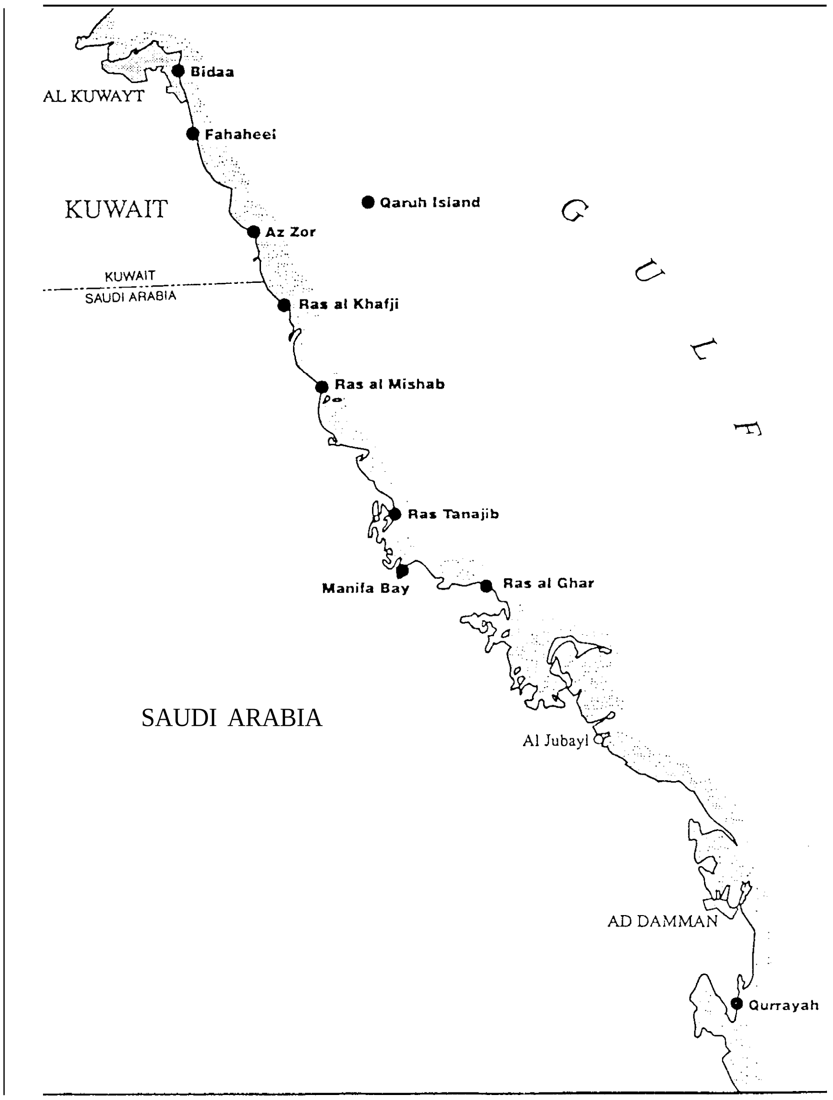
Analyses revealed that the highest levels of contamination were along the heavily-impacted coast of Saudi Arabia between Ras Al Khafji and Ras Al Ghar, where concentrations of total petroleum hydrocarbons (expressed as Kuwait crude oil equivalents) ranged from 62-1400 µg g^{-1} dry Wt in surface sediments (Table 4), 570-2600 µg g^{-1} dry wt in clams (Table 5) and 9.6-31 µg g^{-1} dry wt in fish muscle (Table 6). Gas chromatographic analyses indicated that much of the spilled oil in at least the surface layer of the intertidal zone had substantially degraded within a few months of the spill. However, core sampling more that two years after the war revealed a very contaminated layer at many sites in the intertidal and shallow subtidal just a few centimeters below the sediment surface. Concentrations of the oil-related metals nickel (Ni) and

Table 3
Sampling stations along Gulf coast for analysis of hydrocarbons and trace metals in sediments and biota (from Fowler *et al.*, 1993).

Country		Station	*Location Latitude	Longitude
KUWAIT				
		Ras Al Jousah	29° 22.50'N	47° 59.50'E
		Qaruh Island	28° 49.02'N	48° 46.44'E
SAUDI ARABIA				
		Ras Al Khafji	28° 29.96'N	48° 28.75'E
		Ras Al Mishab	28° 10.64'N	48° 36.89´E
		Safaniya	27° 26.80'N	48° 45.48'E
		Ras Al Tanajib	27° 45.78`N	48° 53.29'E
		Manifa Bay	27° 37.71'N	48° 55.1 1'E
		Ras Al Ghar	27° 37.59´N	49° 12.56'E
		Ras Al Qurrayyah	26° 24.96'N	50° 09.24´E
BAHRAIN				
		Fasht Al Jarim	26° 23.O´N	50° 35.O'E
		Fasht Al Dibal	26° 15.O'N	50° 57.O'E
		+Umm Na San	26° 09.O'N	50° 27.O'E
		Bandar Dar	26° 07.O'N	50° 39.O'E
		Al Malikiyah	26° 06.O´N	50° 28.O'E
		Askar	26° 02.O'N	50° 37.O'E
		+Az Zallaq	26° 02.O'N	50° 29.O'E
U A E				
		Umm Al Quwain	25° 36.O'N	55° 35.O'E
		Dubai	25° 15.O´N	55° 11.O'E
		Jebel Ali	24° 57.5'N	54° 57.O'E
		Abu Dhabi	24° 29.O'N	54° 19.O'E
OMAN				
	Musandam			
		+Jazirat Kun	26° 23.O'N	56° 24.O'E
		Kumzar	26° 20.O'N	56° 25.O'E
		Khasab	26° 13.O'N	56° 14.O'E
		Khor Al Niad	26° 11.O'N	56° 18.O'E
		Bukha	26° 09.O'N	56° 10.O'E
		+Lima	25° 56.O'N	56° 29.O'E
	Muscat			
		Al Qurum	23° 37.O'N	58° 28.O'E
		Mutrah	23° 38.O´N	58° 32.5'E
	Masirah			
		Ras Al Yei	20° 31.5'N	58° 57.O'E
		Haql	20° 21.5'N	58° 48.O'E
	Salalah			
		Raysut	16° 59.O'N	54° 00.O'E

*coordinates in Kuwait and Saudi Arabia determined by portable GPS system.
+Stations not sampled in 1991, only in previous years.

Figure 5.
Map of Gulf showing locations of study sites for sampling of seawater for analysis of hydrocarbons and trace metals (from Hardy *et al.*, 1992)



vanadium (V) were slightly elevated in oil-contaminated sediments from Saudi Arabia but elsewhere in the Gulf were similar to levels measured in earlier years at those sites (Table 7). This initial regional survey demonstrated that hydrocarbon contamination originating from the war-related pollution events was restricted to approximately 400 km from the source; that levels of combustion derived PAH's in the marine environment at that time (e.g. 1-450 ng g^{-1} dry wt for pyrene in sediments) were of the same order as those which have been measured in several coastal areas of the United States and northern Europe; and that outside the immediate area of impact, petroleum hydrocarbon and trace metal levels in sediment and bivalves were generally as low as, or lower than, those concentrations measured at the same sites before the war. Further details are given in IUCN (1992), Readman *et al.* (1992) and Fowler *et al.* (1993).

Table 4.
Concentrations of hydrocarbons in marine sediments following the Gulf War (concentrations are on a dry wt bas s (from Fowler *et al.*, 1993).

Country	Location	Approx. dist. from spill (km)	Sampling date (1991)	Dry wt. / Wet wt.	HEOM* (mg g^{-1})	Kuwait crude oil equivs. (μg g^{-1})	Chrys. equivs. (μg g^{-1})	Total hydros. (μg g^{-1})	Total ali. hydros. (μg g^{-1})	Res. ali. hydros. (μg g^{-1})	Unres. ali. hydros. (μg g^{-1})	Res. / Unres. alis.	Σn-C_{14}-n-C_{34} (μg g^{-1})
Kuwait	Qaruh Island ( )	70	19/6	0.83	0.10	13.0	3.4	28	27	3.0	24	0.13	0.17
Saudi Arabia	Ras Al Khafji (2)	100	20/8	0.84	0.60	1140	200	369	268	8.0	260	0.03	2.20
	Ras Al Mishab (3)	130	21/8	0.72	0.80	1340	240	558	432	52.0	380	0.14	2.00
	Ras Al Tanajib (4)	140	19/8	0.82	0.17	62	11.0	82	66	6.0	60	0.10	2.20
	Manifa Bay (5)	190	21/8	0.85	0.17	260	47.0	129	93	9.0	84	0.11	2.10
	Ras Al Ghar (6)	230	21/8	0.82	0.50	1400	250	671	496	76.0	420	0.18	23.00
	Ras Al Qurrayyah (7)	390	18/9	0.85	-	5	0.9	19	13	3.0	10	0.30	0.90
Bahrain	Al Malikiya (8)	425	16/6	0.62	0.34	6	1.6	41	38	7.9	30	0.26	2.60
	Bandar Dar (9)	425	14/6	0.72	0.04	3	0.6	23	15	1.4	14	0.10	0.26
	Askar (10)	435	14/6	0.73	0.11	14	3.6	35	31	3.0	28	0.11	0.47
U.A.E.	Jebel Ali (11)	1020	29/9	0.79	0.09	5	1.0	16	10	0.7	9	0.08	0.46
	Umm Al Quwain (12)	1060	29/9	0.74	0.05	7	1.4	16	12	0.4	12	0.04	0.25
Oman	Musandam (Khasab) (13)	1140	2/10	0.78	0.01	1	0.2	6	4	0.2	3	0.05	0.10
	Muscat (Al Qurum) (14)	1535	5/10	0.75	-	2	0.4	8	5	0.6	4	0.16	0.27
	Masirah (Haql) (15)	2050	6/10	0.77	0.01	3	0.6	6	4	0.5	3	0.15	0.18
	Salalah (Raysut) (16)	2710	9/10	0.55	0.09	12	2.3	22	16	3.5	13	0.27	1.20

*HEOM = Hexane extractable organic material.
N.D. = Not detected.

	n-C_{17} (ng g^{-1})	Pristane (ng g^{-1})	n-C_{18} (ng g^{-1})	Phytane (ng g^{-1})	Total arom. hydros. (µg g^{-1})	Res. arom. hydros. (µg g^{-1})	Unres. arom. hydros. (µg g^{-1})	Phen. (ng g^{-1})	1-Methyl Phen. (ng g^{-1})	2-Methyl Phen. (ng g^{-1})	Fluor. (ng g^{-1})	Pyrene (ng g^{-1})
Qaruh Island (1)	19	-	22	34	1.3	0.2	1.1	0.8	7.0	8.6	3.0	11.0
Ras Al Khafji (2)	150	120	180	400	101.0	2.0	99	43.0	11.0	27.0	45	25.0
Ras Al Mishab (3)	450	250	190	410	126.0	6.0	120	10.0	43.0	26.0	21	130.0
Ras Al Tanajib (4)	240	140	140	220	16.0	1.0	15	35.0	6.0	7.0	N.D.	4.7
Manifa Bay (5)	300	210	240	390	35.5	1.5	34	53.0	11.0	7.0	16.0	14.0
Ras Al Ghar (6)	2200	1400	3000	3300	175.0	15.0	160	11.0	50.0	110.0	130.0	450.0
Ras Al Qurrayyah (7)	140	80	110	90	5.7	1.0	4.7	26.0	2.9	2.9	1.9	2.7
Al Malikiya (8)	530	30	52	63	3.3	0.6	2.7	9.0	5.0	4.0	13.0	62.0
Bandar Dar (9)	75	36	39	50	7.9	0.3	7.6	1.5	16.0	6.0	3.0	21.0
Askar (10)	110	18	18	24	3.9	0.1	3.8	3.0	26.0	1.5	21.0	38.0
Jebel Ali (11)	210	10	15	11	6.1	0.6	5.5	3.3	7.8	2.7	4.2	3.8
Umm Al Quwain (12)	46	4.5	8.0	7.2	4.0	0.6	3.4	1.7	2.0	2.3	2.2	2.7
Musandam (Khasab) (13)	14	5.1	6.4	3.2	2.4	0.5	1.9	1.5	1.1	1.7	3.0	3.0
Muscat (Al Qurum) (14)	27	10	22	7.4	2.8	0.2	2.6	1.6	2.2	2.1	5.3	3.6
Masirah (Haql) (15)	28	13	13	8.4	1.9	0.1	1.8	0.8	0.6	1.0	1.1	1.0
Salalah (Raysut) (16)	34	13	15	19	5.7	1.3	4.4	3.0	9.6	6.2	8.3	9.4

Table 5.
Concentrations of hydrocarbons in marine b valves following the Gulf War (concentrations are on a dry weight basis) (from Fowler *et al.*, 1993).

Country	Location	Approx. dist. from spill (Km)	Sampling date (1991)	Bivalve species	Dry wt. / Wet wt.	H.E.O.M.† (mg/g)	Kuwait crude oil equivs. (μg/g)	Chrys. equivs. (μg/g)	Tot. ali. hydros. (μg/g)	Res. ali. hydros. (μg/g)	Unres. ali. hydros. (μg/g)	Res. / Unres. alis.	Σn-C_{14} n-C_{34} (μg/g)
S.ARABIA	Ras Al	130	21 8	*Meretrix meretrix* (Clam)	0.12	12	570	107	184	14	170	0.08	6.9
	Ras Al Tanajib (2)	140	19/8	*Meretrix meretrix*	0. 1	8	1040	190	234	24	210	0.11	7.1
	Ras Al Tanajib (3)	140	19/8	*Tapes sulcarius* (Clam)	0.12	30	2600	480	475	55	420	0.[illegible]3	15.0
	Ras Al Qurrayyah (4)	390	18/8	*Trachycardium lacunosum* (Cockle)	0.14	17	86	16	43	23	120	0.19	6.8
BAHRAIN	Al Malikiyah (5)	425	16/6	*Pinctada* ** *margaritifera* (Pearl oyster)	0.15	24	3	0.8	40	14	26	0.54	3.5
	Askar (6)	435	14/6	*Spondylus sp.* *** (Rock Scallop)	0.17	8	27	7.0	124	11	113	0.10	0.9
	Askar (7)	435	14/6	*Pinctada* ** *margaritifera*	0.24	65	33	8.5	108	8	100	0.08	0.8
U.A.E.	Jebel Ali (8)	1020	26/9	*Pinctada* ** *margaritifera*	0.15	19	15	2.8	59	5	54	0.10	1.8
OMAN	Al Qurum (9)	1525	1/10	*Saccostrea cucullata* (Rock oyster)	0.26	29	34	6.2	88	8	80	0.10	2.7
	Masirah (10) (Ras Al Yei)	2050	6/10	*Saccostrea cucullata*	0.31	44	30	5.4	40	19	21	0.90	2.6
	Salalah (11) (Raysut)	2710	9/10	*Saccostrea cucullata*	0.28	25	31	5.9	27	6	21	0.30	2.7

† H.E.O.M. = Hexane extractable organic material.
** = Recently considered to be *P. radiata*.
*** = Tentatively identified as *S. exilis*.

Location	n-17 (ng/g-1	Pristane (ng/g-1)	n-C18 (ng/g-1)	Phytane (ng/g-1)	Tot. arom. hydros. (µg/g-1)	Res. arom. hydros. (µg/g-1)	Unres. arom. hydros. (µg/g-1)	Phen. (ng/g-1)	1-Methy Phen. (ng/g-1)	2-Methy Phen. (ng/g-1)	Fluor. (ng/g-1)	Pyrene (ng/g-1)
(1)	1200	220	480	430	89	12	77	71	79	69	100	470
(2)	700	150	410	700	140	30	110	59	29	82	1200	1400
(3)	1400	460	1060	1200	240	30	210	78	100	110	2100	1500
(4)	1800	180	490	200	27	7.5	19	23	20	18	160	100
(5)	1600	110	24	390	16	4.0	12	N.D.	2	-	12	29
(6)	430	23	57	70	67	5.0	62	N.D.	100	10	9	5
(7)	400	34	26	54	64	7.0	57	N.D.	75	15	N.D.	6
(8)	630	440	66	150	55	4.4	51	19	20	6	6	9
(9)	35	330	29	20	58	4.1	54	3	26	11	N.D.	6
(10)	340	400	28	15	78	8.9	69	20	110	18	9	39
(11)	340	380	22	25	76	3.7	72	20	8	4	N.D.	60

N.D. = Not detected.

Table 6.
Concentrations of hydrocarbons in marine fish samples following the Gulf War (concentrations are on dry weight basis) (from Fowler *et al.*, 1993).

Country/ Location	Approx. dist. from spill (km)	Sample date (1991)	Common Name (local name)	Fish Species	Fish wt (kg)	Tissue*	Dry wt / Wet wt	HEOM† ($mg\ g^{-1}$)	Kuwait crude oil equivs. ($\mu g\ g^{-1}$)	Chrys. equivs. ($\mu g\ g^{-1}$)	Total ali. hydros. ($\mu g\ g^{-1}$)
Kuwait											
Ras Al Jousah	0	20/6	Sea Catfish	*Arius thalassinus*	0.28	M	0.23	29	6.0	1.6	48
Saudi Arabia											
Safaniya	140	20/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0.75	M	0.23	12	17	3.2	58
						L	0.24	110	230	43	2290
	140	20/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0.53	M	0.22	16	31	5	104
						L	0.34	210	160	27	990
	140	21/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0.79	M	0.23	10	9.6	1.8	10.3
						L	0.24	88	205	38	1053
	140	21/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0 77	M	0.28	11	10	2	15
						L	0.23	83	310	57	1870
	140	21/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0.76	M	0.22	18	12	2.3	31
						L	0.27	140	260	48	2200
	140	21/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	1.17	M	0.23	22	10	2.0	25
						L	0.30	150	180	37	750
	140	21/8	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0.49	M	0.24	12	23	4.3	25
						L	0.23	41	240	45	1360
Bahrain											
Fasht Al Jarim	390	16/6	Greasy Grouper (Hamoor)	*Ephinephelus tauvina*§	.42	M	0.22	10	2.0	0.5	6.2
Fasht Al Dibal	410	15/6	Grouper (Burtan)	*Ephinephelus jayakari***	2.40	M	0.22	26	2.0	0.5	30
	410	15/6	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	3.08	M	0.24	29	0.8	0.2	11
	410	15/6	Two-banded Porgy (Fasker)	*Acanthopagrus bifasciatus*	0.75	M	0.24	22	1.2	0.3	5.2
S.W. Bandar	430	15/6	Greasy Grouper (Hamoor)	*Ephinephelus tauvina*§	2.80	M	0.24	19	0.8	0.2	11
Dar Az Zallaq	440	16/6	Pigface Bream (Sheiry)	*Lethrinus nebulosus*	0.59	M	0.24	16	3.8	1.0	26
UAE											
Dubai	1020	28/9	Orange-spotted Grouper (Hamoor)	*Ephinephelus suillus*§	1.43	M	0.22	23	3.6	0.7	23
						L	0.31	106	26	5.0	174
Oman											
Khasab	1140	2/10	Greasy Grouper (Hamoor)	*Ephinephelus tauvina*§	3.00	M	0.22	18	7.3	1.4	20
						L	0.32	104	17	3.3	81
Muscat	1530	5/10	Greasy Grouper (Hamoor)	*Ephinephelus tauvina*§	1.75	M	0.21	28	5.6	1.0	15
						L	0.28	95	33	6.0	190
Masirah	2050	6/10	Greasy Grouper (Hamoor)	*Ephinephelus tauvina*§	2.80	M	0.22	58	3.3	0.6	19
						L	0.29	73	12	2.2	75
	2050	6/10	Pigface Bream (Sheiry)	*Lewthrinus nebulosus*§	2.95	M	0.23	9	2.4	0.4	8.8
Salalah (Raysut)	2710	9/10	Greasy Grouper (Hamoor)	*Epinephelus tauvina*§	2.00	M	0.22	12	3.4	0.6	8.3

*M = Muscle; L = Liver.
†HEOM = Hexane extractable organic material.
††Requires gas chromatographic-mass spectrometric confirmation.
§Currently recognized as *E.coioides*.
N.D. = Not detected.
**Currently recognized as *E.multinotatus*.

Country/ Location	Fish Species	Total ali. hydros. (μg g⁻¹)	Res. ali hydros. (μg g⁻¹)	Unres. ali. hydros. (μg g⁻¹)	Res./Unres. alis.	Σn-C_{14} - N-C_{34} (μg g⁻¹)	N-C_{17} (ng g⁻¹)	Pristane (ng g⁻¹)	n-C_{18} (ng g⁻¹)	Phytane (ng g⁻¹)	Total arom. HCs (μg g⁻¹)	Res. arom. HCs (μg g⁻¹)	Unres. arom HCs (μg g⁻¹)	Phen. (ng g⁻¹)	1-Methyl Phen. (ng g⁻¹)	2-Methyl Phen. (ng g⁻¹)	Fluor. (ng g⁻¹)	Pyrene (ng g⁻¹)
Ras Al Jousah	*Arius thalassinus*	48	10	38	0.26	2.3	320	140	180	170	2	6	5.0	80				19
Safaniya	*Lethrinus nebulosus*	58	13	45	0.29	6.5	460	350	780	750	15	5.0	10	6.2	12	28	11	56
		2290	590	1700	0.35	130	1500	400	1700	840	239	29	210	180	280	270	120	150
	Lethrinus nebulosus	104	26	78	0.33	13	540	350	940	880	21	8.4	12	15	65	93	9.2	140
		990	200	790	0.25	63	2900	780	1900	1200	210	60	150	190	310	200	100	160
	Lethrinus nebulosus	10.3	3.3	7.0	0.47	0.62	72	26	48	32	7.6	4.7	2.9	N.D.	4.4	N.D.	11	15
		1053	13	1040	0.01	64	1200	320	1200	630	155	45	110	120	94	270	640	250
	Lethrinus nebulosus	15	4.3	11	0.39	0.67	46	26	53	33	18	8.0	10	N.D.	9.4	8.2	5.5	6.0
		1870	270	1600	0.17	108	1040	170	1200	460	216	36	180	120	88	240	360	660
	Lethrinus nebulosus	31	5.0	26	0.19	0.87	62	28	80	48	8.7	3.0	3.7	N.D.	13	8.9	35	12
		2200	500	1700	0.29	120	1900	500	1800	970	144	34	110	160	420	300	440	1600
	Lethrinus nebulosus	25	6.0	19	0.32	0.39	54	18	49	30	12	2.8	9.3	5.0	8.7	6.3	6.7	13
		750	140	610	0.23	49	1500	480	1100	650	114	40	74	100	85	79	110	83
	Lethrinus nebulosus	25	5.0	20	0.25	0.83	50	21	69	36	12	6.4	5.8	5.0	11	6.8	60	47
		1360	160	1200	0.13	45	1040	270	1100	480	192	32	160	47	75	170	210	460
Fasht Al Jarim	*Ephinephelus tauvina§*	6.2	6.2	-	-	1.2	7	36	7	2	1.	1.1	N.D.	N.D.	N.D.	N.D.	35	100
Fasht Al Dibal	*Ephinephelus jayakari***	30	5.0	25	0.02	0.53	94	8	20	120	19	5.0	14	7.0	8..0	10		5
	Lethrinus nebulosus		2.0	9.0	0.22	0.49	200	20	6	6	7.3	4.8	2.5	0	N.D.	N.D.	N.D.	12
	Acanthopagrus bifasciatus	5.2	2.6	2.6	00	1.00	90	0	28	10	6.4	6.4	N.D.	N.D.	N.D.	N.D.	N.D.	1.9
S.W. Bandar Dar	*Ephinephelus tauvina§*	1	1.2	9.8	0.12	0.36	59	54	28	35	3.9	3.9	N.D.	N.D.	N.D.	N.D.	N.D.	4.0
Az Zallaq	*Lethrinus nebulosus*	26	4.0	22	0.18	0.70	160	100	230	270	14.7	4.7	10	6.0	18	24	7.0	5.0
Dubai	*Ephinephelus suillus§*	23	6.8	16	0.43	1.2	170	400	34	9	9.2	3.8	5.4	N.D.	4.5	1.8	7.0	5.1
		174	78	96	0.81	8.3	740	2400	200	130	115	77	38	N.D.	30	28	N.D.	59
Khasab	*Ephinephelus tauvina§*	20	4.2	16	0.26	1.2	290	130	45	20	4.8	2.3	2.5	5.1	11	5.0	3.1	14
		81	32	49	0.65	9.0	3700	1900	32	27	192	110	82	N.D.	16	16	N.D.	N.D.
Muscat	*Ephinephelus tauvina§*	15	5.3	9.9	0.53	2.0	310	670	40	53	4.8	2.2	2.6	3.3	5.0	3.8	2.9	3.5
		190	60	130	0.46	24	590	2700	63	510	53	19	34	N.D.	N.D.	N.D.	N.D.	13
Masirah	*Ephinephelus tauvina§*	19	12	7.4	1.62	1.1	150	(3300)††	13	10	18.6	5.6	13	N.D.	4.5	5.9	N.D.	6.7
		75	25	50	0.50	4.5	180	1500	-	30	37	21	16	N.D.	N.D.	N.D.	N.D.	12
	Lewthrinus nebulosus§	8.8	2.0	6.8	0.29	1.0	100	76	-	15	19.7	3.7	16	N.D.	N.D.	15	N.D.	12
Salalah (Raysut)	*Ephinephelus tauvina§*	8.3	.5	6.8	0.22	0.4	7	160	2	5	11.1	3.6	7.5	2.0	2.0	2.2	N.D.	4.3

Table 7.
Trace elements in surface sediments from the Gulf region (µg g^{-1}) (from Fowler *et d.*, 1993).

Location	Date	Cu	Pb	Cd	V	Ni	Ag	As	Co	Cr	Fe	Mn	Zn
Kuwait													
Qaruh Island	06/91	1.20	1.03	0.770	13.2	15.0	0.035	32.6	0.91	2.85	2792	11.7	1.28
Saudi Arabia													
Ras Al Khafji	08/91	3.24	1.70	0.140	12.5	13.8	0.170	20.5	1.38	32.0	5454	41.9	3.41
Ras Al Mishab	08/91	5.53	2.58	0.170	26.2	27.8	0.190	22.7	3.34	69.0	11 003	122	9.48
Ras Al Tanajib	08/91	3.62	3.49	0.089	24.7	15.4	0.200	13.2	2.35	85.3	6120	140	7.39
Manifa Bay	08/91	3.14	4.44	0.250	10.2	7.86	0.120	7.13	0.98	24.6	3374	39.4	7.58
Ras Al Ghar	08/91	3.30	2.62	0.210	21.1	11.3	0.250	11.9	1.92	99.2	7676	131	8.23
Ras Al Qurrayyah	08/91	3.25	3.49	0.100	18.8	11.0	0.120	4.61	1.62	31.0	4153	93.5	10.2
Bahrain													
East Coast													
Askar	01/83	17.6	13.5	0.040	27.4								
	10/83	8.60	5.05	0.083	14.4								
	04/84	7.06	8.94	0.028	19.0								
	09/85	1.51	2.30	0.147	21.9								
	04/86	7.62	15.9	0.011	12.7								
	08/86	4.49	6.78	0.171	8.9	10.0							
	06/91	1.95	11.0	0.190	12.7	16.0	0.036	29.2	1.12	9.86	3441	21.2	2.34
Dar Island	06/91	1.16	1.3		19.3	16.1	0.035	35.2	0.99	3.84	3233	17.3	3.43
West Coast													
Az Zallaq	01/83	11.2	24.0	0.040	14.0								
Umm Na Saan	10/83	3.87	2.44	0.024	4.9								
	04/84	5.03	5.20	0.024	22.3								
Az Zallaq	09/85	1.50	1.88	0.753	36.3								
	04/86	3.59	9.36	0.521	15.9								
	08/86	2.74	3.23	0.144	9.9	9.4							
Al Malikiyah	06/91	3.43	0.64	0.210	19.0	19.6	0.037	31.8	1.66	11.9	4811	39.9	3.79
U A E													
Jebel Ali	01/83	4.6	3.6	0.030	27.9								
	10/83	2.33	1.09	0.018	7.3								
	04/84	2.59	2.19	0.042	10.9								
	09/85	6.90	1.01	0.135	9.7								
	04/86	1.34	5.21	1.10	11.9								
	08/86	1.62	0.63	0.107	70.1	12.8							
	09/91	2.55	0.74	0.100	14.6	14.2	0.097	20.6	1.79	81.8	3594	96.7	1.56
Um Al Quwain	01/83	3.7	3.2	0.040	35.5								
	10/83	3.44	1.49	0.043	17.1								
	04/84	2.87	0.75	0.027	32.1								
	09/85	7.76	0.54	0.049	28.2								
	04/86	1.99	2.96	1.91	22.5								
	09/91	5.03	2.54	0.210	24.9	25.0	0.130	22.5	3.3	71.9	6055	231	3.40
Oman													
Musandam													
(Jazirat Kun)	01/83	4.7	5.5	0.030	11.3								
	10/83	3.38	0.91	0.049	12.2								
	04/84	2.55	1.20	0.079	16.5								
	09/85	5.40	0.98	0.054	12.6								
	04/86	3.11	9.50	0.187	10.2								
	08/86	2.40	1.21	0.189	12.4	9.9							
	10/91	3.15	1.51	0.170	18.1	15.4	0.730	29.3	1.98	66	5051	89.1	7.70
Muscat													
(Mutrah-Daraayt)	01/83	9.4	8.0	0.080	72.0								
	10/83	13.9	3.43	0.122	48.0								
	04/84	7.73	3.46	0.102	70.0								
	09/85	1.61	1.39	0.072	76.2								
	04/86	7.38	7.19	0.219	38.1								
	08/86	8.15	1.98	0.229	29.4	308							
	10/91	10.4	6.79	0.180	48.0	439	0.240	32.0	22.1	357	22 749	310	26.3
Masirah (Haql)	01/83	8.7	2.3	0.070	74.8								
(Ras Al Yei)	10/83	9.90	1.21	0.077	35.4								
(Haql)	04/84	6.93	0.68	0.098	123								
	09/85	9.63	1.02	0.056	76.9								
	04/86	5.29	3.10	0.477	32.5								
	08/86	6.00	0.37	0.310	28.7	46.1							
	10/91	7.01	0.55	0.210	36.8	43.8	0.150	25.0	6.37	138	9555	173	9.85
Salalah (Raysut)	01/83		2.8	0.080	10.4								
	10/83	4.89	1.73	0.096	20.4								
	04/84	4.40	1.71	0.114	80.7								
	09/85	5.96	1.25	0.080	39.7								
	04/86	7.60	2.31	0.926	44.9								
	08/86	4.10	1.49	0.322	36.0	44.5							
	10/91	9.99	25.9	0.700	39.5	34.6	0.240	24.7	5.33	116	11 369	181	24.5

(b) Seasurface microlayer

Petroleum hydrocarbon concentrations in the nearshore sea surface of northern Saudi Arabia have decreased significantly since an initial assessment in August 1991 (Figure 6). Nevertheless, in August 1992 more that eighteen months after the Gulf War oil spill, relatively high and toxic concentrations of contaminants remained in the nearshore surface waters of Kuwait and Saudi Arabia (Figure 7). Toxicity tests on marine invertebrate larvae indicated that the subsurface water column was not toxic, but the sea-surface microlayer at about half the sites sampled demonstrated significant toxicity (Figure 8). The order of toxicity was Khafji (Saudi Arabia) >Fahaheel (Kuwait) >Qaruh Island (Kuwait) >Ras al Mishab (Saudi Arabia) >Manifa (Saudi Arabia). Examination of the geographic distributions of contaminants suggests that, at least in August 1992, the significant sea-surface toxicity at Qaruh Island, Fahaheel and Manifa was largely due to petroleum hydrocarbons, while at Khafji and Ras al Mishab toxicity may have resulted from a more complex mixture of contaminants including high concentrations of heavy metals (data not shown). Slow leaching from nearshore sediments may represent a long term source of toxic contamination to the sea-surface of the Gulf. The surface microlayer represents an important spawning and feeding ground for many fish, shrimps and other shellfish and as a source of transport and deposition of contaminants onto intertidal beaches. Annual monitoring of the sea-surface of the Gulfs hould continue in order to determine the long term persistence of this toxic contamination. Further details are given in Hardy *et al.,* (1992) and IUCN (1992).

Figure 6.
Concentrations of petroleum equivalents in sea surface microlayer at three sites on Gulf coast in August 1991 and 1992 (from Hardy *et al.,* 1992).

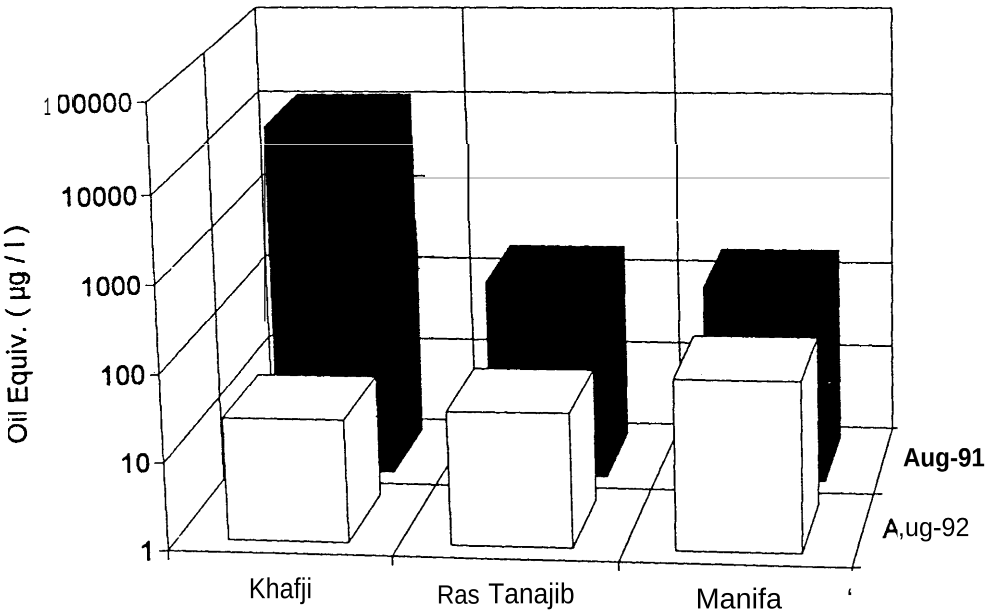


Figure 7.
Concentrations of petroleum equivalents in sea surface microlayer and subsurface water (bulkwater) along Gulf coast in August 1992 (from Hardy *et al.*, 1992).

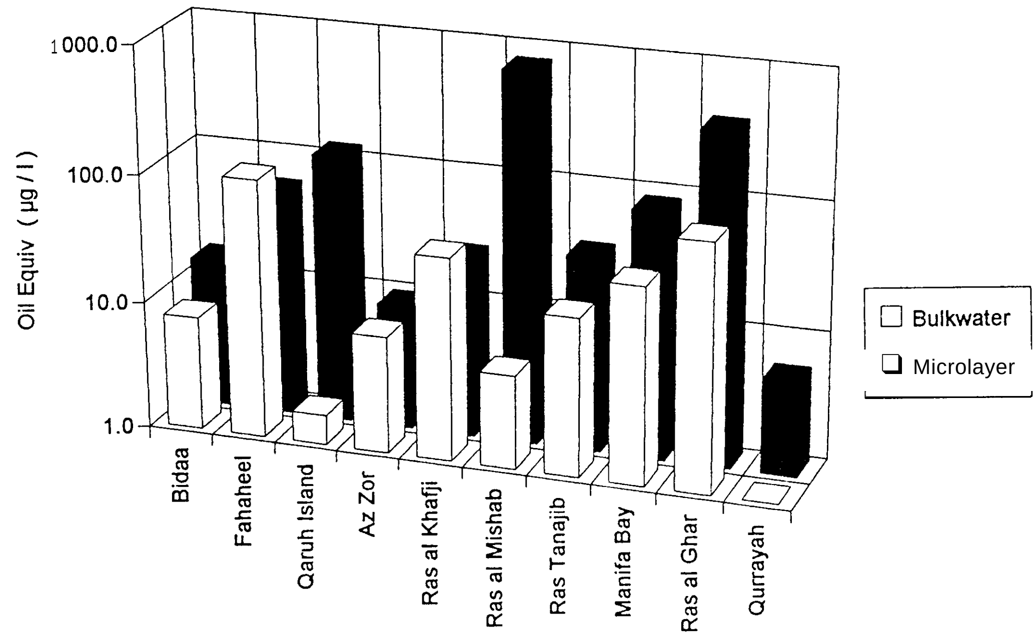
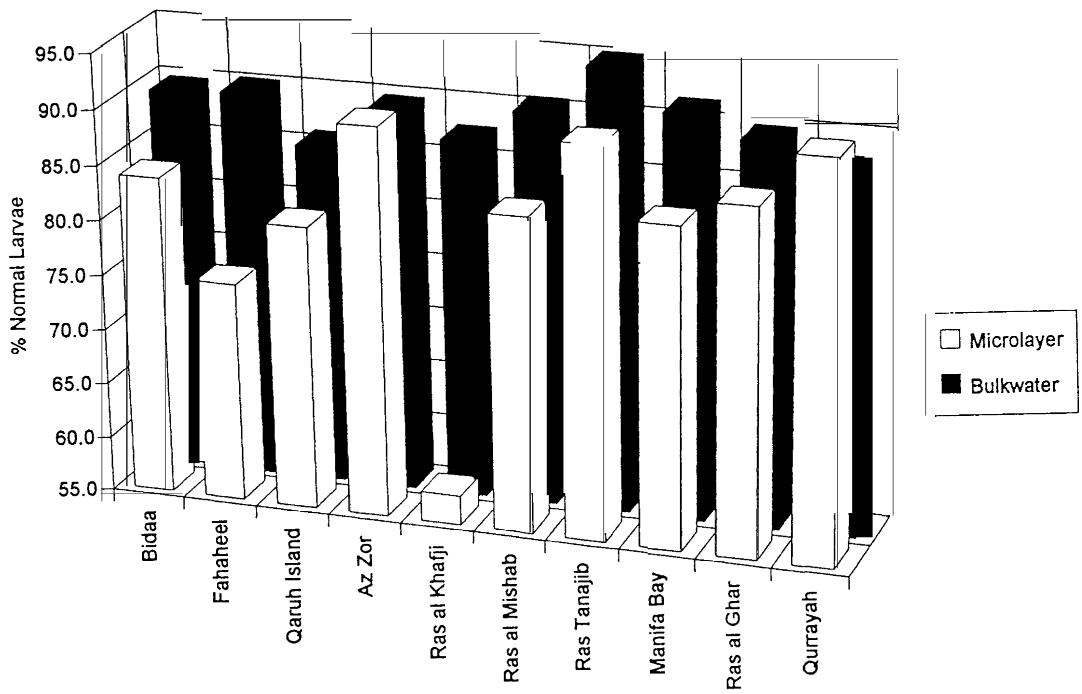


Figure 8.
Percentage of normal sea urchin *(Dendraster excemtricus)* larvae developing when fertilised eggs were incubated in microlayer or subsurface (bulkwater) samples collected from three sites on Gulf coast in August 1992 (from Hardy *et al.*, 1992).



3.4 Coral reef and fish communities

Background and objectives

The coral reefs of the Gulf are the most important repositories of biodiversity in the region and also among the most productive offshore ecosystems (see Basson *et al.*, 1977; Sheppa.rd *et al.*, 1992). As testament to this reef associated fisheries have been exploited by artisanal fishermen since earliest history. Further, there are also several coral cays (islands) in the Gulf, which are a direct product of reef building corals. These cays support significant nesting populations of green and hawksbill turtles and of several species of terns. Hence, both the reef fauna and islands' terrestrial and marine fauna depend on actively growing coral reefs for their existence and survival. Shortly after the 1991 Gulf War concern arose that these ecosystems may have been adversely impacted from oil and /or smoke from the burning oil wells.

Activities

(a) Saudi Arabia

Coral reefs of the Saudi Arabian Gulf islands of Karan, Jana and Jurayd were visited in November 1992 to assess whether there had been any impact of the Gulf War pollution, with particular emphasis on the condition of fish communities. Observations were also made at inshore reefs to the north of Abu Ali.

(b) Kuwait

Reports of stressed reefs and coral death in early 1992 suggested that long term impacts of the Gulf war were evident in the coral reef communities of Kuwait. A repeat of the 1991 post-war survey was therefore undertaken to assess the extent and likely cause of this reported damage. The coral islands of Kubbar, Qaru and Umm al Maradem were visited in 1992, as well as two inshore reefs not surveyed in 1991: Getty, at Ras al Zoor, and a small patch reef located close to a source of the Gulf War oil spill, Qit'at Urayfijan.

Results

(a) Kuwait

At the three coral islands little evidence was found of widespread coral death, with the exception of some *Acropora* and *Porites (see* Table 8). The patchy nature and limited extent of these mortalities, together with the known history of bleaching events and coral kills in the 1980's make it unlikely that Gulf War pollution was the primary cause, although its may have played some role. At Qit'at Urayfijan, however, there was evidence of impact, which was probably closely linked to the war, although coral recovery was well advanced. By contrast the Getty reef, not far from a beach heavily impacted by oil, was completely healthy. At all locations fishes were abundant, and fish communities vibrant. The presence of juveniles and sub adults suggested that recruitment and replenishment of the fish populations has continued since the war. However, analysis of long term trends indicates that there has been an overall decline in population size across species at Kubbar between pre-and post-war counts (Figure 9). Again, although Gulf War pollution may have had an influence, given the fluctuating nature of fish populations observed prior to the war, it is not possible to say that this was the primary cause of the decline. Given the uncertainty surrounding the causes of coral mortalities, and the fish decline at Kubbar, long-term monitoring of populations on Kuwait's reefs should be continued. This will provide the data necessary to underpin management of these important habitats.

Table 8.
Coral cover at Umm al Maradem, west reef, Kuwait between 1984 and 1992 (from Downing and Roberts, 1993).

Porites

	Cover by Porites %	Living %	Dead %
1984	70	67	33
1985	65	15	85
1987	61	41	59
1991	85	51	49
1992	71	42	58

Acropora

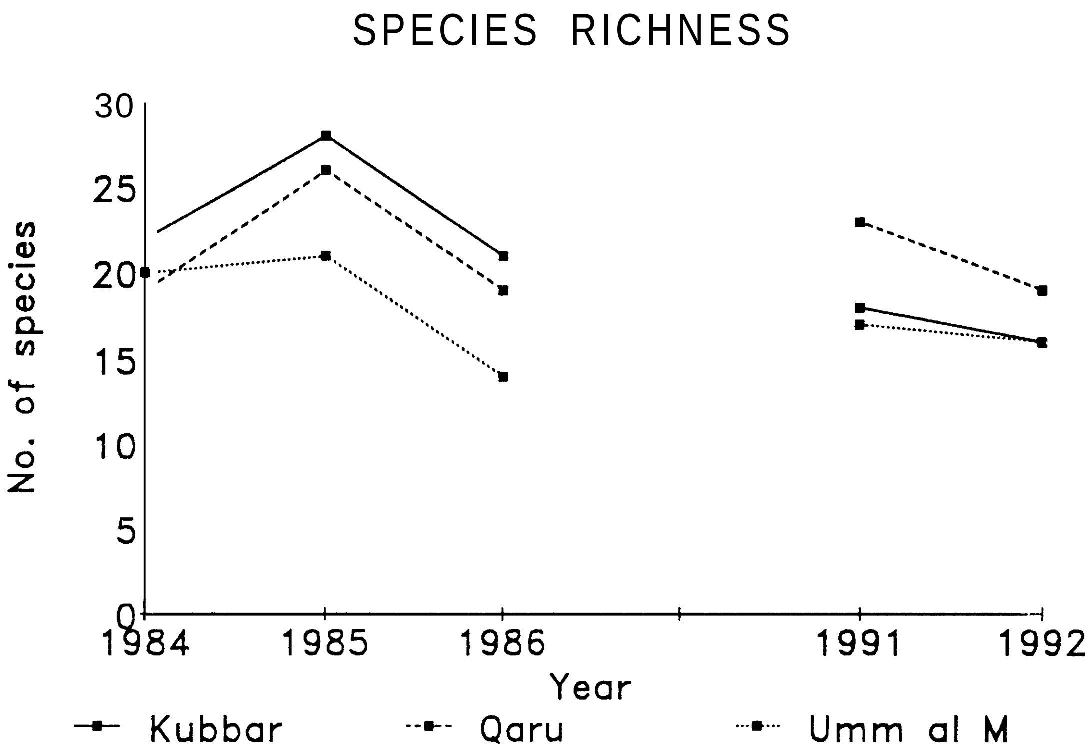
1991	**47**	99	1
1992	**55**	59	41

Further details are given in Downing (in press), Downing & Roberts (1993), IUCN (1992) and Roberts *et al.* (1993).

(a) Saudi Arabia

Patterns of abundance and number of species of fish present suggested that the fish communities were healthy and results were comparable to surveys made prior to the Gulf War (1985 - 87)(Table 9). Levels of recruitment by fish larvae also suggested that replenishment of the fish populations had been good since the war. At Abu Ali almost all fish present were juveniles, suggesting that there had been recolonisation since a mass mortality (probably in December 1991, perhaps due to cold water temperature). By contrast, the coral communities at Abu Ali appeared to be in good health as were communities at Karan and Jana. However, at Jurayd there was severe anchor damage to corals in the lee of the island with large areas of reef virtually reduced to rubble. It is concluded that the island reefs studied have survived Gulf War pollution remarkably unscathed, although more subtle long-term effects cannot be ruled out However, proper management of human activity on these reefs, especially anchoring, remains an urgent priority.

Figure 9.
Numbers of fish species present within 50m x 4m transect at Kubbar, Qaru and Umm al Maradem, Kuwait, during the period 1984-1992 (from Downing& Roberts, unpublished report to IUCN).



Further details are given in Downing &Roberts (1993), IUCN (1992) and Roberts *et al.* (1993).

	Karan Coles & Tarr	Karan 1992	Jana Coles & Tarr	Jana 1992	Jurayd 1992
Chrxant	189.7 (1)	155.0 (2)	185.3 (2)	361.7 (1)	136.7 (1)
Arcfuca	166.5 (2)				
Caevari	110.0 (3)		235.5 (1)		15.3 (5)
Thaluna	69.7 (4)	54.0 (3)	69.8 (4)	35.3 (3)	58.7 (2)
Chrtern	45.3 (5)		18.6 (7)		13.7 (6)
Pomtric	31.0 (6)		29.4 (5)	40.0 (2)	
Ecspulc	23.0 (7)	28.3 4.5)	24.8 (6)	15.0 (5.5)	8.3 (8.5)
Lepcyan	20.0 (8)				
Neosind	15.7 (9)				
Scapers	15.5 (10)				7.7 (10)
Abusaxa		193.7 (1)	127.8 (3)	16.7 (4)	41.7 (3)
Pseduto		28.3 (4.5)	14.8 (8)	15.0 (5.5)	18.3 (4)
Scasord		21.3 (6)			
Lutehre		11.7 (7)	11.6 (10)	11.3 (9.5)	8.3 (8.5)
Chanigr		10.3 (8)			
Psefusc		8.3 (9)			
Lutfuly		8.0 (10)			12.7 (7)
Astsemi			12.6 (9)		
Chamela				13.3 (7)	
Sigcana				12.7 (8)	
Cephemi				11.3 (9.5)	

Table 9.
The ten most abundant fish species observed on counts on Saudi Arabian Gulf islands reported by Coles & Tarr (1990) on 50 x 2 m transects (mean of six counts from 1985-87) and by Roberts 1993) on 50 x 4m transects in 1992 (mean of 3 counts). The rank order of each species is given in brackets after the number observed. Species names are abbreviated as the first three letters of the genus and the first four letters of the species (from Roberts, 1993).

3.5 Coral growth and geochemistry

Background and objectives

Reef corals are particularly sensitive to environmental stresses. Concern therefore arose that the 1991 Gulf War oil slick and/or reduced light and temperatures from the burning oil wells may have affected coral and reef growth. The purpose of this study was to collect small coral colonies for geochemical and related analysis, to determine possible effects of the Gulf war on coral growth and structure.

Activities

Five small colonies of the coral species *Porites Zutea* were collected from each of the reefs surrounding Karan and Jana islands (Saudi Arabia). Well rounded colonies measuring approximately 20-30 cm diameter were chosen from a depth range of 3-5 m on the outer slope zone of the leeward side of each island. Five colonies of the same species were also taken from reefs surrounding Qaru and Umm al Maradem islands (Kuwait). Analyses include sampling of different ‘year-bands’ and quantification of petroleum hydrocarbons, PAH's and stable isotopes. Growth maps for each coral colony are also being produced, to provide a graphic portrayal of annual growth and possible changes in growth patterns over recent years.

Results

Provisional results have been obtained (Figure 10). The diagram relates to the outer four annual rings of a Saudi Arabian Gulf coral. ‘Enrichment’ of fresh oil on the outside and higher concentrations of degraded oil within the head are evident. A computer enhanced scan of an X-ray of a coral from the Gulf is shown in Figure 11. Preliminary analysis has also revealed relatively high levels of mercury (Hg) in the corals from Kuwait (140-230 ng g^{-1} dry wt). Protocols need to be further ‘tuned’ but these initial data are interesting.

Figure 10.

Provisional results of geochemical studies on Gulf corals. The diagram relates to the outer four annual rings of a Saudi Arabian Gulf coral, *Porites Zutea.* 'Enrichment' of fresh oil on the outside and higher concentrations of degraded oil within the head are evident.

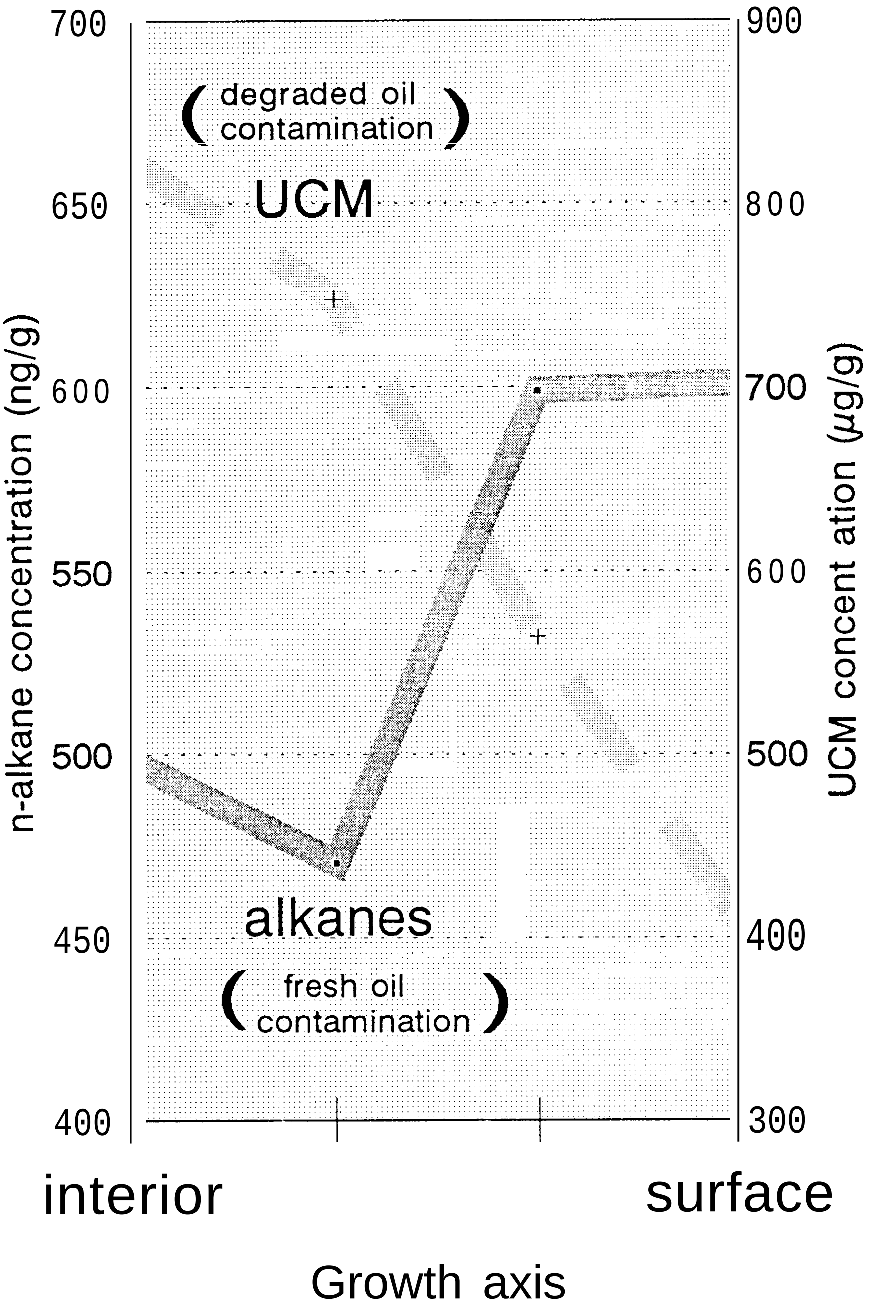
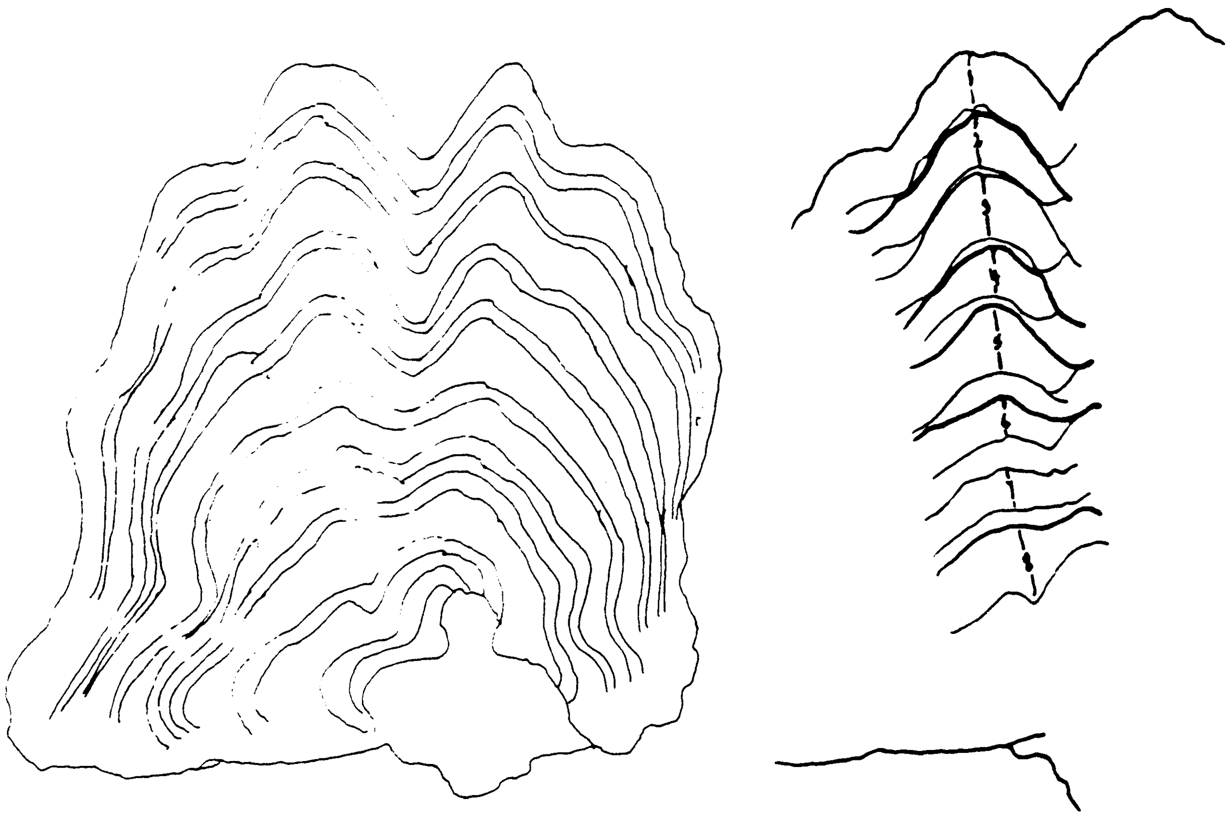


Figure 11.
A computer enhanced scan of an X-ray of a coral *(Porites Mea)* from Qaru Island, Kuwait, the Gulf (Figure ha). The axis of coral growth and 8 year-bands are also illustrated schematically (Figure llb)(both figures from Readman *et al.*, 1994).

a.

b.



3.6 Shrimp stock assessment

Background and objectives

The Gulf's fisheries and its coastal communities have been closely interlinked since earliest history. Maintenance of these and other transboundary resources is therefore a high priority, both nationally and regionally, particularly since the shrimp fisheries represent a multimillion dollar industry. Shortly after the 1991 incursions in Kuwait, concern arose that the stocks might become adversely impacted from the oil slick and burning oil wells. While adult shrimp are relatively hardy animals, their eggs and larvae are less so. Severe reduction in water or habitat quality therefore has the potential to disrupt spawning activity and success. If severe, this can impair recruitment of young shrimp into the fishery, which can be harmful to the stocks. The main objective of this study was assessment of the shrimp fishery along the western Arabian Gulf, to determine possible effects of the 1991 war on the stocks. Quantitative analyses aimed to define the immediate and possible long-term damage to the shrimp stocks and fisheries of the Saudi Arabian Gulf and Bahrain caused by the oil fires, oil slicks and possibly other factors. In addition, the studies helped identify priorities for future research, to assist management develop measures that will allow sustainable utilisation and recovery of the stocks.

Activities

Visits were made to Saudi Arabia and Bahrain in 1992 and 1993. Activities included: i) collection of commercial fishery data aboard a commercial Saudi trawler, ii) collection of commercial catch data for the Saudi Arabian and Bahraini fleets from company records, iii) subsequent analysis of data including Surplus Production Models and Dynamic Pool Models using the well-known ELEFAN size-based assessment models.

Results

(a) Updated analysis of shrimp fisheries

In 1991-92 the Saudi Arabian East coast prawn stock showed a decline in spawning biomass to about 1-10%, and a decline in total biomass to about 25%, of the pre-war level. This is because spawning biomass in autumn fell to zero as observed in the artisanal fleet's landings. The CAI gives higher average values for the 1991-92 period, but in autumn 1991, crucial for autumn spawning, there were few if any adults in the population. This decline in spawning biomass by at least an order of magnitude is likely to cause a reduction in recruitment and make the stock more sensitive to recruitment over fishing. The lack of suitable data makes it impossible to determine the extent to which landings were actually reduced by low recruitment. The low spawning biomass is probably causally related to the decline in stock size and condition that occurred subsequent to pollution by oil spills and oil smoke following the firing of Kuwaiti oil wells in February 1991 (Table 10). It is not certain that the stock can continue to maintain its presently low level of landings, and a retum to the previously much higher landings sustained by the fishery will require great care and sensitivity to the stock biology and to its environment. Revised estimates of landings for 1992 lead to a somewhat reduced estimate of total losses caused by the war from 1990 to the end of 1993, about **US$41 m instead** of the previous estimate of US$55 m. A full assessment of the environmental effects of the war and of their implications for stock assessment and fisheries management are provided below. -

	(a)	(b)	(c) CATCH (T)	(d)	(e)	(f)	(g) EFFORT	(h) CPUE	(i
Year	SAFISH owned	SAFISH contract	SAFISH total	Artisanal total	Other Industr.	Total	SAFISH (boatyrs)	t/boat/yr	SAFISH (boatyrs)
82	777	1478	2255	0 (d)	(a)	2255	4	194.5	11.6
83	970	1221	2:91	219 (d)	(a)	2410	4	242.5	9.9
84	785	1243	2028	438 (d)	(a)	2466	6	30.8	18.9
85	1175	1015	2190	657 (d)	(a)	2847	6	195.8	14.5
86	607	511	118	875	62	2055	6	101.2	20.3
87	1072	507	1579	916	49	2544	9	119.1	21.4
88	1374	446	1820	1218	45	3183	9	52.7	20.8
89	1748	149	1897	1407	426	3730	9	194.3	19.2
90	1208	106	314	808	142	2264	6 (b)	201.3	11.2
91	375	0	375	812	9	1196	4.5 (c)	83.3	14.4
92			556	500 (e)	0 (f)	1056	12	46.3	22.8

Table 10.
Summarised shrimp fishery catch data for the Saudi Arabian Gulf coast from 1982-92, using SAFISH boat years as the nominal effort unit and Catch per Unit Effort (CPUE) in whole fresh t per boat year. The nominal effort unit chosen is the SAFISH owned boat year. Nominal CPUE is measured in t/SAFISH boat/year. (from Mathews *et al.*, 1993).

(b) Bahrain shrimp fisheries

The Bahraini prawn stock is fished very near MSY, and is therefore sensitive to any important environmental impacts. During the pollution caused by the Iraq/Kuwait war in 1991-92, effort fell by less than 10%, but landings fell by about 50%. It is likely that the decline in landings was caused by the war related pollution. A surplus production model was constructed which provides a good fit to the data and suggests that any further increase in effort will lead to little or no increase in landings. Although the fishery shows no sign of biological over fishing, bioeconomic analysis shows that economic returns are low to both owners and fishermen. A moratorium on issuing new licenses should be strictly enforced. An effort reduction policy would lead to increased economic returns and to a situation in which the stock would be less sensitive to environmental impacts. Economic losses caused by the war to the fishery in 1991-92 only were estimated at US$3.35 m. The stock should be monitored to determine if there are any long term effects of the war on the stock and the fishery it sustains.

(c) Integrated analysis of shrimp fishery data

Preliminary analysis of Gulf fishery data suggested that detailed information about the incidence and causes of schooling in prawns is needed to allow assessment of the effects of the Gulf War on landings throughout the western Gulf. All western Gulf prawn stocks support important fisheries, with *Penaeus semisulcatus* dominating the landings. Prior to the 1991 Iraq/Kuwait war, they were all in good condition, and supporting productive fisheries. A new biological model was constructed, incorporating the effects of schooling, effort and environmental factors on prawn landings, in order to provide a clearer understanding of the effects of the war on western Gulf prawn stocks, and to allow their improved management.

Data on mean monthly shot duration (hr/shot) and mean hours fished (hr/day) were analysed so as to understand the schooling process. The east (Saudi Arabian) stock showed intense schooling, characterised by mean CPUES (Catch Per Unit Effort) of 1,000-4,000 kg/hr in July and August, when mean shot duration was **c** 1.0 hr/shot, with a mean of 2-3 hr/day's fishing. In the winter, when schooling did not occur, CPUE fell to 50-150 kg/hr, shot duration increased to 3-4 hr/shot and the fishing day increased to 13-15 hr/day. It appears that fishermen change their strategy to as to adapt themselves to the presence or absence of schooling. CPUE data for Bahrain show that schooling never occurs.

Further analysis of the Gulf's shrimp fisheries is given in Mathews *et al.* (1993).

Note 1: Data for 1990 were mostly from fishing areas South of Jubail, and for 1991 and 1992 are sparse because of the cessation of fishing, owing to security restrictions and to the much lower catch rates which limited the expenditure of effort.

Note 2: Column f = c + d + e. Column h = a/g. Column i = f/h.

(a) Landings included under "SAFISH contract"

(b) Adjusted by x 0.5 to allow for the transfer of boats from the East Coast to the Red Sea owing to the War.

(c) Number of boats adjusted by x 0.45, the ratio of hours trawled in 1991 to 1990 (Table 7). This reflects the reduction in effort because of the suspension of fishing owing to poor landings.

(d) Estimated by linear interpolation between Ot in 1982 and 875 t in 1986.

(e) Estimated.

(f) Data unavailable; assumed on the basis of previous history.

3.7 Shrimp spawning studies

Background and objectives

In view of their paramount socioeconomic importance, the Gulf's shrimp and other fisheries are a high priority for conservation. Shortly after the 1991 incursions in Kuwait concern arose that the stocks might become adversely impacted from the oil slick and burning oil wells. While adult shrimp are relatively hardy animals, their eggs and larvae are less so. Severe reduction in water or habitat quality therefore has the potential to disrupt spawning activity and success. If severe, this can impair recruitment of young shrimp into the fishery, which can be harmful to the stocks. The main objective of this study was assessment of shrimp spawning activity along the western Arabian Gulf, to identify possible changes in egg and larval concentrations (i.e. spawning activity) since the 1991 Gulf War. The study supplements the stock assessment of adult shrimp (3.6).

Activities

Duplicate zooplankton samples were collected at Ras Tanura and Safaniya on the Saudi Arabian Gulf coast in April 1992. Both are known spawning areas of penaeid shrimp including *Penaeus semisulcatus,* the principal commercial species in Saudi Arabian fisheries of the Gulf. Zooplankton and penaeid larval abundance in 1992 were compared with data collected from the same localities during the same period in the 1970's.

Results

At Ras Tanura, mean penaeid larval abundance was significantly lower in 1992 (0.275 m^{-3}) than 1976 (6.77 m-3), whereas mean zooplankton abundance showed no significant change (Table 11). Data also suggest that penaeid larval abundance at Ras Tanura was lower in 1992 than 1975, 1977 and 1978. At Safaniya, both mean zooplankton and penaeid larval abundance were significantly lower in 1992 (0.128 ml m^{-3} & 0.009 m^{-3}) than in 1978 (0.77 ml m^{-3} & 16.70 m^{-3}) (Table 12). Possible reasons for the observed patterns include natural environmental changes, 'normal' background impacts (e.g. coastal reclamation, dredging, oil pollution) and impacts arising from the 1991 Gulf War. It is suggested that interactions between these and perhaps other factors, rather than any single cause, maybe involved. Further details are given in IUCN (1992) and Price *et al.* (1993 b).

Table 11.
Summarised statistics comparing settled plankton volumes, penaeid larval densities and oceanographic conditions at Ras Tanura in 1976 and 1992 (Price et al., 1993b).

	Settled Plankton volume (ml m^{-3})	Penaeid larval density (nos m^{-3})	Temp. Range (deg. C)	Sal. Range (PPt)
1976				
Mean abund.	0.85	6.77		
Oceanogr. cond.			21.3-23.9	40
1992				
Mean abund. (net A)	1.047	0.366		
Mean abund. (net B)	1.019	0.184		
Mean (A & B)	1.03	0.275		
DF	3	3		
t value (paired)	1	1.207		
Significance	NS (2-tailed)	NS (2-tailed)		
Oceanogr. cond.			22.0-22.5	40
1976 : 1992 (mean)				
t-value (unpaired)	0.647	2.847		
DF	6	6		
Significance	NS (l-tailed)	P <0.01 (l-tailed)		

Table *12.*
Summarised statistics comparing settled plankton volumes, penaeid larval densities and oceanographic conditions at Safaniya in 1978 and 1992 (Price et al., 1993 b).

	Settled Plankton volume (ml m^{-3})	Penaeid larval density (nos m^{-3})	Temp. Range (deg. C)	Sal. Range (PPt)
1978				
Mean abund.	0.77	16.704		
Oceanogr. cond.			18.2-19.6	37-38
1992				
Mean abund. (net A)	0.128	0.008		
Mean abund. (net B)	0.355	0.009		
Mean (A & B)	0.241	0.009		
DF	17	17		
t-value (paired)	2.316	0.141		
Significance	P <0.05 (2-tailed)	NS (2-tailed)		
Oceanogr. cond.			21.0-23.0	39-45
1978 : 1992 (mean)				
t-value (unpaired)	4.243	3.946		
DF	23	22		
Significance	P <0.01 (2-tailed)	P <0.01 (l-tailed)		

4. Synthesis and Conclusions

The 1991 Gulf Warg enerated much concern and interest, nationally, regionally and internationally. A question frequently asked of Gulf scientists is whether environmental predictions about the 1991 war have matched reality. Research to date indicates that a simple answer cannot realistically be provided, a contention that can be justified on several counts. First, predictions often have differed widely, ranging from the Gulf becoming virtually lifeless to more or less trivial effects. In addition, not all areas of the Gulf suffered the same overt damage; for instance oiling and petroleum hydrocarbon contamination was confined mainly to the northwestern parts of the Gulf, while air pollution and reduced light and temperature from the burning oil wells were more widespread. Further, different ecosystems that were exposed to oil or smoke were not necessarily affected in the same way. For instance, available data tentatively point towards a decline in Saudi Arabian shrimp populations, while other ecosystems and species groups (e.g. coral reefs) may not have been so heavily impacted. The degree of environmental damage from an event such as a war depends also on the time-scale over which its effects are considered. Over a period of months, and perhaps even one or more years, fauna such as coastal bird populations undoubtedly suffered significant casualties. On the other hand over a time scale of five years (perhaps ten or more years in some instances), species populations and ecosystems may become more or less restored, largely by natural processes. Only time will tell.

A major difficulty in assessing impacts of the Gulf War is dealing with the highly variable spatial and temporal scales over which marine processes and species operate. Many environmental management problems relate to theoretical and practical difficulties associated with scale. For example, natural boundaries of different marine environments are difficult to visualise and often defy definition, particularly in an environment that is heterogeneous and changeable (e.g. the Gulf). Superimposing artificial/human management boundaries upon a natural system that is inherently complex is therefore seldom straightforward. An example is the misalignment common between the scales of natural marine systems (e.g. migratory turtles /open sea /coral islands) and systems attempting to manage them (e.g. national institutions).

Multidisciplinary approaches to modelling and governance have been outlined (McGlade & Price, 1993) to help overcome these and other difficulties. From this work and related studies the following tentative conclusions may be drawn.

1. The extent of the major impact from the oil slick has been determined at abroad geographic level (i.e. the western Gulf extending from Kuwait southwards to Abu Ali). However, a longer-term picture of oil distribution and its fate is not yet possible.

2. The extent of population declines is known for some species groups. Hence, the marked decline in shrimp biomass in Saudi Arabia was associated with the timing of the Gulf War. However, whether war was the actual/only factor responsible is still not completely clear cut. It also appears that the decline is local rather than regional. An extensive time series will be needed to determine whether local decline observed is transient or more permanent.

It maybe that acute impacts (e.g. from the war) in the longer-term maybe no greater than chronic more persistent incursions arising from activities such as coastal habitat loss and dredging.

3. From an understanding of the Gulf's biophysical features (i.e. perturbed nature, short-term dynamics) we would expect ecosystems and species groups generally to recover within approximately five years. Available data on abundance and diversity of reefs, coral fish and intertidal systems (Downing & Roberts, 1993; Krupp & Jones, 1993; Watt *et al.,* 1993) would seem to support this contention. However, on-going monitoring building on earlier studies is needed to determine the long-term persistence of contamination and its ecological consequences. Oil/sediment samples have recently been collected for toxicity testing (Hardy *et al.,* pers.comm.). We would also expect that while populations may have become depleted locally, regional population disruptions are unlikely. However, synergistic effects from impacts unrelated and related to the war (e.g. habitat loss) may be important and prove to have more long lasting effects.

4. As a result of the burning oil wells mean seawater temperatures were reduced by 2.5°C at Manifa (Saudi Arabia) in 1991 compared with the mean over the previous five-year period (McCain *et al.,* 1993). These authors suggest that reproduction of marine organisms in particular might be affected the following year. Reduced temperatures may have been a factor associated with the low post-war abundance of both adult shrimp and larval shrimp. But while regional temperatures and solar fluxes were reduced by the smoke plumes, the effects appear not to have extended to consistently affect regional weather (Gerges, 1993).

5. While enormous socioeconomic effects were felt following the Gulf War, the majority were related to the direct effects of war (i.e. damage to buildings, infrastructures, loss of livelihood, health). Direct effects also arose from damage to the marine environment (e.g. cessation of fishing). However, the major effects appear to have been indirect ones (e.g. use of funds, which in many cases were undoubtedly diverted from other uses such as routine research and monitoring unrelated to oil pollution).

6. Extended forms of governance are advocated to address interconnections between the environmental and human domains, and to deal more effectively with transboundary problems and opportunities. A theoretical framework is laid out, and applied to the setting in the Gulf in McGlade &Price (1993). In particular the need is demonstrated for greater integration of the social and natural sciences; and from this, development of multidisciplinary models to improve understanding of the Gulf and to determine its governing needs.

Whatever the eventual environmental outcome of the 1991 Gulf War, there is a growing realisation that marine renewable resources often contribute significantly to national economies and even geopolitical stability. Indeed their effective assessment and management is fundamental to sustainable development. The recent war highlighted dramatically both the importance and vulnerability of the Gulf marine environment. The role of the Gulf in national, regional and international affairs certainly has never been greater.

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Annex 1

List of acronyms

CAI	Cohort Abundance Index
CITES	Convention on International Trade in Endangered Species
CPUE	Catch Per Unit Effort
CZM	Coastal Zone Management
CEC	Commission of European Communities
EPD	Environmental Protection Department
ESAS	Environmentally Sensitive Areas
GAOCMAO	Gulf Area Oil Companies Mutual Aid Organisation
GCC	Gulf Cooperative Council
IAEA	International Atomic Energy Agency (Monaco)
IBP	International Biological Programme
ICCE	International Centre for Conservation Education
IOC	Intergovernmental Oceanographic Commission of UNESCO (France)
IUCN	The World Conservation Union (Switzerland)
JICA	Japanese International Cooperation Agency
KAP	Kuwait Action Plan
KFUPMRI	Research Institute of King Fahd University of Petroleum and Minerals (Saudi Arabia)
MAB	Man and the Biosphere Programme
MEMAC	Marine Emergency Mutual Aid Centre (Bahrain)
MEPA	Meteorology and Environmental Protection Administration (Saudi Arabia)
MSY	Maximum Sustainable Yield
NCWCD	National Commission for Wildlife Conservation Development (Saudi Arabia)
NOAA	National Oceanic and Atmospheric Administration (USA)
PAH's	Polycyclic Aromatic Hydrocarbons
ROPME	Regional Organisation for Protection of the Marine Environment (Kuwait)
SAUDI ARAMCO	Saudi Arabian Oil Company (formerly ARAMCO)
UAE	United Arab Emirates
UNCLOS	UN Convention on the Law of the Sea
UNDP	United Nations Development Programrne (Saudi Arabia)
UNEP	United Nations Environment Programme (Kenya)
UNESCO	United Nations Educational, Scientific and Cultural Organisation (France)
WWF	World Wide Fund for Nature (Switzerland & Japan)

Annex 2

List of major agencies, organisations and institutions collaborating with IUCN on coastal and marine environmental assessments of 1991 Gulf war

Eastern Caribbean Center, US Virgin Islands
Environmental Protection Department, Kuwait
Intergovernmental Oceanographic Commission of UNESCO, France
International Atomic Energy Agency, Monaco
International Centre for Conservation Education
Japanese International Cooperation Agency
Meteorology and Environmental Protection Administration, Saudi Arabia
National Oceanic and Atmospheric Administration, USA
Regional Organisation for Protection of the Marine Environment, Kuwait
University of Newcastle upon Tyne, UK
University of Western Washington, USA
University of Warwick, UK
United Nations Development Programme, Saudi Arabia
United Nations Environment Programme, Kenya
World Wide Fund for Nature (WWF - International & WWF - Japan)

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2. Price, A. R.G.; Jeudyde Grissac, A. & Ormond, R. 1992. *Coastal Assessment of the Pare National duBanc d'Arguin, Mauritania: Understanding Resources, Exploitation Patterns and Management Needs. x + 44* pp.

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   Volume 3: Maldives. vii+- 38pp.
   Volume 4: Pakistan. vii+ 42pp.
   Volume 5: Sri Lanka. vii+ 67pp.

9. Salm, R. V.; Jensen, R.A.C. & Papastavrou, V.A. 1993. *Marine Fauna of Oman: Cetaceans, Turtles, Seabirds and Shallow Water Corals.* vi + 66pp.

10. Pernetta, J.C. 1993. *Mangrove Forests, Climate Change and Sea Level Rise: Hydrological Influences on Community Structure and Survival, with examples from the Indo-West Pacific.* vi+ 46pp.

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