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

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

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 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.

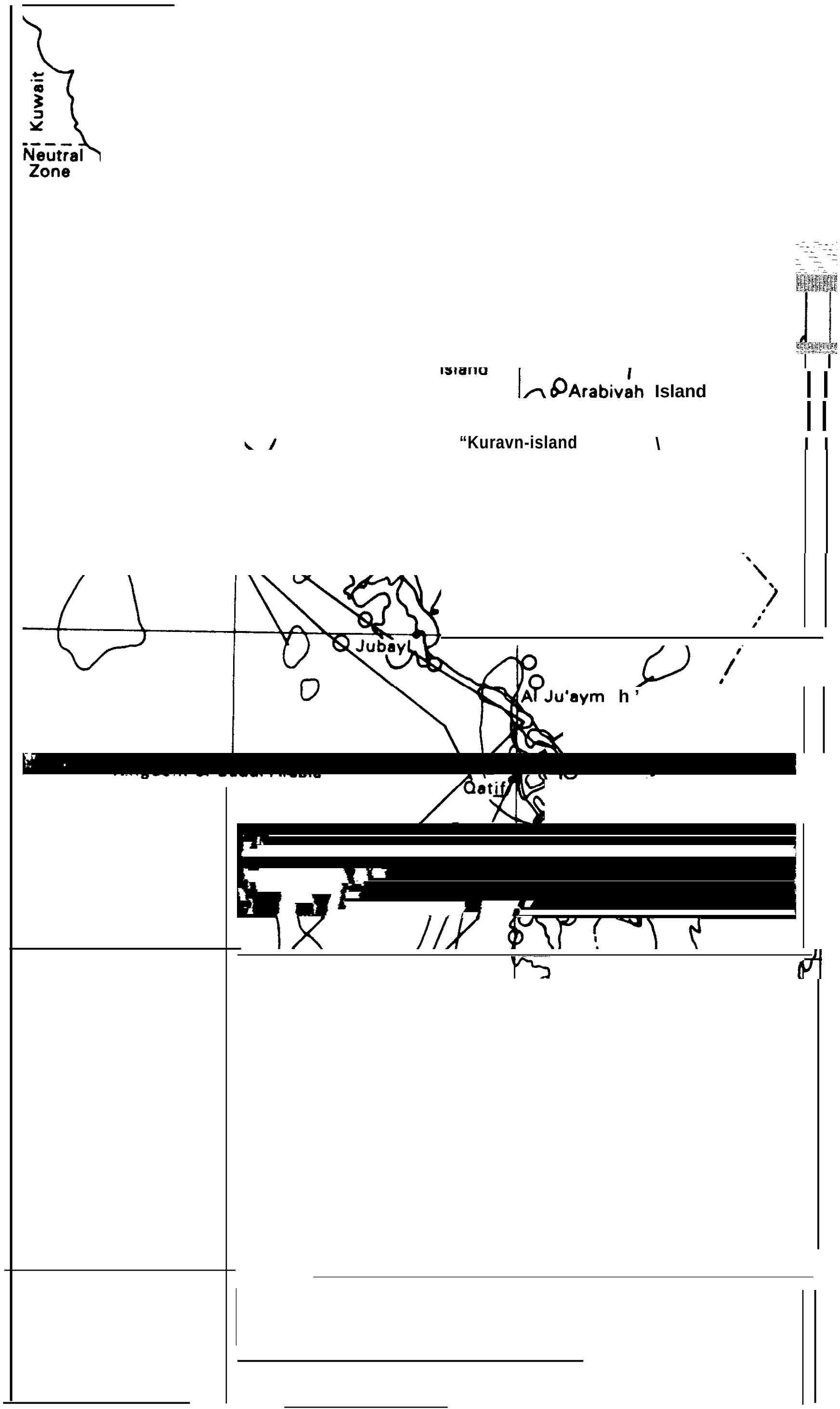
Table 1.
Coastal and marine uses and major environmental pressures in the Gulf (from Sheppard *et al.*, 1992; Price, 1993).

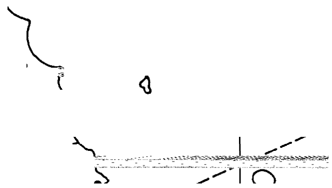
Coastal and Marine Use	Actual or Potential Environmental Pressures
Shipping and Transport	
Shipping	Oil spills; anchor damage
Ports	Coastal reclamation and habitat loss; dredging, sedimentation; oil and other pollution
Residential and Commercial	Coastal reclamation and habitat loss; dredging, developments 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

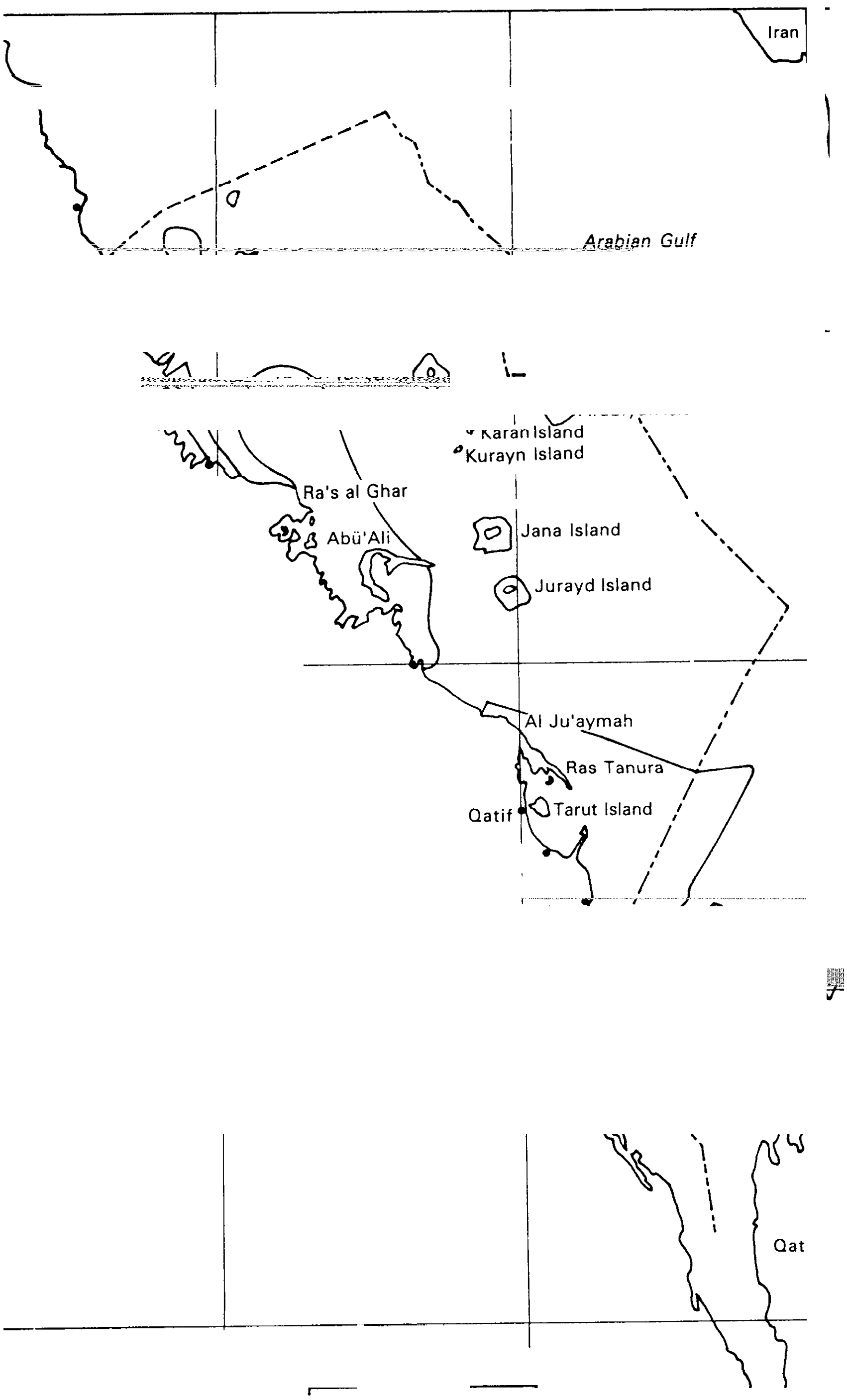
2.3 Previous environmental and biological studies

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

Among the analyses undertaken in Saudi Arabia were identification of principal resource use conflict areas by map analysis


Kuwait
Neutral Zone
Arabivah Island
Kuravn-island
Jubayl
Al Ju'aym
Qatif




Iran
Arabian Gulf
Karan Island
Kurayn Island
Ra's al Ghar
Abü'Ali
Jana Island
Jurayd Island
Al Ju'aymah
Ras Tanura
Tarut Island
Qatif
Qat

3. Post-war Coastal and Marine Assessments

3.1 Initial post-war assessment

Background and objectives

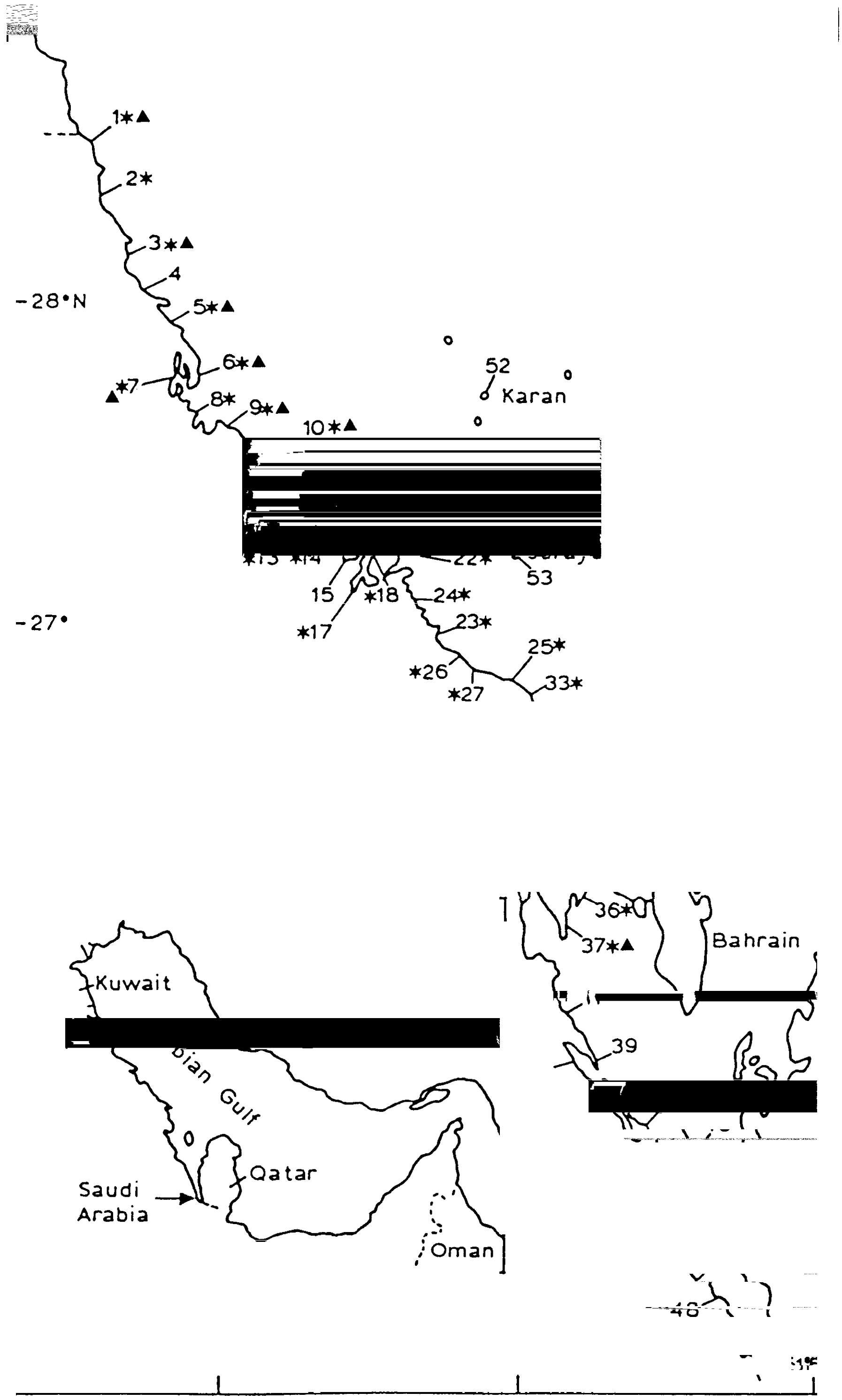
Following the environmental incursions in Kuwait in early 1991, an immediate priority was define the extent and magnitude of environmental impacts and priorities for protection and/or cleanup. The overall purpose of the initial mission was therefore to report on the extent of damage to the Gulf's coastal 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).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23*
25*
*26
*27
33*
36*
37*▲
Bahrain
Kuwait
[redacted]
39
[redacted]
bian Gulf
Qatar
Saudi
Arabia
Oman
48

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**
Algae	*3.5*
Halophytes	*2.7*
Seagrasses	*2.2*
Birds	*0.6*
Fish	**0.3**
Invertebrates	5.1
Use/impact	
oil	**2.0**
Metals, plastics, etc.	
Driftwood	

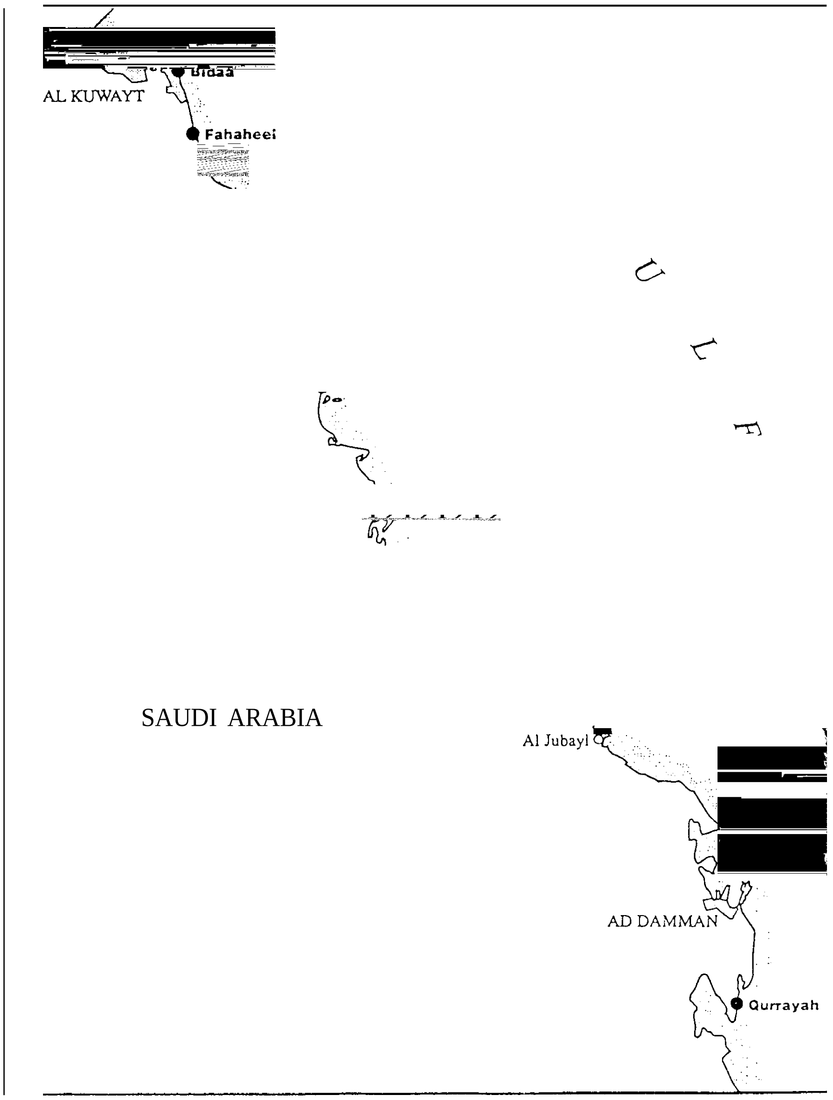
3.3 Petroleum hydrocarbons and other contaminants

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

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

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 [illegible] following the Gulf War (concentrations [illegible] dry wt [illegible] s (from Fowler *et al.*, 1993).

Country	Site	Sampling date (1991)	Dry / Wet	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})	Res. / Unres. alis.	[illegible]
Kuwait	Island [illegible])	19/6	0.[illegible]	0.10	13.0	3.4	28	27	3.0	0.13	[illegible]
Saudi Arabia	[illegible]	20/8	0.84	0.60	1140	200	369	268	8.0	0.03	2.20
	[illegible]	21/8	0.72	0.80	1340	240	558	432	52.0	0.14	2.00
	[illegible]	19/8	0.82	0.17	62	11.0	82	66	6.0	0.10	2.20
	[illegible]	21/8	0.85	0.17	260	47.0	129	93	9.0	0.11	2.10
	[illegible]	21/8	0.82	0.50	1400	250	671	496	76.0	0.18	23.00
	[illegible] 7)	18/9	0.85	-	5	0.9	19	13	3.0	0.30	0.90
Bahrain	[illegible]	16/6	0.62	0.34	6	1.6	41	38	7.9	0.26	2.60
	[illegible]	14/6	0.72	0.04	3	0.6	23	15	1.4	0.10	0.26
	[illegible]	14/6	0.73	0.11	14	3.6	35	31	3.0	0.11	0.47
U.A.E.	[illegible]	29/9	0.79	0.09	5	1.0	16	10	0.7	0.08	0.46
	[illegible] 2)	29/9	0.74	0.05	7	1.4	16	12	0.4	0.04	0.25
Oman	[illegible]) (13)	2/10	0.78	0.01	1	0.2	6	4	0.2	0.05	0.10
	[illegible] (14)	5/10	0.75	-	2	0.4	8	5	0.6	0.16	0.27
	[illegible])	6/10	0.77	0.01	3	0.6	6	4	0.5	0.15	0.18
	[illegible] 6)	9/10	0.55	0.09	12	2.3	22	16	3.5	0.27	1.20

*HEOM = Hexane [illegible] materi[illegible]
N.D. = No[illegible] detecte[illegible]

Ph... (ng...)	1-Methyl Phen. (ng g^{-1})	2-Methyl Phen. (ng g^{-1})	Fluor. (ng g^{-1})	Pyrene (ng g^{-1})

0 0 0

2)

Ta
Concentra[redacted]of h marine b
(from Fow[redacted]*al.*,

Country			Sampling date (1991)	Bivalve species		H.E.O.M. (mg/g)							Σn-C_{14} n-C_{34} (µg/g)
S.ARAB.	Ras Al				0.12	12	570	107	184	14	170	0.08	6.9
	Ras Al Tanajib (2)	140	19/8					0	234	24	210	0.11	7.1
	Ras Al Tanajib (3)	140	19/8		0.12	30	2600					3	15.0
	Ras Al Qurrayyah (4)	390			0.14	17	86						6.8
							3	0.8	40	14	26	0.54	3.5
	Askar (6)	435	14/6				27	7.0	124	11	113	0.10	0.9
	Askar (7)	435	14/6				33						0.8
U.A.E.	Jebel Al			*Pinctada* ** *margaritifera*			15	2.8	59	5	54	0.10	1.8
OMAN				*Saccostrea*[redacted] *cucullata* (Rock oys[redacted]er)			34						
				Saccostrea[redacted] *cucullata*			30	5.4	40	19	21	0.90	2.6
				Saccostrea[redacted] *cucullata*			31	5.9	27	6	21	0.30	2.7

† H.E.O.M. = Hexane extractable organic m[redacted]ter
** = Recently considered to be *P. radiata*.[redacted]
*** = Tentatively identified as *S. exilis*.

Location	n-17 (ng/g	[redacted]	n-C18 (ng/g-1	Ph[redacted] (ng[redacted]	[redacted]	Res. arom. hydros. (µg/g-1)	Unres. ar hydros. (µg/g-1)	P[redacted] (r[redacted]	1-Met Phen. (ng/g-	2-Methy Phen. (ng/g-1)	Fluor. (ng/g-1)	Pyrene (ng/g-1
(1)	1200	[redacted]	480	43[redacted]	[redacted]	12	77	7[redacted]	79	69	100	470
(2)	700	[redacted]	410	70[redacted]	[redacted]	30	110	5[redacted]	29	82	1200	1400
(3)	1400	[redacted]	1060	12[redacted]	[redacted]	30	210	7[redacted]	100	110	2100	1500
(4)	1800	[redacted]	490	20[redacted]	[redacted]	7.5	19	2[redacted]	20	18	160	100
(5)			24	39[redacted]	[redacted]	4.0	12	N[redacted]	2	-	12	29
(6)	430		57	70[redacted]	[redacted]	5.0	62	N[redacted]	100	10	9	5
(7)	400		26	54[redacted]	[redacted]	7.0	57	N[redacted]	75	15	N.D.	6
(8)	630		66	15[redacted]	[redacted]	4.4	51	1[redacted]	20	6	6	9
(9)	35		29	20[redacted]	[redacted]	4.1	54	3[redacted]	26	11	N.D.	6
(10)	340		28	15[redacted]	[redacted]	8.9	69	2[redacted]	110	18	9	39
(11)	340		22	25[redacted]	[redacted]	3.7	72	2[redacted]	8	4	N.D.	60

in s[illegible] lowing t Wa[illegible] are on dry b[illegible]

0 77

410	*Ephinephelus* [illegible]
410	*Lethrinus ne*[illegible]
410	*Acanthopagr*[illegible]
430	*Ephinephelus* [illegible]

1

1

0.22
0.32
0.21
0.28
0.22
0.29
0.23

*M =
†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*.

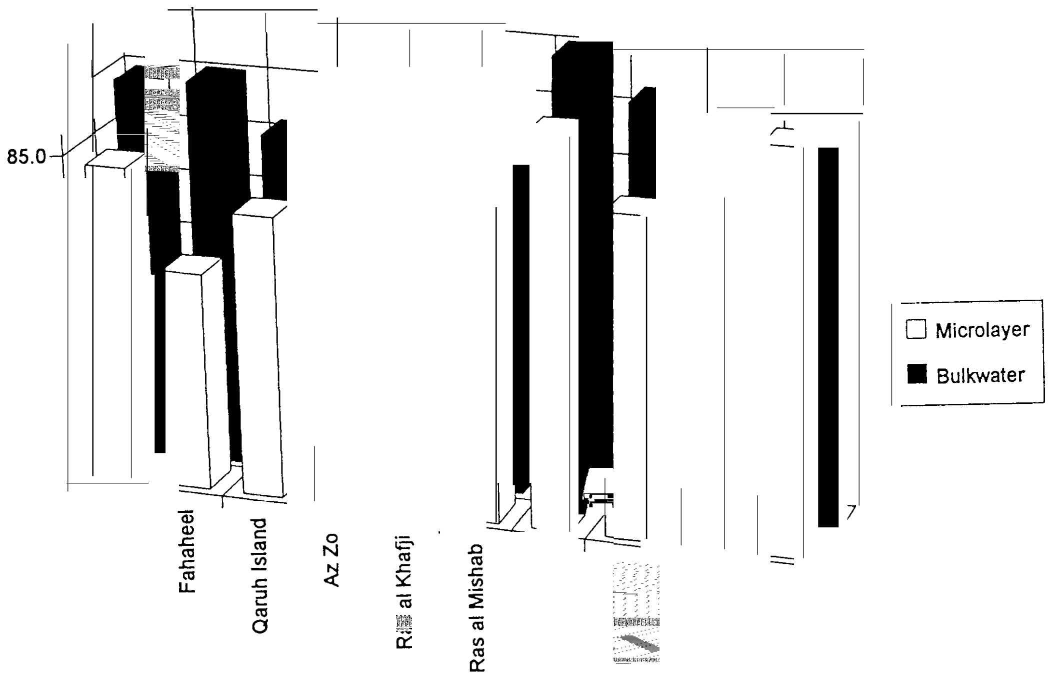
												Unres. arom HCs (μg g^{-1})	Phen. (ng g^{-1})	1-[redacted] Ph[redacted] (n[redacted]	[redacted]yl [redacted])	2-Methyl Phen. (ng g^{-1})	Fluor. (ng g^{-1})
							320	140	180	170								19
									780									56
									1700									150
									940									140
									1900									160
									48									15
									1200									250
									53									6.0
									1200									660
									80									12
									1800									1600
									49									13
									1100									83
									69									47
									1100									460
												1.1	N.D.	N.D.	N.D.	N.D.	35	100
														0	N.D.	N.D.	N.D.	12
									28	10	6.4	[redacted]						.D.
		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
																4	7.0	5.0
[redacted]bai	*Ephinephelus suillus*§	23	6.8	16	0.43	1.2	170	400	34		2	3.8	5.4	N.D.	4.5	1.8	[redacted]	[redacted]
		174	78	96	0.81	8.3	740	2400	200		15	77	38	N.D.	30	28	[redacted]	[redacted]
								130	45	20					11		3.15	14
								1900	32	27					16		N.5.(	N.D.
								670	40	53					5.0		2.16	3.5
								2700	63	510					N.		N.3.	13
								(3300)·	†13	10					4.5		N.N.	6.7
								1500	-	30					N.		N.5.	12
								76	-	15					N.		N.N.	12
									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 ($\mu g\ g^{-1}$) (from Fowler *et d.*, 1993).

Location	Date	Cu	Pb
			1.03
			1.70
			2.58
			3.49
			4.44
			2.62
			3.49
			13.5
			5.05
			8.94
			2.30
			15.9
			6.78
			11.0
			1.3
			24.0
			2.44
			5.20
			1.88
			9.36
			3.23
			0.64
			3.6
			1.09
			2.19
			1.01
			5.21
			0.63
			0.74
			3.2
			1.49
			0.75
			0.54
			2.96
			2.54
			5.5
			0.91
			1.20
			0.98
			9.50
			1.21
			1.51

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

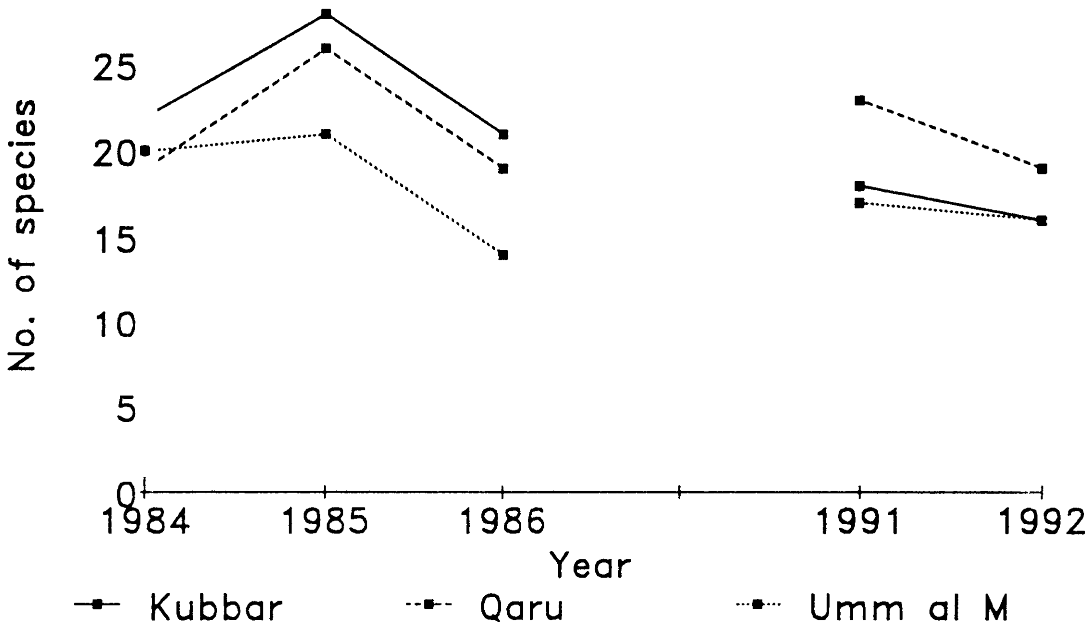
Acropora

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


No. of species
25
20
15
10
5
0
1984
1985
1986
1991
1992
Year
Kubbar
Qaru
Umm al M

Karan Coles & Tarr		Karan 1992		Jana Coles & Tarr		J[illegible]	
189.7	(1)			185.3	(2)	361.[illegible]	(1)
166.5	(2)						
110.0	(3)			235.5	(1)		(5)
69.7	(4)		(3	69.8	(4)		(2)
45.3	(5)			18.6	(7)		(6)
31.0	(6)			29.4	(5)		
23.0	(7)			24.8	(6)		(8.5)
20.0	(8)						
15.7	(9)						
15.5	(10)						(10 [redacted]
					[illegible]	16.7	(3)
					[illegible]	15.0	(4)
					[illegible]	11.3	(8.5
							(7)
						13.3	
						12.7	
						11.3	

coun **reported by Co[redacted]arr**
4m transects i[redacted]
ank order of the nu Species names
three letters oberts, 1993).

3.5 Coral growth and geochemistry

Background and objectives

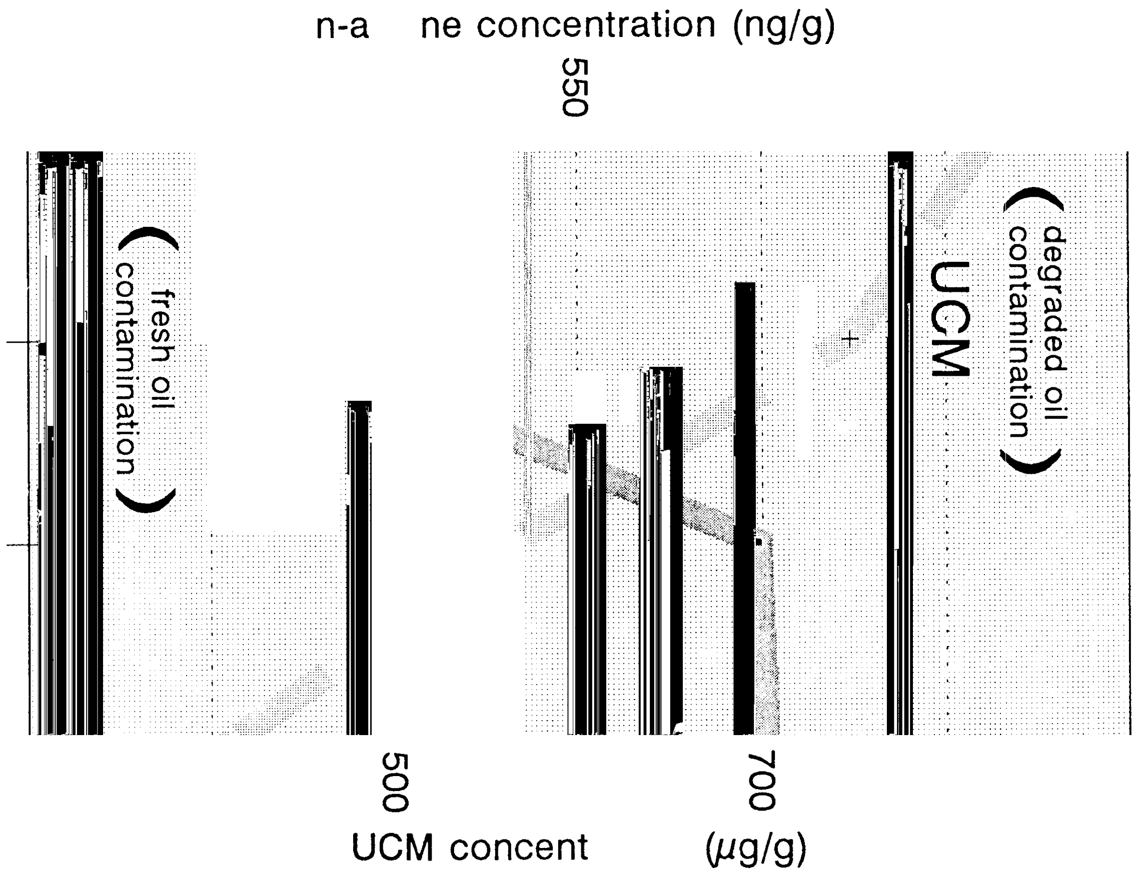
Reef corals are particularly sensitive to environmental stresses. Concern therefore arose that the 1991 Gulf War oil slick and/or reduced light and temperatures from the burning oil wells may have affected coral and reef growth. The purpose of this study was to collect small coral colonies for geochemical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

Activities

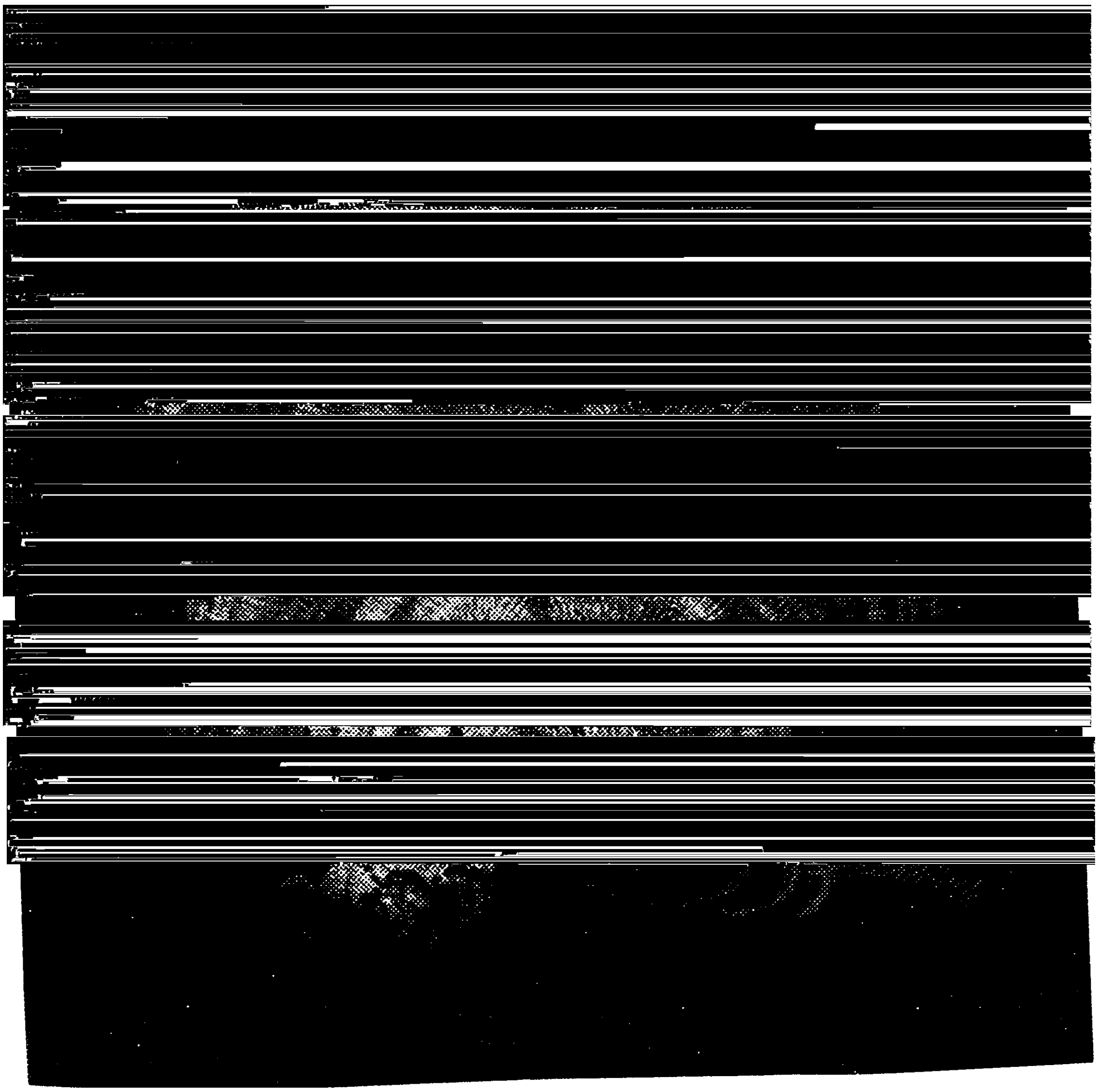
Five small colonies of the coral species *Porites Zutea* were collected from each of the reefs surrounding Karan and Jana islands (Saudi Arabia). Well rounded colonies measuring approximately 20-30 cm diameter were chosen from a depth range of 3-5 m on the outer slope zone of the leeward side of each 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

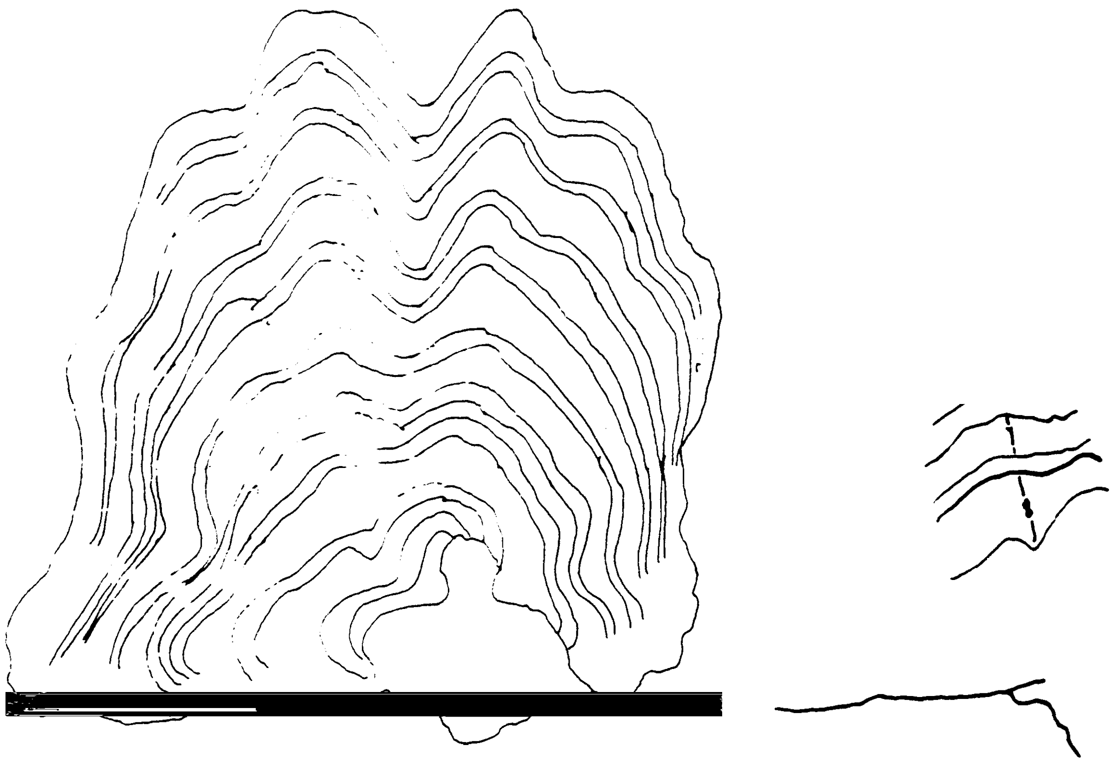
Provisional results have been obtained (Figure 10). The diagram relates to the outer four annual rings of a Saudi Arabian Gulf coral. ‘Enrichment’ of fresh oil on the outside and higher concentrations of degraded oil within the head are evident. A computer enhanced scan of an X-ray of a coral from the 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.



n-a ne concentration (ng/g)
550
fresh oil contamination
degraded oil contamination
UCM
500
700
UCM concent (µg/g)



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,

	(a)	(b)	(c) CATCH (T)	(d)	(e)	(f)	(g) EFFORT	(h) CPUE	(i
Year	SAFISH owned	SAFISH contract	SAFISH total	Artisanal total	Other Industr.	T[redacted]l	SAFISH (boatyrs)	[redacted]	at/yr [redacted]
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[redacted]	9	1897	1407	4[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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

Tab[redacted]
Sum[redacted] data for the Saudi Arabian Gulf coast from 198[redacted]-92, u[redacted] nom[redacted] Unit Effort (CPUE) in whole fresh t per boat ye[redacted]r. Th[redacted] the [redacted]minal CPUE is measured in t/SAFISH boat/yea[redacted] (from[redacted]

(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)

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.*,

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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)

Annex 3

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The following titles are now available in IUCN's Marine Conservation and Development Series:

1. Kelleher, G. & Kenchington, R. 1992. *Guidelines for Establishing Marine Protected Areas. vii +79* pp.

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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