International cooperation during the 1991 Arabian Gulf War oil spill.

Tawfiq, N.I.

and

D.A. Olsen

1 INTRODUCTION

In January of 1991, Iraqi forces initiated the largest oil spill in history when the captains of the tankers Al Qadasiyah, Hitten, Tarik Ibn Ziyad and Al Mutanabbi were directed to deliberately release their cargoes through specially constructed manifolds into the waters of the Arabian Gulf (Table 1). This deliberate spillage of oil and the subsequent releases form Mina al Ahmadi and Min al Bakr terminals created the largest spill in history (Tawfiq and Olsen, 1994), more then 40 times larger than the much publicized Exxon Valdez spill (Table 2).

Coming as it did during a shooting war, the spill and efforts to deal with its massive impacts were played out in front of the largest gathering of the global media in history. As a result the Kingdom of Saudi Arabia was faced with an environmental crisis of unprecedented magnitude in a situation in which its actions were going to be under the intense scrutiny of the global media. Fortunately, the nations of the world community, recognizing the magnitude of the problem, sprang to the assistance of the Kingdom and the Arabian Gulf environment. The following report summarizes the international nature of the response to the Arabian Gulf oil spill and, hopefully conveys the Kingdom of Saudi Arabia's appreciation to its friends during this difficult time.

1.1 SPILL SOURCES

Unlike prior spills[1], whose sources and amounts can be estimated with precision (Koons and Jahns, 1992), it is unlikely that the actual amount of oil spilled during the 1991 incident will ever be known precisely. MEPA's initial estimates of the spill volume were between 6-8 million barrels. Following the war, additional information became available which indicate that the prior estimate should be revised upward to approximately 10.8 million barrels. A summary of the best available information on the amount of oil is provided in Table 2.

Input of oil and oil combustion products from the Kuwait oil fires provided a significant (but unknown) additional contribution to the spill. According to Readman et al. (1992) "...from the best available data it can be estimated that over (about) 250 days during which the wells were burning, some 500

****

[1] Other large spills include the Ixtoc-1 well blowout during 1978 in the Gulf of Mexico (about 4 million barrels), the *Amoco Cadiz* off Brittany in 1978 (1.6 million barrels), the *Torrey Canyon* off England in 1967 (900,000 barrels), and the *Metula* in the Strait of Magellan in 1973 (380,000 barrels). The much publicized *Exxon Valdez* 1989 spill in Prince William Sound in Alaska was only 260,000 barrels.

****

million barrels (67 million tonnes) of oil were emitted or ignited, releasing oil aerosols, soot, toxic combustion products and gases for atmospheric transport and subsequent deposition.
Even if only a few percent of those emissions fell out in the coastal marine environment, they would by far surpass the amounts of crude oil that were spilled."

Thus, although the actual amount of oil spilled is not precisely known, it was certainly the largest spill in history, at least 3 times the Ixtoc blowout in the Gulf of Mexico (3.7 million barrels) and over 40 times larger than the highly publicized Exxon Valdez spill in Alaska (Koons and Jahn, 1992) and over seven times larger than the previous largest spill in the Gulf which was the 1.5 million barrel Nowruz spill in 1985.

1.2 STRUCTURE OF RESPONSE

In the Kingdom of Saudi Arabia, the Meteorology and Environmental Protection Administration (MEPA) is the central environmental agency with responsibility for response to oil spill under the 1991 *National Contingency Plan for Combatting Marine Pollution form Oil and Other Hazardous Substances in Emergency Cases.* The national plan provides clear definition of responsibility in times of oil spill and assigns primary responsibility for protection of facilities to each individual ministry which has facilities or operations along the coast.

Since the plan had only been in effect for less than one month at the time of the 1991 spill, the sheer magnitude of the spill, and the war time conditions had not allowed sectorial ministries sufficient time to prepare and mobilize response. As a result, the spill response required necessitated strong central coordination which was supplied by MEPA at its Oil Spill Response Center (OSRC) in Dhahran.

The (OSRC) became the focus of the Kingdom's response planning with the exception(s) that the Royal Commission for Jubay1 and Yanbu and Saudi Aramco were prepared to carry out their responsibilities under the terms of the Plan and thus, took full responsibility for their own facilities and provided important assistance to MEPA activities.

Within hours following the announcement of the spill by the coalition forces military, MEPA began to mobilize national response as well as initiating efforts to gather additional response as well as initiating efforts to gather additional support from the international community which began to offer assistance as realization of the magnitude of the problem began to appear in the global media.

A key player during this early period was the International Maritime Organization which established a clearing house for international offers, solicited assistance and, later established a trust fund which supported clean up activities.

The following report provides details about the 1991 response as well as information regarding what was actually accomplished. In addition, information is provided which briefly summarizes the current scientific information on the damage to the environment.

1.3 INTERNATIONAL ASSISTANCE

The Kingdom benefited greatly from all of the international assistance both that originating from governments and assistance provided by the private sector.

In the very beginning, Japan, the United States, Netherlands, United Kingdom and Norway provided key contributions which enabled the oil spill response center to protect key strategic infrastructure and begin an effort to protect environmental resources.

International Assistance

The International Maritime Organization (IMO).
IMO played a key role throughout the entire period, coordinating international offers of response and in the later stages, soliciting funding for clean up activities.

IMO maintained technical coordinators in the oil spill response center throughout the duration of the response.

The IMO trust fund supported clean up of the turtle nesting beaches at Karan island prior to the 1991 nesting season as well as clean up of oiled shoreline at Dawhat ad Dafi and Jazirat Al-Maqta and cleaned salt marshes at Masharabah.

IMO technical liason were present throughout the spill response period and provided valuable guidance including design of the mangrove flushing operation at Gurman Island.

Other International Agencies
During the spill response period other international agencies's (UNEP, IAEA, IUCN, CEC) involvement centered mainly on technical assessment of the environmental aspects of the oil spill.

In the period following the war the Greenpeace organization carried out a scientific fact-finding cruise on the vessel R.V. Greenpeace.

The International Union for the Conservation of Nature and Natural resources (IUCN), which has a long-term involvement in Saudi Arabia's coastal zone and conservation programs, supported a series of detailed scientific expeditions which dealt with shore-line impacts, detailed analysis of fishery impacts and potential impacts on the marine environment from the oil fires in Kuwait. Much if this work, and the results from the Mt. Mitchell scientific cruises has appeared in a special edition of *Marine Pollution Bulletin* in 1994.

The Council of the European Community (CEC) in conjunction with Saudi Arabia's National Commission for Wildlife Conservation and Development (NCWCD) worked to establish a wildlife sanctuary in the Raz az Zawr, Mussalamiyah and Abu Ali area. The sanctuary has carried out much of the detailed long-term research on the impacts of the spill.

National Assistance

United States

The United States had a team of highly skilled response advisors, mobilized under their National Oil Spill Strike Force at the Oil Spill Response Center Within a week of the start of the spill. This team included experts from the U.S. Coast Guard, National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Army, and U.S. Navy.

The team's major contributions centered on assisting in response organization, surveillance of the spill and detailed site planning for threatened coastal facilities. An "air eye" surveillance plane equipped with side looking radar was also supplied and provided important detail on the location and coverage of the slick.

The U.S. also supplied the NOAA research ship Mt. Mitchell to the Intergovernmental Oceanographic Commission (IOC) sponsored investigation of the Gulf environment which took place following hostilities. This scientific contribution brought together scientists from throughout the world including many from Gulf nations in a detailed scientific investigation.

Japan

Japan provided key contributions to the response as members of the Japanese Embassy in Riyadh worked closely with OSRC staff to mobilize donations of Japanese spill response equipment (which was the first to arrive in Saudi Arabia) and, following the war, technical and volunteer assistance to assess damage and clean up damaged habitat.

Of particular note were large quantities of response equipment which began to arrive by the end of the first week at the OSRC. As Saudi Aramco and the Royal Commission for the Jubayl and Yanbu industrial cities had installed nearly all of their own equipment by this time, the Japanese contribution constituted the bulk of the second wave of effort.

In addition, since the Japanese contribution was coordinated through the OSRC, its availability enabled MEPA to direct its use for protection of some environmental resources.

Later contributions of technical expertise (through IUCN) and volunteer groups for clean up of the environment, provided a significant component of attempts to clean up some of the damaged environment. The Japanese team of environmental volunteers carried out clean up activities in the Gurmah Island mangrove forest and restored damage to the Arabian Oil Company mangrove nursery at Khafji.

In the years since the war, Japan has also sponsored a series of scientific cruises with the RV Umitaka Maru in which Japanese and Regional scientists have continued investigations of the fisheries and environment of the impacted areas.

Netherlands

The government of the Netherlands underwrote initial involvement of a number of Dutch companies. Most notable of these was Tanker Cleaning Amsterdam who mounted early recovery efforts and set a standard for efficiency that was used to measure subsequent efforts.

Australia

The Australian government provided skilled advisors as well as oil recovery equipment. The Australian experts contributed enormously to the later success of the clean up effort.

Following the war, the Kingdom was received an award for environmental achievement from the *Banksia* Environmental Foundation for the success of the international response which was organized to the oil spill.

Other Nations

Many other nations assisted the effort through donations of expertise or equipment. Each country supplied skilled and committed individuals who contributed both their expertise and many hours of much appreciated effort. These are summarized in Table II.

Commercial offers

Over 500 commercial offers from 23 countries were received by the oil spill response center. Indeed, one of the major problems faced during the early days was simply receiving and reviewing the more than 20,000 pages of FAX communications which were received on the two FAX machines at the response center.

Many of these companies flew staff to Saudi Arabia and one flew in plane loads of equipment, skilled manpower and supplies in order to position itself for work in the response. The technical resource provided by these individual provided a valuable element of the response effort in the early days.

1.4 AREA IMPACTED BY THE SPILL

The spill trajectory carried out along Saudi Arabia's gulf coast and much of the oil came ashore between Khafji and Ras Abu Ali. Analysis of the 1991 spill trajectory posed a difficult problem for trajectory modelers because it originated from multiple sources over most of the northern portion of the Arabian Gulf. Eventually it impacted nearly all of Saudi Arabia's Territorial Sea to some degree (figure 1).
Surveillance data from visual flights, the US Aireye radar plan and the limited remote sensing which was undertaken greatly enhanced OSRC use of the trajectory models. All of these data were of strategic importance in that they enable the response planners to position the limited stores of equipment in areas which were indeed at risk rather than protecting areas which were unlikely to be hit by the oil.

In all, around 650 km of Saudi Arabia's 765 km coastline was oiled. Impacts ended north of Abu Ali (Gundlach, et al., 1993; McCain, et al, 1992a; MEPA,1991a). Indeed, oiling was so heavy, throughout this area, that there is concern that sources of species for recolonization may be lacking (WCMU, 1991).

The majority of the Kingdom's fishery resources (Figure 2) and its designated sanctuaries and environmentally sensitive areas (MEPA/IUCN, 1987; CEC, 1994) were in the area affected by the spill.

1.5 FATE OF THE OIL

Once the oil was released, it followed a variety of pathways into the environment of the Gulf. These are summarized in Table 3 which has been reconstructed from data on the volatility and solubility of the oil under these conditions (Gundlach, et. al., 1985), MEPA oil spill recovery results (MEPA, 1991b), MEPA coastal survey results (MEPA, 1991a), and UNEP/IOC reports (UNEP/IOC, 1991).

Approximately 75% of the volume of oil can be accounted for by the various shoreline surveys, Saudi recovery operations (11% of the total spill), volatilization and dissolution into the water. Approximately 59% of the original spill (6.4 million barrels) has found its way into the marine and coastal environments.

The fate of the unaccounted oil is currently unknown. Michel et al. (1993) did not find evidence for large scale sinking of oil in the near shore subtidal in the Abu Ali area. Some sublittoral was located during the Mt. Mitchell cruise in the area offshore from Tanagib.

1.6 OIL RECOVERY

Response planners decided early on that, given the limitations of manpower and resources as well as difficulties posed by the ongoing hostilities, that the most effective response strategy would be to concentrate efforts on removal of floating oil from the water.

A decision was made to concentrate efforts on shoreline recovery since floating mines posed a hazard to offshore operations and prevailing winds and currents concentrated the oil in shallow waters along Saudi Arabia's shoreline. Offshore recovery was limited to Saudi Aramco which operated 9 recovery vessels and recovered a total 146,000 bbls of oil. The *Al Waasit, a NORPOL* recovery vessel under charter to Saudi Aramco, recovered 87,000 bbls of this.

Notional and international recovery efforts were concentrated at the various sites shown in Table 8. Offshore and shoreside operations recovered a combined total of 1.44 million barrels of oil/water mixture which, when adjusted for water content amounted for 1,163,457 barrels of oil, a record for oil recovery.

1.7 CLEANUP

Immediately following the spill, MEPA undertook a complete survey of shorelines which might have been impacted (MEPA, 1991a, Gundlach et al., 1993, Table 6). A total of 148 sites were identified which could be cleaned of stranded oil. A costed proposal was prepared (MEPA,1991c) in which the costs of cleaning all of the sites was estimated to be $540,000,000.

MEPA, with the assistance of IMO experts reevaluated the initial proposal and restructured it in order to obtain improved operational efficiencies. In the subsequent proposal, the estimated cost was reduced to $210,000,000 (MEPA, 1991d). This reduction also reflected the fact that natural cleanup was taking place at some of the sites. In addition, some and tests of various clean up methods revealed that natural recovery would be less damaging to the environment than the proposed clean up.

Revised proposal planned clean up activities were also suggested, utilizing techniques which had been tested in the course of the KFUPM/MEPA studies (McCain, et al., 1992).

A summary of all cleanup projects undertaken by the OSRC is provided in Table 9. Specific details of the projects funded under the IMO fund can be found in McMurtrie (1992).

2 ENVIRONMENTAL IMPACTS AND STATUS QUO

2.1 COASTAL IMPACTS

Despite the intense interest displayed during the war, a peculiar silence has reigned regarding the Gulf environment during the past few years. Indeed, what little appears in the media, reflects a very selective reading of the scientific evidence which is how beginning to indicate that the Arabia Gulf was subjected to serious and potentially long-term environmental damage. Much of this evidence was developed form research carried out by the Kingdom's scientists in association with IUCN, the European Community, IOC during the Mt. Mitchell Expedition and the cruises of the Japanese research vessel Umitaka Maru. These are briefly summarized in the following sections.

Oil Deposition in Coastal Sediments

Research carried out by MEPA, Greenpeace, IUCN and the ROPME/IOC sponsored Mt. Mitchell cruise all indicated that sediments in the impacted areas are among the most polluted in the world (Figure 3). In littoral areas 1-2% concentrations were common.

The oil penetration of the sediments ranged from 2 to 5 cm. (deeper in places due to penetration of animal burrows (CEC, 1992, 1994; Hayes et al., 1993). In the deepest zone, the oil often remained liquid and some evidence was found of oil from pervious spills (op, cit.). Deep penetration of hydrocarbons in coarse grained sediments was consistently noted by all studies. Some of this oil was eroded and transported into the subtidal region.

Some evidence of natural degradation was found during studies of bacterial samples from heavily impacted coastal areas which were found to be dominated by oil-degrading forms which were at work breaking down stranded and subtidal oil (Al-Hadbrami and Lappin-Soott, 1993).

Inter Tidal Communities

Algal Mats

Millions of gallons of oil still remain in sheltered halophyte marshes and algal mat complexes of Dawhat ad Daffi were total mortality of the halophyte community was observed (Hayes, et al., 1993).

Limited recovery of these algal mats was found in some areas although algal mats in the heavily oiled Abu Ali area were recovering more slowly (Al-Thukair and Al-Hinai, 1993.)

Two years after the oil spill, no sign of blue-green algal growth was observed in areas where the tar layer remains on the surface and is not covered by sediments. In areas where the tar was covered by sediments, extensive growth occurred in a short time (Hoffman, 1994).

Mangroves

Seven mangrove areas were oiled (MEPA,1991a), among them the extensive mangrove stand on Gurmah Island (near Abu Ali) which were heavily oiled with 2-3 cm of oil on the air breathing roots (McCain, et al., 1992a). There was high mortality of both mangroves and associated flora and fauna. Damage was particularly heavy in non-sheltered areas which were frequently covered by high tides. Approximately 30% of the mangroves were killed by the spill (De Clerck and Coppejans, 1994).

It was observed (op. cit.) that *Avicennia marina* responded to the depleted ground water oxygen levels caused by the oil spill by developing high numbers of branched pneumatophores and adventitious roots, thereby enlarging their aerial roots and lenticels for gas exchange (Boer, 1994).

During the spill, a clean up effort was initiated in order to enhance this effect and flush oil from the mangroves with high volume sprinklers (Tawfiq and Olsen, 1993). In treated areas mangrove density was 3.3 times greater than untreated areas (De Clerck and Coppejans, 1994).

Although some success was achieved by the clean up, on-going studies (op. cit.) indicate that deterioration continues. Studies of mangrove leaf Sodium to Potassium ratios (an indication of mangrove stress) in February of 1992 in Gurmah and Al Qatif which (an area not affected by the oil spill; Tokuda, et al., 1992). All of the Gurmah Island samples showed higher ratios than the samples from Al Qatif, a finding indicative of stress in the Gurmah Island mangroves. The number of living trees has continued to decling at all sites (Sadiq and McCain, 1993).

Salt-Marshes

Forty-eight separate salt marshes were oiled during the spill (MEPA,1991a), covering 149km of shoreline. This same survey estimated that 677,000 m^3 of oiled sediment remain in the oiled salt marsh sites.

Salt marsh plant species were heavily impacted by the spill with 30% mortality of *Halocnemum strobilaceum* marsh, 35% of the *Arthrocnemum macrostachyum* marsh and 99% of the *Salicornium* marshes completely killed. However 50% of the inter tidal vegetation did remain alive (Boer, 1994).

Two years later, there were no signs of recovery of damaged inter tidal vegetation within the Gulf Sanctuary area. Occasional seed germination was observed which contrasted with high numbers of germinated seeds in unaffected areas.

The only exception to this occurred in one area in which the oil did not seal the surface but settled into the subsurface sediments (op, cit.)

As many as 1000 dead crabs per meter of beach were counted and large numbers of other dead invertebrates were observed in salt marshes (Sadiq and McCain, 1993).

Sand Beaches And Tidal Flats

Sheltered tidal flats (166 km), exposed tidal flats (20 km), coarse sand beaches (292 km) and fine sand beaches (25 km) were also heavily oiled (MEPA, 1991a). Approximately 556,900 m^3 of oiled sediments were contained in tidal flats and 90,100 m^3 in sand beaches.

Heavy mortality of inter tidal infauna and macrofauna was reported in both of these habitats (Faraj et al., 1992 and Prena, 1992).

No surviving crabs were observed in impacted areas immediately following the spill. Two years later there was slight recovery in one area studied but not in another. Studies of the plankton indicated that there was an abundance of material available for recruitment (Barth and Niestle, 1994).

Burrowing by polychaete worms was observed in some impacted areas, aerating the soil and increasing the rate of natural breakdown in the oiled sediments.

Meiofaunal recovery has been shown to take around 8 years in studies of the Amoco Cadiz (Bodin, 1988).

Sea Grasses

Sea grass communities surveyed one year after the spill
(Kenworthy, et al., 1993) appeared to have recovered from the impacts of the spill and showed leaf productivity rates similar to healthy plants from other areas. Survival may have been due to a relative insensitivity to the effects of the oil demonstrated in laboratory experiments by exposing sea grasses to unweathered Kuwait crude oil (Durako, et al., 1993).

Sampling of the infauna of sea grasses (Jones and Richmond, 1992) indicated as much as a ten-fold reduction when compared to samples taken from other non-impacted areas and samples taken prior to the spill (McCain, 1984; Sadig and McCain, 1993).

Corals

Significant damage to Saudi coral reefs and associated fish was not observed during the Greenpeace or Mt. Mitchell cruises, IUCN followup investigations (Downing and Roberts, 1993; IUCN, 1991, 1992) nor during other short-term studies which occurred. Two reefs near Shuaiba in Kuwait exhibited substantial damage.

Histological analysis of total lipid levels in seven genera of shallow water corals suggests that oil pollution has no effect on lipid synthesis and photosynthesis (Al-Sofyani, 1993).

Damage to coastal ecosystems, clearly demonstrated by these studies may well take decades before full recovery can be completed (figure 4).

2.2 FISHERY IMPACTS

Evidence indicates that fishery resources were heavily impacted by the spill. Saudi Fisheries Company announced that shrimp production was less than 1% of prewar levels (Figure 5) and that the size of the shrimp in the catch caught in 1992 (60-80 per kg) was significantly smaller than the normal size (20-30 per kg).

Prawn stock abundance was 10% of that present during the 1988-89 season (Matthews et al., 1993) and 1994 catch levels were still depressed, at 25% of pre-war landings.

Saudi Arabia's Ministry of Agriculture closed the fishery from July 15 1991 until October 15 in an effort to enhance resource recovery. Losses have been estimated at $55 million (op. cit.). When the fishery resumed, catch retes were less than half of pre-spill levels (14 kg/hr compared to 32 kg/hr).

High mortality of fin fish was observed, particularly around Gurmah Island where densities of 1-2 dead fish per metre of beach were observed (op. cit.) and no reproductive Hamour *(Epinephelus suilis),* a favorite food fish were observed in the catch (Matthews at al., 1993).

The cause of these impacts cannot be directly attributed to the spill or associated ambient air temperatures from March to September, 1991 which were of the order of 3-4 $^{\circ}$ cooler than normal in Kuwait and 0.8-2.4 $^{\circ}$ in Bahrain and Saudi Arabia. This affect has been attributed in part to reduced solar radiation resulting from the plume from the oil fires (Sadiq and McCain, 1993). Whatever its cause, fish growth and reproduction are physiologically cued to temperature and a dramatic change such as this is likely to have some effect.

In addition to temperature, toxicity of the spills and associated slicks was shown to significantly affect planktonic fish and shrimp larvae (Sadiq and McCain, 1993). Prawn larvae and eggs al., 1993). Thus planktonic mortality could be a cause of reduced landings.

2.3 WILDLIFE IMPACTS

Sea Birds

One of the most highly publicized aspects of the spill was its impacts upon the Arabian Gulf wildlife resources. It was estimated (World Conservation Monitoring Unit, 1991), that these included deaths of 15-30,000 off-shore sea-birds, possibly 36 dolphins and 3 Dugongs and three turtles.

In order to treat affected wildlife, a wildlife rescue center was established in Jubail through cooperation between the Royal Commission for Jubail and Yanbu (RCJY) and the National Commission for Wildlife conservation and Development (NCWCD). Commission for Wildlife conservation and Development (NEWCD).

Important technical assistance was recieved from the UK Royal Society for the Prevention of cruelty to Animals. Throughout the period of the spill, the center handled nearly 1300 birds of 28 species (shown in Table 7, from Abuzinada, 1992), several marine turtles and 24 sea snakes. The center activities received broad media exposure and did much to demonstrate the Kingdom's concern for it's environment.

Post spill population census of sea birds (Symens and Suhaibani, 1994) Would seem to indicate that impacts were greater than previously expected and that populations of Gulf sea birds were significantly impacted by the spill with post spill population levels reduced to less than 70% of per-spill levels (Table 8).

Wading shore birds were even more heavily impacted. The Arabian Gulf coast is one of the world's five major wintering areas for wading birds (Summers, et al., 1987). It has been estimated (Zwartz et al., 1991) that 260,000 waders winter in the Saudi Arabian Gulf coast and up to 4 million in the entire Arabian Gulf. In addition, all waders wintering in eastern Africa and the majority of those in southern Africa pass through the Middle East on migrations (Symens and Suhaibani, 1994).

Oiling of inter-tidal habitats where they feed while passing through could have serious implications on their populations. Currently available data clearly indicate a great (83-98%) reduction in wader populations but it is not entirely clear whether or not this represents mortality or avoidance of oiled habitats (Table 9).

Turtles

During the Mt. Mitchell cruise, oil was observed offshore on Al Arabiyah, Karan (an important turtle nesting site), Janna and Jinnah Islands. High priority was attached to clean up of the turtle nesting islands. Thus, a major clean up effort was carried on Karan Island out prior to the 1991 turtle nesting season by Alba International and funded by the IMO fund. Alba removed all of the oiled sediments from the shoreline and replaced them with unoiled sediments from the interior of the island and the NCWCD and UK Military removed the remaining debris from the beaches.

During the 1991 nesting season, Green turtles nested at rates and with hatching success which was similar to historic results (Pilcher, 1992). Hawksbill turtles, while laying similar numbers of eggs (to prior years) only had a 46% nesting success (compared to 87 and 89% in 1986-7 and 80% in 1992).

Although this impact cannot be directly attributed to the spill or a 2.5 ° C reduction in sea surface temperatures which occurred during the period of the Kuwait oil fires (McCain, et al., 1992b); hawksbill turtles do feed upon benthic invertebrates which tend to concentrate hydrocarbons.

A major cleanup effort of these islands was carried out under IMO direction prior to the 1991 nesting season in which oiled sediments and debris were removed from the nesting beaches and replaced with sand from the interior of the islands.

Marine mammals
It was estimated that 14 Dugongs, 57 bottlenose dolphins, 13 humpback dolphins, 2 finless porpose and 8 unidentified cetaceans were killed during the 1991 spill (Preen, 1991).

3 SUMMARY AND CONCLUSIONS

The 1991 oil spill was originally presented as a cataolysmic event and the media were filled with doomsday prediction for the future of the Region's environment. When subsequent analysis indicated that the media claims were overstated, a suspicion developed that environmental damage had been exaggerated as part of the war-time propaganda. As a result, public interest waned and the Arabian Gulf environment lost an important ally in it efforts to restore the damaged environment.

Careful scientific investigation which has followed the event clearly indicates that the spill created impacts on a massive scale over much of Saudi Arabia's gulf coast. Over 1.3 million m^3 of oiled sediment remain on the coast and over 1.5 million barrels of oil from the spill cannot be accounted for and must remain somewhere in the marine environment. Much of the oil is buried up to 50cm deep and is unavailable to weathering and aerobic bacterial breakdown. In many cases this oil still contains toxic fractions, posing a continuing risk to colonizing species.

The coastal ecosystem has been massively affected, including decimation of algal mats; oiling of mangroves (which continue to deteriorate), mortality of 30-40% of salt marsh species; massive mortality of crabs and other infauna of saltmarshes, mangroves and seagrasses and other latent effects which have yet to appear in the scientific literature.

Wildlife were heavily impacted by the spill with an 80% reduction in shorebird populations and 35% reduction in pelagic seabirds. In addition to this, a significant reduction in hawksbill nesting success was observed in 1991 and there was some mortality of marine mammals.

Saudi fisheries were also heavily impacted and there was an apparent collapse of the shrimp fishery in 1991 through 1994 with a consequent cost to the Kingdom of $55,000,000. In addition, fishery researchers noted that the absence of reproductive individuals of important food species. Such impacts in population structure may take some time for recovery.

Some communities, such as coral reefs and seagrass vegetation were not substantially effected. There also has been no evidence of massive pollution in the subtidal or during the Mt. Mitchell cruise in the Gulf sediments. Thus the news is not all bad.

At best, however, the 1991 spill crated massive impacts which are likely to persist for decades (Figure 6) and which will continue to impinge upon the environment as currently covered oil is reexposed. It should serve as a reminder to all that efforts should be made to prevent the use of the environment as a weapon in future conflicts.

The subject of this presentation has centered on the role of international cooperation during the Gulf War environmental crisis. I have presented, in some detail, both the participants in this cooperation as well as the accomplishments which resulted from this gathering of concerned nations and individuals, who were involved in much of the post war clean up activities (table 10).

While the Kingdom of Saudi Arabia is most appreciative of the enormous contribution supplied by all and, at the same time, future international cooperation is required both in understanding the nature of the environmental damage and in cleaning up and rehabilitating the environment.

Modalities for such cooperation must be developed, based on the lessons provided by the Gulf spill experience. First and foremost of these lessons is the fact that very few nations are equipped to deal with large scale environmental disasters of the magnitude of the Gulf spill. The high costs of maintaining expensive pools of technical expertise and equipment in readiness for an infrequent event are not possible for all but the wealthiest of nations. Essentially bilateral cooperation efforts such as the OSRC lack continuity and must be reestablished each time an emergency occurs.

Recognizing such limitations, Saudi Arabia recommended in 1991 to UNEP's Governing Council that a network of Regional Response Centers for response to environmental emergencies be established, based on the UNEP Regional Seas approach. The Saudi proposal would involve Regional "depots" of response equipment and networks of technical expertise which could be promptly mobilized at the onset of an emergency. Resources could be shared between Regions if necessary. Funding (in the case of oil spills) could be obtained after the event through normal liability channels. UNEP has undertaken some pilot efforts towards that direction.

Regardless, of the future of the UNEP exercise, response to environmental emergencies will continue to require international cooperation, particularly between wealthy nations and the underdeveloped nations of the South. We, in Saudi Arabia, as recipients of such cooperation during our time of need are most appreciative of the need and stand ready to support future efforts in this regard.

REFERENCES

Abuzinada, A. 1992. Effects of the 1991 oil spill. Presented at ROPME Symposium on Scientific Studies of the Gulf. 7pp.

Al-Hadbrami, M.N. and H.M. Lappin-Scott. Analysis of Bacteria from oil Contaminated Sediments from Abu Ali area.
ROPME/IOC Scientific Workshop on Results of the RV Mt.
Mitchell Open Sea Cruise held in January, 1993 in Kuwait.

Al-Rabegh, A.H., H.M Cekirge and N. Gunay. 1992. Modeling he Fate of the Al-Ahmadi Oil Spill. Water, Air and Soil Poll 65:257-279. Kluwer Academic Publishers, Netherlands. pp257-279.

Al-Sofayani, A.A. 1993. Variation Levels and Location of Lipids in Corals Tissue of ROPME Sea Area. ROPME/IOC Scientific Workshop on Results of the RV Mt. Mitchell, 1991 Open Sea Cruise held in January, 1993 in Kuwait.

Al-Thukair and K. Al Hinai. 1993. Distribution and Environmental Status of Algal Mats Located on the East Coast of Saudi Arabia Following the Oil Spill. ROPME/IOC Scientific Workshop on Results of RV Mt. Mitchell 1991 Open Sea Cruise held in January, 1993 in Kuwait.

Barth, H.K. and A. Niestle. 1994. Environmental effects of the Gulf War on coastal areas north of Jubail - An Overview. (in) The Status of Coastal and Marine Habitats Two Years After the Gulf War Oil Spill (Abduzinada and Krupp, editors). Courier Forschungsintitut Senkenberg.
(166):11-15.

Bodin, R. 1988. Results of ecological monitoring of three beaches polluted by the "Amoco Cadiz" oil spill: development of meiofauna from 1978 to 1984. Mar. Ecol. Prog. Ser.
42:105-123.

Boer, B. 1994. Status and recovery of the intertidal vegetation after the 1991 Gulf War oil spill. (in) The Status of Coastal and Marine Habitats Two Years After the Gulf War Oil Spill (Abduzinada and Krupp, editors). Courier Forschungsintitut Senkenberg. (166):22-26.

Banksia Foundation. 1992. International Award. Banksia News
Vol. (3) No. 1, p3.

Downing, N. and C.M. Roberts. 1993. Medium term impacts of the Gulf War: the state of the reefs in the north western Arabian Gulf. Mar. Poll. Bull. (27):149-156.

De Clerck, O. and E. Koppejans. 1994. Status of the macroalgae and seagrass vegetation after the 1991 Gulf War oil spill. (in) The Status of Coastal and Marine Habitats Two Years After the Gulf War Oil Spill (Abduzinada and Krupp, editors). Courier Forschungsintitut Senkenberg.

Durako, M.J., W.J. Kenworthy, S.M.R. Fatemy, H. Valavi, and G.W. Thayer. 1993. Assessment of the Toxicity of Kuwait Crude Oil ROPME/IOC Scientific Workshop on Results of the RV Mt. Mitchell 1991 Open Sea Cruise held in January 1993 in Kuwait.

El-Deeb, M.H.A. and I.A. Saleh. 1993. Distribution of Aromatic Hydrocarbons in Bottom Sediments of the Arabian Gulf After the 1991 Oil Spill. ROPME/IOC Scientific Workshop on Results of the 1991 RV Mitchell Open Sea Cruise held in January, 1993 in Kuwait.

Evans, M.I. and G.O. Keijl. 1993. Impact of the Gulf War oil spills on the wader populations of the Arabian Gulf coast. Sandgrouse 15 (1):85-105.

Faraj, M., Al-Dady, S. and A. Al-Kandari. 1992. Biological indicators of the impact of the Gulf environmental catastrophe on Kuwait beaches. Poster Paper presented at the Fourth General Conference, Third World Academy of Sciences, Kuwait, 23-26 November.

Greenpeace. 1991. The Environmental Legacy Of The Gulf War. Greenpeace Report. 40 pp.

Gundlach, E.R., T. Kana and P.D. Boehm. 1985. Modeling spilled oil partitioning in nearshore and surf zone areas. Proc. 1985 Oil Spill Conf. pp. 379-383.

Gundlach, E.R., J.C. McCain and Y.H. Fadlallah, 1993. Distribution of oil along the Saudi Arabian coastline (May/June 1991) as a result of the Gulf war oil spills. Mar. Poll. Bull. (27):93-96.

Hayes, M.O., J. Michel, T.M. Montello, D.V. Aurand, A. Al-Mansi, A.H. Al-Momen, J.R. Jensen and G.W. Thayer. 1993.
Distribution, Mode of Preservation/ Weathering, and Impact of Oil Spilled During the Gulf War within the Intertidal Zone of the Saudi Arabian Coast-One Year Later. ROPME/IOC Scientific Workshop on Results of the 1991 RV Mitchell Open Sea Cruise held in January, 1993 in Kuwait.

IOC/UNESCO. 1991. The effects of the Kuwait War on Marine and Coastal Resources in the ROPME Region (Qatar, UAE, Oman, Iran, Iraq and Saudi Arabia) JUNE-JULY 1991.

IUCN. 1991. Preliminary Assessment of War-Related And Other Impacts Along the Saudi Arabian Coast of the ROPME Sea Area.

KFUPM/RI. 1991. Environmental Damage Assessment Due to Guf war. KFUPM Proposal Submitted to MEPA. 86 pp.

Koons, C.B. and H.O. Jahns. 1992. Commentary on the fate of oil from the *Exxon Valdez*-A perspective. J. Mar. Tech. Soc. Vol. 26 (3). pp 61-69.

Mathews, C.P., N. Kedidi, N. Fita and K. Al-Rasheed. 1992. Appropriate Managerial Response to the Critical Condition of Saudi Prawn Stocks Following the Oil Fires and Oil Slick Originating in Kuwait in February, 1991. Report to Saudi Fisheries Company.

Mathews, C.P., N. Kedidi, N. Fita, A.A. Al-Yahya and K. Al-Rasheed. 1992. Appropriate Managerial Response to the Critical Condition of the Saudi Prawn Stocks Following the Oil Fires and Oil Slick Originating in Kuwait in February 1991. Saudi Fisheries Company Rpt. 49pp, 20 figures.

Mathews, C.P., N. Kedidi, J. Al-Qaseer, I. Al-Qader, A.K.H. Rahdi, N. Fita, A.A. Al-Yahya. 1993. Report on the Effects of the 1990/1991 Iraq/Kuwait war on the North Western Prawn Stocks. Mar. Poll. Dull. (in press).

McCain, J.C., Tarr, A.B., Carpenter, K.E. and S.L. Coles. 1984. A survey of coral reefs and reef fishes in the northern area, Arabian Gulf, Saudi Arabia. Fauna of Saudi Arabia (6):102-126.

McCain, J.C., M. Qurban, D.J.Lennon and N.J. Chesterton. 1992. Remediation of Salt Marshes after the 1991 Gulf Oil Spill. (Ms. in prep.)

McCain, J.C., D.W. Beard and Y.H. Fadlallah. 1993. The influence of the Kuwaiti Oil Fires on Sea Water Temperatures in the Western Arabian Gulf. Mar. Poll. Bull. (27):79-83.

McCain, J.C., M. Hassan. 1992. The effects of the Gulf War on Ichthyoplankton in Saudi Arabian Gulf Waters. (MS in prep.)

McCain, J.C., M. Sadiq, A Al-Rabeh, N. Fayad and Y.H. Fedlallah. 1992a. The Impact of the Gulf Oil Spill on the Coastline of Saudi Arabia. (MS in prep.)

McMurtrie, J. 1992. Cleanup Operations in the Gulf. in Current Environmental Issues in the Gulf (Oct. 22,23) Dubai World Trade Center.

MEPA. 1991a. Coastal Survey Summary Report, Gulf Oil Spill. Unpub. Report.

MEPA. 1991b. Interim Pit Survey Report. Unpub. Report.

MEPA. 1991c. Gulf Oil Spill Shoreline Cleanup Plan. 3 Volumes.

MEPA. 1991d. Kingdom of Saudi Arabia Oil Spill Clean Up Project. Dec. 3, 1991. MEPA Document. 52pp.

MEPA. 1991e. Kingdom of Saudi Arabia Habitat Rehabilitation and Enhancement Project. Dec. 3, 1991.

MEPA. 1991f. Draft Work Plan for Environmental Damage Assessment. MEPA Proposal. 130pp.

MEPA. 1991g. Landfill Survey Report. 13 Aug. 1991. 10 pp.

MEPA. 1992. State of the Environment in the Kingdom of Saudi Arabia. 79pp.

MEPA/IUCN 1987. Saudi Arabia: An assessment of biotopes and management requirements for the Arabian Gulf coast. MEPA Coastal and Marine Management series.
Report No. 5.

MEPA/IUCN. 1987a. Saudi Arabia: An assessment national coastal zone management priorities. MEPA Coastal and Marine Management Series. Report No. 7.

MEPA/KFUPM. 1991. Application of Remote Sensing Techniques to the 1991 Arabian Gulf Oil Spill. in Gulf Oil Spill, 1991. Arabian Gulf Oil Spill Research Program. Interim Report, June, 1991. (7):324:248.

Miller, J.D. 1989. Marine Turtles, Volume I. An Assessment of the Conservation Status of Marine Turtles in the Kingdom of Saudi Arabia, MEPA Coastal and Marine Management Series. No. 9. 289pp.

Neff, J.M. 1987. Biological effects of oil in the marine environment. Chem. Eng. Progr., Nov. 1987:27-33.

NOAA. 1991. NOAA Support of the Arabian Gulf Oil Spill and the Kuwait Oil Fires. (March is, 1991).

Pascoe, D.B. 1992. International Cooperation in Oil Spill Response. in Current Environmental Issues in the Gulf (Oct. 22,23) Dubai World Trade Center.

Pilcher, N. 1992. The Nesting Habits of the Green Turtle *Chelonia mydas* and the Hawksbill Turtle *Eretmochelys imbricate* in the Arabian Gulf During 1991. National Commission for Wildlife Conservation and Development Report. 60pp.

Prena, J. 1992. The intertidal softbottom macrofauna in Dawhat al-Musallamiya and Dawhat ad-Dafi (Western Arabian Gulf), pp. 161-170. In: Final Report of Phase I., Establishment of a Marine Habitat and Wildlife Sanctuary for the Gulf Region. National Commission for Wildlife Conservation and Development and the European Community Commission.

Price A.R.G., P.A.H. Medley and H. Tokuda. 1991. Preliminary Assessment of War-Related and Other Impacts Along the Saudi Arabian Gulf Coast. Draft Report on IUCN/IEA/IOC/WWF Interagency Mission to the Gulf During August 1991. 64pp.

Price A.R.G., C.P. Mathews, R.W. Ingle and K. Al-Rasheed. 1993 Abundance of Zooplankton and Penaeid Shrimp Larvae in the Western Arabian Gulf: Analysis of Pre-War (1990-91) and Post-War Data. Mar. Poll. Bull. (27):273-278.

Price A.R.G., T.J. Wrathall, P.A. Medley and A.H. Al-Momen. 1993. Broad scale Changes in Coastal Ecosystems of the Western Arabian Gulf following the 1990-91 Gulf War. Mar. Poll. Bull. (in press).

Readman, J.W., S.W. Fowler, J.P. Villeneuve, C. Cattini, B. Oregioni and L.D. Mee. 1992. Oil and combustion-product contamination of the Gulf marine environment following the war. Nature Vol. 358 (20) pp. 662-664.

Reynolds, R.M. 1993. Overview of physical oceanographic measurements taken during the Mt. Mitchell cruise to the ROPME Sea Area. ROPME/ IOC Scientific Workshop on Results of the 1991 RV Mt. Mitchell Open Sea Cruise held in January 1993 in Kuwait.

ROPME/UNDP/UNEP. 1991a. Consolidated Rehabilitation for the Environment of the ROPME Region (CRP). 3 volumes.

Sadiq, M. and J.C. McCain. 1993. The Gulf war Aftermath: An Environmental Tragedy. Kluwer Academic Pub., London. 298pp.

Summers, R.W., Underhill, L.G., Pearson, D.J and D.A. Scott. 1987. Wader migration systems in southern and eastern Africa and western Asia. Wader Study Group Bull. (49)/IWRP Special Publication (7):15-34.

Symens and Suhaibani. 1994. The impaot of the 1991 Gulf War oil spill on bird populations - A review. (in) The Status of Coastal and Marine Habitats Two Years After the Gulf War Oil Spill (Abduzinada and Krupp, editors). Courier Forschungsintitut Senkenberg. (166):47-54.

Tawfiq, N.I., A. Khan and I.A. Naja. 1993. Effects of Gulf War oil spill: Variations in Oil and Trace Metal Concentrations in the Water and Sediments of the ROPME Sea Area. ROPME/IOC Scientific Workshop on Results of the 1991 RV Mt. Mitchell Open Sea Cruise held in January 1993 in Kuwait.

Tawfiq, N.I. and D.A. Olsen. 1993. Response by Saudi Arabia to the 1991 Arabian Gulf Oil Spill. Mar, Poll. Bull. (27):333-345.

Tokuda, H., H. Satoh, K. Ryuhsuke and S. Hanawa. 1992. After Effect of Massive Oil Spill During Gulf War Along The Saudi Arabia Gulf Coast. Report on WWFJ Mission Activities in the Gulf on February, 1992. 15pp.

United Nations. 1991. Report to the Secretary General by a United Nations Mission Led by Mr. Abdulrahim A. Farah, Former Under-Secretary-General, Assessing the Scope and Nature of Damage Inflicted on Kuwait's Infrastructure During the Iraqi Occupation of the Country From 2 August, 1990 to 27 February, 1991.

UNEP. 1991. Report on the UN Inter-Agency Plan of Action for the ROPME Region - Phase I: Initial Surveys and Preliminary Assessment. UNEP, 12 Oct. 1991.

UNEP. 1992. Priority Rehabilitation Program (PRP) for the Environment of the ROPME Region. 7 pp.

UNEP. 1993. Report of the Administrative Committee to the UNEP Governing Council (UNEP/GC.17.12).

Vandermeulen, J.H. 1982. Some conclusions regarding long-term biological effects of some major oil spills. Phil. Trans. R. Soc. Lond. B 297:335-351.

WCMU (World Conservation Monitoring Unit). 1991. Gulf War Environment Information Service. Impact on Land and Atmosphere. Final Report.

Zwartz, L., H. Felemban and A.R.G. Price, 1991. Wader counts along the Saudi Arabian Gulf coast indicate that the Gulf harbours millions of waders. Wader Study Group Bull. 63:25-32.

Table 1. Chronology of Sources of the 1991 Arabian Gulf Oil Spill.

19 January	4 Tankers at Al-Ahmadi released cargoes.
20 January	Oil Release at Sea Island terminal.
23 January	Amuriyah near Mina Al-Bakr Terminal releases cargo
24 January	Al-Ahmedi Sea Island Terminal spill announced. US was planes attack and sink Iraqi tanker. Sea Island terminal closed by bombing.
26 January	Mina Al Bakr Terminal oil release. Ras al Zour refinery at Khafji damaged, results in spill.
27 January	Mina al-Bakr spill announced during Military briefing. "Closed" by bombing over the following days. Gen. Swartzkopf announces Mina Al-Ahmadi spill as 7 million barrels, Mina Al-Bakr spill as 5 million barrels.
30 January	Ain Salah and Rumailah release remaining cargoes.
4 March	SLAR flight reports small leakages from all of the above sources. Central Command reported 3 inc pipe leaking at Mina Al-Ahmadi. Total of 6 curren low level sources operating. NOAA estimates that total input is 3-6000 barrels/day[1]. These sources continued until early June (90 days).

****

[1] Leakages from a destroyed pipe rack at Mina Al-Ahmadi, a destroyed loading platform, a single-point mooring a the Sea Island terminal, the Amuriyah, the Al Bakr terminal, a storm drain north of Shu' aybah Port, the Al Fao and Tariq ibn Ziyad were estimated to be releasing a total of 3-6000 bbls/day. These releases gradually diminished over a 90 day period. an average figure of 600 bbls/day is used in spill calculations.

****

Table 2. Sources and Estimated Amounts of Oil Released Into Arabian Gulf Waters.

1.	TANKERS[2]	CAPACITY (DWT)	% RELEASED	RELEASED (BARRELS)[3]
	Al Qadasiyah	155,211	90%	977,829
	Hitten	155,211	90%	977,829
	Tarik Ibn Ziyad	118,139	90%	744,276
	Al Mutanabbi	130,266	90%	820,676
	Al Fao	89,180	20%	124,852
	Amuriyah	155,211	20%	217,295
	Ain Salah	35,388	20%	49,543
	Rumailah	36,000	20%	50,400
	Total (Ton)	874,606		
	Potential (Bbls)[3]	6,122,242		3,962,701
2.	TERRESTRIAL SOURCES			
	Mina Su'ud Refinery[4]			100,000
	Sea Island Terminal (From North Storage Terminal)[5]			6,000,000
	Mina Al Bakr[3]			700,000
3.	SUBSEQUENT LEAKAGE FROM BATTLE DAMAGED TERMINALS & SHIPS[6]			54,000
4.	OIL FROM FIRES			UNKNOWN AT PRESENT
5.	TOTAL VOLUME OF SPILL			10,816,701

****

[2] MEPA, 1991c. The captain of the Smit Tak tug that towed the Al Qadasiyah, Hitten, Al Mutanabbi, Tarik Ibn Ziyad and Al Fao to their present position reported that they were fitted with special steel manifolds which permitted them to direct their cargoes over the side. Oil stains were visible at the outlets of the piping and from hoses lying over the side. An official of the Kuwait Petroleum Company said that the Al Qadasiyah and Hitten were each observed to leave the Shu' ayban port fully loaded, returning two days later empty. Soundings of the vessels by the Kuwait Oil Tanker Company revealed that about 10% of the cargoes remained. The Amuriyah, Ain Salah and the Rumailah were all battle damaged and sunk. The Amuriyah is located east of the Al Bakr terminal and the other two are located in the Khawr Abdallah channel north of Bubyan Island.

[3] 7 Barrels/ton.

[4] MEPA, 1991c. From IMO/Smit Tak Estimates.

[5] United Nations, 1991. UN experts examined Kuwait Petroleum Company records immediately following the liberation of Kuwait. Prior to the war, the North Tank Field contained 10.7 million bbls. After the war the tanks contained 1.5 million bbls. It was estimated that 3.2 million bbls were contained in Iraqi defensive trenches, leaving 6 million bbls as the probable amount released into the Gulf

[6] NOAA, 1991. Based on visual estimates during SLAR and reconnaissance flights at an average 600 bbls/dy over 90 days.

****

Table 3. International Participation in MEPA's Oil Spill Response Center (OSRC) Operations

Australia
- Australian Institute of Petroleum
- Australian Maritime Safety Authority

Denmark

Germany

Italy

Japan
- Japan disaster Relief Team

Korea

Netherlands
- North Sea Directorate

New Zealand

Norway

United Kingdom
- Royal Society for the Prevention of Cruelty to Animals
- Warren Springs Marine Laboratory
- Marine Pollution Unit

United States
- U.S. Coast Guard
- National Oceanic and Atmospheric Administration
- U.S. Environmental Protection Agency
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Army
- U.S. Navy

International Organizations
- U.N. International Maritime Organization
- Commission of European Community Environmentalists
- U.N. Environmental Program
- International Union for the Conservation of Nature
- Greenpeace

Table 4. Fate of oil from 1991 Arabian Gulf Oil spill.

1.	ORIGINAL VOLUME OF SPILL	10,800,000
2.	EVAPORATION OF VOLATILE COMPONENTS (40%)[7]	4,320,000
3.	DISSOLVED COMPONENT (10%)[6]	1,080,000
4.	FLOATING OIL IN SPILL	5,400,000
5.	RECOVERED OIL	
	SAUDI ARABIA[8]	1,163,000
6.	OIL ON BEACHES	
	SAUDI ARABIA BEACHES[9]	1,700,000
	IRAN, QATAR BEACHES[10,11]	1,000,000
	TOTAL	2,700,000
7.	UNACCOUNTED FOR	1,537,000

****

[7] Gundlach at al., 1985.

[8] MEPA, 1991b.

[9] MEPA, 1991a.

[10] IOC/UNESCO, 1991

[11] Although the IOC/UNESCO team reported approximately 500,000 barrels of oil along the Iranian coastline, the mechanism of transport from the 1991 spill is unclear. Recent oceanographic evidence from the Mt. Mitchell cruise (Reynolds, 1993) has shown a strong counter current flowing towards the south along the Iranian Coast as well as wind driven drifts which vary between ENE and WSW at the head of the Gulf. However, lower salinity water from the Shatt al Arab is transported across the head of the Gulf towards Kuwait where it remains as a lens in front of the Kuwaiti coast (Reynolds, 1993). Thus, it would appear that oil deposited from Min al Bakr and several battle damaged tankers in the Northern Gulf would tend to have been carried by the generally anti-clockwise circulation patterns and could not have arrived on the Iranian coast.

****

Table 5. Saudi Arabia's Oil Spill Recovery Operations During the 1991 Arabian Gulf Oil Spill.

AREA	PARTICIPATING AGENCIES	AMOUNT RECOVERED (BBLS)
Saffaniyah	Saudi Aramco, MEPA	25,887
Tanajib	Aramco	15,738
Brice	MEPA	62,286
Sulayq	MEPA	8,675
Bilbul	MEPA, Saudi Aramco	7,744
Tacup Back Bay	Saudi Aramco	77,900
Munifah	Saudi Aramco, MEPA	470,991
Ras Al Zawr	MEPA	556
Mardumah	RCJY, MEPA, Saudi Aramco Japan	231,926
Abu Ali	MEPA, Germany	6,824
Oil Used on Pits and Roads		87,569
Offshore Saudi Aramco		145,000
Total Recovery		1,163,457

Table 6. Length of shoreline type (Kuwait border to west side of Abu Ali) with length of oiled shoreline and volume of oiled sediment (from MEPA, 1991a).

Primary Shore Type	Length	Oiled (km)	Length* (%)	Oiled Sediment Volume** (m^3 X 1,000)
Seawalls, Piers	12.4	9.0	73	0.3
Rocky Shores	55.5	36.9	66	3.2
Riprap	9.9	9.9	100	0.1
Fine Sand Beaches	60.3	57.3	95	22.9
Coarse Sand Beaches	271.1	263.3	97	67.2
Exposed Tidal Flats	0.4	0.4	100	2.3
Sheltered Tidal Flats	132.5	131.0	99	554.6
Marshes	141.2	124.4	99	677.7
Mangroves	8.7	8.7	100	38.7
Not Classified	17.6	3.5	20	-
Islands***	55.4	-	-	-
	765.0	644.4	84*	1,367

* Percent of total shoreline surveyed.
** Approximate volume of oiled sediment/sand.
*** Excludes six offshore islands.

Table 7. Bird Species Treated At Jubail Wildlife Rehabilitation Center (Abuzinada, 1992)

Species	# Treated	% Released
Great Crested Grebe	280	5%
Black Necked Grebe	300	5%
Great Cormorant	350	60%
Socotra Cormorant	400	60%
Guls & Terns	20	50%
Herons	10	50%
Ducks	5	60%
Miscellaneous	20	50%
Total	1285	

Table 8. Impacts of the 1991 Gulf Oil Spill on Sea Birds. (Symens and Suhaibani, 1994)

Species	Population	% Mortality
Grebes	7-10,000	50%
Great Cormorant	24-30,000	22-34%
Socotra Cormorant	30-35,000	25%
Gulls & Terns	260,000	98%[12]
Miscellaneous		
Total		32%

****

[12] There is some evidence that the wading birds may have avoided the areas affected by the spills so that the post spill population declines may not entirely represent mortality.

****

Table 9. Reduction of shore bird populations after the 1991 Arabian Gulf oil spill (from Harbard and Wolstencroft, 1992).

Species	Pre-spill	Post-spill
Dunlin	116,000	8.6%
Little stint	51,000	7.5%
Lesser sand plover	28,000	17.2%
Redshank	9,000	36.6%
Ringed plover	8,000	4.9%
Greater sand plover	8,000	8.5%
Grey plover	7,000	32.5%
Broad-billed sandiper	6,000	8.5%
Curlew	6,000	28.5%
Bar-tailed godwit	6,000	101.0%
Black-tailed godwit	5,000	2.5%
Curlew sandpiper	4,000	42.8%
Terek sandpiper	4,000	66.5%
Turnstone	3,000	53.4%
Oyster catcher	1,000	49.6%
Kentish plover	800	525.8%
Greenshank	500	32.5%
Sanderling	200	335.0%
Total	263,500	17.2%

Table 10. MEPA Clean up projects completed as of 6/1/93 (MEPA, 1991d).

CLEAN UP SITE	ACTION (S) TAKEN	AGENCIES
Karan Island	Cleanup of oiled sand on beach	IMO/ALBA
Gurmah Island	Mangrove Cleanup,using high volume sea water sprinklers and skimming of freed oil.	IMO/TCA/ Japan
Al-Khafji	Cleanup of Mangrove Nursery (As above)	Japan/ IMO/TCA
Dawhat ad Dafi	Cleanup of oiled shoreline, sand, sea grass and debris	IMO/ALBA
Musallamiyah Bay	Test oil removal methods	IMO/ALBA
Jabal An Nuquriyah	Test methods for flushing	IMO/ Denmark
Masharabah	Salt marsh cleaning	MEPA/IMO/ TCA
Dawhat Sulayq	Methods test of salt marsh clean up	MEPA/CMC Martech
Manifah	Test of DE-SOLV-IT for shoreline cleanup with water jetting.	MEPA/CMC
Jazirat al Toyor	Test of DE-SOLV-IT and high pressure, hot water for cleaning rocky shoreline	IMO/LUX/ ALBA
Jazirat Al-Maqta	Cleanup of Oiled Island sand and rock shoreline near Ras Al Mishab with environmental release agent and sea water jetting.	IMO/TCA
Abu Ali	Clean up of beach recovery pits.	CMC/TCA
Mardumah	Beach Cleanup with tilling. Restoration of temporary oil recovery pits.	VECO/MEPA

Figure 1. Area of the Arabian Gulf impacted by the 1991 spill. Coverage is provided from daily reconnaissance flights, SLAR flights, IOC surveys and interviews with Saudi military personnel stationed on offshore islands. Density and color of the dots provides a qualitative estimate of the amount of oil. The KFUPM/RI spill trajectory for the Al-Ahmadi spill is also shown.

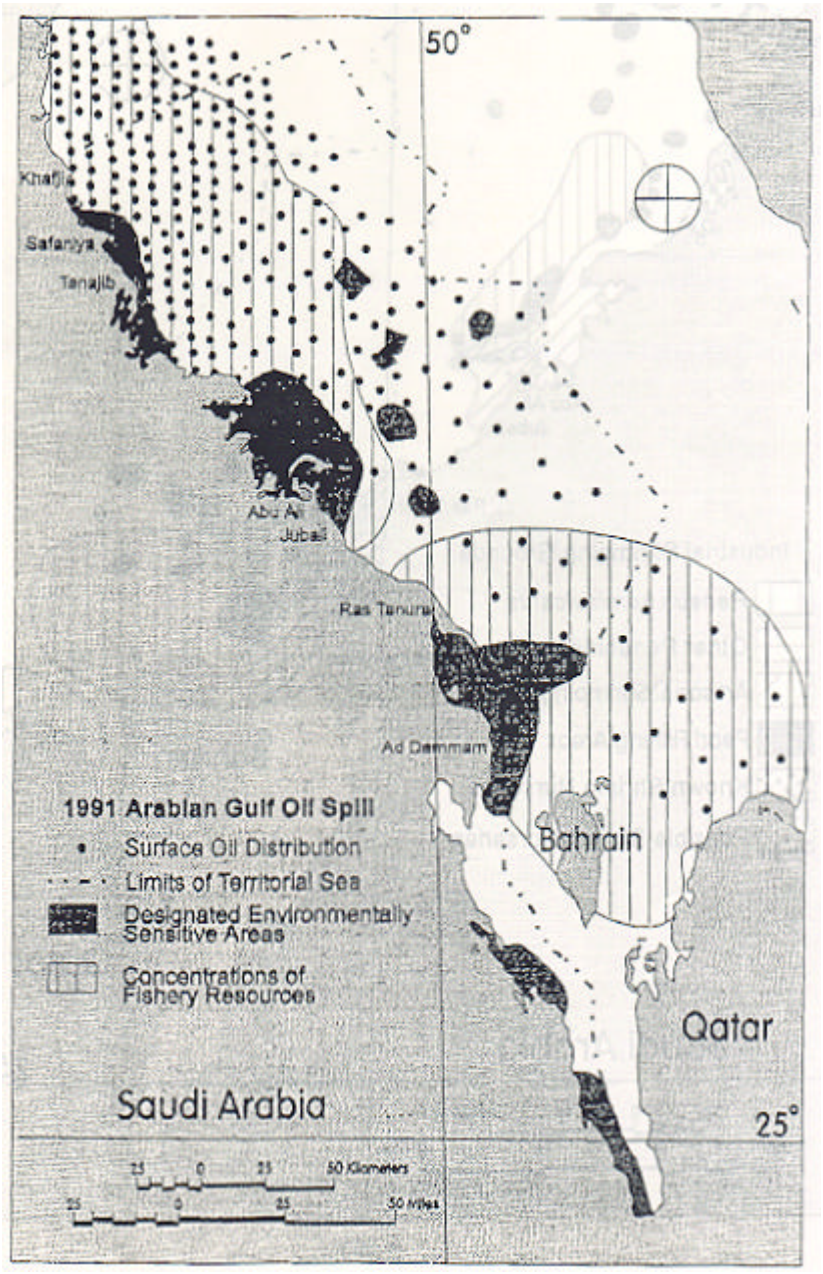

Figure 2. Location of Saudi Arabian fishery resources (MEPA, 1987).

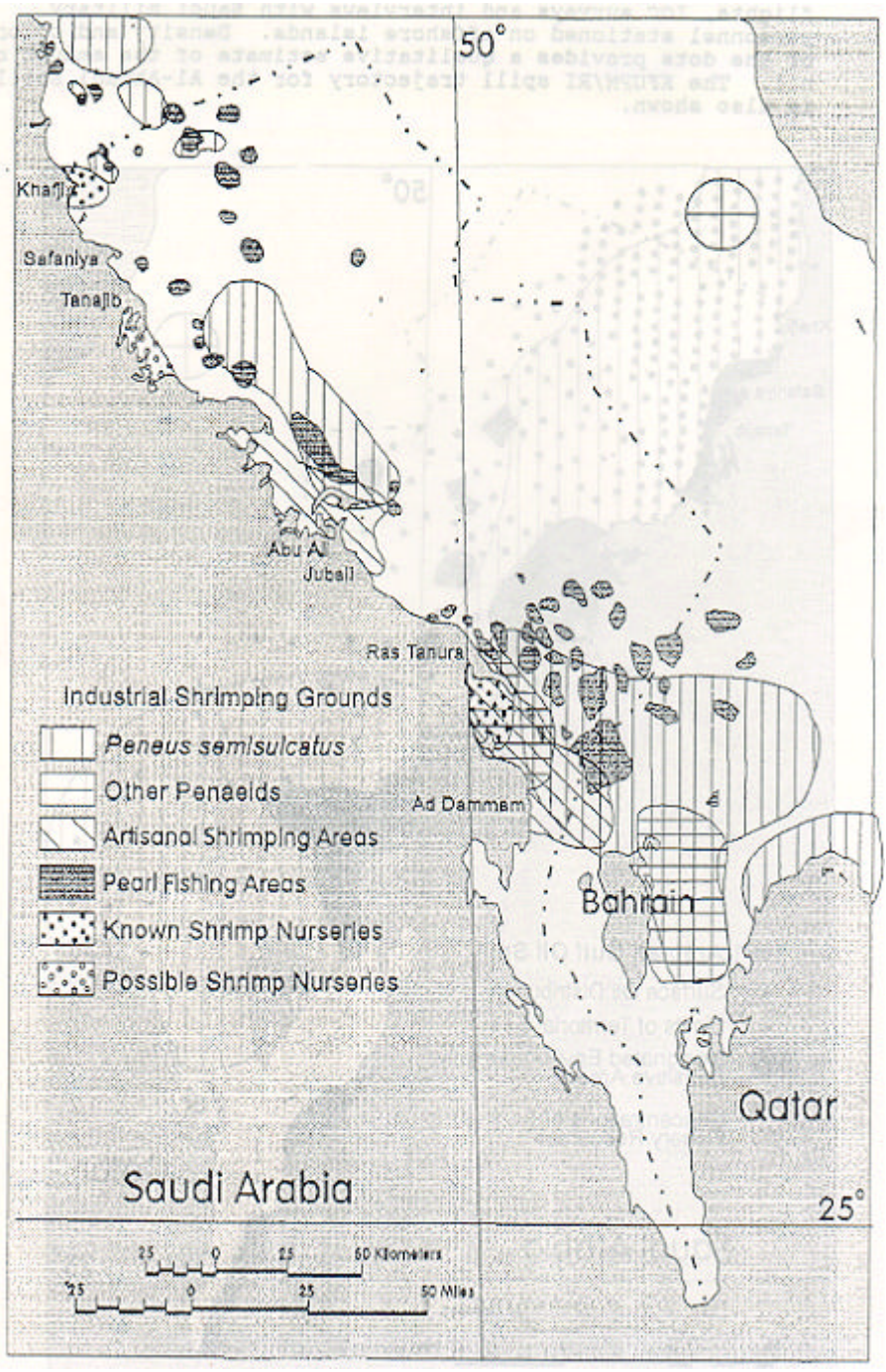

Figure 3. Total hydrocarbon concentrations (PPM) from samples in side the area of oil spill impact and in "Control" areas offshore and to the south of the impact area (data from Tawfiq, et al., 1993). Results are compared to other figures from the literature (shown in the shaded area) from Koons and Jahn, 1992.

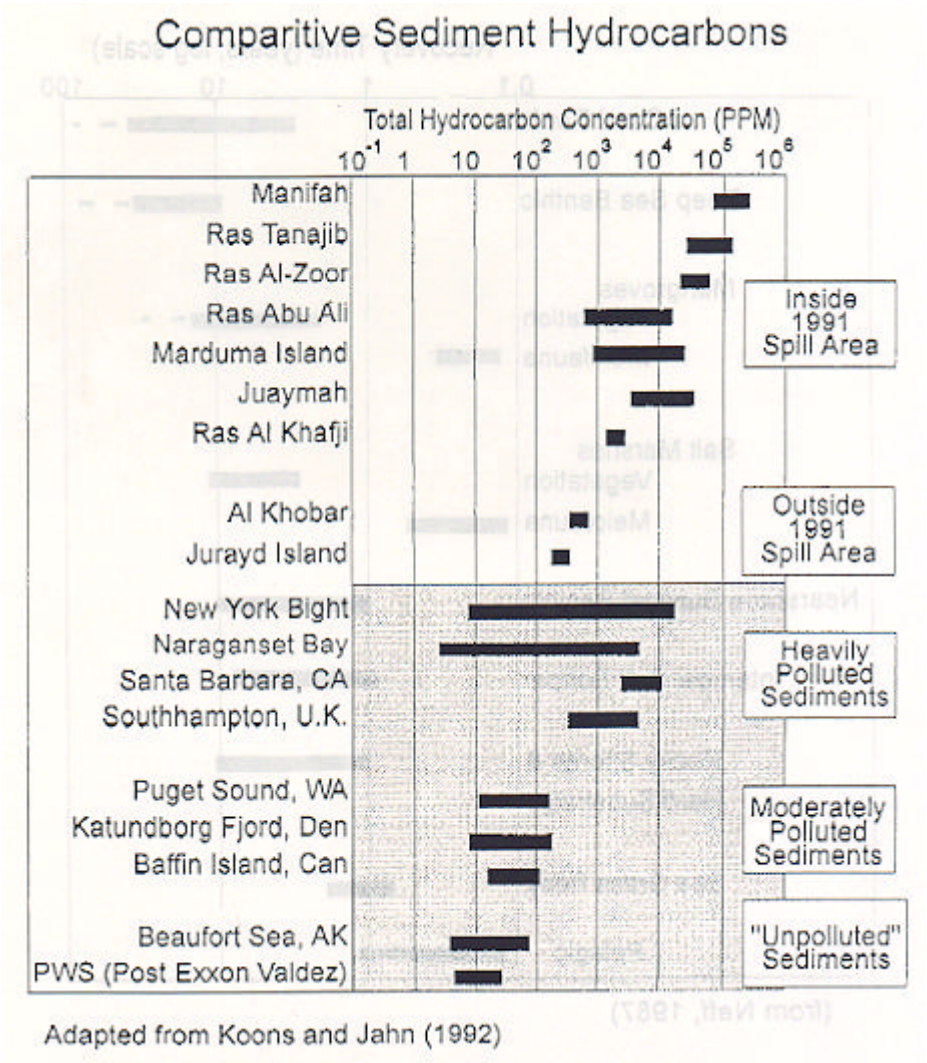

Figure 4. Recovery times for various coastal ecosystems.

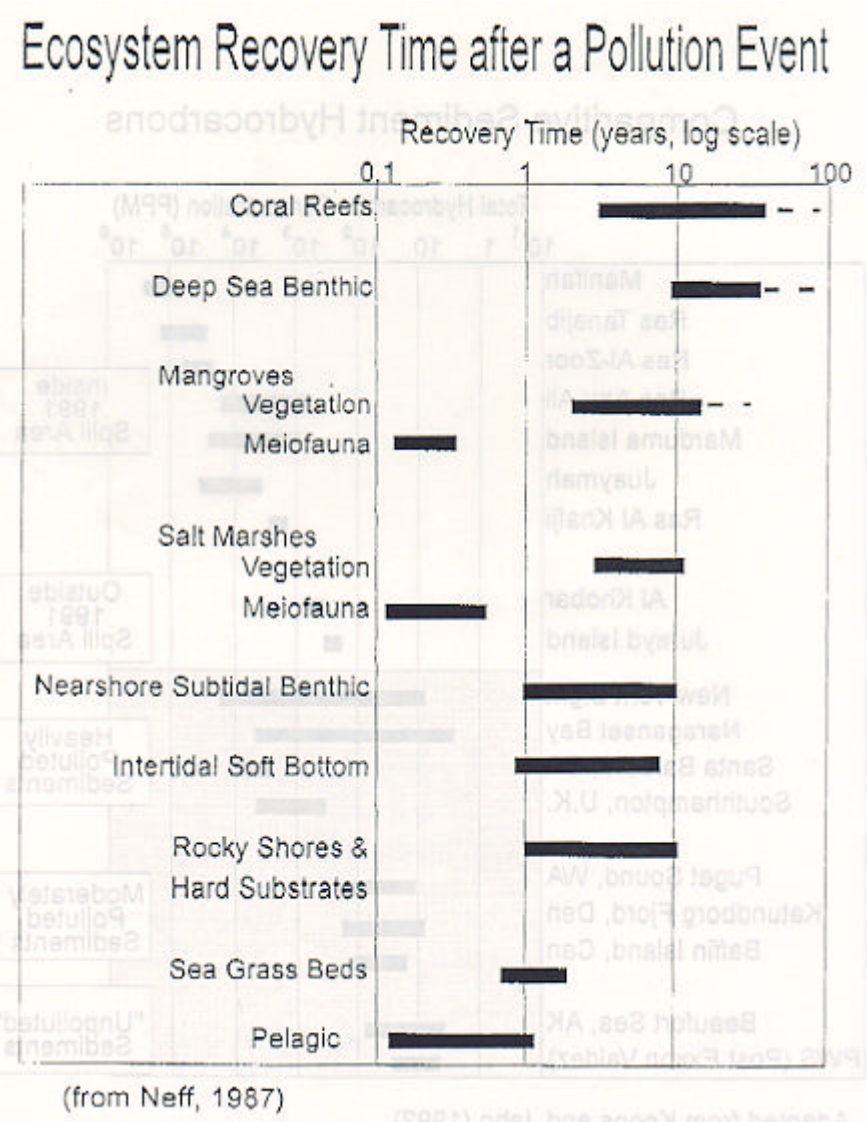

Figure 5. Saudi Arabia Shrimp Landings (1964-1992) as provided by the Kingdom of Saudi Arabia Ministry of Agriculture and Water and from Mathews et al. (1992, 1993) and MEPA (1987).

FIGURES