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REGIONAL REPORT OF THE STATE OF THE MARINE ENVIRONMENT

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In the Name of Allah, the Compassionate, the Merciful

"IT IS HE WHO HAS MADE THE SEA SUBJECT, THAT YE MAY EAT THEREOF FLESH THAT IS FRESH AND TENDER AND THAT YE MAY EXTRACT THEREFROM ORNAMENTS TO WEAR"

QURAN 16:14

FOREWORD

This regional report on the state of the marine environment is prepared in compliance with ARTICLE XVII (d-ii) of the Convention on the functions of the Council which stipulates that "*To review and evaluate the state of the marine pollution and its effects on the Sea Area on the basis of reports provided by the Contracting States and the competent international or regional organizations.*" This provision has been attentively pursued by the ROPME Secretariat, the product of which is this Report as prepared on the bases of the elaboration of expert meetings, as well as the recommendations of the Executive Committee and the Decisions of the Council.

The first attempt to prepare the State of the Marine Environment Report for the ROPME Sea Area was in 1988, when ROPME and UNEP convened a Working Group in which international and regional scientists participated (Linden, *et.al.*, 1990). Two attempts were made by ROPME Secretariat in 1990 and 1993 to update the Report but lack of additional and new data, and changes made as a result of the massive war induced damage to the environment prevented finalization of the Report.

This attempt to produce SOMER comes after more regional data have become available following the release of more data from NOAA Mt. Mitchell (1992) and the 1994 - 1995 Umitaka-Maru (Tokyo School of Fisheries) cruises. The results of Contaminant Screening Projects carried out in cooperation with IAEA - Monaco added a new set of the levels of marine contaminants. Despite the scarcity of nationally produced data, it was decided that the report should come out. Hoping that it will stimulate Member States to pursue their efforts for updating all the relative information and data. This will facilitate new efforts to produce an updated report for the beginning of the New Millennium and publish it by the next Council Meeting in April 2000, during the Ministerial Council Meeting.

ROPME Secretariat hopes that this process can remain dynamic with more new data and information added with each new review. Although the Report departs slightly from previous attempts, it conforms with the format adopted in the Regional Meetings on the State of the Marine Environment.

The efforts made to prepare this very elaborate report have been tedious and very strenuous. Dr. Mahmood Y. Abdulraheem, Coordinator of ROPME has received the main brunt. His pursuance and resilence made the work possible. He played the role of the main editor of this report.

The help received from Dr. Makram Gerges, former Regional Director of UNEP-ROWA is highly appreciated, since his vast experience in the Region was of great benefit.

All the staff at ROPME made some contribution particularly Dr. Hassan Mohammadi, Acting Coordinator, with his meticulous revision was very apt. Miss Nahida Al-Majed, Environmental Specialist and Dr. Peter Petrov, Remote Sensing Officer had facilitated in resolving many difficult issues. Typing and reproduction were carried out by Mr. Francis Picardo and Mr. Basheer Ahmed. All of this work as usual was closely coordinated by Mr. Ibrahiim Hadi, Finance and Administration Officer.

To all of these I extend my gratitude, and above all, to all those who provided us with the information and have sent us their comments from the Member States I express my sincere thanks. Hoping that this Report will add to a better understanding of our Marine Environment.

Dr. Abdul Rahman Al-Awadi
Executive Secretary of ROPME

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INTRODUCTION

The present Report is the first comprehensive regional report on the State of the Marine Environment – SOMER in ROPME Sea Area (RSA). Previous attempts to review the state of the marine environment in the area resulted in the publication by the United Nations Environment Programme (UNEP) in 1990 of a regional review prepared by a Task Team of international and regional experts. Since then more data and information on the state of the marine environment in the RSA have become available. Scientific literature on the region has considerably increased. Analytical techniques have been improved and satellite observations have come more into use for large scale studies, which has enabled ROPME to develop a better understanding of the marine environment including some of the recent changes in the physiogeography and coastal morphology of the region. However, gaps in the knowledge of the region still persist. Thus, this Report could only be based on the data/information available. It should also be noted that war in the region over the period 1980 – 1991 have introduced major geographic and demographic changes in the region, specially in the northwestern part of the RSA, resulting in major ecological changes which further compounded an already impacted marine ecosystem. Unlike war-induced acute changes, the ecological impact of development has occurred over relatively longer period of time, which coincided, with the downing of the petroleum era in the region.

The main objectives of this Report, which is prepared pursuant to decisions by the ROPME Council, are therefore:

1. To document and assess the current state of the marine environment of RSA, given due attention to recent changes in the environmental conditions and the impacts of human activities on the marine environment and coastal areas;
2. To identify the current regional concerns and emerging issues which present major challenges; and
3. To suggest regional strategies and priority actions that commensurate with these concerns and issues to enable the governments and decision-makers of the region to meet these challenges at the national level as well as in regional and global contexts.

The Report is structured in nine Chapters, Chapter 1 gives a brief background about the Regional Organization for the Protection of the Marine Environment (ROPME), the Sea Area addressed by this Report and some socio-economic considerations for the ROPME Region. Chapter 2 reviews on the basis of the best available information to-date, the marine characteristics and resources of the region in order to understand the physical and ecological features of the Sea Area. Chapter 3 discusses the main socio-economic activities and structures, both land-based and sea-based, that are likely to affect RSA. Chapter 4 provides scientific data and information on the marine contaminants, their sources, types, levels and distribution in water, biota and sediments and their possible effects. Chapter 5 presents the major maritime accidents and natural episodic events that have recorded and observed in the recent past in the RSA. Chapter 6 is entirely devoted to a discussion on the environmental consequences of war. Chapter 7 focuses on some measures for the prevention and control of marine pollution and environmental degradation, including policies, legislation and institutional arrangements. Chapter 8 summarizes the current and emerging issues that represent major challenges which need to be addressed at regional levels and their implication at the national level. The identification of these challenges guided the suggestions given in the succeeding Chapter 9. The Chapter proposes relevant strategies for environmental protection and sustainable development of RSA and an "Agenda for Action" that numerates priorities to be set in order to address the most pressing issues and problems described earlier.

This Report is published by ROPME after being reviewed by the Member States, with the hope that it will benefit the environment protection authorities, decision-makers and the scientific community in the region with a balanced assessment of the current state of the RSA. It is also hoped that this Report succeeds in giving a futuristic vision on how to protect and sustain the marine ecosystems as a vital source of life for the present and future generations, taking into consideration that the economies of the region are almost entirely - based on a single non–renewable commodity, which may be threatened by technological break through any time in the future.

SOMER is intended to be periodically reviewed and updated. In the meantime, its conclusions and recommendations for action need to be considered by all those concerned in the respective Member States of the region when formulating national/regional programmes and activities in accordance with the provisions of Kuwait Regional Convention and its Protocols.

Chapter 1

Background

The Regional Conference of Plenipotentiaries on the Protection and Development of the Marine Environment and the Coastal Areas of Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates was convened in Kuwait from 15-23 April 1978. The Conference adopted on 23 April 1978 the Action Plan for the Protection and Development of the Marine Environment and the Coastal Areas, the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, and the Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency.

On 30 June 1979, the Kuwait Convention entered into force after the deposit of five instruments of ratification, in accordance with paragraph (a) of Article XVIII of the Convention. Accordingly, the Regional Organization for the Protection of the Marine Environment (ROPME) was established in 1979 consisting of three organs i.e. the Council, Secretariat and the Judicial Commission. ROPME Secretariat was established in Kuwait in January 1982, after a transitional period during which ROPME programmes were carried out by an Interim Secretariat under the supervision of the United Nations Environment Programme (UNEP), through its Regional Seas Programme.

Since its establishment, ROPME has provided technical coordination to the Kuwait Action Plan and assisted its eight Member States in the implementation of a number of projects, covering environmental monitoring, environmental management (including legislation and preparation of protocols), public awareness building and training.

1.1 The ROPME Sea Area

1.1.1 Definition

The RSA (sometime in the past referred to as the Kuwait Action Plan Region) is the area surrounded by the eight Member States of ROPME: Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United

Arab Emirates. The term "ROPME Sea Area" was coined by Plenipotentiaries of the Member States to achieve unanimity in denoting the area covered by the Kuwait Regional Convention of 1978. It in fact reflects the good will of the Member States to cooperate in protecting their common marine environment in spite of the existing geopolitical boundaries.

According to Article II of the Kuwait Regional Convention, the ROPME Sea Area (RSA) is defined as extending between the following geographic latitudes and longitudes respectively: 16°39'N, 53°3'30"E; 16°00'N, 53°25'E; 17°00'N, 56°30'E; 20°30'N, 60°00'E; 25°04'N, 61°25'E (Figure 1).

1.1.2. Historical perspective

The oldest records of human maritime activity is most likely to be found in the RSA, in the form of trade between Delmon (Bahrain), Oman and India (Price, 1986). For centuries the secrets of riding the monsoons was kept in the hearts of the sailors controlling the trade between the Region, India and Eastern Africa. It was not until the first century BC that the Greeks discovered the monsoons and challenged the Region's sailors. However, by the third century AD and as the Roman Empire declined, the fleets of the Sassainds became the main contenders for marine supremacy in the Region.

The dawning of Islam in AD 610 has radically changed the narrow localized outlook of the peoples of the Region into an amalgam of cultures, especially those of the Arabian Peninsula, Mesopotamia, Persia, the Phoenicians and the Egyptians, to become known as the Moslem Empire. As if these people were awaiting the opportunity, they rapidly spread their new faith from Spain to India, interacting further with the Greek, Chinese and Indian cultures. The shipping and sea trade industries prospered during the Islamic Empire as trade between Moslem ports grew as well as with other countries. The security provided by the power of the new empire and the new developments in sailing technology especially the introduction of the lateen sails, the use of the magnetic compass, invention of the sextant and development of more accurate maps enabled the Moslem sailors to expand trade to China and enjoy supremacy of the seas.

As Moslem empire broke into smaller kingdoms divided by territorial disputes, the domain of the Moslem fleet shrank with time but remained strong in the Region until the arrival of European naval forces in the fourteenth century who came with bigger, metal-based ships and with

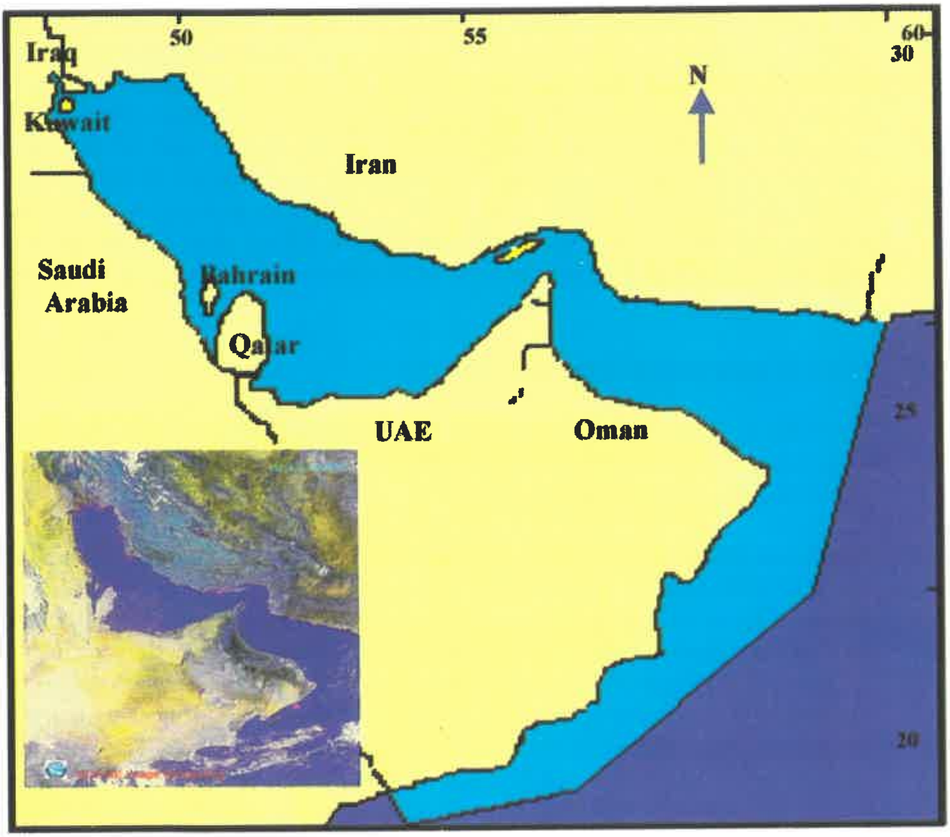


Figure (1) : ROPME Sea Area (RSA) – Geographical boundaries as seen from space.
NOAA / AVHRR data fragment, colour composition. On the North – snow cover on the Zagros mountains. On the Central part of RSA – clouds near U.A.E. coast, on the territory of Saudi Arabia and on the south – clouds near Omani coast. Green, cyan colours represent vegetation, mostly on east coast (I.R. Iran) and Omani coast. There are some spots of irrigated agriculture in the west (Kuwait, Saudi Arabia, Qatar, U.A.E.). Yellow colour represents mainly rough grazing and barren lands.

maritime and sailing knowledge acquired, but further refined, from Moslem sailors. By 1515 the Portuguese colonizers began their campaign to control the area. They were soon followed by the Spanish, Dutch, French and the British. After stiff resistance by the Quwasims, with their fleet of about 700 ships and over 18000 men, that lasted until the second half of the 18th century, the British occupied Ras Al-Khaimiah and marked an end to the supremacy of the "DHOWS" (Price, 1986). Maritime activity in RSA then became restricted to trade with India and Eastern Africa, pearl diving, fishing and inter-regional trade until the time of oil discovery and exploitation in the twentieth century.

1.1.3 Physical-geographical features of the RSA

The RSA as defined above comprises three geographically distinct parts that also exhibit distinct physical and biological characteristics and different meteorological conditions as follows:

a. **The inner RSA**: This is the marine area west of 56°E longitude, extending along NW/SE axis from the Strait of Hormuz to the northern coast with a length of about 1000 km, and is surrounded by high mountains on the Iranian side and low-land on the Arabian side. It is a shallow embayment having a mean depth of about 35 m with maximum depths between 90 and 100 m at its north-eastern side near the coast of Iran, and about 100 m near its narrow entrance at the Strait of Hormuz connecting it to the Gulf of Oman and the Indian Ocean. The Strait of Hormuz is only 56 km wide at its narrowest point and has no sill; the trough simply deepens to more than 100 m through the Strait and drops quickly to more than 2000 m within 200 km outside the Strait. The maximum width of this inner part of RSA is 338 km and its surface area is about 240,000 km^2. The volume of water in this part of RSA is estimated at about 7,800 km^3 by Linden *et al.* (1990) and at about 8,630 km^3 by Reynolds (1993).

The shallowness of this area makes its response to meteorological variables quick and dramatic. Being surrounded by a desert land mass on the one side and mountains on the other, enhances the water evaporation and makes the water exchange through the Strait of Hormuz quite active (Hunter, 1984). When considered closely, it is seen that the area is a mosaic of smaller areas particularly on the western side where one could distinguish an estuarine area in the extreme north near the mouth of Shatt Al-Arab, an extremely shallow area between Saudi Arabia, Bahrain and Qatar (Salwa Bay) and a broad shelf area between Qatar, the United Arab Emirates and Oman (Hassan and El-Samra, 1985). Figure (2) illustrates the bathymetry of the inner RSA.

b. **The middle RSA** comprises the Gulf of Oman, which is a deep basin with depths exceeding 2,500 meters along its central channel and 100 meters at Hormuz Strait. It has free access to the Arabian Sea and the Indian Ocean. It is, however, not in the monsoon belt. In spite of the Strait of Hormuz being narrow and shallow (relative to the Gulf of Oman), it is an important link introducing the ambient oceanic waters to the inner part of RSA and allowing its warm saline water to form a bottom layer exiting via the Gulf of Oman. On the Iranian side, it extends from the Strait of Hormuz to Chah Bahar at the Pakistani border. The bathymetry of this part is also shown in Figure (2).

c. **The outer RSA** extending from Ras Al-Hadd to the southern border of Oman, exhibits a wide range of physico-geographic features ranging from the well developed sandy shores with a large continental shelf to rocky highlands with a narrow continental shelf. It is an integral part of the Indian Ocean, and lies around the low twenties of the northern latitudes, in the monsoon ring, bounded to the north by the relatively mountainous land masses of Oman and Iran, and deepening rapidly to the south with no barriers separating it from the Arabian Sea and the rest of the Indian Ocean.

1.2 Socio-Economic Considerations

The ROPME Region has witnessed, over the past three decades, one of the highest rates of economic growth in the world. As oil and gas production reached commercial scale after the World War II, the ROPME region witnessed an unprecedented influx of man and materials. This unprecedented growth has brought about major changes in the socio-economic structures of the Members States, including the sources and levels of national income, and the methods and rates of utilization and management of natural resources. Oil has been and still is the prime mover in the Region with its proved reserves of 76 billion metric tons and the natural gas reserves of 32.4 trillion cubic meters (1994 estimates).

The rapid urbanization and industrialization in the Region are virtually all based on the petroleum and petrochemical industry. Petroleum and natural gas are also used for the generation of electricity and desalination of

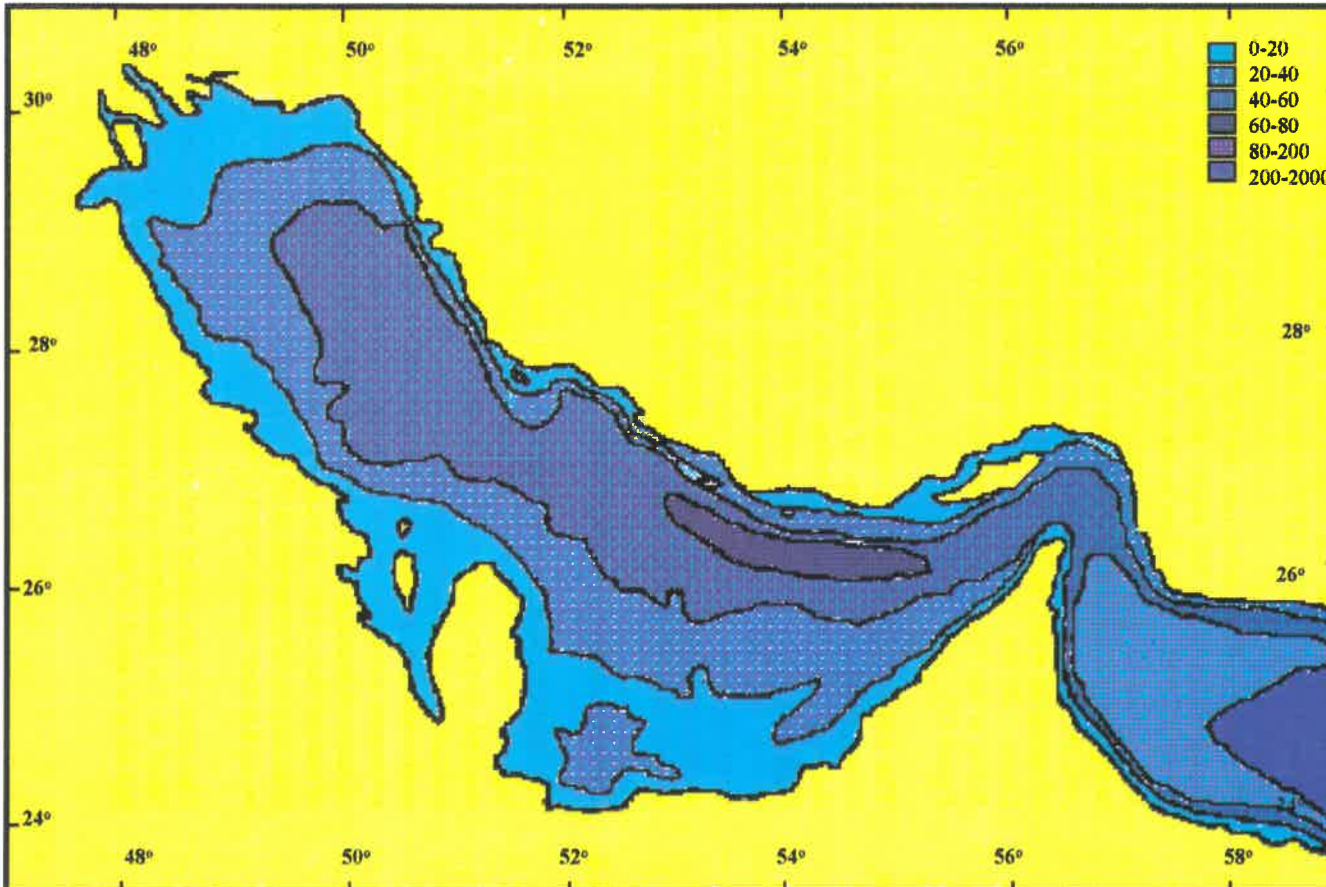


Figure (2) : Bathymetry of the RSA (Adapted from Habashi *et al.*, 1995).

seawater. The capacity of electricity generation in the region is one of the highest per capita in the world, and the production of desalinated water with over five million cubic meters per day is approximately 43% of the world's desalination capacity (1994 estimates). Petroleum is the principal commodity exported by sea and accounts for 75% to 95% of the export earnings of individual counties. Other major activities on the coastal areas are related to trade, fisheries and light industries.

The ROPME Region today bears the scars of decades of non-sustainable exploitation of its natural resources, coupled with the recent environmental devastation of two major wars. The rise in industrialization, together with a high population growth and rapid urbanization have resulted in ever-increasing environmental problems of the Region. Almost all development projects have been established on the coasts, as that provides an easy access to the international maritime transportation, a practical solution to the importation and exportation of raw materials and products and also provides the water sources needed for essential industrial uses and for potential discharge to the marine environment, hence, affecting the most productive areas of the marine environment. Also, with the exception of Iran, Iraq and Saudi Arabia, the majority of the residents are coastal dwellers and virtually every town or city of some significance is located on the sea. This clearly indicates the scarcity of habitable land in the Region and the close juxtaposition to and dependence on the sea. The impact of concentration is more pronounced when high rates of population growth are considered. Table (1) gives the estimated population together with the coastal population and the population density in the coastal areas for ROPME Member States in 1998 (Population Reference Bureau, 1999).

In this connection, two relevant facts are worth mentioning. The first is that from the total population of ROPME Member States, estimated at 114.3 million (in 1998), about 15.5 million, i.e. 13.6% live on the coast along a coastline of about 6,166 km, with an average population density of 1,592 inhabitant/km (Table 1 and Figure 3). It should be noted, however, that in five countries of the region (Bahrain, Kuwait, Oman, Qatar and UAE) an average of about 64% of the total population lives on the coast. The second is that the Member States of ROPME have for several years now diversified their sources of national income. This is mainly through industrialization and better use of renewable resources. However, most of the newly

Table (1) : Estimated population, coastal population and the coastal population density in the ROPME Member States estimated for the year 1998.

Member States	Population (est. 1998)* (million)	Coastal population (million)	Percentage of coastal population	Length of the coastline (Km)	Coastal population** density (person/km)
State of Bahrain	0.6	0.564	94%	126	4,476
I.R. Iran	64.1	6.41	10%	1,950	3,287
Republic of Iraq	21.8	1.744	8%	90	19,378
State of Kuwait	1.9	1.336	37%	350	3,817
Sultanate of Oman	2.5	1.575	63%	1,700	926
State of Qatar	0.5	0.29	58%	510	569
Kingdom of Saudi Arabia	20.2	1.818	9%	790	2,301
United Arab Emirates	2.7	1.809	67%	650	2,783

* (Population Reference Bureau, 1999).
**Obtained by dividing coastal population by length of the coastline.
Discrepancy of the data may be attributed to inconsistent differentiation for coastal areas.

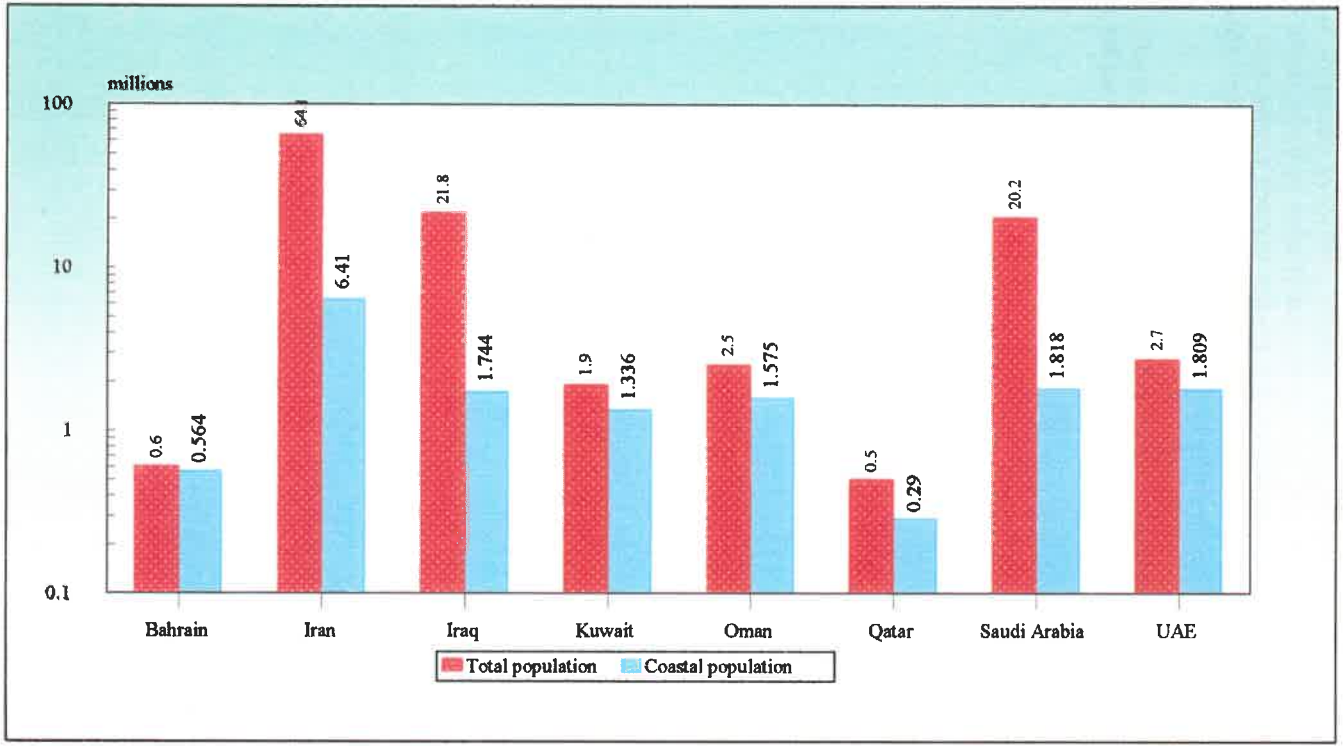


Figure (3): Total and coastal populations in the ROPME Member States developed economic activities in the various countries of the region are still directed towards and concentrated in the coastal zone as stated above. This of course added more pressure on the already stressed marine and coastal area of the region, where most of the oil resources and industries existed for years.

It is with this background in mind and based on the existing scientific data and information that the present State of the Marine Environment Report is being prepared.

CHAPTER 2

MARINE AND COASTAL ENVIRONMENTS OF ROPME SEA AREA : CHARACTERISTICS AND RESOURCES

The general climatic and meteorological conditions prevailing in the region, as well as the physical, geological, chemical and biological characteristics of the RSA are described below in the first part of this Chapter, so as to provide a reasonable review of the characteristics of the marine and coastal environment in the Area, based on the best available data and information.

In the second part, a brief account is given of the living and non-living resources of the RSA, which have been or are being exploited in the region, with a view to establishing the possible impact of development activities on the marine environment.

The scientific information used in this review include data obtained from ROPME's Marine Pollution Monitoring and Research Programme, initiated under the Kuwait Action Plan (KAP) since the early years of its existence.

ROPME's regional monitoring programme, originally known as the "18-Month Monitoring Programme", initially aimed at recording the oceanographic characteristics of the RSA as well as collecting baseline data on the levels of various oil and non-oil pollutants (Behbehani, 1985).

ROPME has developed its monitoring programme over the years to include coastal monitoring by Member States as well as expanding to include data obtained from open sea cruises, remote sensing and through applying advanced techniques such as the Geographic Information System (GIS). Further, in all ROPME's monitoring activities, international standards and "Reference Methods" are routinely used in accordance with ROPME's Manual of Oceanographic Observations and Pollutant Analyses Methods (MOOPAM) and the application of quality assurance (QA), quality control (QC) and intercalibration is mandatory

2.1 Characteristics

2.1.1 General climatic and meteorological conditions

The RSA is located in the North-Temperate tropical margin, a region that encompasses most of Earth's deserts. This region marks the boundary between tropical cellular circulation and the synoptic weather systems of mid-latitudes. Sinking dry air in these latitudes produces clear skies and arid conditions (Reynolds, 1993). Local climate is influenced strongly by the Taurus and Pontic mountains of Turkey, the Caucuses mountains of Iran, and the Hejaz mountains of the Arabian Peninsula. Extra-tropical storms generally track from northwest to southeast along the axis of these mountain ranges.

The RSA is therefore characterized by primarily dry climate that is associated with desert conditions. The general climate can be described as being very hot and dry in summer and relatively cool in winter with small amounts of rainfall in winter and spring (MEPA, 1989; Qatar, 1990). The winter and spring seasons in the region are very short, usually consisting of a two-month winter typically occurring in December and January, and often, only a single spring month typically occurring in March or April (Ali, 1994).

Seasonality in the RSA is closely correlated with air temperature. The temperature distribution of the RSA throughout the year shows a range of values with the general pattern closely following topographic features and the local circulation. Winter is characterized by mean daily temperature below 20°C. The temperature in the northern part of the RSA is lower than in the southern part. In contrast to the cooler winter temperatures, the summer season is defined as the interval when mean daily air temperature is consistently greater than 30°C. In general during the summer, air temperatures are extremely high. The Arabian Peninsula and the ROPME region are considered to be one of the hottest areas in the world (Takahasi and Arakawa, 1981). Temperatures in excess of 49°C have frequently been recorded at some stations in the region especially in the northern part of the RSA (Qatar, 1990; MEPA, 1989; Safar, 1985; Al-Kulaib, 1990). In 1997 a record temperature of 84°C in the sun and 52°C in the shade was reported in the open desert of Kuwait. While it is not unusual to record sub-zero temperatures in early morning of winter months of Kuwait. These large temperatures require special adaptation capabilities in terrestrial and marine flora and fauna.

The amount of **precipitation** in the region varies greatly, but a general trend of decreasing precipitation exists from north to south. The variability in rainfall is primarily due to the occurrence of thunderstorms, which in general do not have a well-defined pattern of occurrence on the Arabian Peninsula and the RSA. Annual precipitation in the RSA averages 152 mm and is limited almost entirely to the winter months, (Fouda, 1998). Hassan and Hassan (1989) gave an average precipitation value of 78 mm/yr. Here again, there is a large degree of variability from year to year, even within the same country. In the winter of 1997, up to 60 mm of rain fell over parts of Kuwait and Saudi Arabia within a period of 3-4 hours.

The wind regime over the region of the RSA and the Arabian peninsula indicates that three types of wind prevail during the year: (i) Winter and summer Shamal (Shamal is an Arabic that means "North"); (ii) Kaus (a local term used to describe a wind from the southeast; and (iii) winds that prevail in coastal areas due to the sea breezes (Ali, 1994). However, the most prominent weather phenomenon in the RSA is the "Shamal" wind that blows down the axis of the RSA from the northwest in both summer and winter. The winter Shamal usually sets in with great abruptness and force between November and March, but seldom exceeds 10 meters/second. While a relatively rare event, the Shamal brings some of the strongest winds and highest seas of the season to the region.

The Kaus, on the other hand, blows from the south-southeast ahead of an approaching cold front. The Kaus winds increases in intensity as the front approaches, reaching to gale force. It should be noted that Shamal blow on the NW part of RSA and picks up humidity as it blows down the RSA axis. The Kaus increases in force as it blows towards the northwestern part, bringing more humidity in the summer months.

In the southern part of the RSA, winds are mostly westerly. Near the western side of the Strait of Hormuz, southwesterly winds are predominant. Wind patterns in the Gulf of Oman are strongly influenced by tropical circulation of the Arabian Sea with southwest monsoon winds during the summer and northwesterly in the winter months. A strong "sea breeze" occurs along the entire coastline, especially along the Arabian Peninsula. Driven by the intense temperature difference between the land and water surfaces, the sea breeze circulation adds a landward component to all winds. The effect of these winds is to drive floating pollutants to the beach much faster than they would move otherwise. Moreover, ground based thermal inversion is a common phenomenon, occurring up to 90% of nights over Kuwait mostly at 200 - 300 meters above the ground (EPC, 1992). Unlike sea breeze phenomenon, thermal inversion prevents plumes released into the air above the discontinuity layer from settling back on land. This had a profound affect on the behaviour of the oil well fires of Kuwait in 1991.

Figure (4) represents the historical data of some physical variables for selected locations in the RSA. The Figure shows that the annual mean temperature varies between 24.2°C as reported in Bushehr (Iran) and Ras Khafji (Saudi Arabia) and 30°C in Seeb (Oman). The annual mean relative humidity varies between 44.9% reported in Abadan (Iran) and 69.4% in Sharjah (U.A.E.). The annual mean barometric pressure adjusted to the mean sea level varies between 1007.1 mb reported in Jask and Queshim Island (Iran) and 1011.9 mb reported in Dhahran (Saudi Arabia). The annual mean precipitation varies between 39.7 mm/yr reported in Tarif (U.A.E.) and 230.1 mm/yr in Bushehr (Iran).

Dust and sandstorms are one of the important weather phenomena in the northern countries of the RSA: Kuwait, southern Iraq and Iran. This area is susceptible to these storms because of its low topographic relief, scanty vegetation cover, light-textured top soils and recurring strong and turbulent winds. These devastating phenomena have widespread adverse effects on the environment, the economy and the quality of life.

The dust storms passing over the northern part of the RSA are considered to be a major source of marine sediments (Khalaf *et al.*, 1982; Al-Bakri *et al.*, 1984). One interesting aspect of dust fallout in the area is its possible effects on the movement and fate of oil spills on the sea surface, acting as a sinking mechanisms for oil droplets (Foda, 1984).

The amounts of dust fallout in the various dust storm regions have been discussed in Khalaf *et al.* (1980) who determined the monthly amounts of dust fallout along the coastal area of Kuwait for the period April 1979 – March 1980. They recorded the highest fallout in July (1002.7 t/km^2) and the lowest in November (9.8 t/km^2). Environment Public Authority in Kuwait (1996) used a high volume sampler in Shuwaikh Industrial Area to monitor TSP. Samples were collected over a period of 48 hours, with TSP determined for the volume of air sampled. Results showed that the

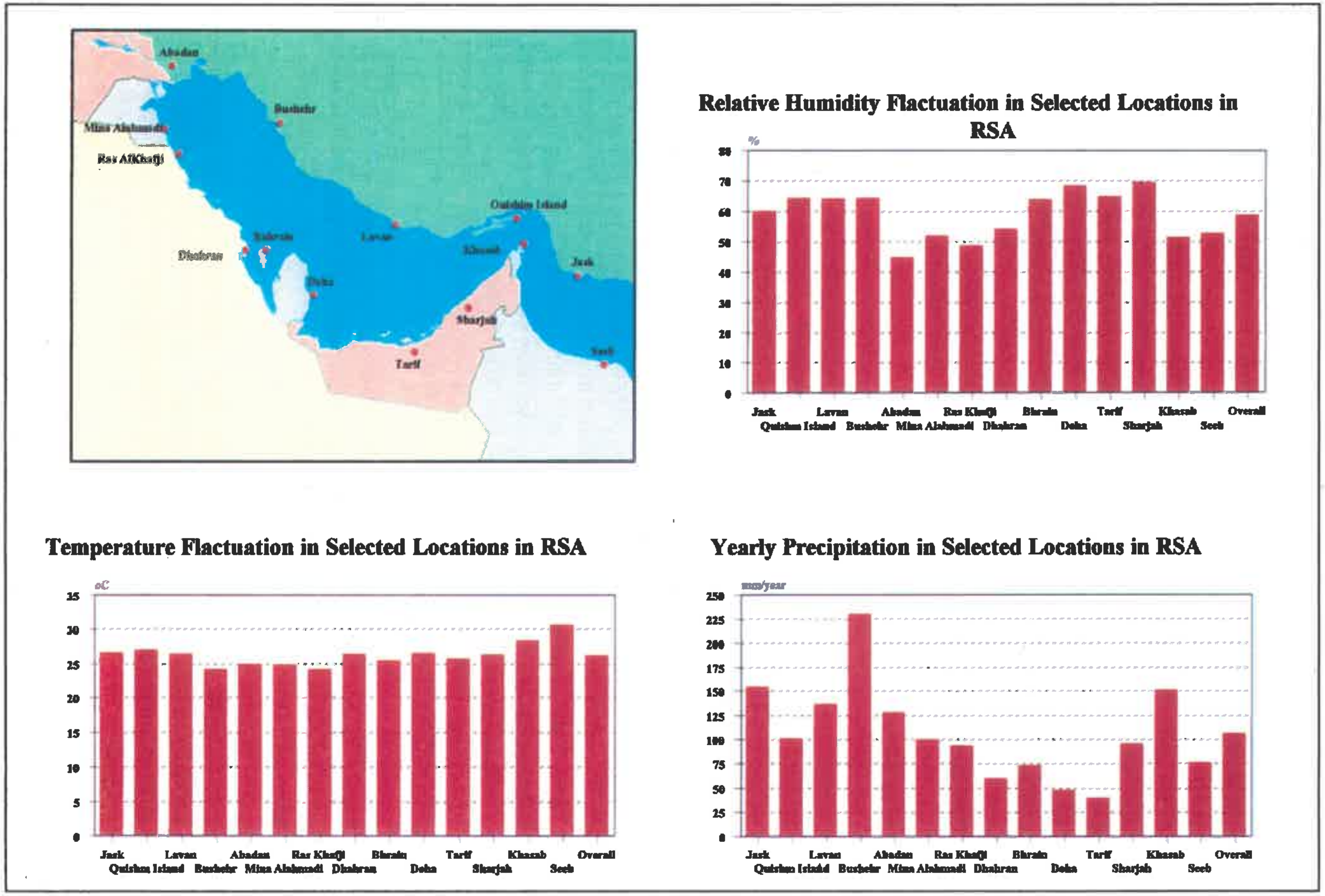


Figure (4): Historical data of selected variables for locations surrounding the RSA.

maximum concentration 315 μg/m³ was recorded at August while the minimum 132.7 μg/m³ was recorded at April. The overall mean was 207.8 μg/m³ (EPA, 1996).

Dust can also act as a carrier for various types of pollutants, especially pesticides, by adsorbing them on the suspended particles and transporting them to remote areas (Risebrough *et al.*, 1968). Suspended dust can be transported over distances of up to several thousands of kilometers (Darwin, 1846, Delany *et al.*, 1967 and Prospero *et al.*, 1970) and eventually deposited partially in the Sea Area.

2.1.2 Physical characteristics, tidal movement, water circulation and water balance

2.1.2.1 Physical oceanographic characteristics

General description of the hydrographic structure of the RSA has been reported by several authors, e.g. Grasshoff (1976), Brewer and Dyrssen (1985), Hunter (1986), Dorgham and El-Gindy (1991), El-Gindy and Dorgham (1992).

A more comprehensive picture of the hydrographic structure of the RSA could be obtained from the results of three basin-wide studies carried out by different research vessels. Emery (1956) reported on a 1948 summer cruise by the German ship Meteor, Brewer and Dyrssen (1985) reported on the 1976 Winter-time Expedition of the Atlantis from Woods Hole Oceanographic Institution – USA, and Reynolds (1993) reported on a 1992 100-day Oceanographic Cruise by the NOAA Research Vessel Mt. Mitchell of (USA). Several investigations of coastal water circulation patterns have also been carried out by individual countries.

The surface water temperature in RSA varies between 12°C in winter and >35°C in summer (Figure 5). The temperature difference between summer and winter is greatest (>20°C) in the northwestern part and least (<11°C) at Hormuz.

Due to high rate of evaporation in RSA, salinity increases gradually from southern to northern parts of the region with lower salinity along the Iranian side. In summer, the surface salinity varies from 34 off the Omani coast on the Arabian Sea, to 37 in the Gulf of Oman and up to 42 just off Bahrain. Salinities as high as 70 have been repeated in the Gulf of Salwah at its extreme southern extremity (Basson *et al.*, 1977). In winter, the salinity is somewhat higher than in early summer in the upper NW of RSA, apparently due to the variation of fresh water influx from Shatt Al-Arab and meteorological effects, particularly evaporation (Figures 5 and 6).

A surface flow of water of high temperature >28°C and low salinity about 37 enters the Sea Area through the Straits of Hormuz during the summer season (Figures 5 and 6). This flow is also observed in the winter with temperature >20°C and salinity 39 (Figures 5 and 6). The annual seawater temperature variations in the area, which reaches up to 20 m depth in May and to deeper depths in February, might be related to air temperature and the vertical mixing intensity. The strong mixing in February leads to a vertical homogenety and changes extended to deeper-layers (Figure 7a). In May, the thermocline acts as a barrier and limits the variation to the upper 20 meters (Figure 7b).

According to the available data, the vertical thermal structure of the RSA has the following features:

a) In the winter time, north of Qatar, the water column is almost perfectly mixed top to bottom.
b) In the summer time, the northeastern end of the RSA becomes a two-layer system with a well-mixed surface layer and a well-mixed bottom layer which is a residual of the winter water.
c) At the extreme northern end, the depth becomes shallow enough that surface and bottom mixing can stir the water column over its full depth.
d) At the southern end of the RSA, the two-layer system persists year round. The upper layer of fresher water intruding from the Gulf of Oman to replace water lost by evaporation and the lower more saline water exits to complete the reverse-estuarine circulation.

2.1.2.2 Tidal movement

Tides in the RSA are complex and vary from semi-diurnal to diurnal. The tidal range is large with values greater than 1 m everywhere (Lehr, 1984). The dimensions of the Inner RSA are such that resonance amplification of the tides can occur and the result is that the semi-diurnal constituents have

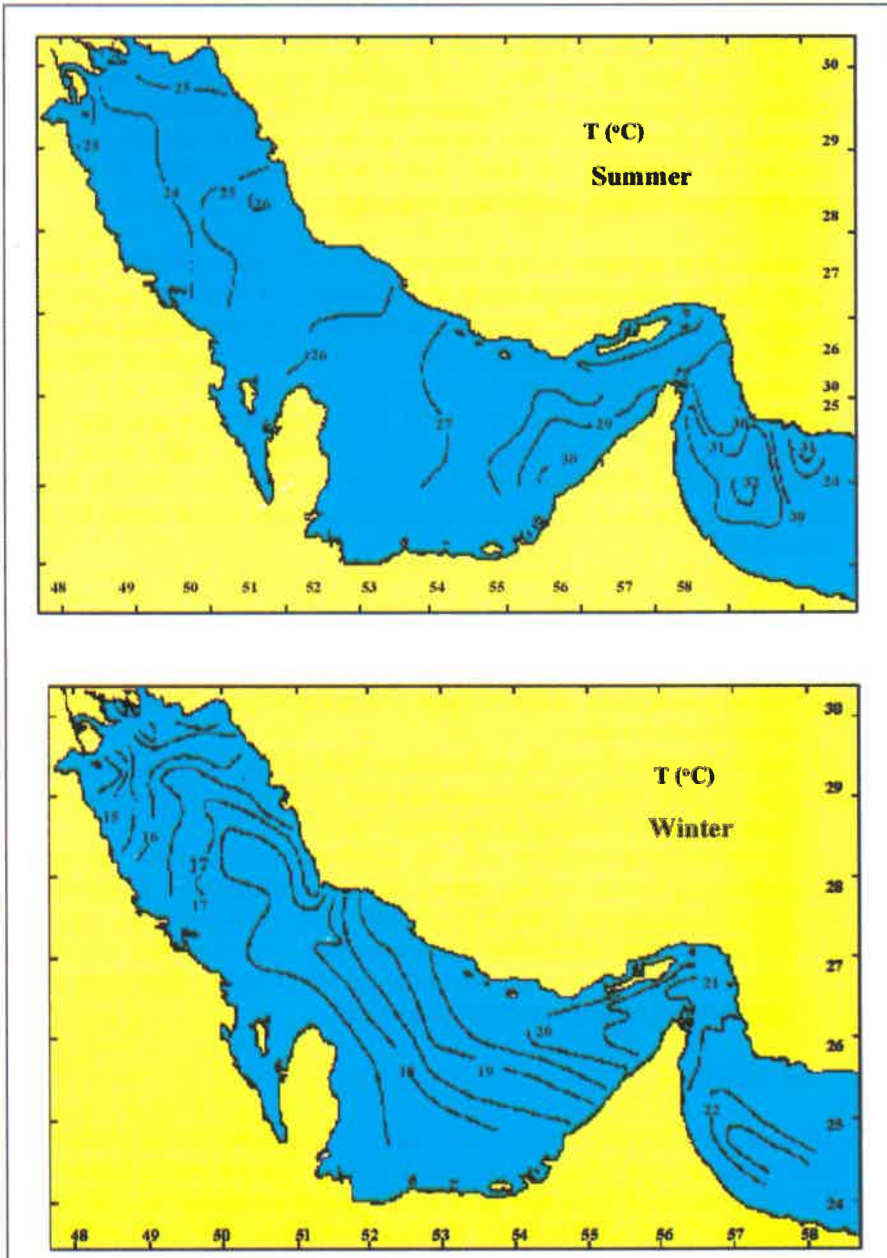


Figure (5): Horizontal distribution of surface temperature during early summer and winter seasons (After Reynolds, 1993).

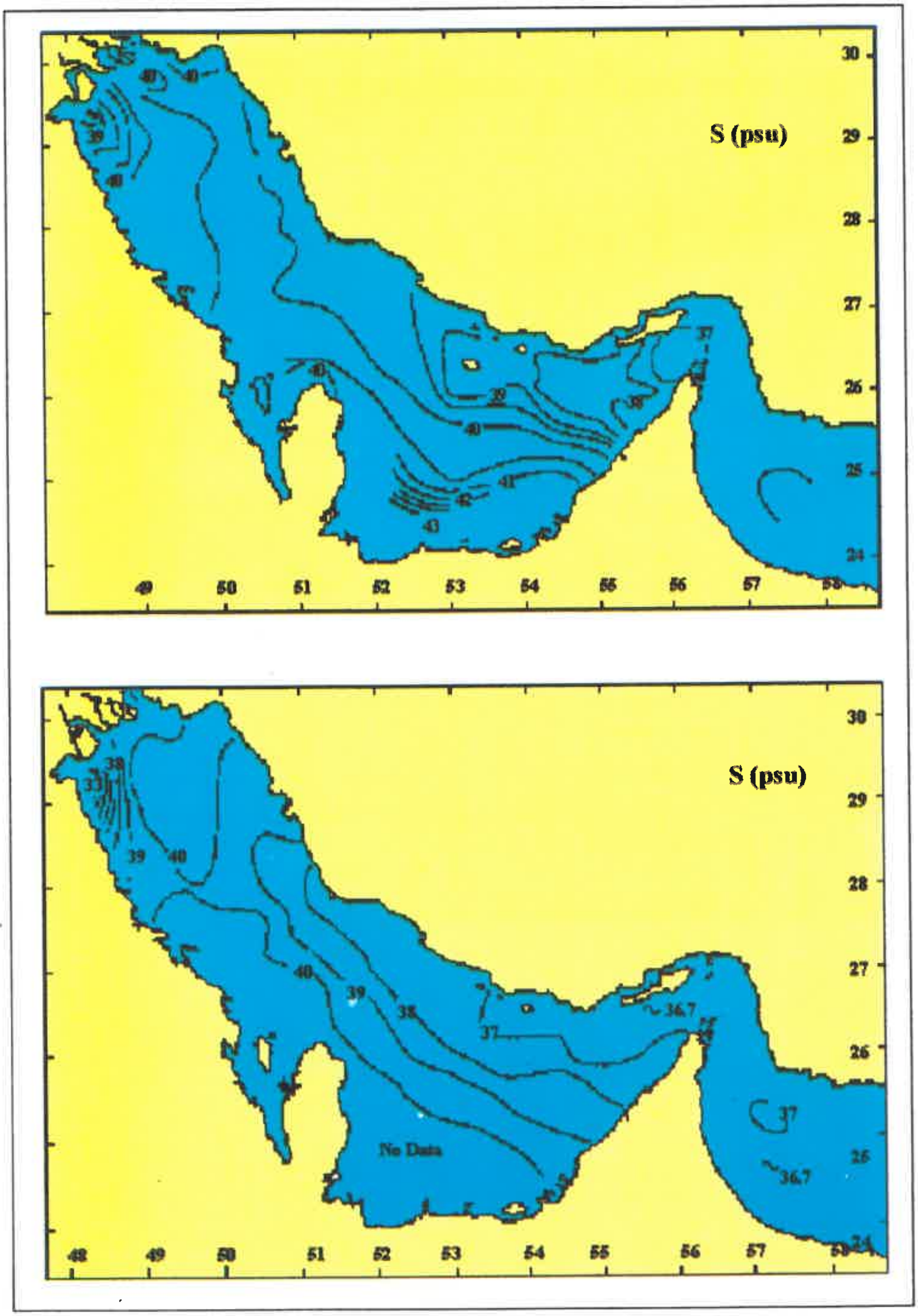


Figure (6): Horizontal distribution of surface salinity during early summer and winter seasons (After Reynolds, 1993).

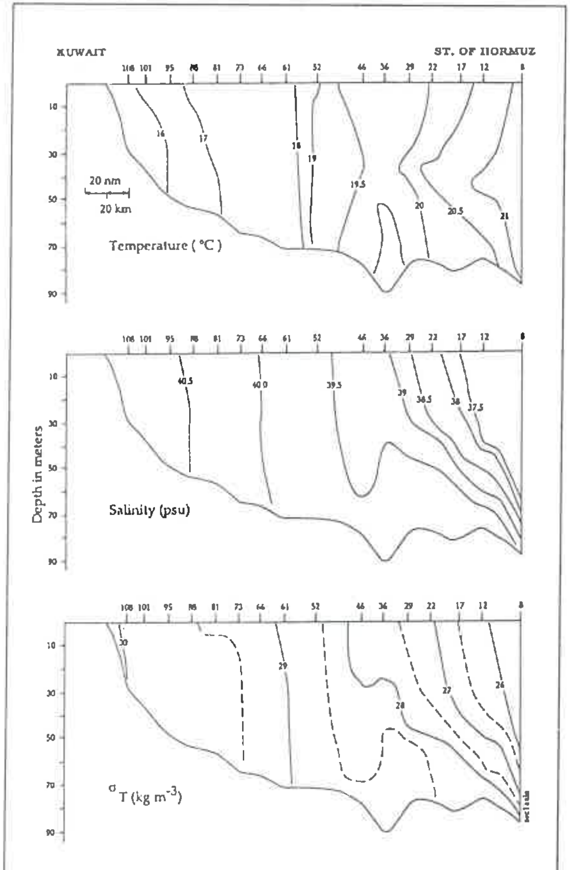


Figure (7a): CTD cross section along the axis of RSA from Leg 1 (winter) survey.

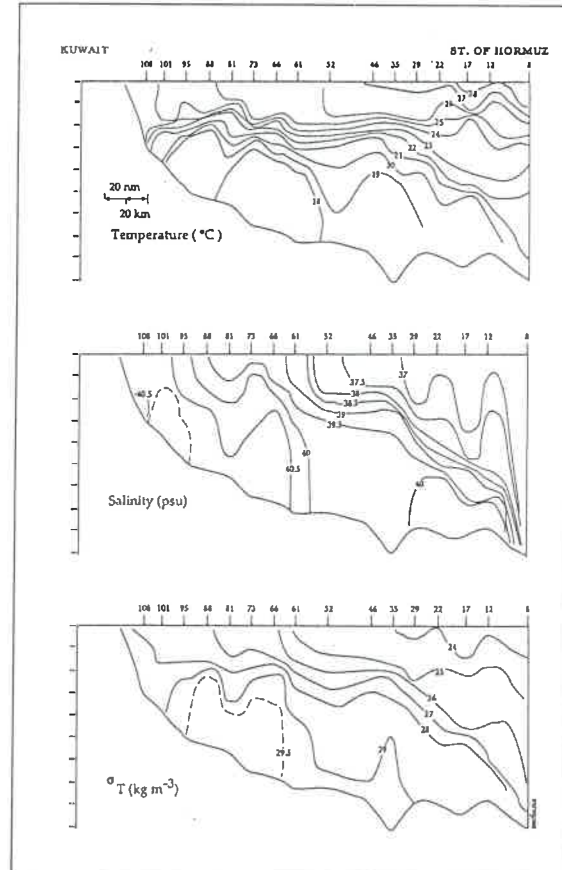


Figure (7b): CTD cross section along the axis of RSA from Leg 6 (summer) survey.

(Reynolds, 1993)

two amphidromic points while the diurnal constituents have one amphidromic point, in the centre near Bahrain. The tides in RSA are basically semi-diurnal. The tidal range is least in the central basin of the area, being about 1 to 2 meters in Bahrain. In the northwest, at Shatt Al-Arab delta, tides are normally about 2.5 meters, and in the South (in the Gulf of Oman), the range is about 2 meters. In Dubai (U.A.E.) and Lengeh (I.R. Iran) ranges of 3 to 4 meters are observed (Linden *et al.*, 1990).

The four main harmonic constituents of the tidal regime in the RSA as calculated by the British Admiralty (1976) were M_2, S_2, O_1 and K_1 (Figure 8). Particular combination of the constituents to repeat itself requires about 19 years, although suitable approximation can construct an artificial tide cycle of about 24.8 hours which enables the main features of the Sea Area tides to be studied.

The maximum amplitude of the four harmonic tidal components at the head of RSA and at the Strait of Hormuz is listed in Table (2).

Table (2) : Maximum amplitudes of the four harmonic tidal components

Component	**M_2**	**S_2**	**K_1**	**O_1**
Maximum Amplitude (in meters)	0.8, 0.9	0.25, 0.25	0.5, 0.3	0.3, 0.2
Location : 1st figure occurs at head of the RSA and second at the Strait of Hormuz				

The tidal regime in the Omani coastal waters is predominantly of the mixed, prevailing semi-diurnal type i.e. there are two high waters and two low waters per day with a large diurnal inequality in high and low water levels.

Average ranges around the Omani coast are between 1.5m and 2m, and maximum ranges are of the order of 3 m (WIMPOL, 1986). Another important and interesting feature observed at some locations of the coast, for example in Kuwait, is that the semi – diurnal nature of tides may create a complex air exchange region as wind speed, wind direction and coastal morphology interact, affecting both the flow of air and seawater.

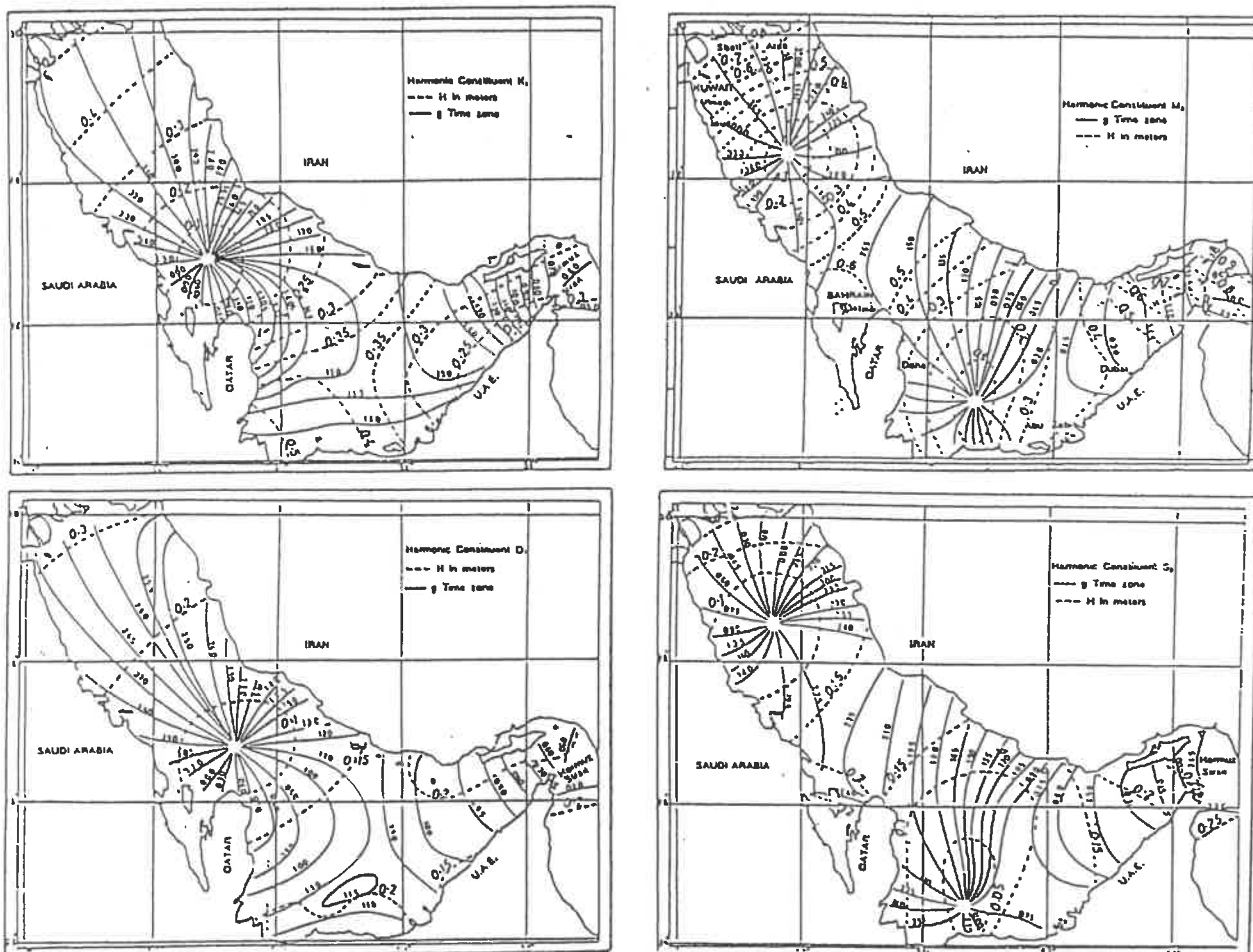


Figure (8) : Main harmonic tidal constituents in RSA (British Admiralty, 1976)

2.1.2.3 Water circulation

Direct current measurements have not been made systematically in the RSA. Early hydrographic studies (Schott, 1918; Emery, 1956; Sugden, 1963; Brewer *et al.*, 1978) have indicated that the surface water movement is cyclonic inside the RSA. Evaporation and wind forcing have long been suggested as the major driving forces maintaining the RSA circulation. The former, i.e. evaporation has been emphasized by Sugden (1963) and Hunter (1982), while Wright (1974) and Hughes and Hunter (1979) argued for the importance of the latter.

The early studies of the water circulation in the RSA suggest that the net freshwater loss to the atmosphere is replaced by a surface inflow in the Strait of Hormuz. Throughout the year and against prevailing Shamal winds, relatively low-salinity water enters the Inner Sea Area through the Strait of Hormuz freshening the hyper-saline Inner Sea water. As it enters, it undergoes evaporation, becomes more dense and sinks to exit the Inner Sea as a high-salinity undercurrent through the deeper portion of the Strait of Hormuz. This circulation is called “reverse estuary flow”.

Hunter (1982) made a quantitative assessment of surface currents using ship drift data collected by the British Meteorological Office up to 1981. The proposed surface current pattern in the four seasons and the all time mean flow field generally indicate a surface flow westward into the RSA along the Iranian coast (~ 10 cm/sec). The inflow from the Strait of Hormuz is quite evident and appears to be stronger (about 20 cm/sec) in summer and weakest (about 10 cm/sec) in spring and autumn.

An early sketch by Hunter (1983) shows that the main features of the residual circulation in the RSA (Figure 9) are characterized by:

(a) High- and low-salinity water exchange in the Strait of Hormuz.
(b) Density-dominated circulation in the central and southern Inner Sea.
(c) Frictional balanced, wind-dominated regime in the NW Inner Sea.
(d) Evaporation-induced bottom flow.

The actual pattern of circulation is more complex than that shown in the sketch. Surface inflow occurs year round, but is more pronounced and

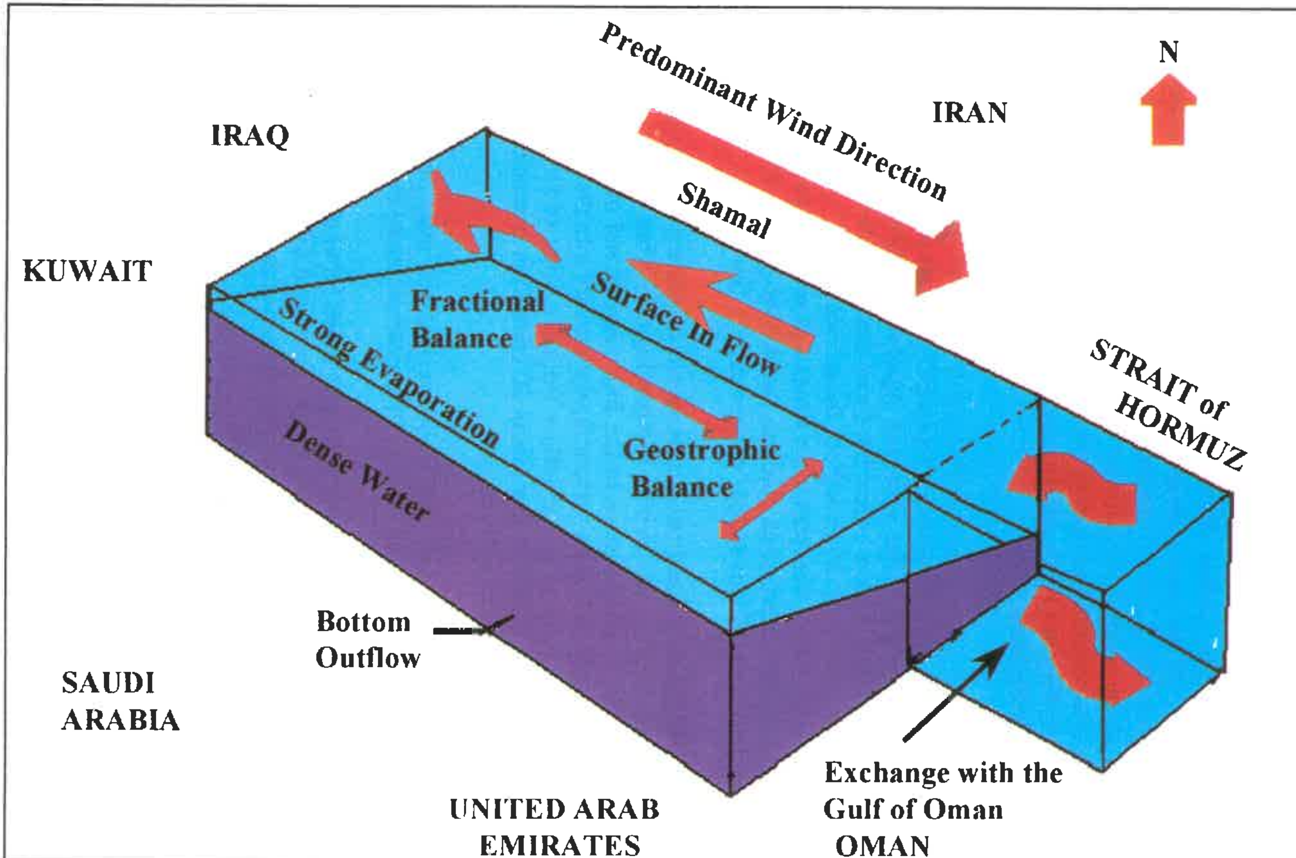


Figure (9): Density-driven circulation of the RSA (Hunter, 1983).

extends deeper into the Inner Sea in the summer. However, in the winter the density difference is primarily due to the relatively low salinity water of the Gulf of Oman, where in summer both temperature and salinity strengthen the density difference.

Reynolds (1993) used progressive vector diagrams (cumulative sums) of the filtered current vectors to study surface circulation in the RSA. The results substantiated the density-driven, reverse-estuary circulation pattern and clearly demonstrated the general pattern of in flowing surface current and out flowing bottom current. Overall mean currents were in the neighbour hood of 5 cm/sec., and a weak, cross-basin flow of about 2 cm/sec was evident in the records.

A three-dimensional hydrodynamic model was developed by Chao *et al.* (1992) to study the circulation in the inner RSA. The model contains realistic basin geometries and bathymetries of the inner RSA and a good portion of the Gulf of Oman and is driven by monthly climatological winds, evaporation and net heat gain by the Sea Area and the Shatt Al-Arab discharge. The model generates additional details of the circulation patterns that are otherwise unavailable from observations. Figure (7) shows, the surface features obtained from the model in winter (January) and summer (July). The model succeeds in reproducing the seasonally varying cyclonic circulation in RSA. The cyclonic circulation is maintained by a surface geostrophic inflow and a bottom geostrophic outflow in the Strait of Hormuz. In the Gulf of Oman, the current toward the RSA tends to follow the southern boundary, accompanied by an anticyclonic eddy to the north.

The hydrodynamical models of the RSA developed at King Fahd University of Petroleum and Minerals - Research Institute (KFUPM/RI) have been used to compute the flows in the RSA driven by density gradient using the two sets of data collected on Legs 1 and 6 of the Mt. Mitchell cruise (Lardner *et al.*, 1993). The basic model in current use is called HYDRO1 (Version B). This model covers the whole RSA with a rectangular grid of approximately 10 km in size, the direction of the grid being chosen roughly parallel to the Saudi coast. The computed currents for Leg 1 (February 1992) are shown in Figures (10a) and (10b) while Figures (10c) and (10d) show the corresponding currents for Leg 6 (June 1992). The Figures show the expected reverse estuarine flow, with inflow through the Strait of Hormuz near the surface and outflow on the lower layers of the water column. Figures (10e) and (10f) show the combined flow generated by the density gradients and the average winds for June.

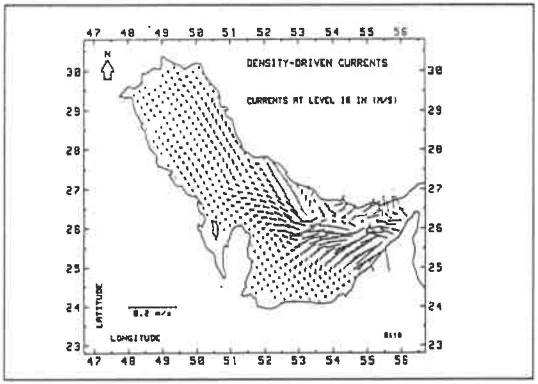


Figure (10a): Computed density-driven flow on the free surface using data collected on Leg 1 of the Mt.Mitchell cruise).

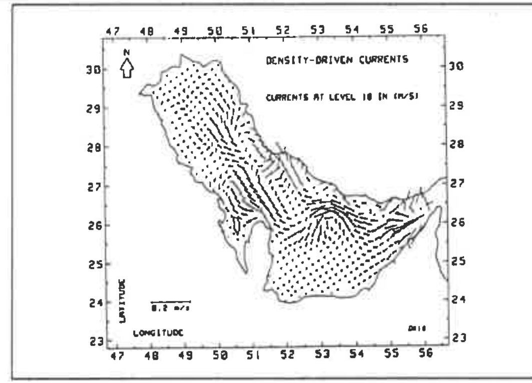


Figure (10b): Computed density-driven flow on the free surface using data collected on Leg 6 of the Mt.Mitchell cruise.

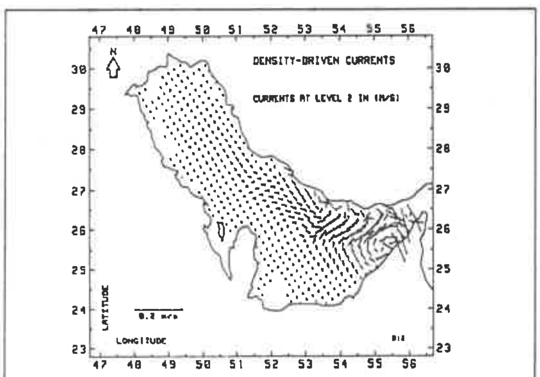


Figure (10c): Computed density-driven flow near the bottom using data collected on Leg 1 of the Mt.Mitchell cruise.

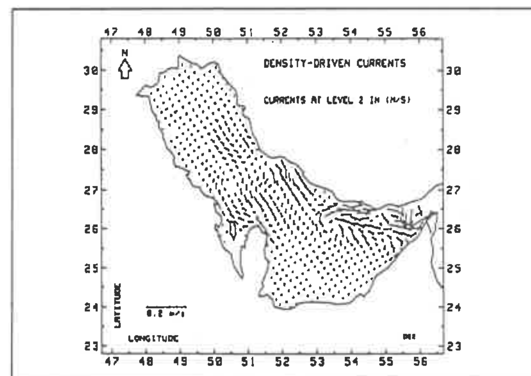


Figure (10d): Computed density-driven flow near the bottom using data collected on Leg 6 of the Mt.Mitchell cruise.

(After lardner *et al*., 1993)

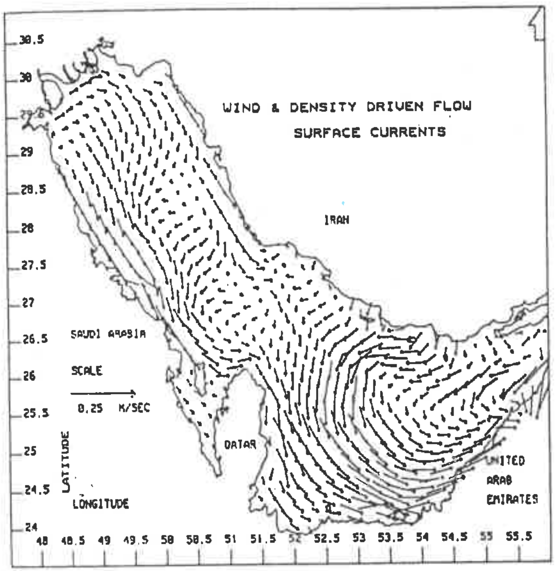


Figure (10e): Computed surface flow driven by the average June wind combined with the density gradients from Leg 6 of the Mt.Mitchell cruise.

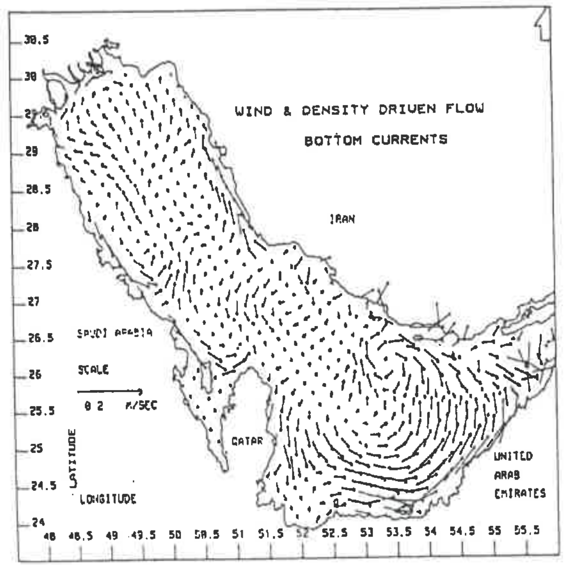


Figure (10f): Computed bottom flow driven by the average June wind combined with the density gradients from Leg 6 of the Mt.Mitchell cruise.

(After lardner *et al.*, 1993)

In the Strait of Hormuz, there is a surface inflow with velocities reaching 15 cm/sec. The flow persists up the Iranian coast with speeds of 10 cm/sec almost as far as the Qatar peninsula. Near the bottom in this region, there is an opposite outflow towards the Strait. On the Emirates side of the RSA, the flow is strongly dominated by the wind, which generates an easterly surface flow of magnitude 12 -15 cm/sec. This flow drags the bottom flow with it in the same direction (Lardner *et al.*, 1993). The pattern of surface velocities around the northern coast of Iran is anti-clockwise in both Figures (10a) and (10c), surface velocities, however, being quite small (less than 4 cm/sec.).

According to both Hunter's schematic circulation model described earlier [Hunter (1983), Figure (9)], and that proposed by Reynolds (1993) for the RSA (Figure 11), the flow is predominantly density driven with surface flow inward from the Strait of Hormuz and adjacent to the Iranian coast. A southward coastal flow is present along with entire southern coast of the RSA. The flow stagnates east of Qatar, where high evaporation and sinking forms a dense, bottom flow to the northeast and out of the Strait of Hormuz.

Circulation in the Gulf of Oman is dominated by a clockwise gyre in the west and a counter-clockwise gyre in the east. The interface between the two counter-rotating gyres is a region of upwelling along the Iranian coast. The circulation pattern seems to exist in winter and summer, but its strength and the upwelling depend on prevailing winds.

The only extensive set of current measurements were carried on the SE coast of Oman in Kuria Muria Bay by Hunting Surveys Limited (1984-1985). The data shows a persistent westerly current set up in Kuria Muria Bay during the SW monsoon at a time when offshore currents were set approximately NE. Simultaneous wind measurements close to the mooring location show that wind direction was predominantly easterly, suggesting that local conditions here are considerably different from those further offshore. The data also suggests a dominance of wind driven currents over tidal currents. Current speeds throughout the year were < 20 cm/sec, with maximum speeds of 40 cm/sec which is attained only occasionally.

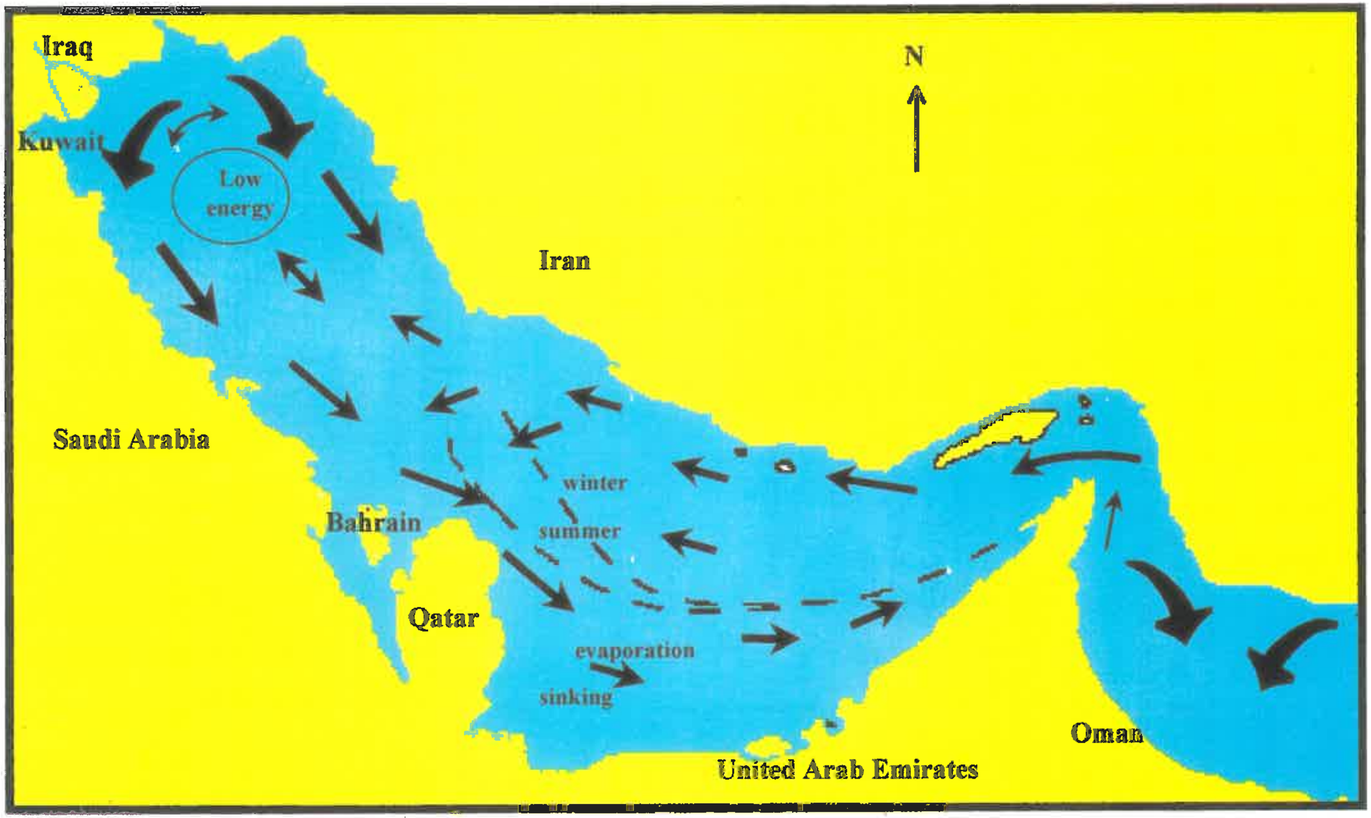


Figure (11): Schematic of Surface Currents and Circulation Processes (After Reynolds, 1993).

2.1.2.4 Water balance

i) Evaporation

Evaporation has a profound effect on the water and salt balances in the RSA and is one of the controlling factors in the process of water exchange with the Gulf of Oman through the Strait of Hormuz. Few attempts have been made to estimate evaporation from different zones of the RSA using different techniques.

Privett (1959) calculated evaporation from the open water of the RSA as 144 cm/yr. The maximum rate was in December and the minimum in May. Meshal and Hassan (1986) estimated evaporation from the coastal water of the central region of the RSA using the Esbesen and Reynold's (1981) formula. They found that the monthly mean evaporation from the coastal water of the region reaches its maximum value of 29.3 cm in June and a minimum one of 8.1 cm in February, with a total evaporation rate of 202.6 cm/yr. Accordingly, evaporation from the whole RSA may be taken as the mean of the two above mentioned values i.e. 172 cm/yr (Said, 1998).

ii) Precipitation

The amount of the annual precipitation on the RSA fluctuates considerably but the average precipitation over a period of 17 years is 78 mm/yr, which corresponds to 1.9×10^{10} m^3/yr (Hassan and Hassan, 1989).

iii) Land run-off

Most river inflow into the RSA occurs in the north and primarily on the Iranian side (Figure 12). Recent flow measurements (Reynolds, 1993) show that, Shatt Al-Arab is a nexus of three major rivers: the Tigris (Dijlah) and Euphrates (Al-Furat) rivers together provide an annual average of 708 m^3/sec and the Karun adds 748 m^3/sec. Thus, the total average outflow of the Shatt Al-Arab is 1456 m^3/ sec. Other major rivers are the Hendijan (203 m^3/sec), the Hilleh (444 m^3/sec), and the Mond (1387 m^3/sec) to give a total of 1.1×10^2 km^3/yr, equivalent to 46 cm/yr which is much higher than that of the value used by Al-Hajri (1990) of 16 cm/yr, probably the two figures represent the actual range of flow in view of erratic nature of river flow in the region.

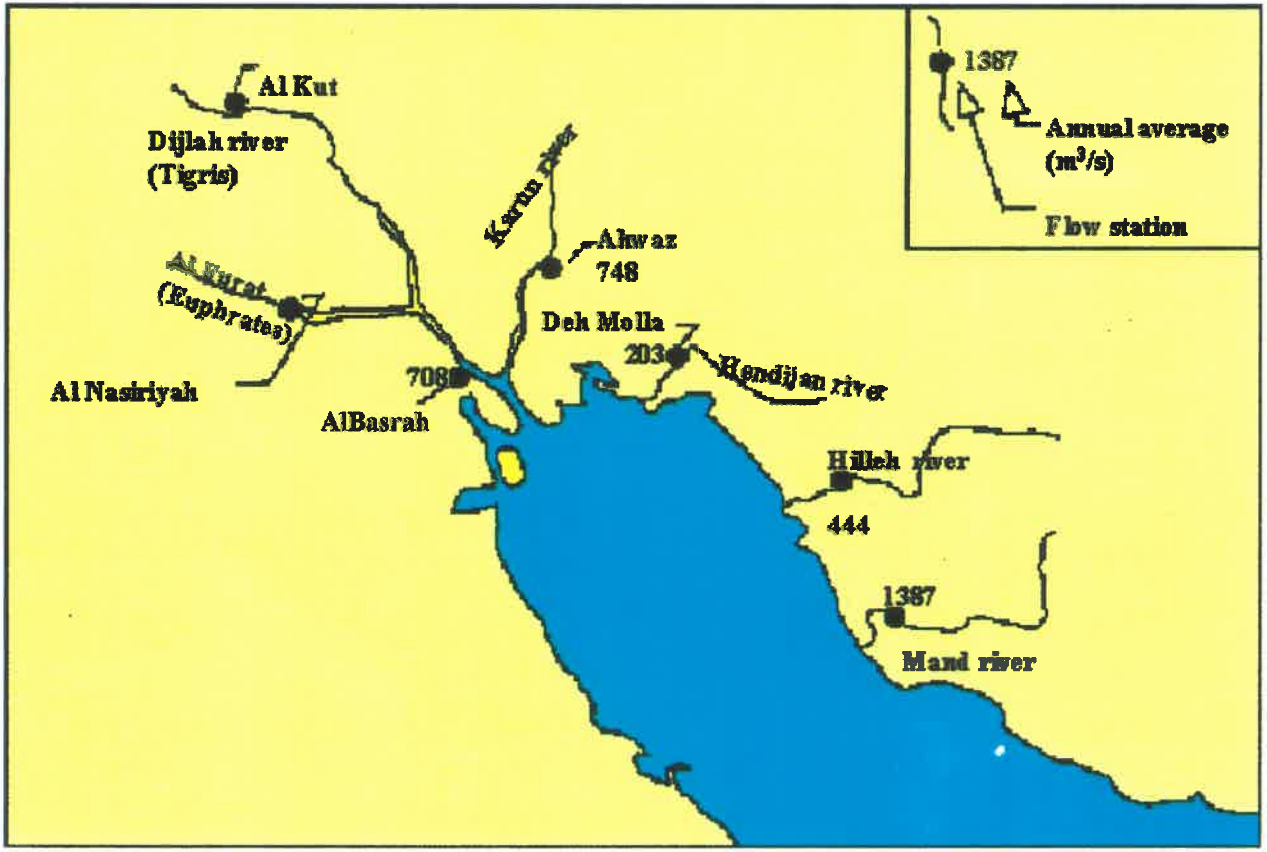


Figure (12): The major rivers flowing into the northern RSA (After Reynolds,1993).

Based on available data and information on the three components of the water budget (evaporation, precipitation and run-off) such as those given above, attempts were made to calculate the water budget in the RSA and reach the water balance in the inner basin. Table (3) compares the results obtained by ROPME (1988) and Reynolds (1993).

Table (3): Water balance for the Inner RSA

		ROPME (1988)	**Reynolds (1993)**
Basin	Evaporation 1/ Precipitation 2/ Runoff 3/ Total loss	-350 km^3/yr 24 km^3/yr 5 km^3/yr -321 km^3/yr	-412 km^3/yr 19 km^3/yr 11 km^3/yr -283 km^3/yr
Strait of Hormuz	Inflow 4/ Outflow 4/ Total gain	2696 km^3/yr 2375 km^3/yr 321 km^3/yr	10600 km^3/yr 10317 km^3/yr 283 km^3/yr
	Volume of basin 8,400 km^3 Surface area of basin 240,000 km^2 Mean Depth 35 m		
	Residence time	3-5 yr	2.1 yr.

1/ A value of 0.4 g/cm^2/day (equivalent to 1460 mm/yr) average those given by Privett (1959) has been used (compared with 100 mm/yr for the Mediterranean Sea).
2/ A precipitation of 100 mm/yr has been used.
3/ Average value given by Hartman *et al.* (1971).
4/ Computed from the water and salt balances, taking a salinity of 37 for the surface inflow and of 42 for the bottom outflow.

Accordingly, renewal (residence) time, defined as the time it takes the water entering the inner RSA from the Gulf of Oman to completely flush the basin, is estimated at 3-5 years (ROPME) and 2.1 years (Reynolds). These values are important for consideration of the fate of contaminants. The two values are within the range suggested by Hughes and Hunter of 2 - 5 years (Hunter, 1985). However, without exact knowledge of the circulation in the Strait of Hormuz these values should be regarded as approximate.

2.1.3 Geological and sedimentological characteristics

2.1.3.1 Geology

Geologically, the RSA has evolved by the interaction of the African and Eurasian plates. The Arabian Plate has been gradually moving north eastward, under thrusting Eurasia, for a considerable time. These movements have led to the slow closure of a vast waterway which once linked the Mediterranean and Indian Ocean, and in which a thick column of oil and gas bearing sediments, in excess of 10,000 m has accumulated.

In the northwest, the closure of the ancient seaway has been completed, and the former marine area is covered with the flat alluvial lands of the fertile crescent of Iraq and Iran. This lowland has been formed by the deposition of the load of sediment supplied by the Tigris-Euphrates-Karun fluvial system attracted to the low depression between the stable Arabian Shield and mobile fold belt of Iran, a composition for major river systems (Figure 12).

In the south, the history has been more complicated and the movements of the plates transporting Arabia and the adjacent Indian Ocean floor to the north-east has resulted in the anomalous Oman mountain range on the Arabian side of the depression.

The Inner Sea is a flooded-valley estuary. The evidence for the changing landscape of the region is provided by: drowned physiographic features obviously formed above or close to sea level such as valleys, coastal beach dune complexes, and abrasion platforms; and also by the presence of sediments with textural and compositional properties which indicate a shallow water origin (e.g., shallow water oolitic sands). Faunas found in the sediments show shallow-water characteristics at present depths well below their original levels of formation.

Since its formation about 20 million years ago, the inner part of the RSA has undergone several changes in sea level (Figure 13), the latest which took place about twenty thousand years ago when the inner RSA went completely

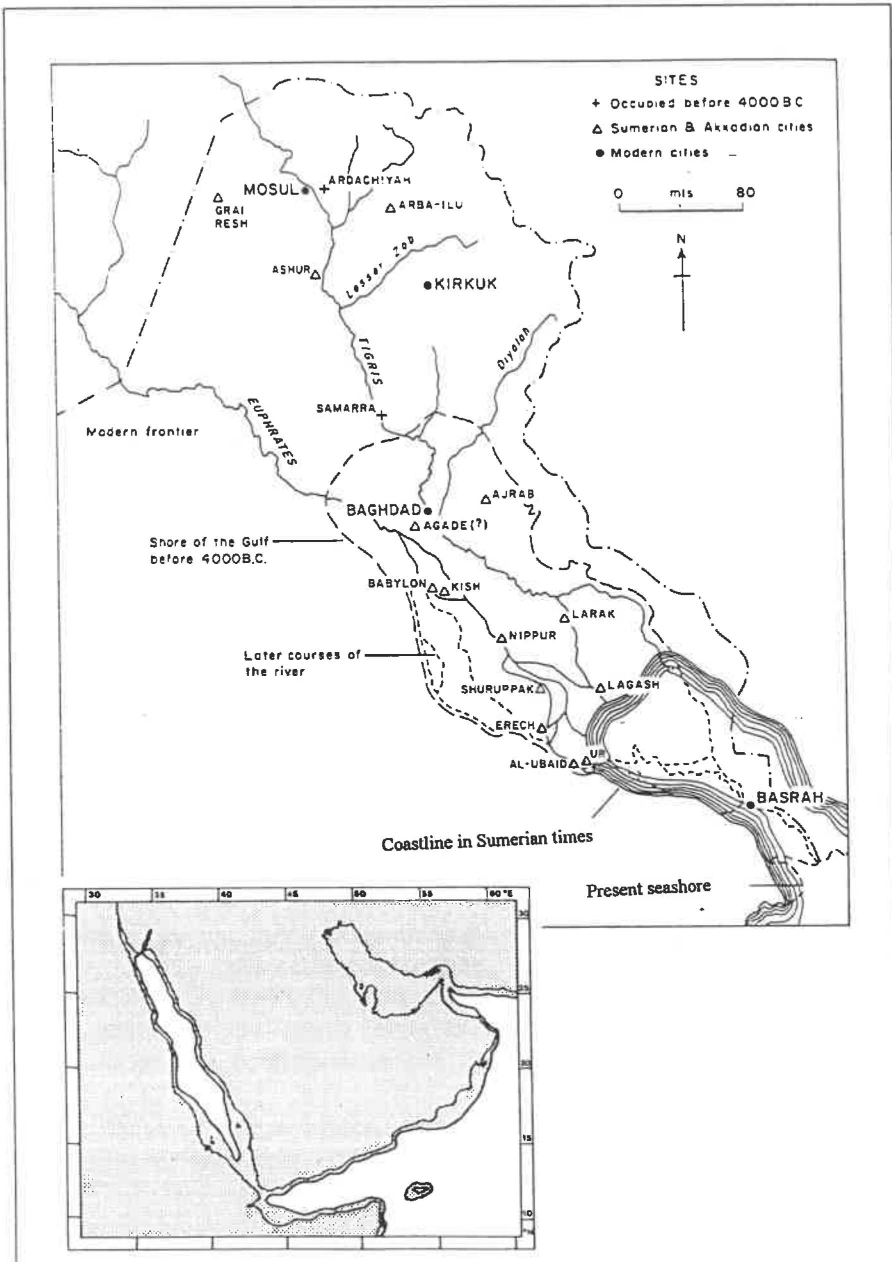


Figure (13): Changing shorelines at the head of the RSA (from Lloyd, 1943 after Taiba Al-Asfour, 1982).

dry, to begin refilling about 10,000 years ago. Thus, this part of the RSA can be considered to be geologically young in view of the fact that marine life started to be re-established only recently during the Holocene transgression (Sheppard, 1993).

The geology of the inner part of the RSA have been reviewed by Purser (1973) and more recently by Sheppard (1993). The oceanic part of the RSA, the Gulf of Oman and the Arabian Sea, occupy the north western corner of the Indian Ocean and thus has witnessed the major tectonic events and other geological processes. The inner part of the RSA, however, represents a surface extension of the Indian Ocean connected at the Strait of Hormuz. It is a sedimentary basin, shaped to a great extent by a tertiary fold system which causes its deepest depression, the run along its northern side, separating the geological stable Arabian peninsula plateau from the Zagros Mountains of the Eurasia Plateau which is steeper and geologically active. No part of the RSA has a continental shelf edge and there is no large changes in bathymetry, except at the Omani eastern coast (Purser and Siebold, 1973). The movement of the Arabian plate, rotating anti-clockwise by 7° during the pre-quaternary time, was a spectacular geologic event. It pushed the Musandam mountains of Oman towards I.R. Iran, creating the uniquely fjords structure and narrowing the Strait of Hormuz which has restricted the flow of water (Purser and Siebold, 1973; Sheppard, 1993)

At approximately 7000-6000 BP, the advancing waters of the rising sea engulfed the coastal deserts and depressions, and the RSA had an outline very similar to that seen today. The exact position of the shoreline in the northwestern part of the region is still poorly known. Beach ridges and related features on the Arabian shoreline indicate that the coastline has in place prograded seaward 4-5 km since 4500 BP.

The movement of the plates continues today, as the slow inexorable movement of Arabia to the northeast causes under thrusting, adjustment in the basement, and associated earthquakes and volcanoes in Iran. On the stable, Arabian Shield, movement has continued along basement faults, many with N-S trends and this has resulted in gentle warping and the production of broad gentle anticlines and synclines in the cover rocks, in marked contrast to the highly folded structures found in Iran. The sedimentological characteristics of the RSA as observed recently are discussed below.

2.1.3.2 Sedimentological characteristics

The RSA owes its sedimentary nature to the heavy rainfall during the Pleistocene which brought sediments from the Tigris and Euphrates rivers flowing through the marshes of Iraq and I.R. Iran (the Ahwar or Khors), the Karun and Karkha rivers from the Iranian Zagros mountains and the now extinct Al-Batin river from the highlands of the west central part of the Arabian Peninsula. The riverine input is reflected in the composition of bottom sediments (Figure 14). It can be seen that the fine (mud) sediments predominate the northwestern part of the RSA and reflecting the influence of the river inputs into the area. Much of the RSA floor is biogenic sediment, produced mainly from microorganisms, predominantly Foraminifera. There is a wide range of other limestone-producing fauna and flora such as corals and some calcareous algae, though in terms of sediment production these are quantitatively unimportant. Carbonate sands are predominant in Saudi Arabia and the U.A.E. coast, whereas, on the Iranian side these are mixed with a greater proportion of terrigenous sediments from the wind, and numerous small riverine inputs (Purser and Siebold, 1973). It should also be noted that relatively large amounts of sand are deposited by the prevailing NW winds blowing across the axis of RSA. Khalaf *et al.* (1986) estimated that as much as 100 t/km^2 of sand are deposited annually in the inner RSA. Figure (15) shows the distribution of sand dune fields across the Iraqi western desert and extending into the Kuwaiti territories. The sedimentary nature of the inner RSA that is induced by the gradual topography resulting from fluctuation in sea level and the favourable conditions for carbonate producing biota are reflected on the bathymetry of the area (Figure 2).

i) Sediment sources and processes

The unusual local climate of high aridity with evaporation in excess of precipitation over most of the area and the preventing oceanographic conditions control the supply , distribution and accumulation of sediments which characterize the sea floor and coastal regions. The northwest "Shamal" strong winds provide aeolian influx of fine sand, silt and clay. In some areas, as of Qatar and Saudi Arabia, coarser quartz-rich terrigenous sediment can be seen moving into the shallow marine areas in the form of aeolian dunes.

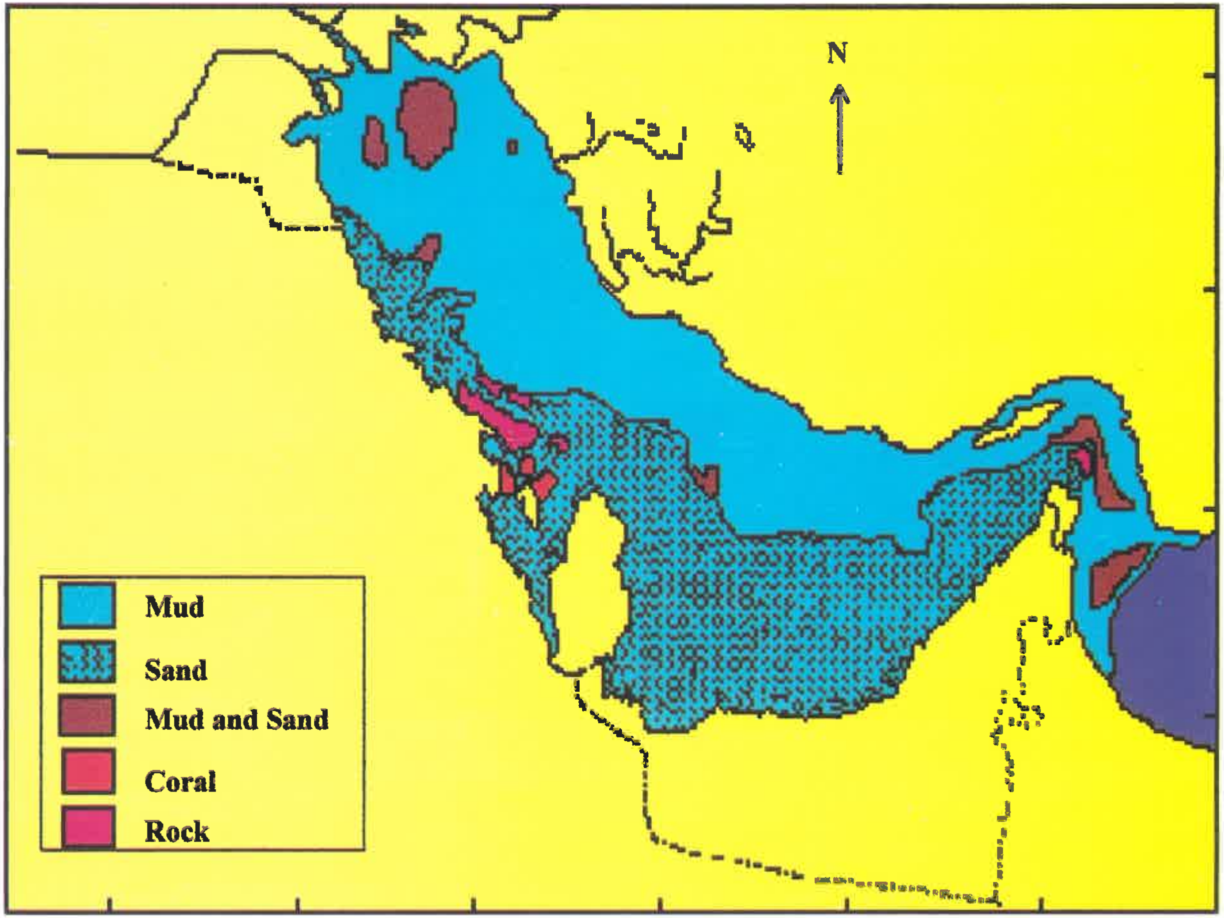


Figure (14): Sediment types in RSA (After Carpenter *et al.*, 1997)

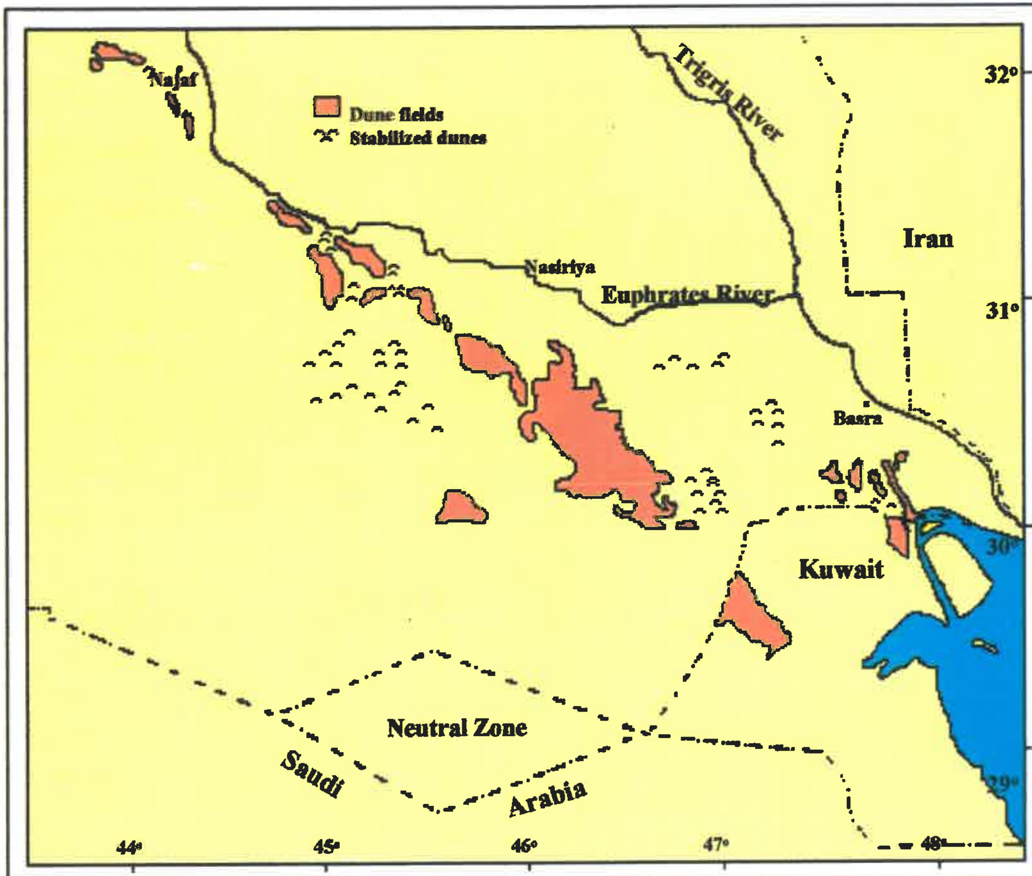


Figure (15): Distribution of sand dune fields in Kuwait and southern Iraq. (based on Skocek and Saadallah, 1972).

The other important supplier of sediment is the marine water through the biological activity. The physical breakdown of skeletal debris by wave, tidal and storm currents are also important in the production of skeletal debris. Direct chemical precipitation of carbonate to produce mud-sized calcium carbonate is also of importance. Biochemical precipitation of calcium carbonate has been observed in the area (Seibold, 1973) (Figure 16).

Finally, taking into consideration the nature of the sediments, the tidal current patterns, the bathymetry and low energy characteristics of the northern part (Figure 17), it was suggested (Al-Ghadban *et al.*, 1993) that the northern part of RSA, in general, represents a deposition environment with somewhat low sediment movement. The net transportation of the sediment is southward. However, in areas of relatively high energy which includes the southern offshore area and the western part, more sediment transportation is taking place. It is inferred that the sediments move N-S with a net sediment transport parallel to the axis of RSA.

ii) <u>Regional distribution of bottom sediments</u>

The textural characteristics and regional grain-size distribution of bottom sediments in the RSA were discussed in detail by Al-Ghadban *et al.* (1996). Being subdivided originally into seven textural classes, the classification was simplified by grouping the sediments into four main classes: sand, muddy sand, sandy mud and mud. Data obtained from the grain-size analysis, simplified textural classification and lithologic description of the selected samples have been used to construct a map showing the regional distribution of the various textural classes of bottom sediments in the RSA (Al-Ghadban *et al.*, 1996).

Most of the area is covered with fine-grained sediments (mud and sandy mud) which occupy the deeper offshore areas as well as the sheltered depression in coastal areas. On the other hand, coarse-grained sediments (sand and muddy sand) occur mainly in the western area (offshore Bahrain, Qatar and U.A.E.) and as patches on and around islands and the rocky bottoms of the bathymetric highs. The deposition of finer sediments along the eastern Iranian side compared with the western side is attributed to the counter-clockwise circulation from the Indian ocean, whilst the deposition of poorly sorted sediments near the eastern side and in the northwestern area is probably due to the effect of tidal currents, river influx and deposition of aeolian sediments.

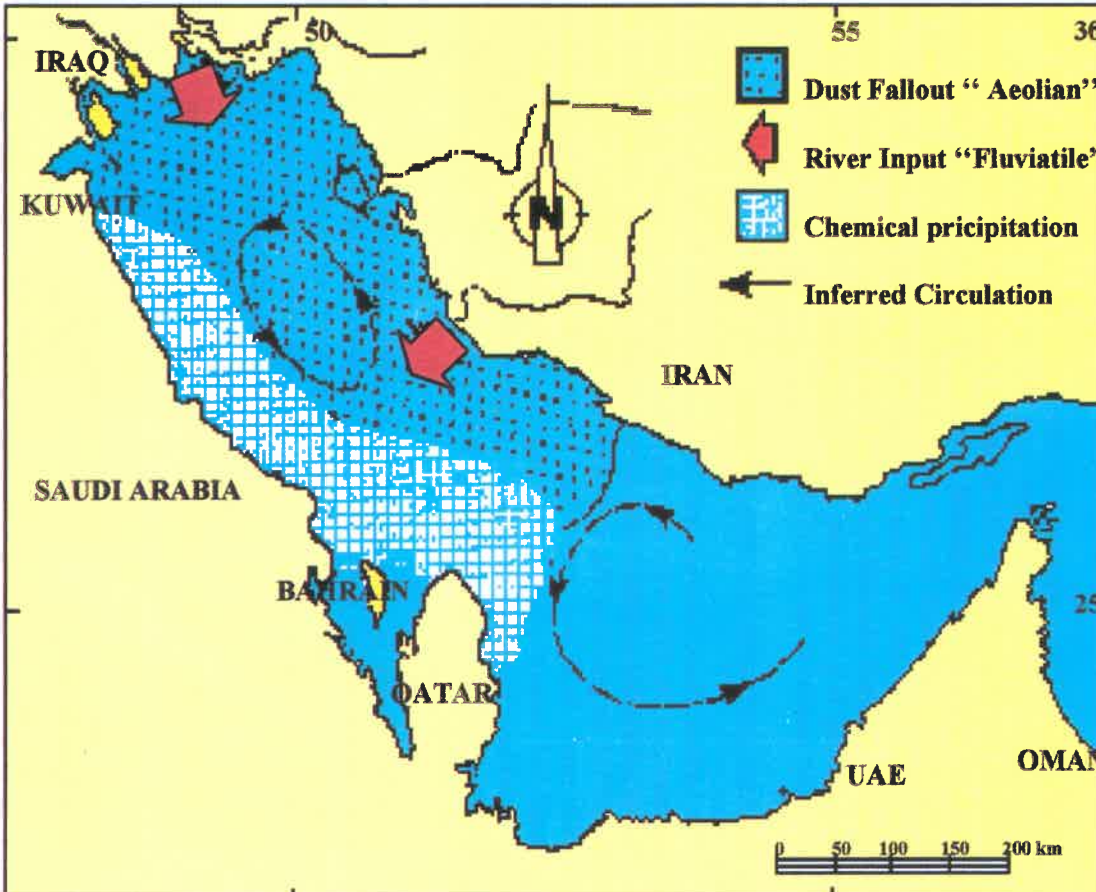


Figure (16): Generalized model showing the potential sources of bottom sediments (after Al-Gadban *et al*., 1998).

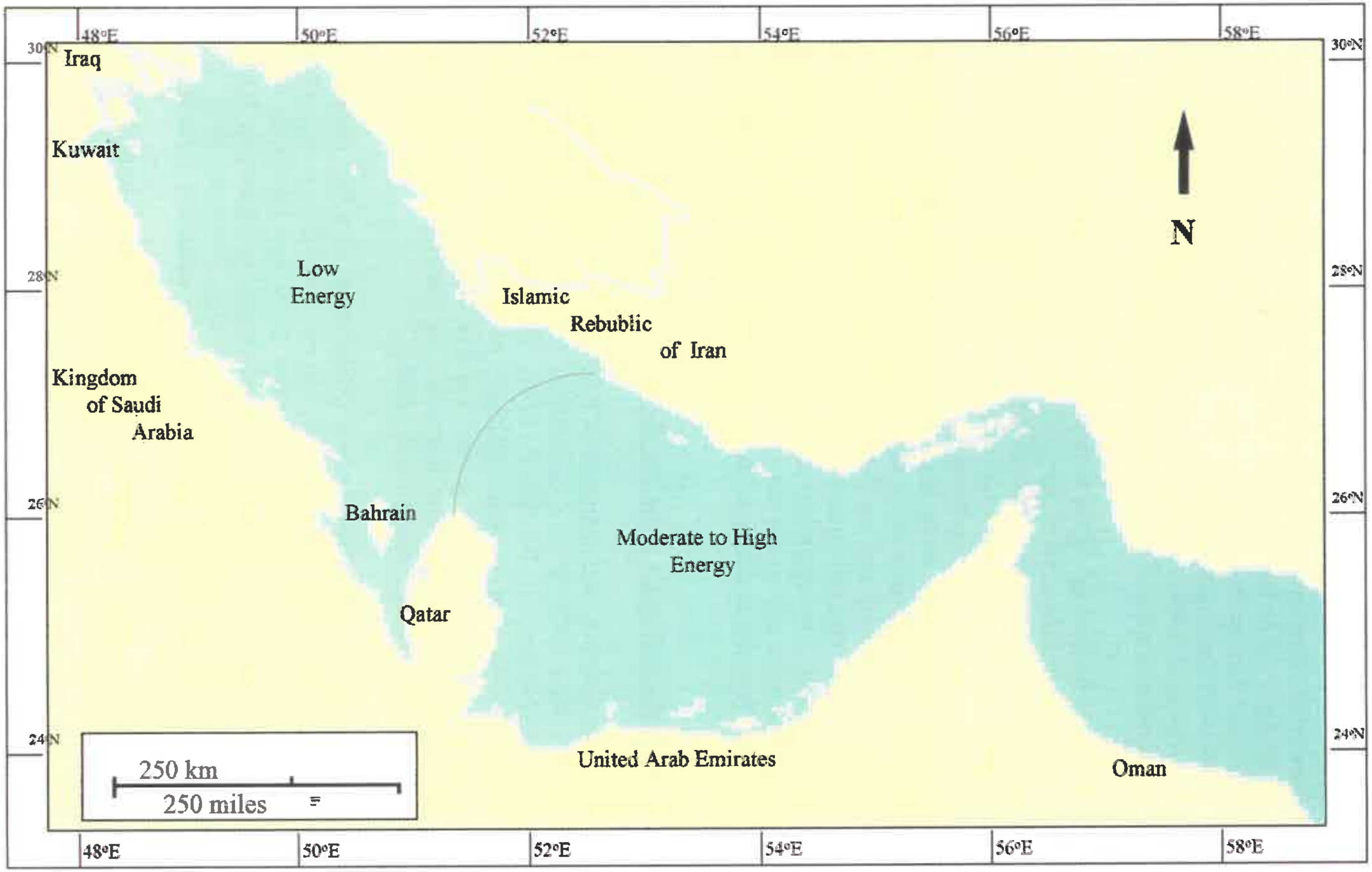


Figure (17): Inferred energy map, based on sediment textural and hydrodynamic regime of the area (Al-Ghadban *et al.*, 1993).

Suspension is thought to be the most important process of transportation and deposition. Suspension and hence low energy conditions prevail in the area, particularly in the northern part, which could be described as a low energy zone with low sediment movement. In contrast, the southern part represents a relatively moderate to high-energy zone with higher sediment movement. A north-south sediment transport from the northern part is inferred, with a net movement parallel to the axis of the region.

The gross mineralogy of the bottom sediments is biased towards carbonates, clay minerals, and a small amount of quartz and feldspars. Carbonates are represented by low-Mg calcites (of detrital origin), high-Mg calcite (of biochemical precipitation origin), dolomite, and aragonite. Low and high-Mg calcites were found to be the most common carbonates species in the area. Clay minerals form more than 70% of the clay-size fraction of marine sediments. Comparison of the average frequency of light minerals with those of the dust fallout and the Tigris-Euphrates basin sediments shows close resemblance in the light minerals constituents of the dust fallout and the RSA environment. This resemblance suggests that substantial quantities of the very fine sand and coarse silt fractions of the region are of detrital origin, derived from the dust fallout (Kulak and Saadallah, 1973; Al-Ghadban *et al.*, 1998).

2.1.4 Chemical oceanographic characteristics

Data on chemical characteristics of ROPME Sea Area have been increasing greatly since 1975, when a consultative meeting on marine sciences in the area was held in Paris (Grasshoff, 1976). However, comprehensive data that give a total view of the water chemistry of the area are still limited. In the literature one can find many good but sparse works that have been conducted in the area during the last few years as can be seen from the recent bibliography (Farmer and Docksey, 1983).

During the Umitaka-Maru Cruises (1993-1994) in RSA, measurements of oxygen, chlorophyll-a, ammonium, nitrates, phosphates and silicate were conducted along 5-7 transacts between 28°N and the Strait of Hormuz. Results of the overall mean of dissolved oxygen as reported by Hashimoto *et al.* (1995) varied between 4.18 ml/l reported in December 1993 cruises and 4.80 ml/l in January 1993. The lowest oxygen value was 1.0 ml/l reported at 71 m depth. The results indicated that the surface water of RSA is well oxygenated. Chlorophyll-a concentrations were relatively high at stations on the Iranian coast and near U.A.E. coast. However, the overall mean was varied between 0.80 μg/l in December 1993 to 1.35 μg/l in January 1993. Ammonium ion concentrations were relatively constant in all the measured samples. The overall mean ammonium ion concentrations varied between 0.75 μmol/l (December 1994) to 1.91 μmol/l (January 1993). Nitrates overall mean concentrations varied between1.07 μmol/l (December 1994) to 2.10 μmol/l (December 1993). It is worth noting that nitrate as well as nitrite was not detected in some water samples along Saudi Arabian coast. The overall mean concentrations of phosphates varied between 0.34 μmol/l (December 1993) to 0.51 μmol/l (December 1994). The overall mean concentrations of silicates varied between 1.93 μmol/l (January 1993) to 4.74 μmol/l (December 1993). The maximum values of nitrates, phosphates and silicates were observed in water samples near the Iranian coast (Figure 18) (Hashimoto *et al.*, 1995). The results were found to be comparable with earlier investigations made by R/V Mukhtabar Al-Bihar during the years 1983, 1984 and 1985 (Hassan and Samra, 1988). However, in shallow estuarine areas, e.g. Kuwait Bay levels have been shown to range from 29.6 to 76.1 μg/l for nitrates, from 16.4 to 24.1 μg/l for phosphate and from 397 to 590 μg/l for silicates (EPD, 1994.). Figure (19) illustrates the semi-diurnal variation in nutrient levels measured under more oceanic conditions Sudh (Oman) in August 1985.

2.1.5 Biological characteristics and major habitats

2.1.5.1 Biological productivity

i) Primary and secondary productivity

The productivity of the marine ecosystem of the RSA, particularly in the inner RSA and except at the mouth of rivers, is mostly associated with the mudflats. However, if compared with other seas, we find that water column primary productivity is still relatively higher than that of the Red Sea, but lower than that of the Arabian Sea (Sheppard, *et al.*, 1992). Evidence suggests the system is nutrient-limited (N-limited), which may explain the massive increase of productivity around river mouths and sewage outfalls. However, the ecosystem apparently has a limited capacity for high levels of nutrients, as oxygen levels become low during the summer months with temperatures exceeding 30°C. Measurement of chlorophyll-a ranging from 0.2 to 0.86 mg/m^3 have been reported in the ambient marine environment of

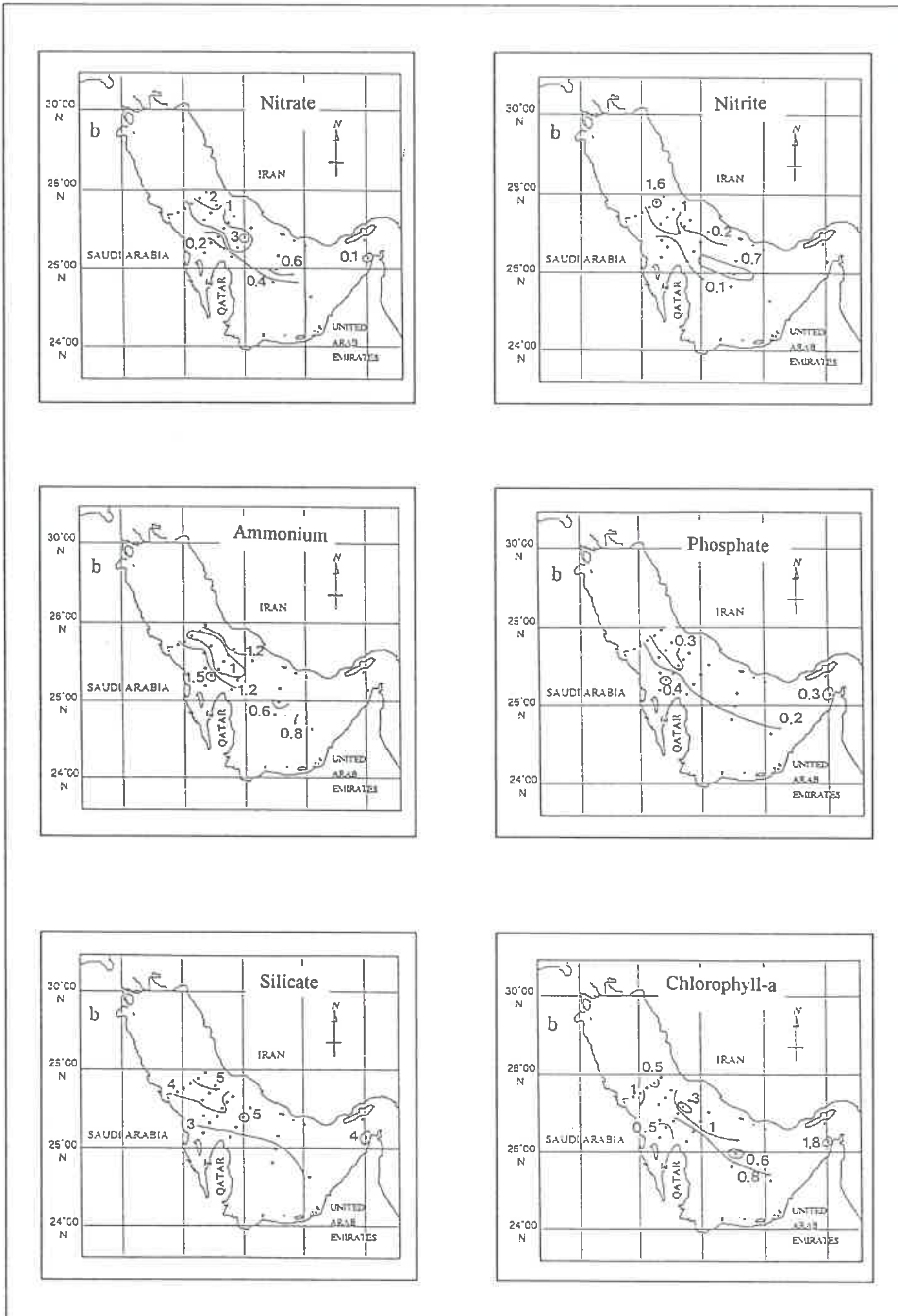


Figure (18): Levels of nutrients and chlorophyll-a in RSA, 1993-1994 (Hashimoto *et al.*, 1995)

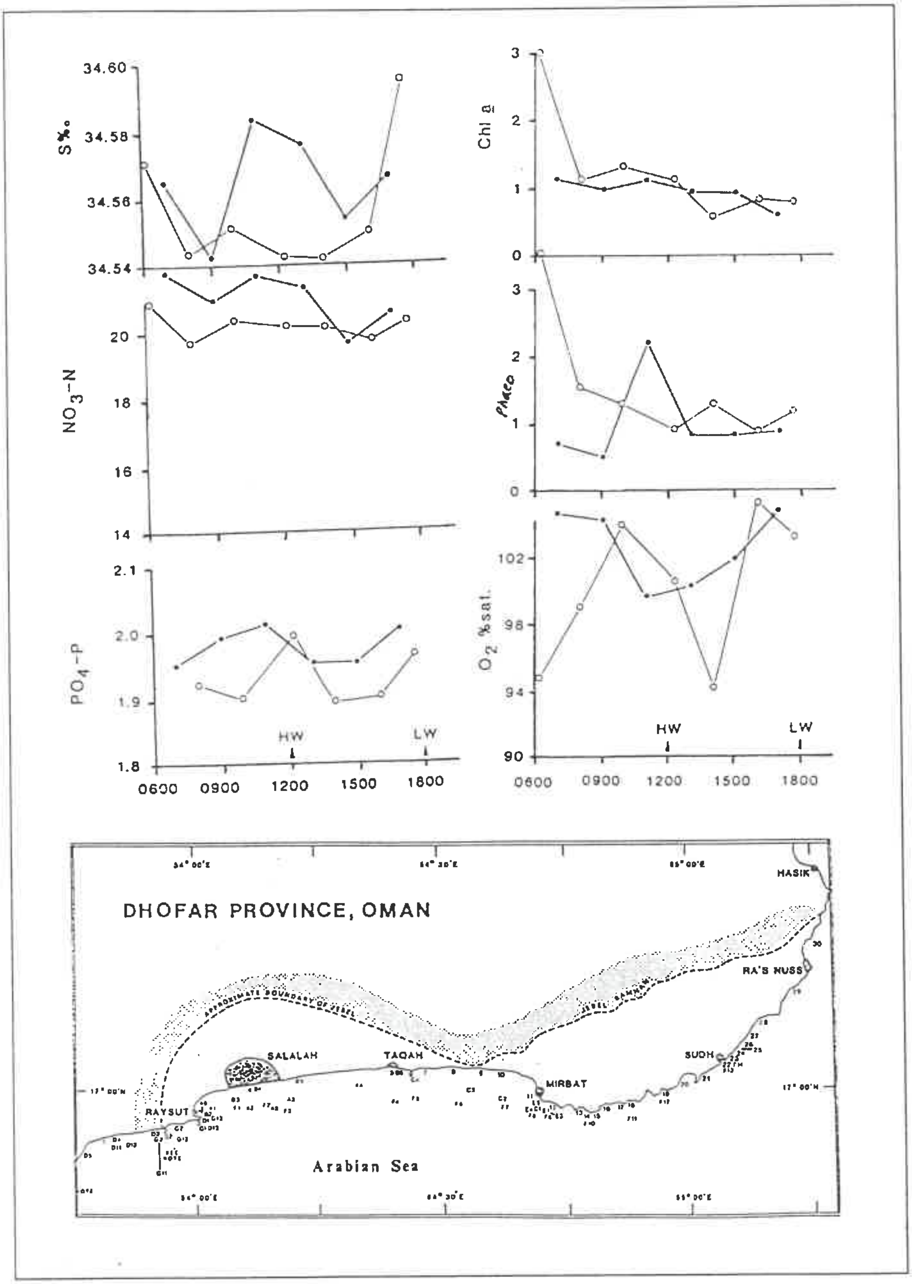


Figure (19): Semi-Diurnal variations in hydrographic parameters observed at stations 25 26 on 21 August 1985 , Oman. All times shown are local (ROPME, 1988).

the inner RSA (Sheppard, 1993) which is not particularly high, whereas values around 0.5 mg/m^3 and greater have been reported from the Arabian Sea waters. Measurements carried out during the R/V Umitaka-Maru cruises (January 1993, December 1993 and December 1994) ranged from 0.44 - 2.84 mg/m^3 in a homogenous vertical distribution (Hashimoto, *et al.*, 1995). The mean daily primary productivity in the area studied was estimated to be 0.51 g $C/m^2/day$ (ranging from 0.12-1.27 g $C/m^2/day$ (Hirawake *et al.*, 1998). Chlorophyll levels in Kuwait Bay have been reported to range from 1.3 to 3.37 mg/m^3 (EPD, 1994), whereas in Khor Al-Zubair (Iraq) the maximum value reported was 1.59 mg/m^3 (Al-Abaychi and Ghani, 1986). Based on the data available, the distribution of productivity in the inner RSA is shown in Figure (20).

Utilizing remote sensing analysis, chlorophyll levels were estimated for several coastal areas in the RSA. Figure 21 illustrates such applications (Petrov, 1998). High productivity areas are marked on the satellite images of I.R. Iran (Figure 21a and 21b) and U.A.E. (Figure 21c and 21d).

ii) <u>Zooplankton</u>

Zooplankton biomass in RSA varies both temporarily and spatially, as environmental factors vary from one to another and within seasons. Zooplankton derivative of up to about 2850 $species/m^3$ was reported by Basson *et al.* (1977) off coral islands. Price *et al.* (1993) compared abundance of zooplankton and penaeid shrimp larvae between the years 1975 - 1978 and 1992. They found that total zooplankton ranged between 0.85 ml/m^3 at Ras Tanura (1976) and 0.77 ml/m^3 at Safannia (1978) compared to 1.03 ml/m^3 and 0.24 ml/m^3 in 1992 respectively. Penaeid shrimp also showed a wide range from 6.77 nos/m^3 at Ras Tanura in 1976 and 16.704 nos/m^3 in 1978 at Safannia to 0.275 nos/m^3 and 0.009 nos/m^3 in 1992 respectively. Mean wet weight of total plankton and mean dry weight of dominant zooplankton including copepoda, ostracoda, chaetognatha and appendicularia were 14 g/m^2 and 526 mg/m^2, respectively. High biomass was observed in the northeast of the area where seawater with high temperature, low salinity and high concentrations of nutrient and chlorophyll-*a* was observed. Mean production in the area was 32 mg $C/m^2/day$. Large percentage in production by planktonic ostracoda next to that by copepoda is typical of this area. Secondary production in the area is comparable to those of upwelling areas, which have high productivity in the world oceans.

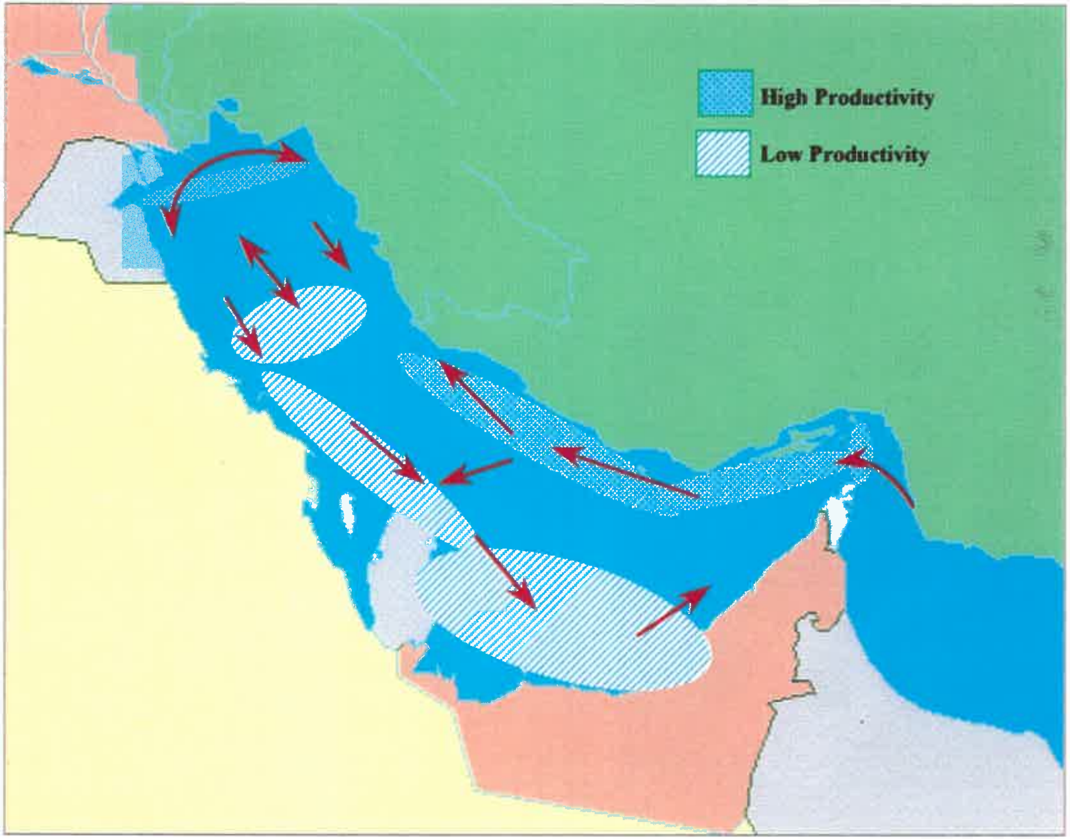
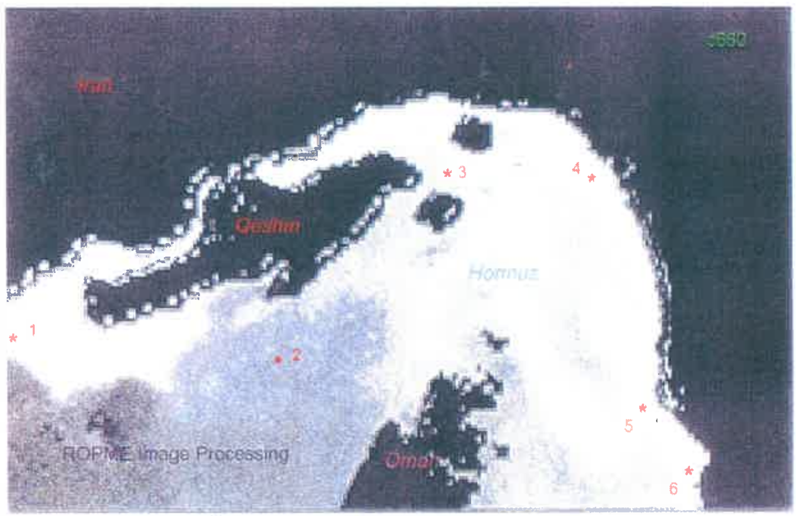
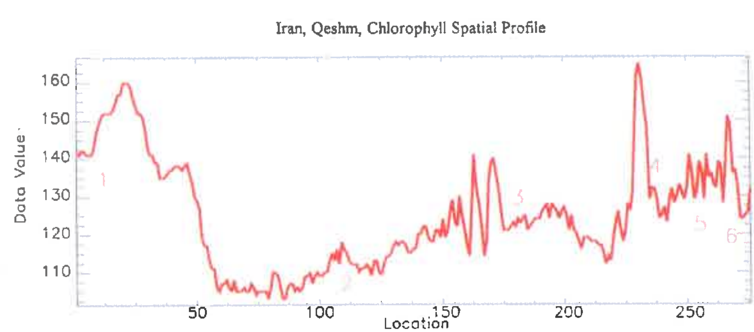


Figure (20): Distribution of productivity in the inner RSA (After Hashimoto *et al.*, 1995).

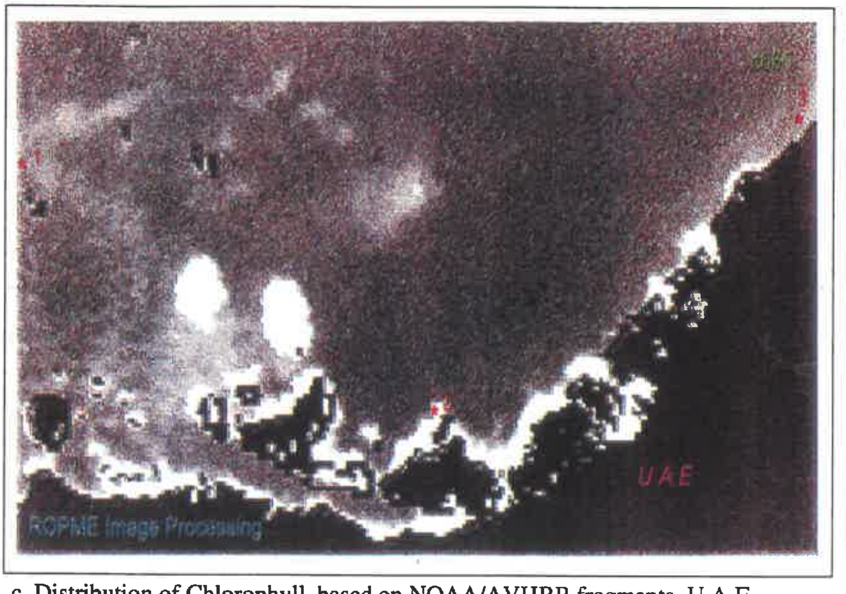


a. Distribution of chlorophyll, based on NOAA/AVHRR fragments, Qeshm Island, I.R.Iran. Lighter tones represent higher concentrations.

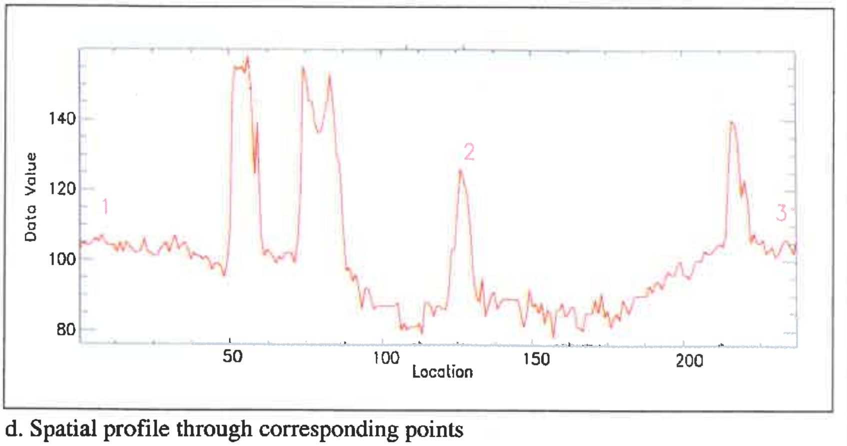


b. Spatial profile through corresponding points

Figure (21 a&b): Chlorophyll levels in I.R.Iran utilizing remote sensing analysis (ROPME, 1998).



c. Distribution of Chlorophyll, based on NOAA/AVHRR fragments, U.A.E. Lighter tones represent higher concentrations.



d. Spatial profile through corresponding points

Figure (21 c&d): Chlorophyll levels in UAE. utilizing remote sensing analysis (ROPME, 1998).

The major zooplankton groups were enumerated and identified during the Umitaka-Maru cruise (Al-Yamani *et al.*, 1998). Mean abundance of zooplankton was 20645/m^3 (± 3282). Copepods were the most dominant group with a mean of 10680 ± 1383/m^3. It was ranging from 41.3 to 62.7% composition of the total zooplankton abundance. Calanoids and Cyclopoids were equal abundant at all sampling stations, whereas Ostracods were more abundant along the eastern coast of RSA (Al-Yamani *et al.*, 1998).

2.1.5.2 Major habitats

Deep and coastal habitats in the RSA are extremely variable and support a large variety of productive marine ecosystem. It ranges from exposed beaches to rocky highlands. Sand, mud and rock exists in both intertidal and sub littoral zones. Artificial structures (platform, jetties, etc.) and offshore islands play a considerable role in the variability of resources existing in the RSA. Sub littoral mud habitat are predominant in northern and eastern part of Inner RSA, while sand predominates in southern and western areas. Sub littoral rock exists in the Straits of Hormuz, in conjunction with islands and the southern coast of Oman.

Jones (1985) reviewed the coastal and marine habitats found in the RSA, categorizing them into benthic deep and shallow subtidal habitats, intertidal habitats, rocky shores, sand shores and mud shores. He further indicated that the interaction of the physical factors in RSA produces a severe regime for the marine biota of the region, especially intertidally, so that diversity is lower within the inner part of the Sea Area than in the Gulf of Oman and the Indian Ocean in general. Although biological and ecological data on the marine biota of the region is dispersely available, with some coastal areas receiving more attention than others at least four critical marine habitats, coral reefs, intertidal marshes, mangroves and seagrass beds, and kelp forest, have been recognized in the Region (Basson *et al.*, 1977; Barratt, 1984; Price, 1985). In addition, the importance of others such as intertidal sand and mud flats, algal dominated shores, and subtidal algal coral zones has been stressed (Price, 1985). In the pursuing paragraphs, a brief description is given of the major and critical habitats in the RSA.

i) Seagrass beds

Soft substrate seagrasses provide a mostly indirect food source and habitat for both resident fauna and temporary visitors, including commercially important fish and crustaceans. (e.g. *Penaeus semisulcatus*). At least, four seagrass species are present in RSA, of which *Halodule uninervis* and *Halophila ovalis* are the most prevalent (Sheppard *et al.*, 1992). Further offshore, however, they appear to be patchy and less prevalent at least along the coast of Saudi Arabia. In Bahrain, however, they are more extensive, though they do not generally extend deeper than 8 m (Price *et al.*, 1993). There appear to be more species at the Shatt Al-Arab entrance. These does not seem to be published description of seagrass associated with the Shatt Al-Arab. It is thought that there exist other species which are unique in the area.

In the inner part of the RSA, more than 600 species of animals have been recorded among seagrasses (Basson *et al.*, 1977; McCain, 1984; Coles and McCain, 1990). Despite regional variation, available data suggest that both species richness and abundance of fauna are greater in the RSA than in Red Sea, at least in its northern parts (Biomass estimated at 0.05 - 0.24 g dry weight/m^2). Benthic fauna (within seagrasses and sand/silt) in the RSA are principally suspension feeders, which utilize more abundant organic particulate than occur in the clearer waters of the northern Red Sea.

Except for dugongs, green turtles, sea urchins and fish most species consume seagrass indirectly as detritus, after being broken down by mechanical and microbial action. To obtain an approximate qualification of productivity, Price and Coles (1992) has estimated that seagrass bed area as Tarut Bay (Saudi Arabia) could support production of 2 million kg of fish annually. The potential for sustainable development of commercial species of fish and shrimp is obvious.

ii) Coral reefs

Hard bottom substrates include coral reefs and rock coastal formations. Their mix of colours and atmosphere tranquillity has fascinated divers in the RSA, some describing them as jewels of the sea. Historically, they were identified for their richness in fish and other marine life as well as the source for building material, and alter for ornament collectors. Although thought not to be present in such extreme conditions beyond than 23.5°C North and South of the equator, their presence in the RSA is a unique example of the adaptation by marine organisms. There are numerous patch reefs in the RSA, with coral islands representing the peak of their development. Because of scouring by loose sand in the water column, patch reefs support fewer and less dense communities than island coral reefs, which have extensive reef flats which extend to depth of 10 - 20m.

Given the extreme environmental conditions in the inner RSA, and the areas relatively short age in geological terms (<10,000 years), lack of opportunity resulting from absence of an intermediate platform in the Gulf of Oman, coral diversity is low in Indo-Pacific terms. About 55-60 zooxanthellate species have been identified in RSA (Sheppard and Sheppard, 1991). This is to be compared to about 200 species in the Red Sea and over 500 species (80 genera) from the western Pacific Ocean. Thus, given the protection and maintenance of the integrity of the ecosystem in the RSA, the potential for more species to drift from the Indian Ocean and settle in the RSA is one of the greatest gifts this generation can give to future generations.

The coral reefs in the inner part of the RSA occur in an environment with great extremes of temperature and salinity, as well as high turbidity. Normal winter temperature in the RSA is amongst the lowest at which coral reef exist (Downing 1985). Both species diversity and percent coverage decrease approaching the shore, suggesting the coral survival is limited where physical conditions are more extreme. Only 57 hermatypic coral species occur on offshore island reefs, 24 of them are found on inshore reefs, and no corals are found where salinities exceed 46 (Fouda, 1997).

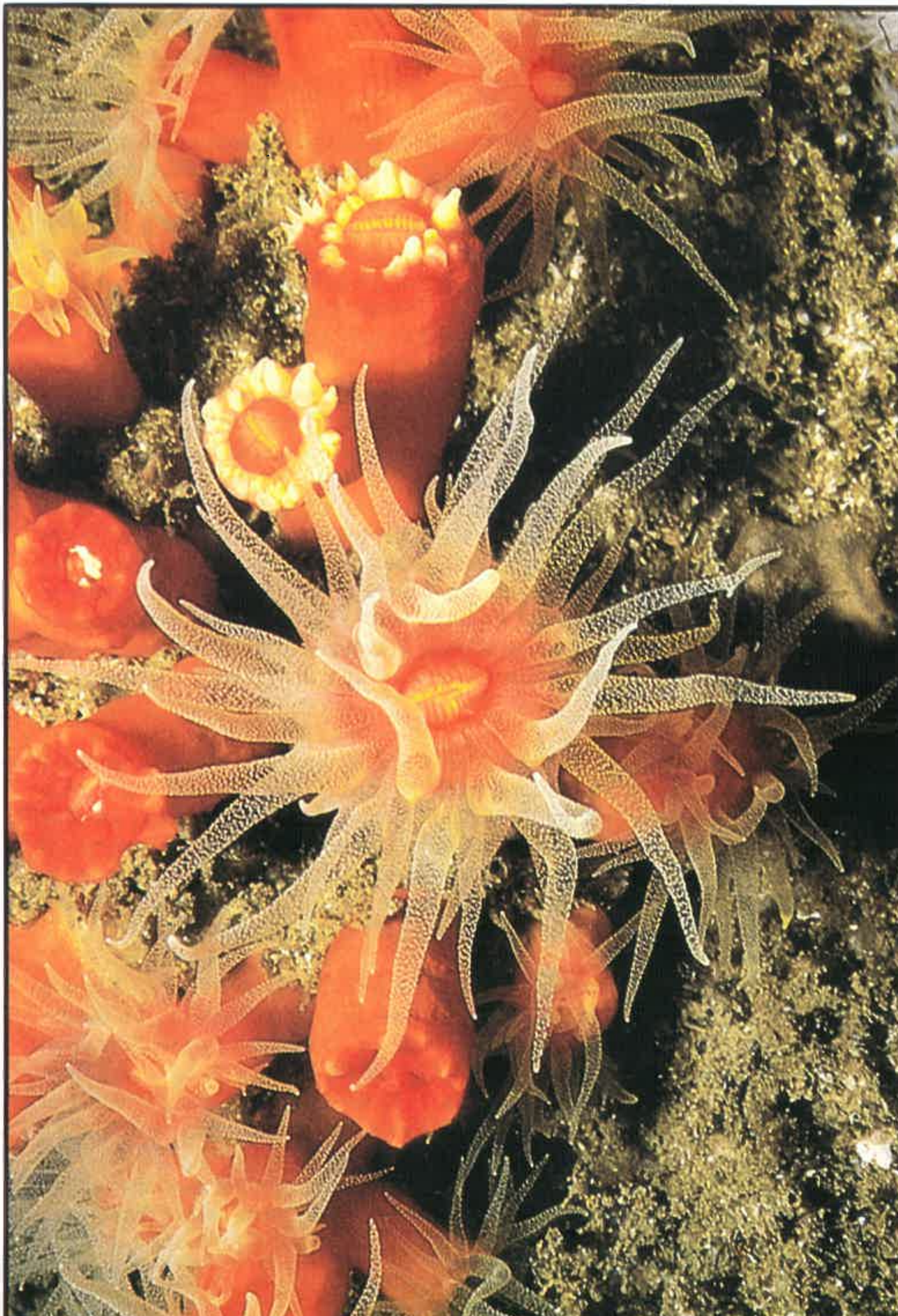
The most northerly reefs in the inner part of RSA lie around the coral islands off Kuwait where around 26 coral species are present, and like all known reefs in the RSA, they support insignificant coral growth below 15 m deep. Corals also occur in isolated colonies on rocky outcrops on the southern mainland of Kuwait but towards the north of Kuwait, the influence of the Shatt Al-Arab's estuaries conditions precludes corals. The Saudi Arabian islands have well developed reefs, with approximately 50 coral species occurring (Fouda, 1997). Patch reefs close to the mainland are much less diverse (Coles, 1988; McCain *et al.*, 1984).

Coral reefs in Bahrain and west of Qatar appear to be fairly representative of reefs located in the RSA near the mainland. Bahrain has numerous reefs along its northern and northeastern sides. The largest extent of patch reefs form a chain leading to deeper water north of Bahrain, estimated to provide a larger area of substrate than all coral islands of the Inner RSA combined (Price, 1993). Thirty-one coral species from 19 genera have been reported from Bahrain (Sheppard, 1985). Acropora of valenciennesi dominates cover > 80% over large areas at the 2-5 m depth around Fasht Adhm and other smaller northern reefs. *Porites compressa* co-dominates between 5 and 10 m depth at which diversity is greatest. *Porites nodifera* constructs substantial framework in higher salinity areas, and in these areas diversity is poor.

Water around Qatar is generally shallow which present major constraints against reef development. The west of the country borders the Gulf of Salwa where salinities are double that of oceanic water and thus, coral reefs are absent. On the northern and eastern coasts, salinities are less elevated and there is extensive coral growth. Coral reefs are shallow and are low in diversity but are well developed along the east coast. They are the central part of a long and broad line of reefs, which extend from Bahrain, down the east coast of Qatar and along the coast of the U.A.E. Shinn (1976) examined several transects leading out from the north and east coasts which crossed extensive reef areas consisting of many kilometers of *Acropora* thickets with some *Porites* and brain corals. A total of eight species of coral have been identified.

In U.A.E., numerous offshore islands and banks provide marginally more favourable conditions for coral reefs (Kinsman, 1964; Shinn, 1976). They are formed primarily from *Acropora* of a branching to tabular form, and also from large colonies of *Porites* and some faviids. Rosen (1971) records 14 genera from the coast. However, a wide range of coral species were found to at least 6 m depth, providing coral cover of < 3%, on a centrally located rocky headland near the large town of Khor Fakkan (Sheppard, 1985).

On the Iranian 2000 km long coast, Harrington (1976) identifies ten different habitats and describes eight islands extending from Asaluyeh to Bandar Abbas. The easternmost of these islands are surrounded by extensive coral reefs but no barrier reefs. Coral reefs ion depths of 6 m have also been sighted in the area of Chah Bahar. However, except for the work of Harrington (1976) and Marini (1985) most of the published work on the ecology of the Iranian coastal areas is related to fisheries (IUCN/UNEP, 1988). Mergner (1984) reported 19 coral species from Hormuz Island, probably bearing great resemblance to those in the Omani side of the Strait.



Tubastraea (Photo : Francis)

In the Sultanate of Oman there are four regions which support coral growth (Salm, 1993): the Musandam Peninsula at the entrance of the RSA; the rocky shores, bay and islands adjacent to the capital area (Muscat, Gulf of Oman); the strait west and south of Masirah island; a number of sheltered bays along mainland Dhofar in the south and the Al-Halaniyat islands offshore (Arabian Sea). The other parts of the Oman coast either lack corals or support limited growth of small scattered colonies. This is because of absence of suitable stable substrate like in Al-Batinah coast or seasonal upwelling of cold water, vigorous algal growth and heavy wave action along most of the Arabian Sea coast (Fouda, 1997). There are 91 species of corals belonging to 53 genera and 18 families (Sheppard and Salm, 1988; Salm, 1993). Coral diversity increases south toward the equator with Musandam (41 genera), Muscat (42 genera) and Dhofar (48 genera). On Masirah island there are 27 genera which reflect the isolation of this island (Salm, 1993). The Fahal Island has the highest coral diversity in the Sultanate. The variety of substrate, depths and exposure to waves and currents in the vicinity of the island are the principal determinants of this high variety of corals (Fouda, 1997). *Porites* is the dominant builder of framework reefs through the Sultanate (Salm, 1993)

iii) Algal communities

There are several areas with hard substrate in the Omani coast which are not dominated by corals but by algae instead. This may occur in shallow coral reef areas, when algae tend to be filamentous greens and small browns which grow as "algal lawn" (Sheppard *et al.*, 1992). Algal communities in most of these areas are seasonal. Their seasonality is correlated with water temperatures where the inner part of the RSA, is coldest in winter whereas the Arabian Sea is coldest during the summer upwelling. Brown algae in most depths are of small species, while large forms occur on reef crests and in the rocky platforms of stream where upwelling is important. Green and red algae are ubiquitous.

In I.R. Iran, extensive grass beds are found near the mouth of rivers and in the area of Chah Bahar (Harrington, 1976).

In Oman, growth of kelp and other brown algae is strongly seasonal. Maximum growth of *Sargassopsis zanardinii* occurs during the peak of the upwelling in August. By the end of September growth has almost completely stopped and blade decay has begun, although at the exposed site at Ras Sadha low level plant growth occur until mid-October, probably due to the higher nutrient levels (ROPME, 1988). Highest values of standing crop and biomass were obtained from inshore locations of moderate exposure and offshore locations. Dense population of mature *S. zanardinii* were found all along the rocky coast from Mirbat eastwards and northwards to Haik at 0-9 m (ROPME, 1988). Barratt, *et al.*, (1986) identified 204 algal species from the Ecklonia community (> 6.5m depth) and 206 species from the exposed rock platforms. The vegetation beneath the algal canopies includes at least 90 other species and many areas show algal lawns similar to those on reefs. The kelp community support a large number of grazers and organisms at other trophic levels. Two major grazers of *Sargassopsis zanardinii*, are the green turtle *Chelonia mydas* and the rabbit fish *Sigenus oramin* that also feed to a lesser extent on *Ecklonia radiata*. Grazing and erosion of plants is high, with a significant part of the production entering the energy flow via detritus (Barratt *et. al.*, 1986).

iv) Mangroves

Mangroves are salt-tolerant trees usually found in association with mudflats. Globally, mangrove ecosystems contain more than 60 species of trees and provide living space for more than 2000 species of fish, invertebrates and epiphytic plants (Clough, 1993).

Mangroves in the inner part of the RSA are much less extensive than before the era of intense development in the Region. Only about 125 - 130 km^2 of mangrove vegetation remain, 80% of which are on the Iranian side which have been estimated in 1970s to be 8900 hectares (Harrington, 1976). Due to the severe climatic conditions in conjunction with limited habitats and niches (Sheppard *et al*, 1992) only one eurythermal and euryhaline species, *Avicennia marina* occurs in the RSA. Since air temperature drops to freezing in winter over the extreme NW part of the Inner RSA, mangroves trees are not found in Kuwait and most of NE coasts of Saudi Arabia.

Along the Oman's coast and islands, mangroves are scattered upon more than 20 sites, Northern Batinah, Capital area extending to Sur, Gulf of Masirah and Bar Al-Hikman, and the Dhofar region (Fouda, 1995a). Mangrove vegetation of *Avicennia marina* is varying from 2 - 6 m in height in the Gulf of Oman and up to 10m in the Arabian Sea (Fouda and Al-

The growth of mangrove and dense vegetation along mangrove creek at Qatar

Muharrami, 1996), whereas in the inner part of RSA proper trees are poorly developed and often stunted (1 - 2 m) at least along western shores (Price *et al.*, 1993).

Oman's mangrove communities include faunal assemblages of fish (more than 100 species), crabs, shrimps, *Penaeus indicus* and *P. semisulcatus*, shells and clams. Large wildlife includes over 200 bird species, three turtle species and four mammal species. Birds include cormorants, herons, egrets, spoonbills, flamingos, many waders, gulls and turns. Mahout and Bar Al-Hikman (Oman) hold internationally important concentrations of shorebirds, notably crabplovers, sandplovers, demlins and redshank. Green turtles, loggerhead and hawksbill turtles are often seen nesting on sandy shores of mangrove areas. Gross primary productivity in Avicennia stands have been estimated to be <1 kg $C/m^2/yr$, however the value of mangrove is much more important biologically (IUCN, 1987).

In Qatar, mangroves occupy the area to the northeastern coast, where it intermingles with the Sabkha frontier vegetation. *Avicennia marina* (alqurm) is the only species present in Qatar (Sadooni and El-Kassas, 1998).

v) Tidal mud flats

Tidal mud flats represent the greatest contributions to primary production in the RSA (Price *et al.*, 1993). The most extensive mud flat systems are located in the NW of RSA in the approximity of the Shatt Al-Arab delta (Jones, 1986). Detailed studies of mud flats carried out in Saudi Arabia (McCain, 1989; Feltkemp *et al.*, 1994) and in Kuwait (Halwagy and Halwagy, 1977; Jones, 1998; Al-Bakri, 1989) have shown that the cyanophyta-dominated algal mats covering mud flats, accounts for most of the productivity in RSA, providing a major feeding area for wintering waders and passage migrants which fertilize these flats as they feed during their brief stay (Zwart *et al.*, 1991). Tidal mudflats also include sabkahs which also support mats of cynophyta, diatoms and bacteria, e.g. nitrogen fixing bacteria which also contribute to the overall productivity of tidal mudflats. McCain (1984) identified 624 species of organisms in tidal flats, compared to 452 in the sand biotope and 360 in the seagrass beds of the eastern coast of Saudi Arabia.

2.2 Living and Non-Living Resources

2.2.1 Marine populations

2.2.1.1 Fishes

Unlike the more stable tropical marine environment, the predominantly arid, subtropical RSA is characterized by a generally low diversity of fish species, although individual species may occur in high numbers (Fouda, 1997).

The inner part of RSA supports more than 500 fish species, most of which live in pelagic or soft substrate demersal habitats (Price *et al.*, 1993) and at least 125 species are found on the reefs (Sheppard *et al.*, 1992), 85 fish species from reefs off Kuwait (Downing, 1985), 71 species from Bahrain (Smith, 1987), 106 species from reefs in Saudi Arabia (McCain *et al.*, 1984; Coles and Tarr, 1990; Krupp and Muller, 1994). On the other hand, approximately 1000 fish species were recorded from the Gulf of Oman and the Arabian Sea (Fouda and Hermosa, 1993; Randall, 1995), most of them are reef species.

Environmental extremes in the inner part of RSA have limited the distribution of many species (Coles and Tarr, 1990; Price *et al.*, 1993). Peak fish species diversity and population densities of the dominant species are attained on the well-developed offshore reefs of Saudi Arabia while seasonal variation in these parameters is particularly high at the nearshore reefs (Coles and Tarr, 1990; Krupp and Muller, 1994). Fish diversity falls off moving northwards and southwards of Saudi Arabia, as environmental conditions become more extreme. Probably the richest reef fish fauna will be found on the Iranian reefs, near the Strait of Hormuz (Price *et al.*, 1993). These reefs lie in deeper waters and are supplied with oceanic water inflowing through the Strait. On the other side, the high diversity of Oman's fish fauna is attributed to the diverse coastal habitats, wide climatic spectrum and its unique geographic location in the upwelling region of the northwestern region of the Indian Ocean (Fouda, 1997).

2.2.1.2 Crustacea

As mentioned earlier, a few species of lobsters (spiny and shovel nose) exist in the RSA. Other crustacea also exist, but shrimp is the most dominant and commercially important species.

The shrimp fishery based on penaeids, mainly *Penaeus semisulcatus* and *Metapenaeus affinis*, is conducted by both industrial trawlers and an artisanal fleet of over a thousand boats (van Zalinge, 1984). Richest resources are off the coasts of Iran and Kuwait with smaller catches taken from the Saudi Arabian, Bahrain and Qatar waters. Peak catches totalled 17,200 tons in 1967-1968, but dropped thereafter with fluctuations causing the collapse of fishing companies in some years (FAO, 1980; 1981a). Management policies include the establishment of a closed seasons for fishing for shrimps and other crustacea. However, further research is required to identify the causes of recruitment failure and its possible link with landfill in some areas.

2.2.1.3 Marine mammals

Dugongs or sea cows are strictly herbivorous. Seagrasses form their staple diet. In the inner part of the RSA, some herds of these marine mammals were discovered for the first time in 1980s. The largest ever record herd of over 600 individuals was observed in the Gulf of Salwah between Bahrain and Qatar peninsula (Preen, 1989). The overall population in RSA between Ras Tanura and Abu Dhabi is estimated to be 3500 - 7500 individuals, making the inner part of the RSA the most important area for these species in western part of its range, and second in global importance only to Australia. Other marine mammals of interest include whales and dolphins, i.e. Brydes whale and the Humpback whale, Bottlenose dolphin and Indo-Pacific humpbacked dolphin. Other dolphins and whales known to inhabit adjacent parts of the Indian Ocean are also likely to occur in inner part of the RSA.

About 20 dolphins and whales species exist in Oman's open waters, representing 25% of all known species in the world (Bladwin and Salm, 1994). They vary greatly in size from the slender agile spinner dolphins (< 2 m in length) to the huge sperm whales (> 20 m in lengths). The Indo-Pacific humpback dolphin, common dolphin, spinner dolphins, pan-tropical spotted dolphin and Bottlenose dolphin are the most common dolphins in Oman. Some dolphins occur in very shallow water (Indo-Pacific humpback dolphin), others in sheltered coves and bays (e.g. Bottlenose dolphin), and still others can be seen in groups of 10 to 20 individuals (common dolphin) or mixed with others, chasing fishes.

Priacanthus hamrur (Forskal) (Photo : Petron)

2.2.1.4 Marine reptiles

Turtles

Marine turtles form a prominent part of the fauna of the RSA which contains some globally important nesting beaches. In RSA, marine turtle populations have two components: (i) a small resident population, individuals of which are sometimes encountered in seagrass areas; (ii) a much larger migratory population, which breed on offshore coral islands, including Karan and Jana islands in Saudi Arabia. All the five pantropical species are known in the region: Hawksbill, Greens, Leatherbacks, Loggerheads and Oliver Ridley.

In Bahrain, the Green Turtle, Hawksbill, Leatherback and Loggerhead (*Chelonia myda, Eretmochelys imbricata, Dermochelys coriacea* and *Caretta caretta*) have been reported.

In Qatar, the island of Sharaawh has nesting populations of Hawksbill Turtles (*Eretmochelys imbricata)*; hatchlings are seen in early July but nesting numbers are reportedly very low (Ross and Barwani, 1981).

In I.R. Iran, Green Turtles (*Chelonia mydas)* nest in small numbers at Bushehr (Bandar Abbas) and Ras Beris. Hawksbill Turtles (*Eretmochelys imbricata)* occur in significant numbers in the area from Taheri (Siraf) to Bandar-e-Lengeh, at Qeshim Island and from Tang (Bandar Tang) to the Pakistani border (Groombridge, 1982; Ross and Barwani, 1981).

Green Turtles are the most commonly seen species in Oman, and nest on at least 275 beaches spread along the entire coast. An estimated 50,000 to 60,000 green turtle egg clutches are laid each year in the Sultanate, the effort of about 20,000 turtles or more. This gives Oman probably the greatest number of nesting green turtles of any single Indian Ocean nations.

The most important part of the region for turtles is the Arabian Sea (Oman), both in terms of number of breeding species and abundance of individuals (Ross, 1979; Salm and Salm, 1991). Recent findings have confirmed that Masirah Island holds the world's largest nesting population of Loggerhead, estimated at 30,000. Other significant sites are along the Dhofar coast and around Al-Halaniyat Islands. Hawksbill turtles exist in considerable numbers notably at Daymaniyat Island. The other turtles (Olive Ridley and

Leatherhawks) are not present in significant numbers in Oman (Fouda, 1997).

Sea snakes

Other marine reptiles of scientific interest include sea snakes, in particular species of *Hydrophis*. The group generally are found in muddy, warm waters, and their preferred habitat is relatively abundant in the inner part of the RSA, whose soft substrate habitats are contiguous with other sea snake-rich areas in the Arabian Sea and around India (Gasperetti, 1988; Sheppard *et al.*, 1992).

2.2.1.5 Birds

The RSA supports a diverse marine bird community of great international importance. Huge numbers of seabirds breed on the offshore islands, especially Socotra Cormorant (most of the world population) and terns *Sterninae* (Gallagher *et al.*, 1984) (e.g. Bridled Tern, White-cheeked Tern, Lesser Crested Tern). The intertidal zone is estimated to support up to four million waders Charadrii in winter, making the RSA as one of the five most important regions of the world for wintering waders (Zwarts *et al*, 1991). The intertidal and shallow subtidal zones are also internationally important in winter and during migration seasons for populations of about 20 other waterbirds species including grebes, cormorants, herons, flamingos, gulls and terns.

The inner part of the RSA is particularly important for wintering waders, passage migrants and breeding seabirds. Pre-war (1991) surveys have been undertaken during along with western RSA (Zwarts *et al.*, 1991). During the winter survey, a total of 21 wader species represented by nearly 30,000 individuals were recorded. Important species included oystercatchers, ringed plovers, lesser sandplover, little stint, dunlin and others. Mud flats were found to support greater wader feeding densities than either rock flats or sand flats. Extensive mud flats occur along the shores of most, if not all, the inner part of the RSA. Highest wintering wader counts in Saudi Arabia were found on the intertidal mudflats of Tarut Bay, Dawhat and Dafi and the northwestern part of Musallamiya. Each year an estimated quarter of a million waders winter in the Saudi Arabian part of the RSA, and for the whole inner part of RSA the number may be as high as 1 - 2 million.

The inner part of the RSA is also an important feeding area for passage migrants which winter further south, and which breed up to 15,000 km away in the far north. Over the spring, these supplement the numbers of wintering birds. Waders are the most important migrants in the RSA, occurring in even larger numbers than during winter. Evidence has now accumulated showing that intertidal flats function as vital feeding areas for many migrating waders, and clearly play an essential role in the life cycle of these bird species.

Offshore islands provide major nesting sites for at least three different terns. The commonest is the lesser-crested tern, with an estimated 25,000 pairs nesting on five Saudi Arabian islands. It appears that the inner part of the RSA represents the breeding area for a large part of the world's population. Other seabirds, such as Socotra cormorant, a species confined to the Arabian Peninsula also breed along parts of western RSA coast.

In the northern parts of RSA, along the coasts of I.R. Iran, about 88 species of birds are recorded. Among them 19 species are resident and 69 species are wintering either passage migrants (46 species) or breeding sea birds (23 species).

In Bahrain, the islands are of international importance on account of a small colony of breeding Sooty Falcon *(Falco concloor)* and a large proportion of the world population of Socotra Cormorants *(Phalacrocorax nigrogularis)*. The flamingo *(Phoenicopterus ruber)* is present throughout the year, and the Osprey *(Pandion haliaetus)* breeds there as well.

Gallagher *et al.* (1984) described the status of breeding colonies of seabirds from several localities around the coast of Qatar and on its islands. These include at least four species of terns (*Sterna* spp.) and occasionally the Socotra Cormorant *(Phalacrocorax nigrogularis)*.

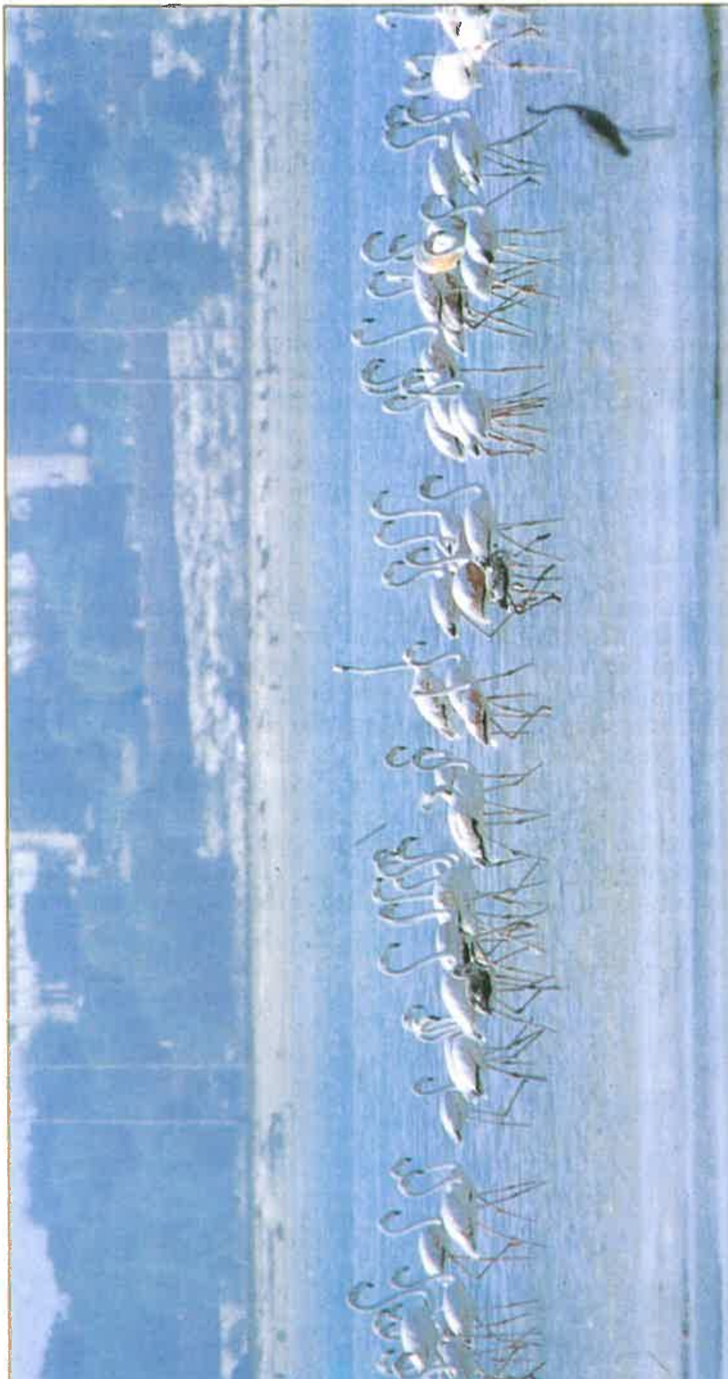
The avifaunal assemblage of U.A.E. mangroves is a biogeographical combination of Paleartic and Indo-Malaysian bird communities with some unique elements, for example, the endemic Kalbaensis subspecies of White-collared Kingfisher *Halcyon chloris* breeds at the single type locality - Khor Kalba, Sharjah, with a total (world) population of only 44 pairs (Aspinall, 1996). Other ornithological interest includes : Booted Warbler *Hippolais caligata*, breeding at Khor Kalba and nowhere else in Saudi Arabia, two colonies of Crab Plover *Dromas ardeola* in Abu Dhabi Emirate, sustained by mangrove-dwelling crabs and being the only known examples in the Western RSA, as well as regionally important breeding or wintering populations of

Indian Pond Heron *Ardeola grayti*, Western Reef Heron *Egretta gularis* and Clamorous Reed Warbler *Acrocephalus stentoreus*. In addition, the invertebrate productivity of U.A.E. mudflats supports 1-3 million visiting waterfowl annually and is doubtless attributable, in part, to the continuous (leaf) litter input from mangrove.

The major coastal bird habitats in Oman include: offshore waters, islands and islets, coastal cliffs, rocky shores (e.g. Musandam), sandy beaches (e.g. Batinah Coast), tidal flats (e.g. Bar Al-Hikman), Khawr environment and mangroves (e.g. Qurm in Muscat). Examples of birds include cormorants, herons, egrets, spoonbills, flamingos, many waders, gulls and terns. Bar Al Hikman and the surrounding areas, including Mahout Island, hold internationally important concentrations of shore birds, notably crabploves, sandploves, dunlies and redshank. Zwarts, *et al.* (1991) suggested that the coastal area of Saudi Arabia are host to millions of waders.

2.2.2 Non-Living resources

Before the petroleum era in the Region, the small coastal communities relied on the sea, not only for food but also for building materials, especially sand and coral rocks. Wood from mangrove trees and other coastal plants were harvested for fire wood. The dawning of the petroleum era (1950s) witnessed the introduction of desalination plants that converted seawater into steam and brine. The steam is used to run electricity turbines and produce potable water (by mixing with ≅ 10% brackish water (mined from the aquifers). The brines are used to produce salt, chlorine and caustic soda. Desalination/power plants stations are run by oil and/or gas, since it is the most easily available source of energy. However, oil and gas remain the dominant non-living resource exploited in the coastal and marine areas of the RSA.



Pheonicopterus ruber (Photo : Richardson)

CHAPTER 3

SOCIO-ECONOMIC ACTIVITIES AND STRUCTURES AFFECTING ROPME SEA AREA

The state of the marine and coastal environment is largely dependent on the human, social and economic activities that take place both on land, particularly in the coastal zone, and at sea. It is of prime importance, therefore, to focus on those activities that are likely to affect the marine and coastal environment in the RSA. In this context, this chapter of the report will briefly review both the land-based and sea-based activities that represent potential sources of pollution in the RSA, bearing in mind that UNEP and ROPME are publishing a special report on land-based sources and activities, and that the available data are generally limited at this stage of report preparation.

3.1 Land-Based Activities

3.1.1 Industrial development

The RSA has witnessed an unprecedented growth in the industrial sector over the past 30 years. The most common in the region's heavy industries include desalination and power plants, petroleum refineries and petro-chemical industries. These are major contributors to the chemical oxygen demand (COD) pollution load. Light industries include agricultural and livestock productions and food/beverages industries which are generally contributing to the biological oxygen demand (BOD) loads.

Unfortunately, since the rapid assessment study on "Land-Based Sources of Pollution within KAP Member States" conducted by ROPME in 1984, no further regional assessments have been carried out. Recent data on effluent discharges from heavy and light industries are generally lacking and need to be developed for the region, using both the rapid assessment approach and ground truth observations and assessments.

The following are the main industry-related waste source categories that are of potential effect on the marine environment in the RSA. Since most of the data in Tables given below are rather old (1985-1987), they should be carefully interpreted and taken only as indicators.

3.1.1.1 Liquid industrial wastes

Industries, which are mostly located on the coast usually discharge their effluents to the sea. According to ROPME reports, the desalination and power plants are discharging the maximum percentage of effluent volume estimated at 48% of the total effluent discharges and account to some of the BOD, COD and SS (Suspended Solids) loadings. Next to the desalination and power plants, the petroleum refineries have been reported to contribute 28 % of the total waste volume to the RSA and are major contributor to the COD, oil and metals load. Petrochemicals and other industries contribute only 19 % and 5 %, of the total discharge to the RSA respectively (Figure 22). Both industries also contribute to the oil loading produced by oil export which are responsible for the high load of oil contaminants in the RSA.

The few data sets available to ROPME on industrial liquid waste discharges into the RSA from Member States for the period 1985 – 1987 indicate that the highest calculated contaminant discharge load is oil (102,440 t/yr) accounting for 55% of the total contaminants discharged. Other discharges include SS (47,061 t/yr, 25%), BOD (27,002 t/yr, 14%) and N (11,440 t/yr, 6%). The distribution percentages of contaminants from industrial liquid discharges in the RSA are summarized in Table (4) and Figure (23).

Table (4) : Summary of industrial liquid wastes discharged into the sea from ROPME Member States (1985 – 1987).

Total	**Contaminants**						
Discharge	BOD	COD	SS	TDS	Oil	N	Total
t/yr	27,022	N/A	47,061	N/A	102,440	11,440	187,963
%	14	N/A	25	N/A	55	6	100

BOD: Biological oxygen demand; COD: Chemical oxygen demand; SS: Suspended Particulate; TDS: Total dissolved solids; N: Nitrogen.

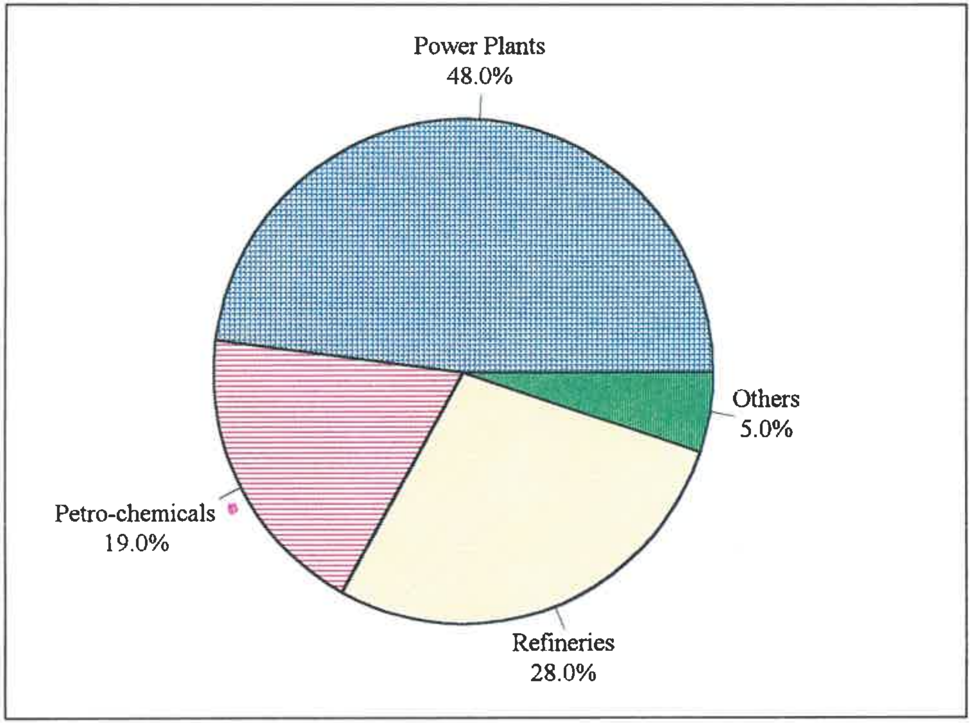


Figure (22): Land-based sources of pollution to the coastal zone of RSA.

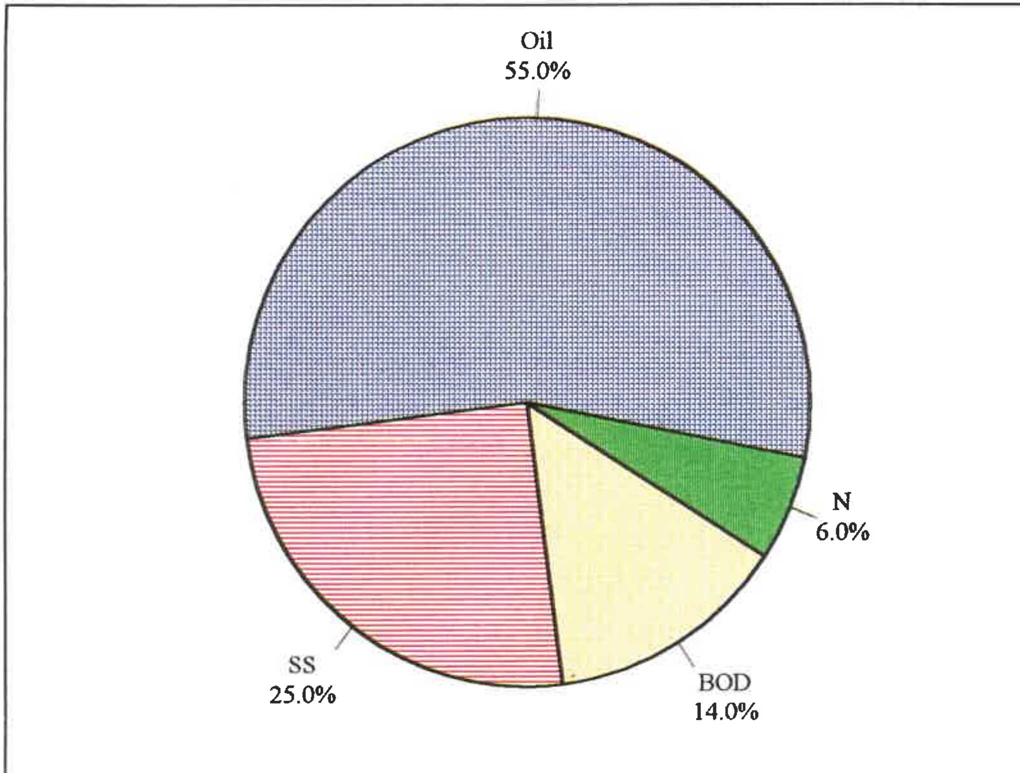


Figure (23): Distribution percentage of industrial liquid contamination discharged into RSA.

3.1.1.2 Solid industrial wastes

Solid wastes are also generated by the various industries in the region and may also affect the RSA if not properly managed and handled. According to ROPME's rapid assessment data, oil sludge represents the main industrial solid waste in the RSA. A summary of the amounts of industrial solid waste loads produced in the RSA for the period 1985 – 1987 are given in Table (5) which show that about 15% of the industrial solid wastes produced in the RSA consists of oily sludges (about 188,000 t/yr). It is to be noted here that the industrial solid waste makes up 26% of the total solid waste generated in the RSA. Abu-Gharrah and Abdulraheem (1999) estimated that industrial solid waste in the region to be around 1.4 million t/yr (28% of total waste generated).

Table (5) : Summary of solid wastes loads from industrial sources in ROPME Member States (1985 – 1987).

Solid Wastes	Oil sludges	Other	Total
t/yr	187,953	1,088,277	1,289,114
%	15	85	100

Notes :

- Oily sludges are generated from refineries and oil export terminals.
- Others are mostly products of industrial processes, including wood, cartoon, plastic, spare parts, minerals, drilling, mud, paints and solvents.
- Solid waste load for Saudi Arabia was reported only as a total quantity.

3.1.1.3 Atmospheric industrial emissions

The third category of pollution loads resulting from land-based industrial processes is the atmospheric emissions that may eventually reach the marine environment by deposition.

Major sources of air pollution in the RSA, particularly the more industrialized centres, include oil refineries, oil gathering centres, and oil platforms; petrochemical and fertilizer plants and motor traffic. It may be added that smoke from the incomplete combustion of fuels is currently a serious environmental problem in the region.

The primary emission sources from these industries include: flaring, venting and purging gases; combustion processes such as diesel engines, plant exhaust and gas turbines; fugitive gases from pits, loading operations and tankage and loosed from process equipment; airborne particulate from soil disturbance during construction and from vehicle traffic; particulates from other burning processes such as testing garbage sludge burning.

The principal emitted gases include carbon monoxide, methane, volatile organic carbons and nitrogen oxides. Emissions of sulphur dioxides and hydrogen sulphide can occur and depend upon the sulphur content of the hydrocarbon and diesel fuel, particularly when used as a power source. High sulphur content can also lead to odor production. The emission loads are summarized in Table (6) and Figure (24). Air emission estimates do not emphasize the source but combine several sources together (ROPME, 1997).

Table (6) : Summary of atmospheric emissions from ROPME Member States (1985 – 1987).

Total Emissions	Contaminants						
	Particulates	SO_x	NO_x	HC	CO	Others	Total
t/yr	894,109	1,041,416	532,784	230,111	1,073,345	76,990	3,847,755
%	23	27	14	6	28	2	100

SO_x: Sulphur oxides, NO_x: Nitrous oxides, HC: Hydrocarbons

3.1.2 Domestic wastewater discharges

The main category of domestic wastes affecting the marine and coastal environment is domestic sewage discharges into the RSA, which are either partially treated or untreated.

Early studies undertaken for ROPME by UNEP Group of Experts in 1980 and by ROPME Group of Consultants in 1986 showed that the total volume of treated and untreated sewage discharged to the RSA at that time was about 157,236 x 10^3 m^3/yr. A more recent estimate of sewage treatment plants in the RSA the combined capacity is more than 2 million m^3/day, out of which 35% of treated effluents are used (Abu-Gharrah and Abdulraheem, 1999).

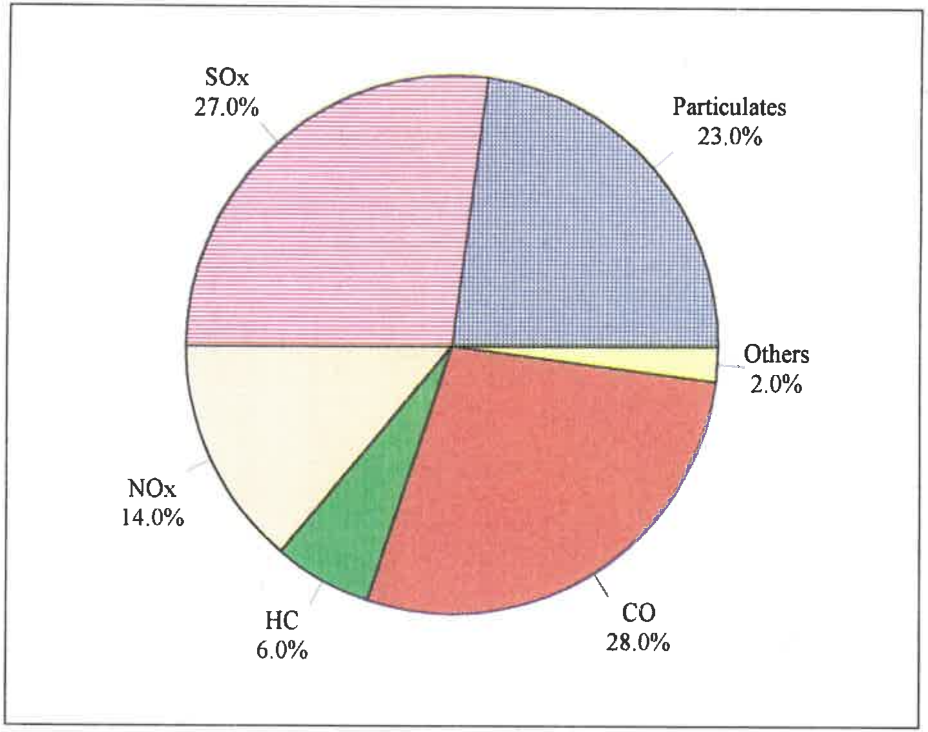


Figure (24): Atmospheric emission from RSA.

Other estimates of domestic liquid wastes discharged into the RSA from ROPME Member States indicate that the total load of pollutants discharged to the RSA is 940,033 t/yr. Table (7) and Figure (25) provide details of the contaminant amounts and percentages.

Table (7) : Summary of domestic liquid wastes discharged into the sea from ROPME Member States (1985-1987)

Contaminants	Discharge	
	t/yr	%
BOD	17,765	1.89
COD	29,799	3.17
SS	26,191	2.79
TDS	840,543	89.42
TON	1,766	0.19
N	2,963	0.32
SO_4	12,437	1.32
P	8,294	0.88
NO_2	43	0
NO_3	232	0.02
Total	940,033	100

TON: Total Organic Nitrogen; N: Nitrogen compounds; SO4: Sulphates: NO2: Nitrite;NO3: Nitrates; P: Phosphates

In spite of the significant development in the Region, the capacity of the existing sewage treatment facilities in some ROPME Member States is still below the capacity required to cope with the growing populations in coastal cities. It is to be noted in this connection that treated sewage effluent is a valuable resource for irrigation in the arid coastal zones of the countries of the region and the sludges arising from the treatment of sewage can be used as agriculture fertilizer or for land reclamation, when it is not contaminated with high levels of metals, oils and organic chemicals. Recognizing this fact, several countries in the region have expanded the networks of sewage treatment plants. However, the cost of constructing distribution networks has limited the extent of utilization of treated effluents as stated above.

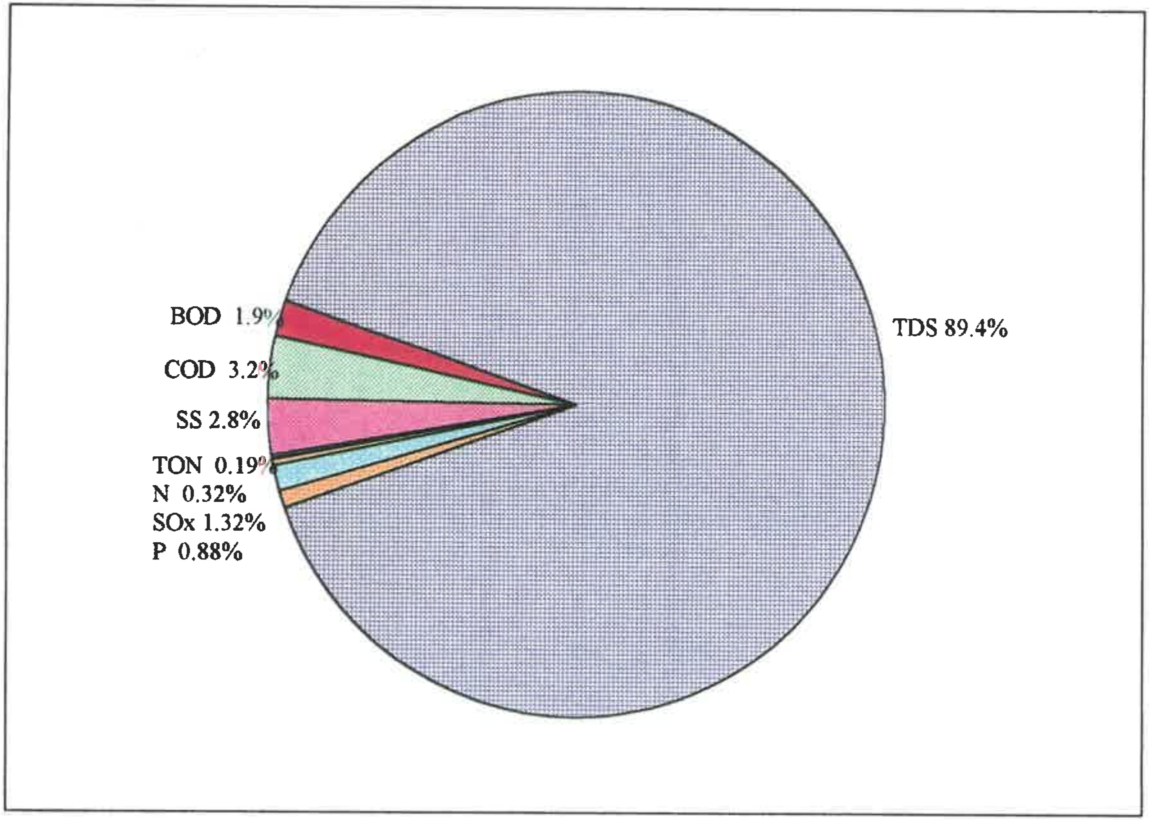


Figure (25): Distribution percentage of domestic liquid contamination discharged into RSA.

3.1.3 Management and discharges of river basins

Human activities along river basins as well as the engineering works and structures such as man-induced alterations and dams built on rivers have significant effects on the marine and coastal ecosystems associated with these rivers. The effect will be both on the hydrological and biological cycles, through changing the pattern of river flows and on the quality of water discharged into the marine environment, which usually carries large amounts of dissolved and particulate material to the sea. Further, Al-Saad *et al.* (1998) reiterated that oil refinery effluent and losses during loading operations are identified as the major sources of oil contamination in the waters of the Shatt Al-Arab river which empties into the North-West RSA.

As stated earlier, in the RSA, most river inflow occurs in the northwestern end of the Sea Area, primarily from Shatt Al-Arab system and Iranian side rivers. The Shatt Al-Arab is a nexus of three major rivers Tigris, Euphrates and Karun (Figure 12). Recent data indicates that the Tigris and Euphrates rivers together provide an annual average of 708 m^3/sec and the Karun River provides 748 m^3/sec. Thus, the total average outflow of the Shatt Al-Arab is 1456 m^3/sec. Other major rivers are the Hendijan (provides 203 m^3/sec), the Hilleh (444 m^3/sec), and the Mand (1387 m^3/sec). The total river run-off is 11×10^{10} m^3/yr, equivalent to 46 cm/yr of depth (Reynolds, 1993).

On the other hand, several dams have been constructed on the major tributaries of Shatt Al-Arab. According to Linden *et al.* (1990), five major dams in Turkey, Syria and Iraq have been built on the Tigris and Euphrates and are controlling the river flow. On the third main tributary of Shatt Al-Arab, the Karun in Iran, there are two major dams. In addition there are plans for construction of more dams in the future. Recent information indicates that these dams have reduced the flow of water through Shatt Al-Arab drastically, enough to allow extensive drainage operations to be carried out in the "Alahwar" area (wet land) of Iraq in recent years.

With the filtering role of the Iraqi wet lands being eliminated and the newly constructed drainage channel discharging river water into Khor Al-Zubair (at the Iraq – Kuwait border, around Warba Island), has resulted in reduction of the salinity, increased nutrients input and likely to bring more agriculture drainage into the area.

It should be noted that the issue of the dams on the Shatt Al-Arab is not only a water issue for the countries in which the major rivers run through. Fisheries resources in the NW part of the RSA are significantly affected by the levels of fresh water and nutrients provided by these rivers. Thus, reduction of river discharge into the RSA is a wider regional significance than what is given to it now.

In view of the above activities in the largest river basin in the RSA, it becomes essential that the impact of these activities on the coastal and marine ecosystems in the northern part of the RSA be carefully monitored and studied. Initiating river basin management arrangements for the major rivers should be high in the regional agenda.

3.1.4 Coastal development and physical alterations

The coastal zone of the RSA is becoming, like any other coastal area world-wide, under increasing pressure resulting from the high pace of development and the extensive economic activities that take place there. By the early 1990's, some countries of the region, have already developed >40% of the coastline (Price and Robinson, 1993), and recent reports indicate that coastal investment in the region is estimated to be worth between US$ 20 and 40 million per kilometer of the coast (Fouda, 1998).

Most of the coastal development projects require extensive dredging and land reclamation operations to be undertaken in the coastal zone. Several such projects have been or are being implemented in ROPME Member States. For example, in Bahrain such activities have considerably increased in the 1970s, serving both industrial and residential purposes. Some reclamation operations involved large areas for constructing industrial complexes and for building the King Fahd causeway connecting Bahrain to Saudi Arabia. The reclaimed land in Bahrain increased the surface area of Bahrain from 661.87 km^2 in 1975 to 700 km^2 in 1994, thus changing the area of the coastal zone by adding about 39 km^2 to its area in less than 20 years. Such magnitude of physical alteration in the coastline had several adverse environmental effects on the coastal environment including damage to the spawning ground of various marine species and to seagrass beds, removal or alteration of the benthos that form the main source of food for many commercial fish species, increase in siltation due to the outslip of fine sediments, release of fine material during dredging operations resulting in increase of water turbidity that my irritate or clog fish gills, interfere with visual feeding and inhibit photosynthesis.

Similar reclamation activities exist in Kuwait, where considerable parts of the intertidal areas along Kuwait City and some sections along the southern coast have been reclaimed. Land reclamation disturbed the natural hydrodynamic conditions of the coastal water and the fill material is not stable under local beach processes, so significant erosion problems have developed along most of the fill edge of the reclaimed areas. Al-Bakri *et al.* (1985) indicated that the effect of these reclamation activities is not only the partial or total loss of the upper intertidal areas but also the modification of the physical nature of the adjacent tidal flats. Such modification would naturally be accompanied by loss of the ecosystem and death or migration of the marine inhabitants of the affected areas.

In Saudi Arabia much of the commercial and residential development along the coast has taken place in coastal cities, particularly around Jubail and further south around Tarut Bay, Dammam and Khobar. Particularly around Tarut Bay, the coastal area has had major landfilling activities. There, landfilling not only causes permanent destruction of coastal habitat, it also can have indirect environmental impacts such as sedimentation, which has been just as severe. Changes in water circulation in the vicinity can alter the structure of the resident plant and animal community.

Likewise in other ROPME Member States, coastal development projects are taking place at a high pace to develop and establish aquaculture facilities in Iran, high density single-family dwellings in Oman and modern urban centres, industrial complexes and desalination plants in U.A.E. (Fouda, 1998).

Additionally, in some cases, construction of causeways, or other structures that block the flow of water and slow natural flushing action can make the area around the construction more susceptible to water pollution.

War, in addition to its catastrophic impacts on man and the environment has caused profound changes in the coastal areas of the RSA. Millions of Palm trees were cut or destroyed in the exchange of fire between Iran and Iraq during their war, which last about nine years. Additionally, alteration of water ways, destruction of top soil by movement of heavy equipment, laying of mines and bunker construction have also impacted the fragile estuarine environment around the Shatt Al-Arab delta. The war in Kuwait also inflicted severe changes in the coastal areas including massive oil spills, construction of beach fortifications, movements of heavy military equipment, laying of mines. Removal of mines and detonation of unexploded ordnance has also resulted in further damage to the environment.

3.1.5 Other activities and pollution sources

Recreation and tourism facilities

Recreation and tourism facilities are developing at a fast rate in many countries of the region. These include building of marinas, facilities for water sports, fishing, marine parks, archeological citing and other recreational activities. Such facilities are expanding and developing considerably well in Bahrain, Oman and U.A.E. where they are extensively used by both local nationals and expatriates and by visiting tourists. They are also being established in Saudi Arabia at Jurayd and Jana Islands, Jubail, Muntazah, Dawhat As'sayh and Zalum and Al-Khobar; in Iran at Kish and Qeshim Islands and in Kuwait at the water front and Al-Khiran recreational areas.

With the development of recreation and tourism facilities in the coastal area as an important industry for the diversification of national economies, a number of luxury modern hotels and furnished holiday apartments and extensive range of restaurants have been built with the necessary coastal roads and other infrastructures to cater for the diverse needs of individual travelers and tourist groups. These installations, when built haphazardly or not managed in an environmentally sound manner could have adverse effects on the marine and coastal environment. Thus, they should therefore be carefully monitored and regulated with a view to protecting this valuable resource against degradation, damage and misuse.

3.2 Exploration and Exploitation of the Living Marine Resources

Although the region is quite rich in terms of commercial fin fish and shellfish species, the fisheries sector plays only a minor role in national economics. In most Member States of ROPME, the contribution of the fisheries sector to the gross domestic product (GDP) is less than one percent. For example, it is 0.3% for Bahrain while in Kuwait the fisheries and aquaculture activities represent together 0.1% and in Qatar the fisheries and agriculture represent together 1.0% of the GDP. However, it has been indicated that in the Sultanate of Oman revenue from fish was 36.5% of the total oil export revenue for 1984 and is presently the most important export product after petroleum (Linden *et al.*, 1990). The Islamic Republic of Iran has also intensified efforts to develop its fisheries resources in recent years.

Of the eight countries in the region, only four have significant shrimp fisheries with approximately 180 trawlers in operation (Iran 80, Kuwait 70, Saudi Arabia 20, Bahrain 10), (FAO, 1997).

Over 1,000 fish species, six species of shrimp (*Penaeus semisulcatus, P. indicus, Metapenaeus affinis, M. stebbingi, M. monoceros, Parapenaeopsis stylifera*), two species of spiny lobsters (*Panulirus homarus homarus, P. versicolor*), one species of shovel nose lobster (*Thenus orientalis*), one species of cuttlefish (*Sepia pharaonis*), one species of abalone (*Haliotis mariae*), one species of crab (*Portunus pelagicus*) support the commercial fisheries in this region (Mohammed *et al.*, 1981; Johnson *et al.*, 1992; Fouda and Hermosa, 1993; Krupp and Muller, 1994; Abdulqadar, 1994; Siddeek *et al.*, 1997; Fouda, 1997). Until almost middle of the century, pearl oysters (*Pinctada margaritifera* and *P. radiata*) represented a major source of income in the RSA. The environmental extremes of the area has limited the distribution of many species, some live as close to their thermal tolerance limits as 1°C during some parts of year. Figure (26) shows the locations of trawling grounds in the inner RSA.

The total marine harvest for this region ranged between 337,000 and 531,000 metric tons during 1985-1993, almost all of the harvest produced from territorial waters. Artisanal fisheries contributed over 79% of the total landings. Figure (27) shows the combined landings from all Member States for the ten year period 1985 - 1994. The overall total landings have shown a downward trend since 1992 when they peaked at 531,445 tons with successive declines in 1993 and 1994, though landings at the end of this decade are still significantly higher than at the beginning 337,300 tons versus 504,300 tons (FAO, 1997).

The landings of invertebrates include mainly shrimps, but also squid, various crabs, abalone and spiny and slipper lobsters have been increasing since 1991 but are still not at levels of 1987 - 1988 when they peaked at 26,081 t in 1989 (Figure 28). This decline is mainly due to decrease in shrimp and to a lesser extent in lobster, landings that has occurred principally in Oman (FAO, 1997).

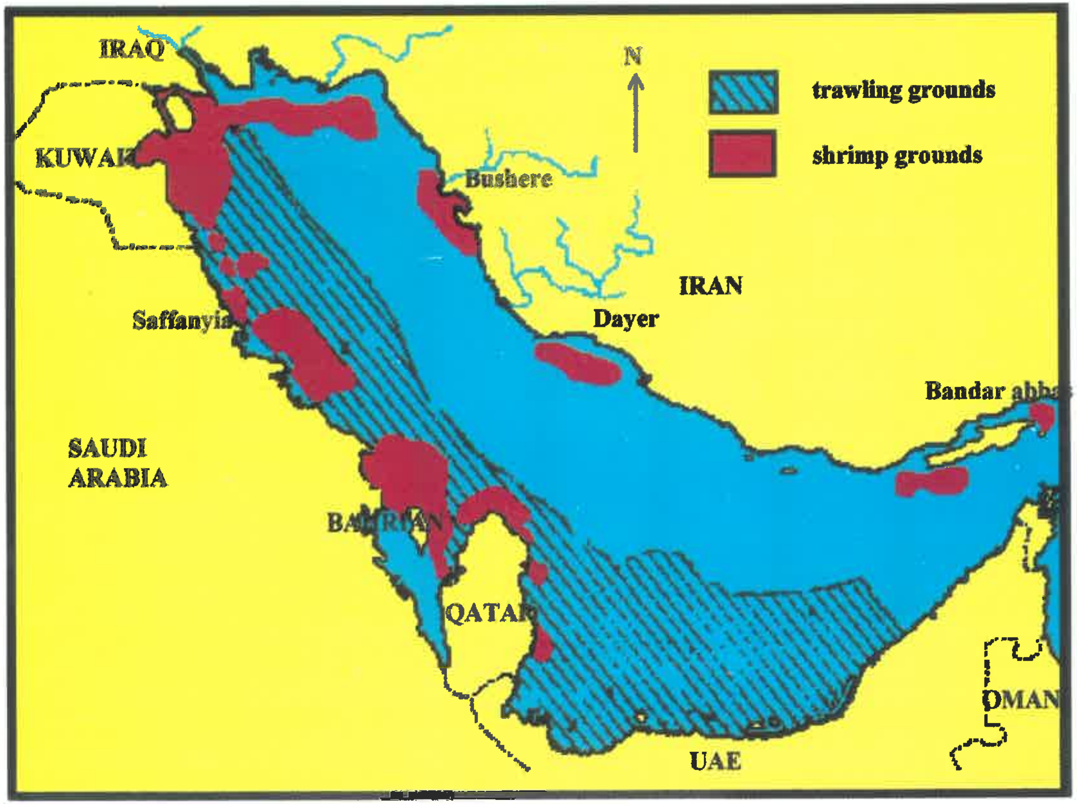


Figure (26): Productive trawling grounds in the southern coasts of RSA (After Sheppared *et al.*, 1993 and Mathews *et al.*, 1993).

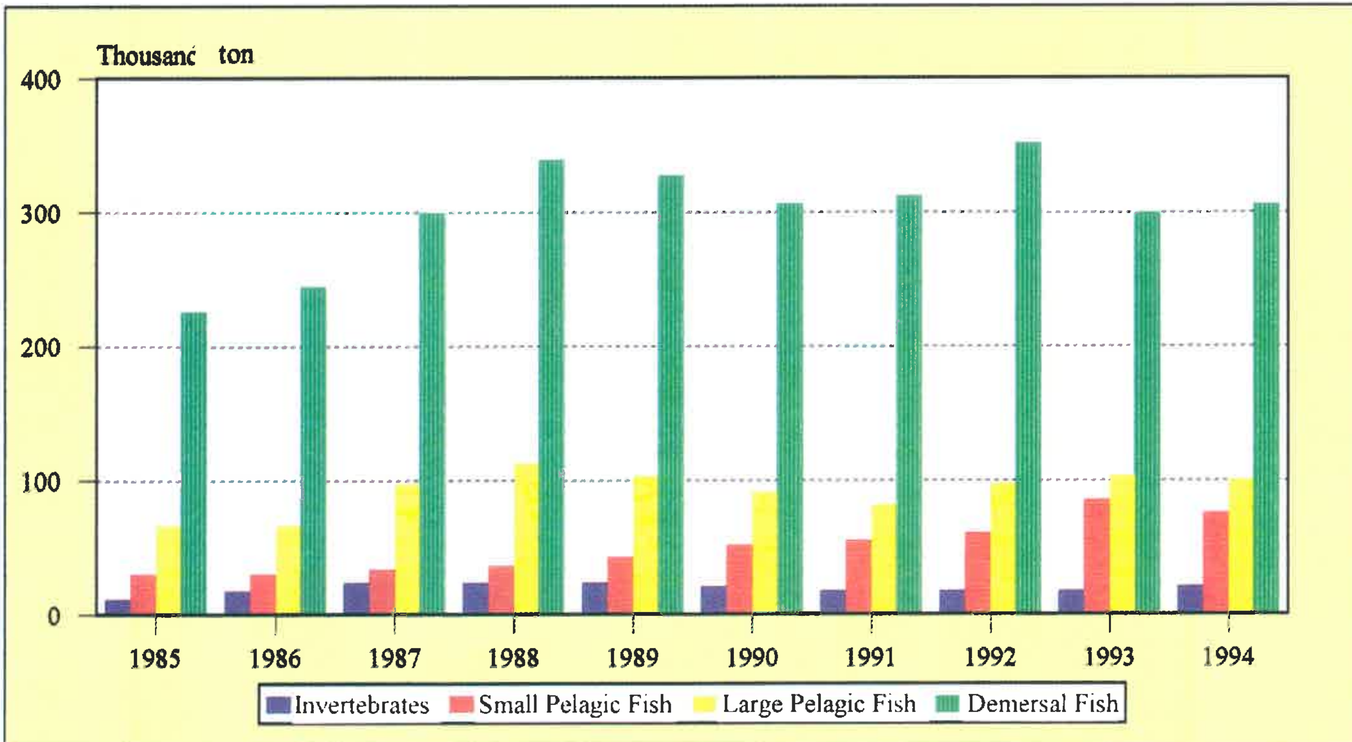


Figure (27): Reported landing (ton) by major fisheries groups, 1985-1994.
(Committee for the development and management of the Fishery Resources of the Gulf, 1997).

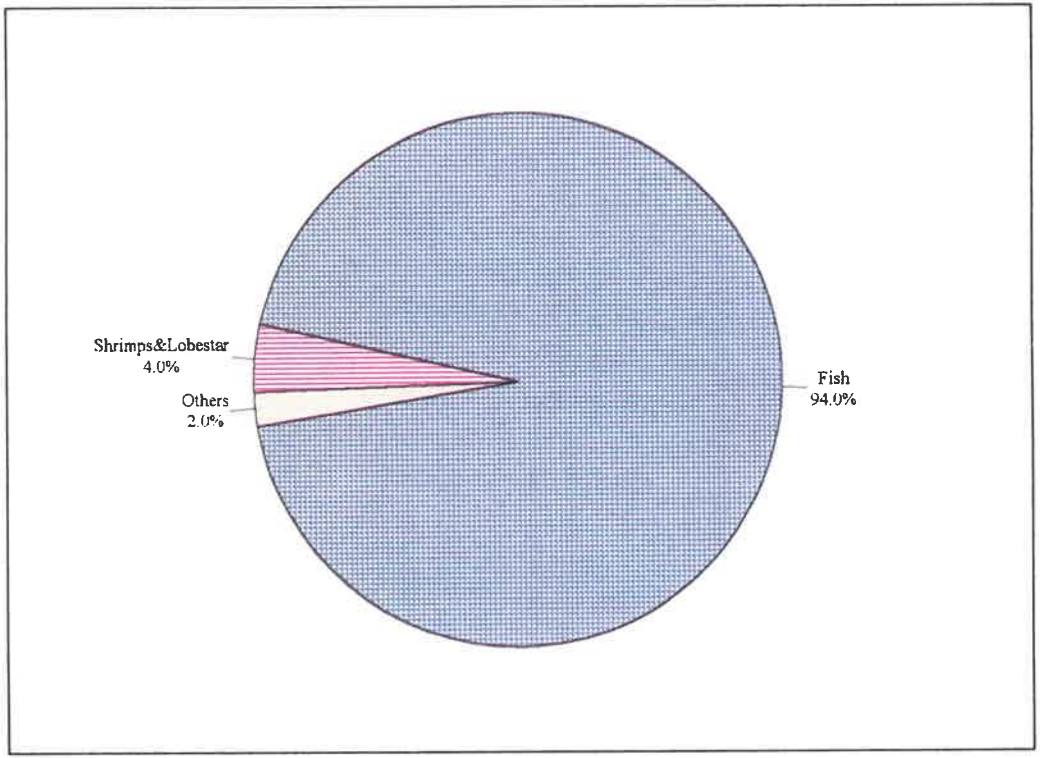


Figure (28): Fisheries of the ROPME Sea Area, 1989.

In general, fisheries of the region are suffering from over exploitation. This is particularly true in the case of the shrimp fisheries. Despite increasing effort, landings in Kuwait and most other state in the Region have remained fairly stable. Recruitment indices show, however, that the stocks have declined since 1965 in Kuwait. Catch rates in Saudi Arabia have also declined in the last year or two in the industrial fisheries. Total landings in Iran have similarly been declining from 1977 to 1984-1985 and are presently less than 5,000 ton. In Bahrain there has been an increase in landing over the last 4-5years, as a result of increased efforts (171 ton in 1979-80; 778 ton in 1984-85 and 1,000 ton in 1987), (FAO, 1997).

Based on the official fishery statistics, the total catch of finfish in the region in 1986 was 230,000 tons. More recent statistics (FAO, 1997) show that the total marine harvest in the ROPME region ranged from 337,000 to 531,000 tons during 1985-1993 with a peak of 531,445 ton in 1992.

Environmental degradation, e.g. from land reclamation has also led to the elimination of nursery areas for shrimps. Furthermore, the reduced rate of outflow from Shatt Al-Arab may have had quite significant negative effects on the reproduction. To these factors could be added the effects of bottom trawling and the destruction it causes to benthic communities. It should also be pointed out that the years of war in the region had contributed significantly to decline of fisheries, particularly in the northwestern part of the region.

Several countries have taken remedial measures to protect the shrimp stocks. These include imposing of a closed season for shrimp fisheries and decreasing of fishing efforts (no new licenses and a limit to the size of the fishing boats).

3.3 Exploitation of Non-Living Marine Resources – Sea Based Industrial Activities

Oil and gas are produced from offshore fields deposits by almost all of the countries of the region. In addition, seawater is extracted for desalination and steam production to generate electricity. Seawater is also used for cooling purposes in large industries, e.g. refineries.

There are approximately 34 offshore gas and oil fields in the region with additional fields waiting exploitation. In all there, are over 800 producing offshore wells with the largest numbers being in Saudi Arabia, Iran and the United Arab Emirates. As many as 50 wells can be drilled from a single platform (Ryan and Brown, 1985). The major hazard of offshore drilling is well blowout. For example, in the three years period between 1980 and 1983 four major spills have been caused by well blowouts (Table 8). The longest recorded blow out in the region is that of Nowruz which not only involved several platforms with multiple wells but also lasted for over a year, spilling more than a million barrels of crude oil into the RSA.

Environmental impacts are possible at all stages of offshore oil industries. During the initial surveys to locate reserves, the explosives used can kill fish, and other seismic survey techniques interfere with commercial fishing. When a field has been identified, assessment of its potential involves exploratory drilling from ships or temporary platforms, which produce the same impact as any large vessel anchored for an extended period. The discharges of drilling mud may cause additional problems. Once the presence of hydrocarbons in commercial quantities has been demonstrated, production facilities are set up. These may involve gravel islands created from dredged material from nearby borrow pits or from onshore gravel deposits, with material trucked to the island site over substantial causeways. Such islands cause multiple impacts both by the associated dredging and dumping and by physical alteration of coastal processes.

The most common method of exploitation is from steel or concrete production platforms, which may weigh many thousands of tons. The impacts of these structures stem partly from operational releases and partly from accidents. To some extent the latter can be avoided by good safety practice. Operational discharges are for the most part regulated by international agreements.

In addition to these environmental effects, off shore oil exploitation has other impacts. The presence of rigs and pipelines creates exclusion zones for fishing vessels and other shipping, while the debris associated with offshore oil operations can damage fishing gear or entangle ships' propellers. Also, offshore wells can be a target for military action, as shown by several events in the RSA, or sabotage, with consequent pollution of the neighbouring waters.

Table (8): Major oil spill incidents due to well blowouts during 1980 –1983[@]

Date	Incident	Source and Location	Cause of Spill	Type of Oil	Volume of Spilled Oil (barrels)
August 1980	Bahrain	Source unknown, possible Juaymah Field, Saudi Arabia 26°57'N 50°50"E	Unknown	Heavy Crude	20,000* - 40,000**
October 1980	Hasbah	Well No.6, Hasbah Field Saudi Arabia	Blowout due to drilling accident	Heavy Crude of 20 API	50,000
January 1983	Nowruz	Eight wells in Nowruz Oil Field, Iran 29°32'42"N 49°29'07"E	Blowout due to military action	Heavy Crude of 20 API	500,000***
Unknown	Khafji	Well K-156I Khafji Oil Field Saudi Arabia	Blowout	Unknown	Unknown

[@]Till August 31, 1983
* Bahrain Oil Company
**Estimated by Lehr and Belen (1983)
*** Estimated as of August 31, 1983
Oil spills resulting from 1991 War are not included.

A newly emerging problem, is the question of decommissioning and disposal of oil installations. In some parts of the world, platforms are reaching the end of their useful lives and decision must now be made on how to deal with them. If left in place they would need highly expensive maintenance but would be non-productive, unless some new use could be found for them. Back in 1983, the total cost of removing all the 445 platforms then existing in the Middle East and the RSA region was estimated at US$ 382 millions (GESAMP, 1990). Guidelines and standards for the removal of offshore structures have been developed by IMO.

In 1993, ROPME Member States have adopted a Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf (ROPME, 1993). The Protocol and its Guidelines aim at controlling the pollution resulting from all types of offshore operations including exploration and exploitation of resources, conduct of seismic operations and the disposal of drill cuttings in the seabed on the continental shelf. With the implementation of this protocol it is expected that damage caused to the marine environment from exploitation of non-living resources will be reduced.

The utilization of seawater for the production of distilled water by desalination is a major industry in the area. The distilled water produced is blended with about 10% brackish water to produce potable water. The amount of water drawn into the plants is about 10 to 12 times the amount produced. The rest is used as cooling water. The effluents are normally 5°C higher than the ambient seawater temperature with an increase in salinity of about 3 psu. The effluents also contain residual chlorine (mainly as brominated, iodated arid chlorinated organic), corrosion products and polyphosphates. The effects of discharged water on the sea area as a whole is probably minor, but the long-term effects in the nearshore shallow areas may be considerable (Ali and Riley, 1984).

The utilization of brines produced by desalination plants to produce chlorine, caustic soda, sodium hydrochloride and sodium chloride by using the mercury cell technique has resulted in the release of large quantities of mercury into the marine environment. However, most such plants have since then been replaced by new ones utilizing the membrane technique.

Other exploited non-living marine resources include gravel and sand. There are no statistics showing quantities of removed material or the impact on the ecosystem but since these materials are taken from coastal areas, damage is likely to result in areas directly and indirectly affected.

3.3.1 Dredging

As mentioned earlier, wide-scale dredging activities are taking place inmost of the coastal areas of the RSA, particularly in countries undertaking land reclamation operations. Regular dredging operations may also be carried out to keep harbours, rivers and other waterways from silting up, or in association with new construction and engineering works offshore.

Uncontaminated dredged material, if properly handled, causes few problems in the long term, and indeed can serve a variety of useful purposes, including land-fill, building of artificial reefs and reclamation of previously damaged coastal sites. If dumped at sea, its physical impact must be taken into account and careful selection and management of the dump sites is important.

About 10% of dredged materials are contaminated from a variety of sources, including shipping, industrial and municipal discharges, and land run-off. Typical contaminants include oil, heavy metals, nutrients and organochlorine compounds. Dumped dredged material has liquid and suspended particulate phases, but the greatest potential for impact generally lies with the settleable or solid-phase material which may affect benthic organisms by smothering and physical disruption of habitats; bioaccumulation and toxicity from both soluble and suspended phases may also occur.

Contaminated dredged material may slowly release its adsorbed burden and result in long-term exposure of local habitats to one or more contaminants. However, laboratory and field studies show that leaching into the water column of chlorinated hydrocarbons, petroleum and metals is slight. Nutrients are released at concentrations much greater than background but mixing processes tend to mitigate effects. The major impact at disposal sites with small current velocity and low wave-energy is the physical mounding of the material. Benthic recolonization of these mounds is relatively rapid on fine-grained sediments and slower on coarse-grained material.

No single method of sea disposal, or category of sea disposal site, is suitable for every type of dredged material or industrial waste. All alternatives need consideration at the planning stage to ensure that the waste has the smallest possible environmental impact (GESAMP, 1990).

3.3.2 Maritime transport

Marine transportation, including tanker operations, other shipping activities and accidental spills from ships accounts for an estimated 46 % of the total input of oil to the world oceans and seas (GESAMP, 1990).

About 50% of the total exports of crude oil in the world originates in the countries around the RSA, Figure (29), it is natural to assume that this involves a heavy traffic of crude oil and product tankers to and from the RSA through the Strait of Hormuz. Import and export movements of general cargo as well as the local traffic have increased. The total vessel movement through the Strait of Hormuz exceeds 10,000 vessels/yr, about 60% of which are oil tankers.

Besides the dirty ballast water, other types of waste are generated by ships. All ships produce bilge water, oil slops from centrifugation of bunker oil, leakages and from washing of engine rooms. These are much smaller amounts, but with a higher content of oil. Ships also produce sewage and garbage as all other households. Table (9) summarizes the quantities of oil that have been discharged in the marine environment in 1981 and 1989 (IMO). Although the total of chronic oil input has reduced, the geographical distribution is not uniform. Figure (30) is an attempt to compare the estimates of oily wastes amount to about 140,000 metric t/yr (or (108 metric t/yr). This is based on 10,200 vessels passing through the Strait of Hormuz annually. Garbage is estimated at 8.3 metric t/yr Abdulraheem (1997). This situation is reflected by the amount of hydrocarbons found in marine sediments, Figure (31) and in the wide distribution of tar balls on beaches (especially in Oman). The average tar concentration collected from three transects near Muscat (Oman) during 1993-95, ranged from zero to over 5 kg/m. The concentrations for samples collected during November 1993 were averaged 10-100 times the concentrations of other periods. This level of tar pollution was among the highest previously measured in the world and is a greater amount than was measured anywhere on the Oman coast a decade ago (Coles and Al-Riyani, 1996).

Table (9) : Total estimated annual quantity of oil (tons) that entered the marine environment (Globally) due to marine transportation activities in 1989 and 1981, respectively.

		1989	1981
Tanker operations			
Crude oil – long haul	45,600		
Crude oil – short haul	20,300		
Product – long haul	20,800		
Product – short haul	71,900		
Sub total :		158,600	700,000
Dry docking		4,000	30,000
Marine terminals and bunkering		30,000	20,000
Bilge and Fuels :			
Machinery & bilges	64,000		
Fuel oil sludge	186,800		
Oily ballast from fuel tanker	1,400		
Sub total :		252,600	300,000
Accidental spills			
Tanker accidents	114,000		
Non-tanker accidents	7,000		
Sub total :		121,000	420,000
Scrapping of ships		2,600	---
Total		568,800	1,470,000

Note : The MARPOL 73/78 Convention regulates the discharge of the ship generated waste. However, in order for ships to deliver their waste adequate reception facilities must be provided.

In a study conducted by ROPME (1986) it was estimated that based on oil production and export figures for 1986 a minimum of approximately 2,900,000 tons of oily wastes comprised of 2,500,000 tons of ballast water and 400,000 of dirty bilge, sludge and slop oil will be dumped into the sea.

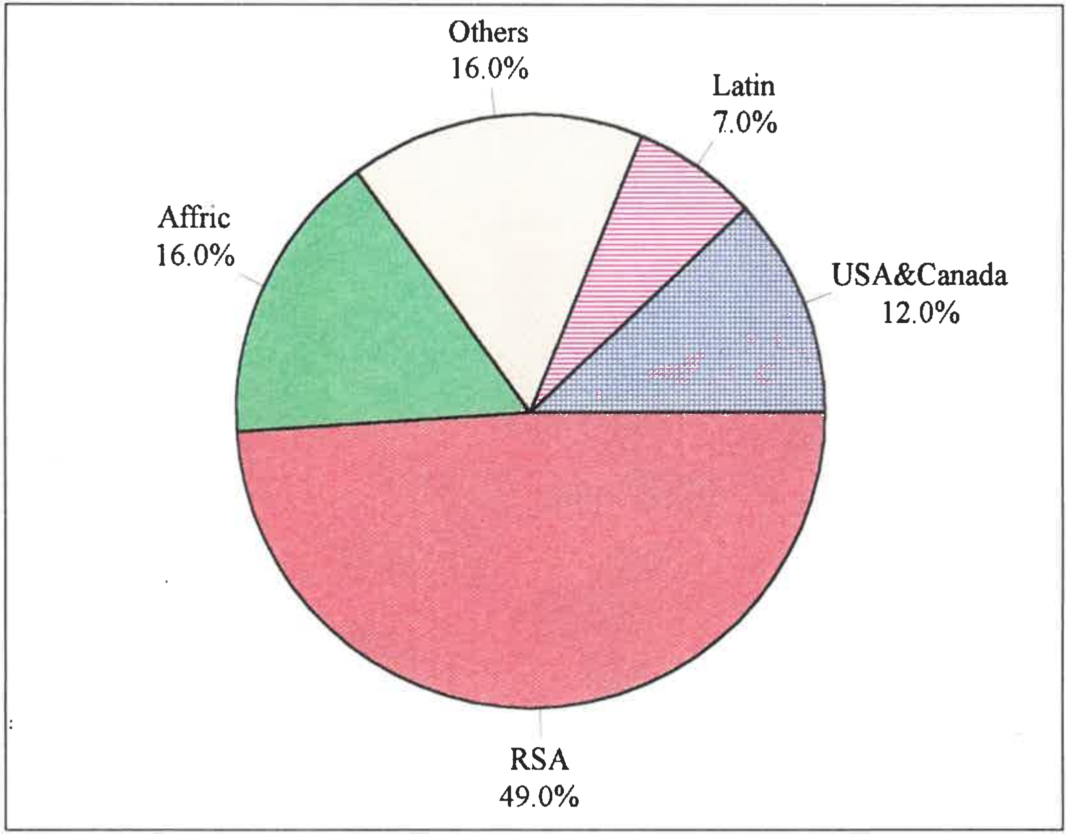


Figure (29): Crude oil export.

Tar washing ashore at Mina Al Fahal lumps in intertidal zone

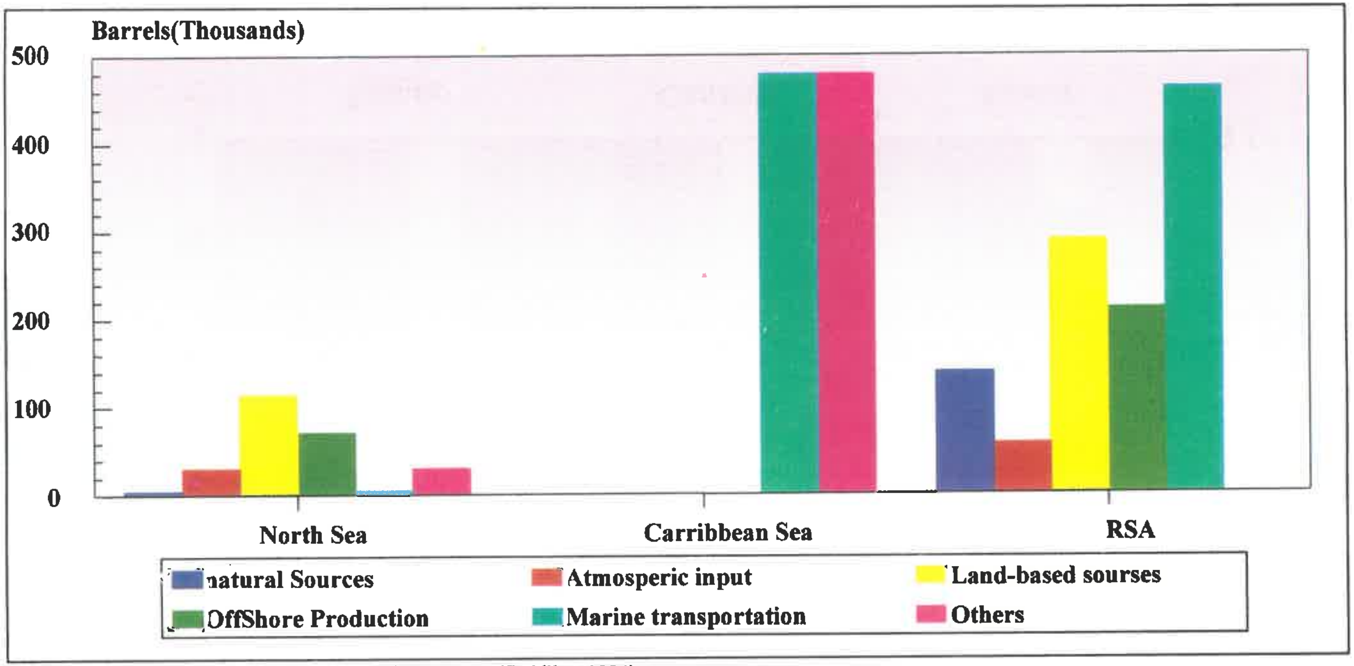


Figure (30): Sources of oil in some Regional Sea Areas (Saddller, 1994).

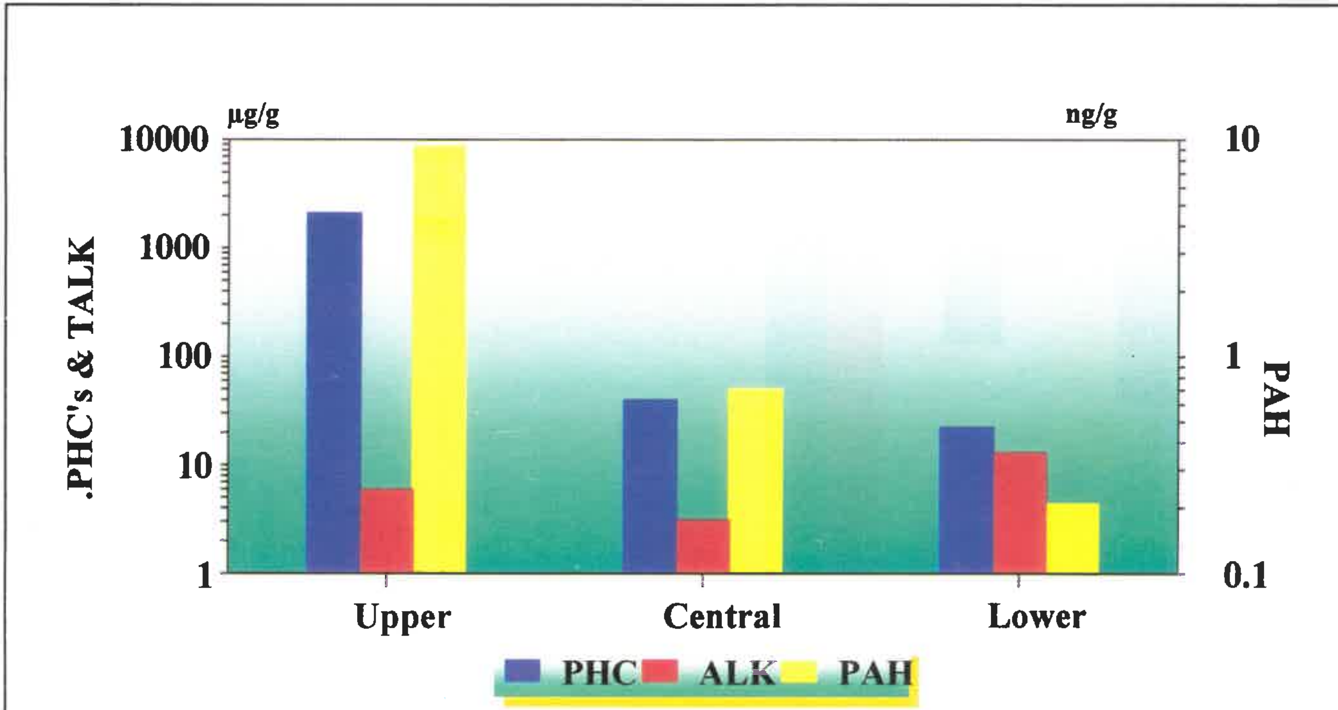


Figure (31): Distribution of hydrocarbons in sediment from RSA (AL-Majed *et.al.*, 1995).

Estimations for maximum quantities are for a total of 7,850,000 tons of oily discharges of which 7,100,000 tons will be ballast water and approximately 750,000 tons will be slop oil, oily bilge and oily sludge. There are no data for transportation of hazardous materials in the regional waters. However, most of these are probably chlorine and ammonia and petroleum products such as kerosene. With the increase in the number of refineries in the region the transport of refined materials will increase thus creating more hazardous conditions and greater potentials for marine pollution in case of spillage (Linden *et al.*, 1990)

3.3.3 Pipeline networks

A large network of thousands of kilometers of pipelines is lying on the bottom of the sea in the region. These pipelines carry oil, gas and production water from the offshore oil wells to shore facilities and terminals. These pipelines and other offshore oil installations make navigation in the Sea Area difficult. Frequently the submerged pipelines are ruptured with resulting leakage of oil or oil products. However, few data is available to evaluate the quantities of oil releases from such accidents, as they are often not reported. The practice of burying pipelines in coastal areas is rarely followed because of the high cost involved. Sediment entrapment techniques around pipelines have also been used to provide protection from anchoring ship and dredging vessels.

CHAPTER 4

MAJOR CONTAMINANTS OF THE MARINE ENVIRONMENTAND THEIR EFFECTS

In their evaluation of land-based activities that impact the marine environment, Regional and international expert have prioritized the following source categories according:

- Oils (hydrocarbons) and combustion products (e.g. PAHs)
- Physical alteration, sediment mobilization and destruction of habitats
- Sewage and nutrients
- Litter
- Atmospheric deposition
- Persistent organic pollutants (POPs)
- Heavy metals
- Radioactive substances

Each of the above source categories was assessed in accordance to its potential impacts, its magnitude or geographic coverage and the availability of the legal, administration and technical capacity for control

Although the principal marine contaminants in the RSA are land-based, offshore oil production operations and shipping activities also contribute significantly to the overall impact of human activities on the marine environment.

4.1 Types, Levels and Distribution in Water, Sediment and Biota

While the source categories are addressed in Chapter (5), this chapter focuses on specific groups of contaminants whose observed levels and distribution in the water column, sediments and biota are being used as indicators of the health of the marine environment. Biological indicators (i.e. population assemblages, diversity indices and other ecological relationships have not been used by government agencies in the Region as part of their marine pollution monitoring programmes.

4.1.1 Trace (Heavy) metals

Trace (Heavy) metals are natural constituents of all environments and are found in seawater, marine organisms and sediments. Therefore, it is essential to know their natural background levels in the marine environment. Trace metals in sediments from different locations in the RSA have been the subject of several investigations. Table (10) summarizes the concentrations of Zn, Pb, Cd, Ni, Mn, Fe, V and Cu in unpolluted marine sediments of different locations in the RSA. The results show significant differences in trace metal values reported for the same area. One of the main factors in this variation is the grain size of the sediments sampled. For example, the values of trace metals in Kuwaiti coastal sediments are much higher than those reported in the nearshore areas of Bahrain and Qatar and U.A.E. All the northern nearshore areas in the RSA such as Kuwaiti, Iraqi and Iranian coastlines are close to the estuaries of the major rivers on Shatt Al-Arab and the northeastern Iranian side. Substantial quantities of trace metals are known to be transported annually by major rivers associated with suspended sediments (Horowitz, 1991).

It is well established that trace metal tend to be concentrated in the finer grain sizes of bottom sediments. Therefore, trace metal concentrations in the fine-grained muddy sediments of the Kuwaiti coasts would be much higher than those in the coarse sandy deposits covering the nearshore areas of Bahrain, Qatar and U.A.E. (Al-Abdali *et al.*, 1996). The average of the trace metals level in nearshore sediments of northeastern Iran, Kuwait (Anderlini *et al.*, 1986) Saudi Arabia (Sadiq and Zaidi, 1985) and Bahrain, Qatar and U.A.E. (Fowler *et al.*, 1993) was calculated by Al-Abdali *et al.* (1996) and compared with their obtained levels of trace metals (Table 10). These computations lead to the following estimates, which may be considered as guidelines for the natural background levels (upper limits) of trace metals in the dry, silt-clay fraction of unpolluted bottom sediments of RSA. Zn: 30-60 µg/g, Pb: 15-30 µg/g, Cd: 12-2.0 µg/g, Ni: 70-80 µg/g, Mn: 300 –600 µg/g, Fe: 10-20 mg/g, V: 20-30 µg/g and Cu: 15-30 µg/g, (Al-Abdali *et al.*, 1996). The reported levels of trace metals in sediment samples collected during the Mt.Mitchell cruise were found to be comparable with the levels reported for sediments collected during the Umitaka-Maru cruises (Al-Majed *et al.*, 1998a). The exception was Cu and V, which could be attributed to the differences in the sampling locations. The concentration of Hg varied between 0.042 – 0.375 µg/g, with an overall mean of 0.169 $\pm$ 0.070 µg/g. The highest Hg concentration (0.375 µg/g) was that reported for the heavy oily contaminated sediments (Al-Majed *et al.*, 1998b).

Table (10) : Mean and range values (in parentheses) of trace metal concentrations (µg/g) in unpolluted marine sediments of different areas in the RSA.

Reference	Zn	Pb	Cd
Kuwait			
Anderlini *et al.*, 1986	55 (30-80)	25 (20-30)	1.25 (0.5-2)
Literathy *et al.*, 1989	60	4.7	0.21
Basaham and Al-Lihaibi, 1993	109 (91-127)	–	–
Saudi Arabia			
Sadiq and Zaidi, 1985	11 (6-16)	1.2 (0.7-1.7)	3.9 (3.2-4.5)
Basaham and Al-Lihaibi, 1993	35.5 (6-65)	–	–
Fowler *et al.*, 1993	6.5 (3-10)	3.05- (1.7-4.4)	0.81 (0.1-0.25)
Northeastern Qatar			
Basaham and Al-Lihaibi, 1993	12.9 (12.2-13.6)	–	–
Qatar/Bahrain			
Basaham and Al-Lihaibi, 1993	26.3 (12.2 - 32.2)	–	–
Bahrain			
Basaham and Al-Lihaibi, 1993	3.1 (2.3-3.8)	12.3 (0.5-24)	0.4 (0.01-0.8)
U.A.E.			
Fowler *et al.*, 1993	2.5 (1.6-3.4)	2.9 (0.5-5.2)	0.96 (0.02-1.9)
Oman			
Fowler *et al.*, 1993	8.8 (7.7 - 9.8)	4.11 (1.2-7.2)	0.38 (0.06-0.7)
[1)]**I.R. Iran** (Northern RSA) (S^2)	(44.4 - 81.5)	–	–
(Ghods Cruise, 1996) (R^3)	(37.4 - 72.8)	–	–
Northeastern Iranian coast*	5.5	25	1.25
ROPME Sea Area			
Al-Abdali *et.al*, 1996 (Mt.Mitchell Cruise)	(0.7-40)	(0.2-64)	(0.4-1.0)
ROPME Sea Area			
Al-Majed *et.al*, 1998 (Umitaka-Maru Cruises)	(4.2-410.3)	(1.0-64.3)	(0.06-0.40)

[1)]Range for three stations at three different depths (10, 30, 50 m)

(S^2)The concentration in ppm for the first upper 1 cm layer

(R^3)The concentration in ppm for the remaining 1-10 cm layer

*TM values are estimated as equivalent to those recorded in Kuwait coastline sediments by Anderlini *et al.*, 1986.

Ni	Mn	Fe (mg/g)	V	Cu
103 (86-120)	450 (300-600	16 (12-20)	40 (30-50)	22.5 (15-30)
115.9	432	–	49	27.5
179.5 (150-209)	745 (550-940)	20 (12-28)	109.5 (85-134)	42 (34-50)
37(24-50)	69.5 (10-129)	–	132.5 (0.9-24)	10.3 (6.8-13.8)
60 (4-116)	140.5 (19-262)	9.8 (0.02-19.5)	25.5 (2-49)	14.5 (2-27)
18 (8-28)	89.5 (39-140)	7.2 (3.4-11)	19 (19)	4.5 (3-6)
5.8 (4.9-6.7)	35 (17.7 - 52.3)	0.006 (0.004-0.007)	3.2 (2.7-3.6)	3.2 (2.7-3.6)
6.5(0.2 - 12.8)	50 (42.8-37.2)	0.008 (0.006-0.01)	4.6 (2.7-7.4)	3.9 (3.8-4)
15 (9-20)	57 (17-97)	4.6 (3.2-6)	23 (9-36.6)	9.6 (1.5-17.6)
18.9 (12.8-25)	237 (231)	4.8 (3.6-6)	20.7 (7.3-36)	4.2 (1.3-7.0)
26 (9.9-46)	200 (89-310)	8 (5.0-11)	29.2 (10.4-48)	7.90 (1.7-14)
(66.9 - 137.9)	(222.8 - 690.7)	(1.07 - 3.23)	–	(23.1 - 39.4)
(56.7 - 145.6)	(217.7 - 640.0)	(1.31 - 3.32)	–	(21.7 - 35.4)
103	450	16	40	22.5
(2.3-89)	(17-405)	(0.90-26.0)	(2.6-41.5)	(0.2-18.0)
(1.9-109.2)	(8.9-517.0)	(1.4-34.5)	(1.4-99.9)	(2.3-142.0)

Some data on the levels of heavy metals in fish and bivalves from the area are shown in Table (11). Comparison of levels in bivalves taken from different areas may be difficult since sometimes different species were sampled at different times of the year. Information on sex, size, weight, stages of development are often lacking. In general, increased levels of Pb, Hg and Cu have been found in areas influenced by port activities and heavy industry. In rock and pearl oysters in Bahrain increased concentrations of Pb were noted in an area affected by effluents from a refinery (Linden, 1982). In samples of rock oyster from Oman, Fowler (1985) reported a more or less consistent decrease in the Cu concentrations in station from north to south along the coast. This was probably related to higher anthropogenic input in the more industrialized north. The levels of Cd in pearl oysters from Um Al Quwan, U.A.E. (11-34 µg/g) and in mussels from Raysut Head, Oman (16-26 µg/g) reported by Fowler (1985) also appear to be slightly elevated. Increased concentrations of V were found in bivalves from northeast Bahrain and from Jebel Ali, U.A.E. and Kuwait Bay (Linden, 1982; Fowler, 1985; EPD, 1986). High levels of vanadium may be related to oil contamination in the area.

As a part of Umitaka-Maru cruises in RSA, Al-Majed *et al.*, (1998c) reported the following levels for trace metals in different fish species based on dry weight: Cd: 0.01–0.28 µg/g, Pb: 0.46–2.67 µg/g, Cu: 0.83–18.14 µg/g, Ni: 0.05–6.07 µg/g, Zn: 11.88–67.30 µg/g, V: 0.05–0.4 µg/g, Mn: 0.05–3.03 µg/g and Fe: 0.05–57.45 µg/g. The obtained levels of trace metals may not pose serious consequences to human health.

The levels of Hg varied between 0.250 –3.201 µg/g with a mean of 0.8 $\pm$ 0.52 µg/g. The organic mercury MeHg varied between 0.144 – 2.944 µg/g with a mean of 0.760 $\pm$ 0.540 µg/g. The levels of organic mercury were linearly correlated with the inorganic mercury (Al-Majed *et al.*, 1998b).

4.1.2 Oil and petroleum hydrocarbons

Petroleum hydrocarbon (PHCs) concentration in seawater in the northwestern region have been reported to be in the range of 0.10-0.33 µg/l (EPD, 1986). Another study reported the concentration level at the surface,

Table (11) : The range of trace metals in biota from RSA (µg/g dry weight)

Area	Sample type	Hg (7)	Cd	Cu	Pb	V	Remarks
Bahrain	Bivalves	0.1-0.18	3.3-4.2	3.9-16.4	1.0-4.5	1.7-6.6	1), 3), 4)
Bahrain	Bivalves	0.009-0.1	1.5-5.0	3.0-37.5	1.0-30.0	0.6-95.0	2), 3), 4), 5) 6)
Bahrain	Fish	0.135-0.397					1)
Bahrain	Fish	0.004-1.07	0.0003-0.071	0.1-0.47	0.1-0.03	0.1-0.7	8)
Kuwait	Clams	0.023-0.2	0.2-0.5	4.9-11.4	0.7-3.4	0.2-3.4	9)
U.A.E.	Bivalves	0.015-0.041	2.6-34.2	3.0-9.7	0.39-0.9	1.6-25.0	1), 4)
U.A.E.	Fish	0.055-0.332					1)
Oman	Bivalves	0.023-0.226	6.2-25.5	7.0-265	0.3-3.5	1.1-4.7	1), 5)
Oman	Fish	0.06-0.213					1)
Kuwait	Clams	0.02-0.20	0.1-0.9	11.8-18.0	2.2-3.6	1.2-3.5	10)
Iraq	Clams	0.3-1.0 0-0.6					11)

1) Fowler (1985); 2) Linden (1982); 3) Rock Scallops; 4) Pearl Oyster; 5) Rock Oyster; 6) Mussel;
7) Hg-values in wet weight; 8) Linden, (1990); 9) EPD (1986); 10) Literathy *et al.*, 1986;11) MSC (1986)

at ten meters depth and at the bottom to be in the range of 0.7-4.6, 0.7-7.71 and 1.1-4.8 µg/l respectively (Literathy *et al.*, 1986). From the western-central region PHCs concentrations in seawater were reported in the range of 0.12-1.4 µg/l (KFUPM/RI, 1987), while the corresponding figures from the southwestern region were in the range of 0.48-16.8 µg/l (Fowler, 1985).

The concentrations of PHCs in sediments starting at north-western region passing through the western-central region to south-western region were 0.3-310, 0.5-816, 0.1-119 µg/g dry weight respectively (Burns *et al.*, 1982; Douabul *et al.*, 1984; Zarba *et al.*, 1985; Fowler, 1985; Literathy *et al.*, 1986; EPD, 1986) (Table 12)

Table (12) : Levels of petroleum hydrocarbons in sediments from the RSA (in µg/g dry weight)

Area	Concentration ranges	Reference
Iraq	0.4 - 44.0	Douabul *et al.*, 1984
Iraq	3.3 - 9.3	MSC (1986)
Kuwait	2.0 – 310.0	Zarba *et al.*, 1985
Bahrain *	6.3 – 950.0	Linden, 1982
Kuwait	13.7 – 375.0	Literathy *et al.*, 1986
Kuwait	0.3 – 80.0	EPD, 1986
Bahrain	0.5 – 8.6	Fowler, 1985
U.A.E.	0.1 – 14.7	Fowler, 1985
Oman	0.1 – 119.0	Fowler, 1985
Oman	0.8 – 19.0	Burns *et al.*, 1982

*Values were obtained using GC technique.

The lower concentrations represent background levels while the upper range shows concentrations in areas under direct influence of petroleum input. Concentration levels of up to 3.950 µg/g dry weight have been reported from more industrialized parts of the west-central region (Linden, 1982).

Different species of bivalves have been analyzed for PHCs (Table 13). The concentrations found are sometimes rather high, although such organisms have usually been collected in areas close to industrial outlets or other point sources of PHCs. However, direct comparison of the results from different locations is difficult, as different species have been collected and the analytical techniques may have varied considerably between different laboratories.

Table (13) : Levels of petroleum hydrocarbons in bivalves from the RSA (µg/g dry weight)

Area	Species	Conc. (range)	Technique	Reference
Bukha, Oman	Rock Oyster	40 – 558	GC, p-fraction	Badawy *et al.*, 1985
Al-Qurum, Oman	Rock Oyster	6.5 – 85	GC, p-fraction	Badawy *et al.*, 1985
Masirah, Oman	Rock Oyster	5 – 354	GC, p-fraction	Badawy *et al.*, 1985
Al Zallaq, Bahrain	Pearl Oyster	13 – 19	Fluorescence P+a fraction	Fowler, 1985
Askar, Bahrain	Rock Scallop	41.8 – 84	Fluorescence P+a fraction	Fowler, 1985
U.A.E (3 areas)	Pearl Oyster	7.2 –29.7	Fluorescence p-fraction	Fowler, 1985
Bahrain (6 areas)	Pearl + Rock Oyster	28 – 220	GC, p-fraction	Linden, 1982
Kuwait (6 areas)	Pearl Oyster	39 - 348	GC, p-fraction	Anderlini *et al.*, 1981
Saudi Arabia (12 Stations)	Clam (1)	1-21	GC, p-fraction	KFUPM/RI, 1987
Kuwait	Clam (2)	0 – 683.3	Fluorescence	Literathy *et al.*, 1986
Kuwait	Clam (2)	7.2 – 91	Fluorescence	EPD, 1986
Iraq	Bivalve (3)	7 –35	Fluorescence	MSC, 1986

Note: (1) *Meritrix meritrix*; (2) *Cercinata callipyga*; (3) *Corbicul fluminea*

Investigations of the impact of the 1991 war oil spill was carried out during the R/V Mt. Mitchell cruise in the RSA, paying particular attention to PHCs concentrations in the surface sediment of RSA as an indicator of such impact. Abdali *et al.* (1993) showed that the high values of total petroleum hydrocarbons (TPHs) in both sandy and muddy sediments from the open sea stations 24-88 µg/g and 266-1448 µg/g, respectively, are significant and could be an indicator of the impact of the 1991 oil spill. In the mean time, previously studies offshore areas, showing PHCs levels in the range of 0.1-1.5 µg/g (Fowler, 1985), have showed higher values when revisited in 1992. PHCs levels ranged from 10-20 µg/g in the offshore stations and up to 50 µg/g were reported in the nearshore stations (Literathy *et al.*, 1992). Moreover, a comparison of total organic carbon percentage (TOC%) of three periods presents another indication of the 1991oil spill. The recent values of (0.46-2.8%) are higher than those of the 1989 samples (0.5-0.8%) as reported by Literathy *et al.* (1992) and the 1982 samples (0.4-1.0%) as reported by Khalaf *et al.* (1982).

The same data was used to demonstrate the spatial distribution of oil hydrocarbon concentrations in sediments along the axis of the RSA, Figure (32). Furthermore, Abdali *et al.* (1993) reported an average of total petroleum hydrocarbons concentration in sediments of the RSA 54.25 ± 58.092 µg/g dry weight for the top 2 cm sediments. The remaining of the 15 cm column taken had an average of 212.45 ± 396.68 µg/g dry weight.

Halogenated hydrocarbons that may be of interest in the marine environment include halogenated methanes, mainly bromoform which have been determined in the vicinity of power/desalination plants. Levels ranging from 10-90 µg/l were measured near the outfalls (Ali and Riley, 1986). Low concentrations could be traced over a much larger area. The significance of bromoform in the environment may attributed to the sensitivity of embryonic and larval stages of marine organisms and to the possibility of mimicking hormones released by marine organisms and thus interfere with the chemical communication system of these organisms causing disruption of their life cycle.

4.1.3 Nutrients

As stated earlier domestic sewage discharges is considered one of the main land-based sources of pollution in the RSA. Nevertheless, limited scientific data is available on the contamination by nutrients in the RSA. However, signs of eutrophication close to some industrialized areas (e.g., methanol/ammonia plants) are common (Linden, *et al.*, 1990) where dense

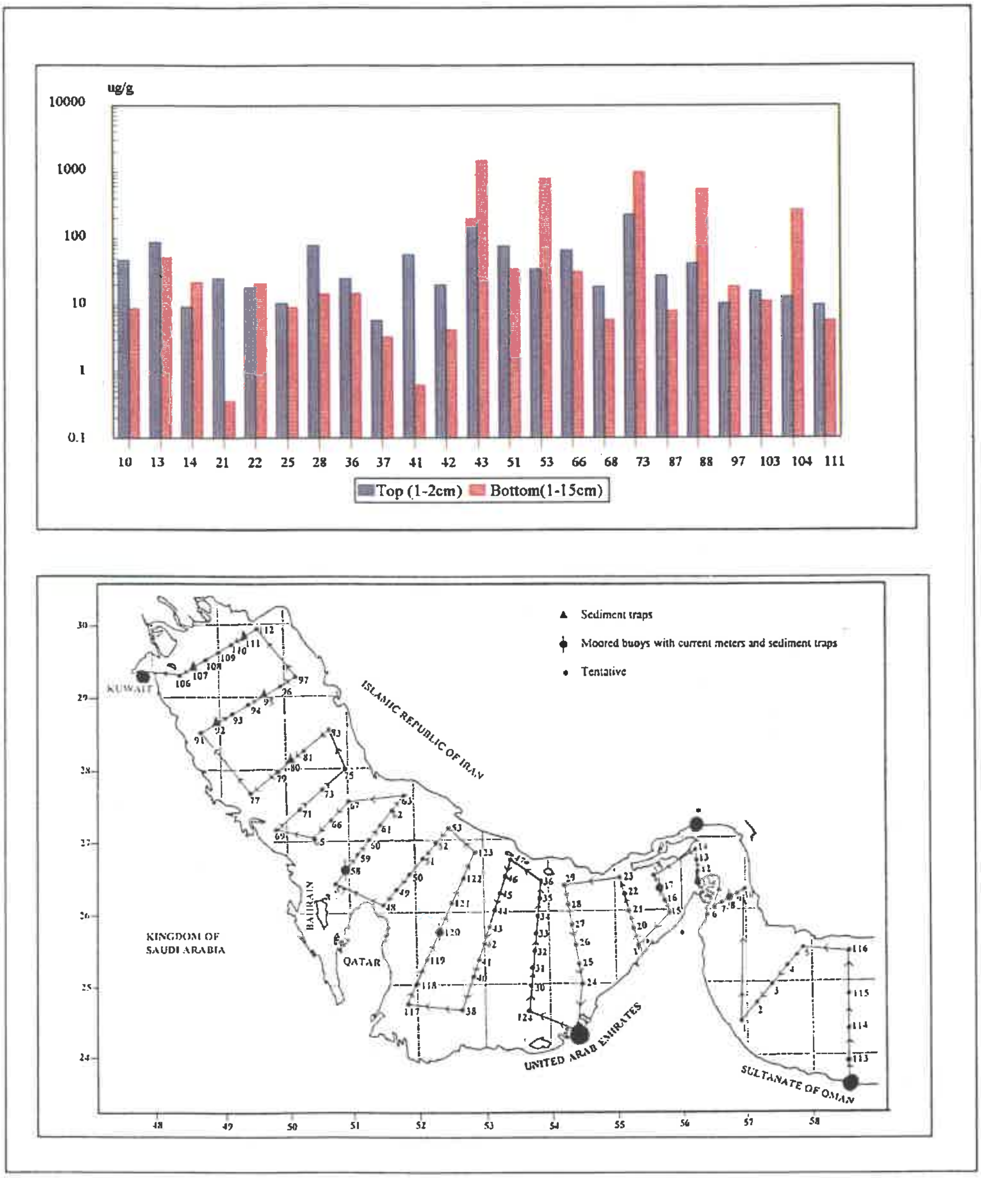


Figure (32): Levels of TPHs in top and bottom sediments collected from RSA (Al-Abdali *et al.*,1993).

mats of filamentous green algae in the intertidal zone are obvious signs of organic pollution and increased levels of nutrients in the water. Moreover, the increase in numbers and production capacity of fertilizers for plants, and detergents manufacturing also warrants a careful consideration of the input of nutrients into the RSA (ROPME, 1995).

So far, there is not yet an inventory of significant marine areas in the region where nutrient inputs are causing or likely to cause pollution directly or indirectly. However, concentrations of dissolved inorganic nitrogen (probably the nutrient of most concern) show the highest values in the northeastern region of the RSA. These are likely to be primarily related to river discharges. The relatively sparse temporal data on nutrient levels in coastal waters suggest that nitrogen loading is increasing in some inshore areas. Some unusual levels of ammonia and nitrate reported for such areas have no clear explanation in terms of anthropogenic or other potential sources.

It should be noted that the levels of nutrients are in many cases lower than in other coastal areas, but in the low energy and shallow bays and intertidal areas, the intensive heat of the summer months reduces the oxygen content for the point where relatively low levels of nutrients are enough to produce anoxic conditions

Future efforts to study impact of nutrients to the marine environment should be confined to inshore areas receiving treated domestic or other waste discharges likely to contain substantial amounts of nutrients. Efforts should be made to examine temporal variability in the context of primary productivity seasonality in the region with greatest emphasis on the regions in the vicinity of discharges from the major rivers entering the RSA.

4.1.4 Litter

Litter is an increasing problem in the RSA from mainland, shores and ships. It is estimated that 1.2 - 2.6 kg/person/day of plastic waste is generated on ships, much of which is thrown overboard (Anbar, 1996).

The ROPME's shallow coastal areas are now being used as repositories for large quantities of industrial, commercial and residential trash and other solid waste. Often this takes the form of plastics, metal containers, wood, tyres and even-entire scrapped automobiles at some localities. Oil sludge constitutes, in terms of quantity, of the most important type solid waste (Linden *et al.*, 1990). Much of the lighter debris has become spread along widespread tracts of shoreline through wind and water movements

Littering of the shoreline is a very obvious sign of environmental deterioration in many parts of the region. Particularly near more densely populated areas this has rendered many beaches unsuitable for recreation. The litter has probably in most cases been left there by visitors. Even in very remote areas, the beaches found to be severely contaminated by litter, probably transferred by the sea to the beaches.

Data on solid waste loads from industrial, domestic and other sources in the region are very limited and need to be collected, analyzed and compared with data from other regional sea areas.

4.1.5 Persistent Organic Pollutants (POPs)

Persistent organic pollutants (POPs) are organic compounds of natural or anthropogenic origin that resist photolytic, chemical and biological degradation. They are characterized by low water solubility and high lipid solubility, resulting in bioaccumulation in fatty tissues of living organisms. POPs are semi-volatile and, therefore, able to move long distances in the atmosphere, and are also transported in the environment in low concentrations by movement of fresh and marine waters, resulting in wide-spread distribution across the earth, including regions where they have never been used. Thus, both humans and environmental organisms are exposed to POPs around the world, in many cases for extended periods of time.

Over the past several years, the risks posed by POPs have become of increasing concern to many countries. This result in actions to protect human health and the environment being taken or proposed at the national level, the regional level and, more recently, in international initiatives, such as the Global Programme of Action for the Protection of the Marine Environment from land-based activities.

Examples of POPs include: many persistent pesticides (e.g., dieldrin, DDT, toxaphene, chlordane), several industrial compounds (e.g., polychlorinated biphenyl (PCBs), chloroparaffins) and some degradation, industrial and combustion by-products [e.g., PAH, polychlorinated dibenzofurans (PCDFs), and hexachlorobenzene (HCB)].

POPs emissions originate almost exclusively from anthropogenic activities associated with the manufacture and use of certain organic chemicals, with some melting and refining processes, with some chlorine-based pulp and paper manufacturing, with leaks, spills and dumping of these materials, with the combustion of both fuels and wastes and with the application of pesticides.

The PAHs are a major group of POPs and benzo(a)pyrene (BaP) is commonly used as an indicator of presence and carcinogenicity of PAH in air (Figure 33). PAHs are generated from incomplete combustion of organic matter, particularly fossil fuels. Anthropogenic high temperature processes are the major sources and involve a wide range of applications.

Assessment of chlorinated hydrocarbons in sediment and biota from the region has been reported by Linden (1982), Badawy *et al.* (1985), Fowler (1985), EPD (1985) and Literathy *et al.* (1985). In general the data indicates relatively low levels of contamination by these compounds compared to other regional seas. Levels of aldrin, lindane, dieldrin and DDT in sediments from the northwestern part of the region were all below 1 ng/g (Literathy *et al.*, 1986). The levels of PCB's in the northwestern part of the region were generally below 5 ng/g (Literathy *et al.*, 1986). Levels comparable to these ranges have been reported for Bahrain, Qatar, U.A.E. and Oman (Fowler, 1985). The levels of DDT ranged from 1 -11 ng/g in fish from the northwestern part of the region. Endrin levels ranged from 1-7 ng/g in most fish samples but reached 45 ng/g in few cases (Douabul *et al.*, 1987). DDT levels in clams from Kuwait ranged from 8.8-88 ng/g whereas dieldrin values ranged from 2.2-36 ng/g and other compounds were below 1 ng/g (Literathy *et al.*, 1986). Concentrations of DDT with metabolites in bivalves ranged from below the detection limit upto 30 ng/g in oysters from Abu Dhabi (Fowler, 1985). Levels of aldrin, DDD, DDE, DDT, dieldrin, endrin and lindane were generally below 5 ng/g in the tissues of clams collected from the west-central coastline, except for a station near a landfill where relatively higher values were obtained (KFUPM/RI, 1987)

Other halogenated hydrocarbons that may be of interest including halogenated methanes, mainly bromoform which have been determined in the vicinity of power/ desalination plants. Levels ranging from 10-90 μg/l were measured near out-falls (Ali and Riley, 1986). Low concentrations could be traced over a much larder area.

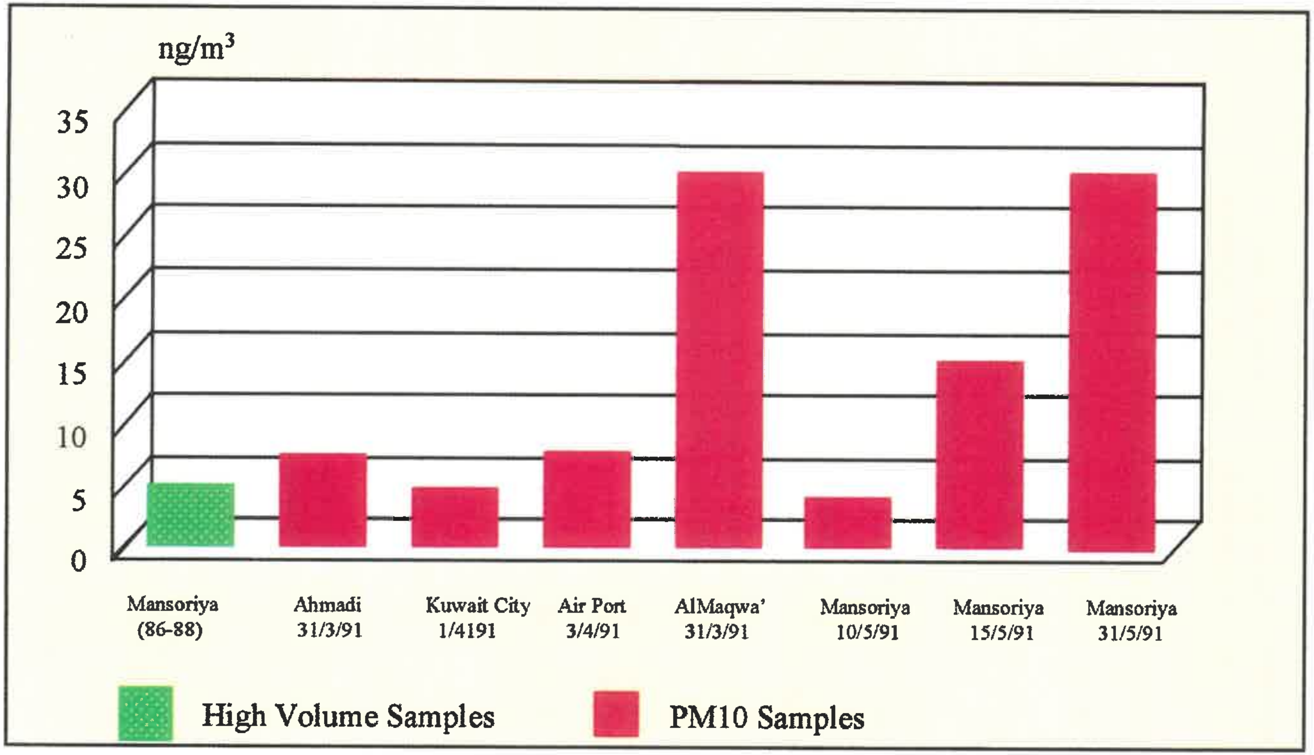


Figure (31): Benzo(a)pyrene levels (ng/m^3) in particulate matter before and after Gulf War, Kuwait (LHVP, 1991;Al-Majed *et al.*, 1991)

In order to develop quantitative data on the production, use and environmental distribution of POPs in the marine environment of RSA, ROPME Secretariat is to carry-out a Pilot Study with a view to determine types and amounts of POPs manufactured or used in the Region and to assess the significance of their presence in the marine environment.

The main objectives of the Pilot Study are to:

- Carry out surveys of Land Based Activities/Sources in RSA.

- Identify POPs more specific to the RSA .

- Compile information on production and use of POPs by various sectors.

- Assess the amount of POPs unintentionally produced by different sectors.

- Assess inputs of POPs into the marine environment from different point and diffuse sources.

- Carry out training workshops on sampling and analyses of POPs, including a Quality Assurance Component.

- Assess the spatial and temporal distribution of POPs in the ROPME Sea Area.

- Assess capabilities and constraints for compliance and trend monitoring of POPs.

- Review existing national policies, strategies, programmes and measures for the reduction and/or elimination of emissions and discharges of POPs.

- Prepare a Regional Plan of Action for the reduction and/or elimination of emissions and discharges of POPs, as well as for the regional monitoring programme.

- Propose elements for a National Plan of Action to reduce and/or eliminate POPs emissions and discharges, as well as to provide for national monitoring programme.

4.1.6 Radioactive substances

Radioactive substances (i.e., materials containing radio-nuclides) have entered and/or are entering the marine and coastal environment, directly or indirectly, as a result of a variety of human activities and practices. These activities include production of energy, reprocessing of spent fuel, military operations, nuclear testing, medical applications, etc. Other activities such as the transport of radioactive material pose risks of such releases. Radioactive materials can present hazards to human health and to the environment. Suspected radioactive contamination of foodstuffs can also have negative effects on marketing of such foodstuff.

Because of the limited activities involving the use and release of radio-nuclides in the RSA, low priority has been assigned to radioactive substances. However, some Member States have regulations concerning management of hazardous materials (including radioactive substances). These regulations include transport, storage, use and disposal of hazardous wastes. Nevertheless, the use of radio-isotopes in various activities warrant some attention to releases of radio nuclides from such anthropogenic sources.

As the offshore drilling activities expand in the Region, concern over disposal of material in the associated waters in the marine environment is also growing.

4.2 The Contaminant Screening

Under the ROPME-IAEA Contaminant Screening Project, an initial survey of contaminants took place in Kuwait, Bahrain and U.A.E. in June 1994. As an extension of this project samples have been collected from the both sides of the Strait of Hormuz, the central and NW part of the inner RSA in 1997. Duplicate samples were collected in cooperation with IAEA-Monaco in order to allow for better transparency and exchange of results with the national laboratories concerned. The sampling locations are shown in Figure (34).

The results of the survey project indicate that relatively high concentrations of petroleum hydrocarbons are recorded in some of the locations in Kuwait, probably showing the effects of war. Samples from U.A.E. are

Figure (34): Sediment and biota samples collected for the Contaminant Screening Project (ROPME, 1998).

comparatively uncontaminated with the exception of Bidya, which was exposed to an oil spill in 1993 where both sediments and biota were contaminated. Of the Bahrain samples, Jasra was relatively more contaminated whereas at Askar relatively high levels of PAHs were encountered.

In general, the results of the survey show that river discharges and highly industrialized areas have the highest levels of contaminants. For example, Khor Bubiyan (Kuwait) and Abadan (I.R. Iran) show contamination with degraded as well as fresh oil. PAHs were reported in sediment from Abadan and Qatar. However, fish sampled in the survey contained low levels of PAHs.

Sterol analyses, which are used as an indication of contamination with sewage, were found in Kuwait Bay, Jasra (Bahrain), Abadan and Qatar.

The levels of organochlorine compounds (OC) in sediments and biota from Kuwait, Bahrain and U.A.E. were found to be within the levels reported early 1980s for the region. The exception is Kuwait Bay where PCBs and DDE (OC) were found, suggesting linkage to flow from Shatt Al-Arab which has relatively high content of OC residues, although still below levels that would cause concern.

Trace element levels (e.g. Hg, Cu, Zn and Pb) tend to be generally higher in sediments collected around industrial areas and also around river out-falls such as Abadan, Askar and Kuwait Bay. However, the results of Hg analyses in biota were still around the values obtained in the 1985 - 1986 surveys.

Chapter 5

Major Accidents and Natural Episodic Events

5.1 Oil Spills and Tanker Accidents

The RSA has always been under potential threat of oil pollution by virtue of handling massive quantities of oil within its waters, be it during exploration or transportation by sea.

Examination of the data in the annual statistical reviews of British Petroleum (BP) indicates that more than 50% of the global marine transport of oil was shipped from the ROPME Member States between 1973 and 1980. Between 1981 and 1987 the marine transport decreased substantially (annual average 42%) due to the protracted Iran-Iraq war. Thirty-nine confirmed incidents of oil pollution, out of a total of 422 reported from May 1981 to June 1987 in the RSA (Sen Gupta *et al.*, 1993). The incidents varied from sighting of oil sheen to oil well blowouts. The volume varied from a trickle to 500,000 barrels (68,000 t) reported from the Nowruz oil well blow out due to military action during the Iran-Iraq war in 1980-1988 (Linden *et al.*, 1990).

The massive oil spill of 1991 war, where as much as 10 millions of barrels of oil were released from oil terminals in Kuwait and Iraq or spilled from sunken vessels into the marine environment of the RSA, is by far the largest in the history. The adverse effects and vast environmental damage resulting from this spill are now well documented.

Tanker accidents also represent a major source of oil spills. Golob and Brus (1984) estimated that 57% of oil spills result from tanker transport accidents. Fortunately, for many years, the RSA has been saved from major accidents involving super tankers. However, few incidents resulting oil spills of varied magnitudes have taken place between 1996 and 1998 as shown in Table (14). These incidents resulted in a total of 16,400 metric tons of oil spilled in the marine environment as a result of using substandard barges in transporting oil across the RSA (MEMAC, 1998).

Table (14) : Total amount of oil spilled in RSA*

Date of Incident	Type	Type of Incident	Location	Type of Oil	Amount Spilled	
					Metric tons	US Gallons
15.6.1996	Barge	Sank	29° 08.5'N, 049° 15'.7E	Gas Oil	600	176,470.58
30.3.1997	Barge	Capsized	26° 50'N, 050° 47'.5E close to Bahrain	Gas Oil	2100	617,647.05
11.7.1997	Barge	Collision to Breakwater	Sharjah Breakwater	Diesel Oil	5000	1,470,588.20
7.1.1998	Barge	Partly sank	25° 30'N, 055° 23'.4E Ajman Coast	Mix of refined black oil	6000	1,764,705.80
15.1.1998	Barge	Partly Sank	27° 36'N, 051° 26'.2E Ras Al Motaf, I.R. Iran	Refined fuel oil	2000	588,235.29
14.2.1998	Coastal Tanker	Sank	25° 56'.2N, 055° 21'.5E 23' East of Abu Musa Island	Gas oil	700	205,882.35
5.3.1998	Coastal Tanker	Leakage	26° 37'N, 050° 57'E Close to Bahrain	Refined black oil	Few Gallons	Few Gallons
				Total Spilled	16,400	4,823,529.27

*Period June 1996 - June 1998
All figures given to the very best estimation and specific gravity for conversion to US Gallon used 0.0034
(MEMAC, 1998)

Evidently, oil spills of appreciable magnitude would require immediate action on the part of the State concerned. In case of a major oil spill, the resources of a single State may not prove to be sufficient to handle the situation alone. It will therefore require increased regional cooperation to maximize the utilization of resources that can be made available in the region under an effective regional response to such emergencies. With the absence of regional oil spill contingency plane that threat of a major oil spill overwhelming the limited resources of any State remains of a high probability. Moreover, without reception facilities adequate to receive wastes of tankers, a port state control scheme and a legal system that provide a deterrent against oil pollution, the input of oil wastes and other wastes into the RSA well continue.

5.2 Mass Mortalities of Marine Organisms

In recent years there has been an increasing number of unusual environmental events in marine ecosystems. These have included a number of large-scale disease events and die-off of a variety of marine and coastal organisms, including marine mammals, fish, reptiles and birds, and the apparently unprecedented occurrence and proliferation of certain algal species (ROPME, 1997).

These repeated mass mortality or fish kill phenomenon has always caused economic losses in the fisheries sector and anxiety among fish consumers in the affected State or States in the region, and hence became a serious environmental problem in RSA.

Marine mortality often coincide and appear to be correlated with a variety of environmental factors. These factors have included high levels of anthropogenic contaminants in the affected ecosystems or in the tissues of the affected organisms, unseasonably warm temperatures, novel disease agents, biotoxins and changes in food supply.

<u>Some recorded events of marine mortalities in RSA</u>

1. In 1986, during the period between 23 August and 30 October, dolphins, dugongs, fishes and turtles were found dead on the western and eastern shores of RSA. Figure (35) illustrates the locations of the heaviest mortality

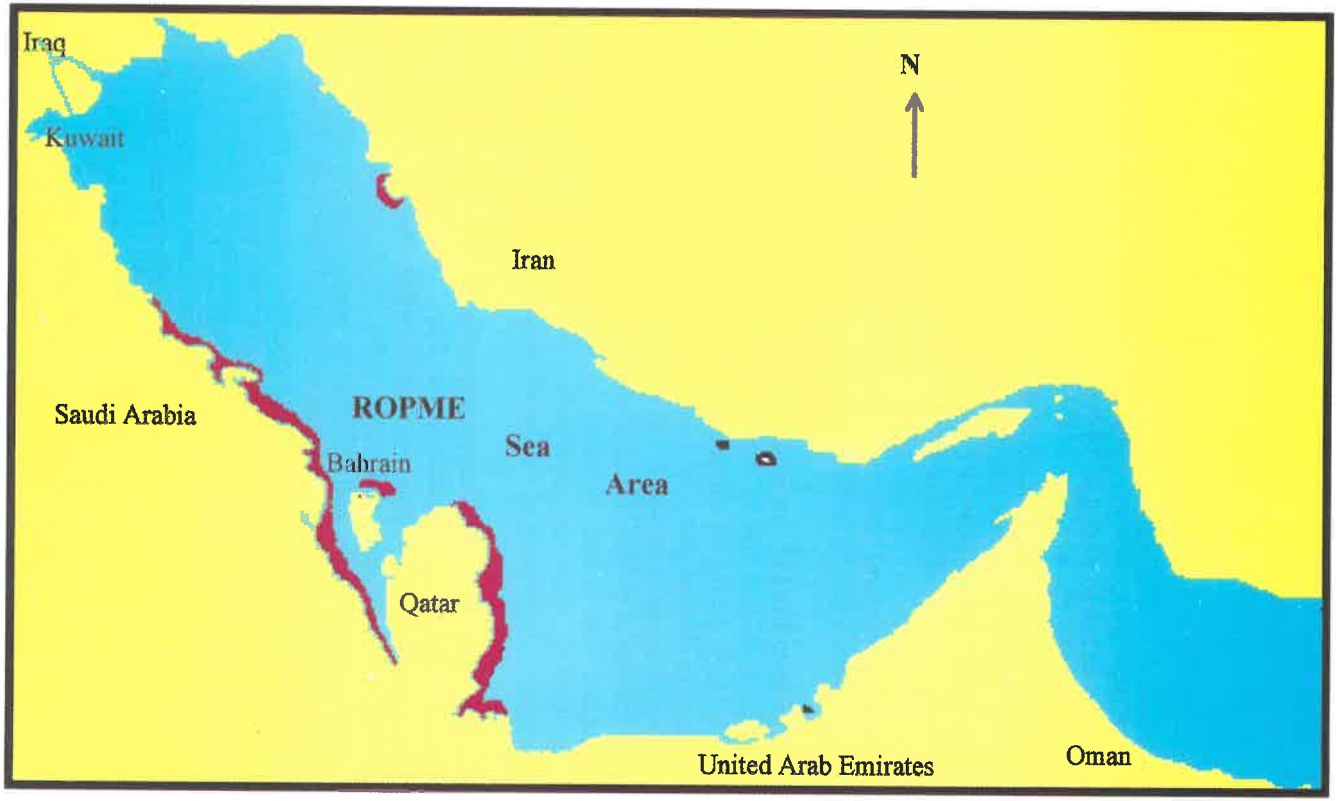


Figure (35): Locations of marine animal mortalities in RSA, 24 August - 30 October 1986 (ROPME, 1997).

sites in the RSA. The heaviest mortalities occurred between late August and late September 1986, resulting in the death of a large number of dolphins and fishes in Um-Saaed area on the eastern coast of Qatar and the eastern coast of Saudi Arabia (ROPME, 1997).

The extensive surveys carried out on the Saudi and Qatari coasts as well as in other ROPME Member States showed that this mortality incident included marine mammals, fishes, turtles, invertebrates and birds. In the marine mammals category: a total of 527 dolphins were reported dead on the coasts of Qatar (358), Saudi Arabia (141), Bahrain (18), Iran (6), Kuwait (2), and U.A.E. (2); 7 dugongs (*Dugong dugong*) and one whale of unknown species (20 feet long). In the fish category: estimated-4000 – 8000fishes of different species and lengths (generally greater than 60 cm). In addition, 58 marine turtles were found dead and about 10,000 or more cuttle fish "bones" were associated with the remains of the dead fish and a small number of dead crabs and a few dead birds were recorded. Subsequent to this event and on 10 November 1986, up to 2000 terns were found dead off the Saudi Coast.

2. A large scale fish kill was reported in the Iranian coastal waters of the RSA between 15 August and 30 September 1993. This took place less than two months after sinking of the Russian merchant ship, *CAPTAIN SAKHAROV* offshore to the southwest of Lavan Island with its cargo of 40 containers spilling chemical substances. This resulted in the immediate mortality of large schools of pelagic fishes (Indian oil-sardine) in the offshore waters of Lavan and Kish Islands, followed by high mortality of demersal and benthic fishes (catfish, silver seabream, yellow fin seabream and flathead) in August-September (Department of the Environment, I.R. Iran, 1998).

3. During 1993, 1994 and August-September 1996 similar phenomena were observed in several locations in the RSA, namely Bahrain, Iran, Kuwait, Oman, Qatar, Saudi Arabia and U.A.E. where thousands of fishes of many species, some dolphins and turtles were found dead on the coast of these countries. Reports on mortalities in the Iranian coastal water alone indicate that in this period (1993-1994) a total of 22 dolphins, 3 whales, 2 whale sharks and many turtles were found dead on the shores of Bushehr Province (DOE, 1998).

4. During the period 22 July – 7 September 1996, a large-scale fish kill of demersal fishes (silver seabream, yellow fin seabream and flathead) was

observed in the Iran coastal waters of Bushehr. This event was attributed to unusually high water temperature and low dissolved oxygen content of Bushehr coastal waters at the time of the fish mortality (Department of the Environment, I.R. Iran, 1998).

5. A fish kill incident was again observed in the month of August 1998 in the coastal areas of Bahrain. Investigating the possible reasons of this phenomenon, satellite images of the actual sea surface temperatures in the RSA were obtained and specimens of the dead fish were analyzed. The conclusion was that given the reported increase in water temperature in the sea area and the fact that the fish examined tend to congregate mainly in the shallow waters, thermal shock/lack of oxygen seems to be the most likely possible cause of fish death. Figure (36) illustrate the high sea surface temperature (35°C) observed in August 1996 and 1998 compared to the sea surface temperatures in the same month of August 1995 (32° – 34°C) and 1997 (30° – 33°C) all over the inner RSA.

5.3 Eutrophication

Eutrophication generally occurs as a result of discharging excessive amounts of nutrient-rich wastes into the marine environment. Sources of nutrients are diverse including industry, agriculture and sewage disposal. A number of industrial processes contribute to the problem such as methanol/ammonia production, an oil refinery, slaughter-house and livestock industry, sewage treatment plants, as well as the release of untreated waste water. In addition, intensive blooms of pelagic algae in offshore areas appear to become more frequent. This may be a sign of a more large-scale eutrophication also in offshore areas.

Rivers provide a major input of nutrients to the sea, but such materials remain largely within the shelf areas, only a small fraction of the nutrients ultimately reaching the open ocean, which remains oligotrophic. Over the past few decades increased discharges of nutrients to the coastal zone have occurred worldwide. In some locations, the increases in concentrations of dissolved nitrate and phosphate and of organic carbon, together with organic accumulations in the sediments, have brought about changes in the structure of planktonic and benthic communities, often with substantial ecological and economic consequences. There have also been increases in the number and extent of episodic events, such as exceptional plankton blooms, which alter

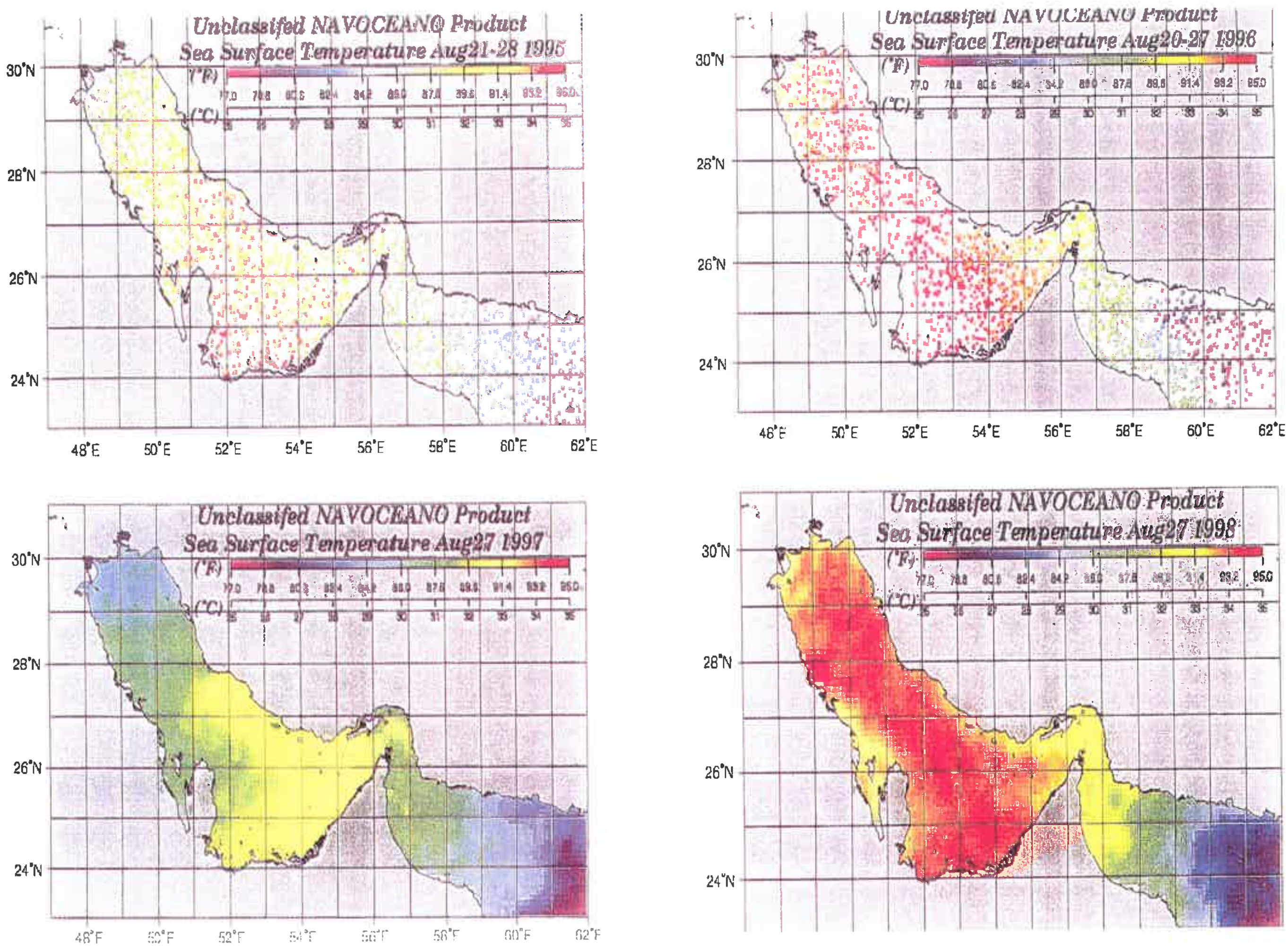


Figure (36) : Sea surface temperature in the RSA as observed by satellite in the month of August 1995, 1996, 1997 and 1998.

natural ecosystems and threaten the mariculture industry and coastal amenities. Algal blooms have also been associated with some of the frequent episodes of seafood contamination by biotoxins, sometimes with very serious consequences for human health. It is seldom possible to connect with certainty unusual algal blooms to enhanced nutrient levels and detailed studies of some recent cases have not shown convincing cause-effect relationships. There is clearly a need for a better understanding of the dynamics of phytoplankton growth in coastal waters and it is recommended that appropriate studies be undertaken (GESAMP, 1990).

In spite of the limited scientific data available on the biological effects of the contamination by sewage and nutrients in the marine and coastal environment of the RSA, there seems to enough evidence that eutrophication occurs or may occur in certain locations in the region particularly close to the urban and industrialized areas.

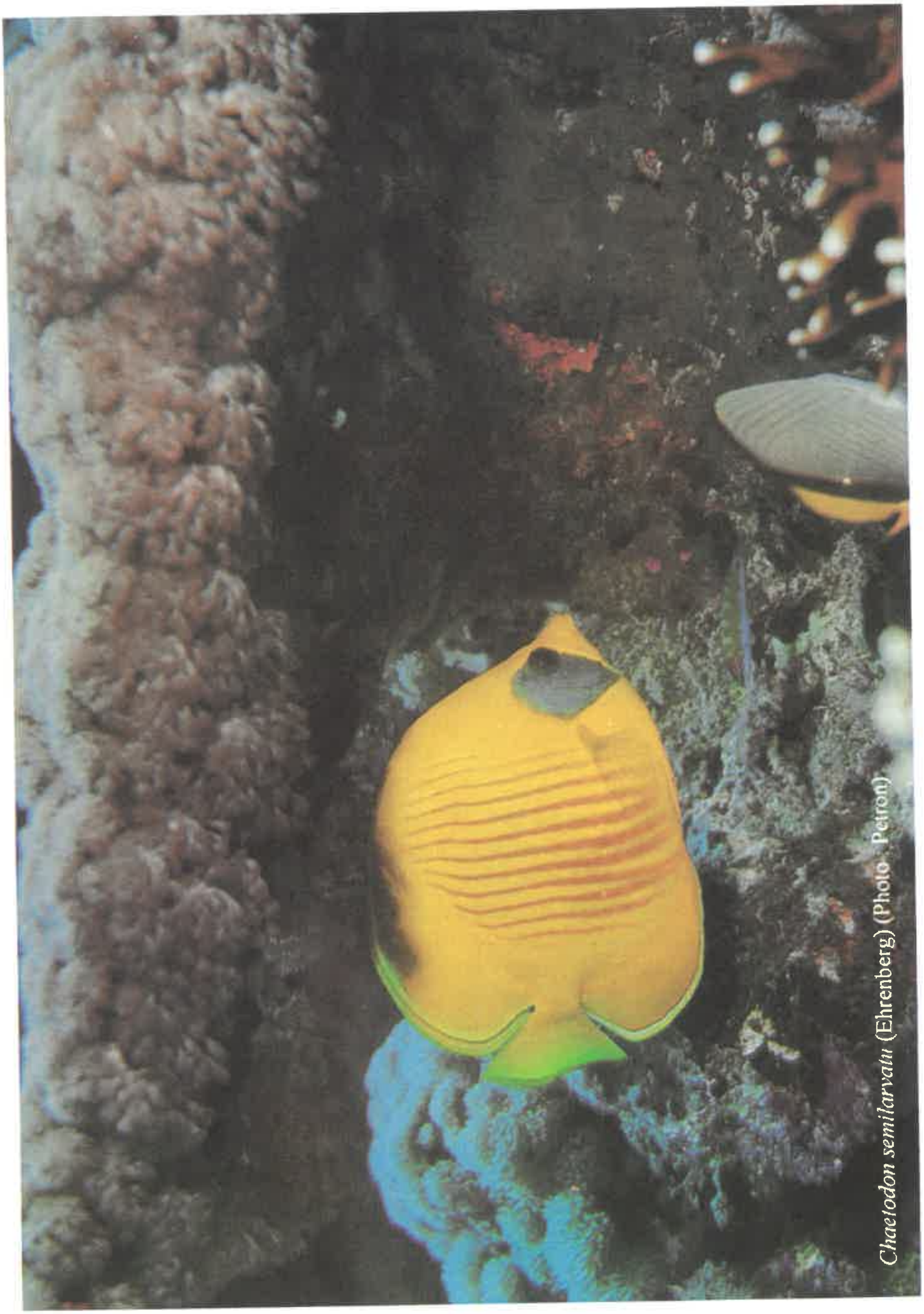
Linden *et al.* (1990) indicated some signs of eutrophication on the northern coast of Bahrain where dense mats of filamentous green algae were observed in the intertidal zone giving obvious signs of organic pollution and increased levels of nutrients in the water.

Similar pollution problems from sewage and agro-based industries caused increase growth of benthic algae in the north-west RSA off Shatt Al-Arab and signs of eutrophication were also observed in Kuwait Bay and in the coastal waters of Dhahran (Saudi Arabia), Abu Dhabi (U.A.E.) and Muscat.

There are also reports on local 'red tides' in Bahrain and Saudi Arabia. This may be taken as a sign of abnormal conditions in the pelagic zone, possibly related to eutrophication (Linden *et al.*, 1990).

Considering the future, it is relevant that the current anthropogenic inputs of nutrients are at least comparable to those from natural sources and that these inputs are related to present population densities in coastal regions and their hinterland. Within the next 20 to 30 years a near doubling in human population is projected and even greater rates of increase are expected in some coastal areas. Such changes will inevitably be accompanied by increases in agriculture and live stock production and by further expansion of mariculture. Thus, anthropogenic inputs could then be on larger scale.

Given that these increases occur predominantly in coastal areas where waste treatment facilities are few and population growth is most rapid, it is therefore expected that the most severe effects will be found in areas with dense and increasing coastal populations and on coasts with restricted water circulation. Studies have therefore been encouraged by ROPME, as part of the LBA Programme of Action, to estimate the scale and severity of these potential effects and to encourage appropriate and effective action, which might include radical changes in techniques for sewage disposal, and other land-based activities.



Chaetodon semilarvatu (Ehrenberg) (Photo: Petron)

Chapter 6

War and Armed Conflicts and their Impacts on ROPME Sea Area

The ROPME region was most unfortunate to witness the consequences of two wars in one decade. The war between Iraq and Iran started in 1980 and lasted for eight years when cease-fire agreement was reached and peaceful negotiations started between the warring nations in 1988, the occupation of Kuwait by Iraq in 1990 ignited the second war in 1991 between the Iraqi and the Coalition Forces. This war, although it lasted for only 35 days, from 16 January 1991 until 26 February 1991, it had far reaching effects on the environment of the region (Gerges, 1993).

This chapter focuses on the impacts of war and armed conflicts and the associated military operations and hostilities on the environment of the RSA.

6.1 The Iraq-Iran War (1980 – 1988)

The most dramatic environmental episode of this war that had direct effect on the RSA was the blowout of the Nowruz offshore oil well.

6.1.1 Nowruz oil well blowout

As a result of the exchange of hostilities during the Iraq-Iran war, the Nowruz oil wells in the northern part of RSA off the Iranian coast was hit. Consequently, an estimated amount of one million barrels (150 metric tons) of crude oil was spilled in the marine environment throughout the 16-month period from February 1983 to May 1984 when the last well No.3 was successfully capped (Olfat, 1984). This makes the Nowruz oil spill the longest recorded spill in the region. Other estimates indicate that the oil spilled during this period amounted to 2-4 million barrels (Reynolds, 1993).

6.1.2 Extent, fate and effects of Nowruz oil spill

The oil spilled from the Nowruz oil field formed patches, which moved in the RSA under the influence of the prevailing wind and current conditions.

According to satellite images taken at the time of the spill, these patches followed a general southward route. Passing the west bound of Abuzar oil field, they continued to drift to the south across the offshore waters of Saudi Arabia, reached Bahrain and Qatar shores, and finally ended up in the coastal waters of the United Arab Emirates (Olfat, 1984). The spilled oil reportedly sank in the open Sea Area, due to deposition of sediment onto the oil slick at sea by dust storms (Michel *et al.*, 1993). The part of the oil that reached the Saudi Arabian coast produced asphaltic pavement on the north shore of Abu Ali while other asphaltic layers and patties were observed at a number of locations in the Dawhat Ad-Dafi and Ras Tanaquib areas (Hayes *et al.*, 1993).

Early reports on other effects of the Nowruz oil spill indicated that a large number of turtles, dolphins, fish, sea snakes and birds were found dead in the Iranian coastal waters and near Bushehr (Olfat, 1984).

6.2 The 1991 War : An Environmental Crisis

The 1991 war between Iraq and the Coalition Forces over of Kuwait resulted in an unprecedented environmental crisis; the largest in history in scope, extent and impact. The most obvious environmental problems associated with this war are the impacts caused by the largest oil spill on record, the effects of the burning of the Kuwaiti oil fields, and the damage to the terrestrial environment caused by massive troop movements and by oil lakes formed in the Kuwaiti desert from the damage oil wells on fire. Perhaps not so obvious, but nevertheless potentially serious, are those impacts associated with the release of wastes during ground and air battles, potential release of toxic materials into marine and riverine environments from sunken ships and damaged onshore and offshore facilities, and the deployment of land and sea mines.

6.2.1 The oil spill

An estimated 6 – 8 million barrels of oil were spilled into the RSA from two major sources: four sunken and leaking vessels, including Iraqi oil tankers, and release of oil from the Kuwaiti Mina Al-Ahmadi Sea Island terminal and the Iraqi Mina al-Bakr loading terminal. Additional sporadic discharges occurred from these and other sources through June 1991. Several hundred thousand barrels of oil seeped from damaged Kuwaiti and Iraqi oil facilities and several small Iraqi tankers sunk in the northern part of the sea area produced additional pollution through the spring and early summer of 1997 compared to other known oil spills. This oil spill is by far the largest spill in the marine environment ever recorded (Figure 37). Moreover, atmospheric fallout from Kuwait's damaged wells gradually introduced a considerable additional quantity of oil in the form of small oil droplets and oily soot (Gerges, 1993). These circumstances and the statements made by the officials of the Kuwait Oil Company (KOC) to the environmental team of the United Nations missions to Kuwait (16 March – 4 April 1991) to assess the scope and nature of damage inflicted on Kuwait during the Iraqi occupation (United Nations, 1991) lead to higher estimate of about 10 million barrels for the oil spill as quoted sometimes by other authors.

However, the final official estimate of the oil spill as claimed by Kuwait authorities indicates that the total amount of oil discharge and spilled from various resources into the RSA reaches in excess of 9 million barrels (PAAC, 1999).

6.2.2 Extent, fate and effects of the oil spill

As can be seen from satellite images (Figure 38), the spill moved rather rapidly along the coastal waters of Kuwait and Saudi Arabia. It was travelling over 600 km before being stopped by Ras Abu Ali, where the huge slick was blocked by Abu Ali Island and its causeway to the mainland causing the heaviest impact on the northern shoreline of Saudi Arabia.

As the oil continued to move into the area, it backed up into the farthest recesses of the embayments north of Abu Ali Islands. The most heavily affected areas were the lagoons, salt marshes and bays located between Ras Al-Khafji in the north and Ras Abu Ali in the south. Figure (38) shows the extent of the oil spill and types of oil slicks on March 16,1991, indicating the existence of large areas of oil sheen offshore and heavier, emulsified oil along the coast (WCMC, 1991).

Tawfiq and Olsen (1993) suggested that as oil traveled south rapidly, a significant amount was lost to evaporation or landed on beaches. They estimated that at least 40% of the spilled oil has rapidly disappeared due to evaporation, 10% was dissolved and about 50% remained afloat. Of this floating oil about 22% were recovered, 50% were stranded on beaches and the remaining was unaccounted for. However, there seems to be more

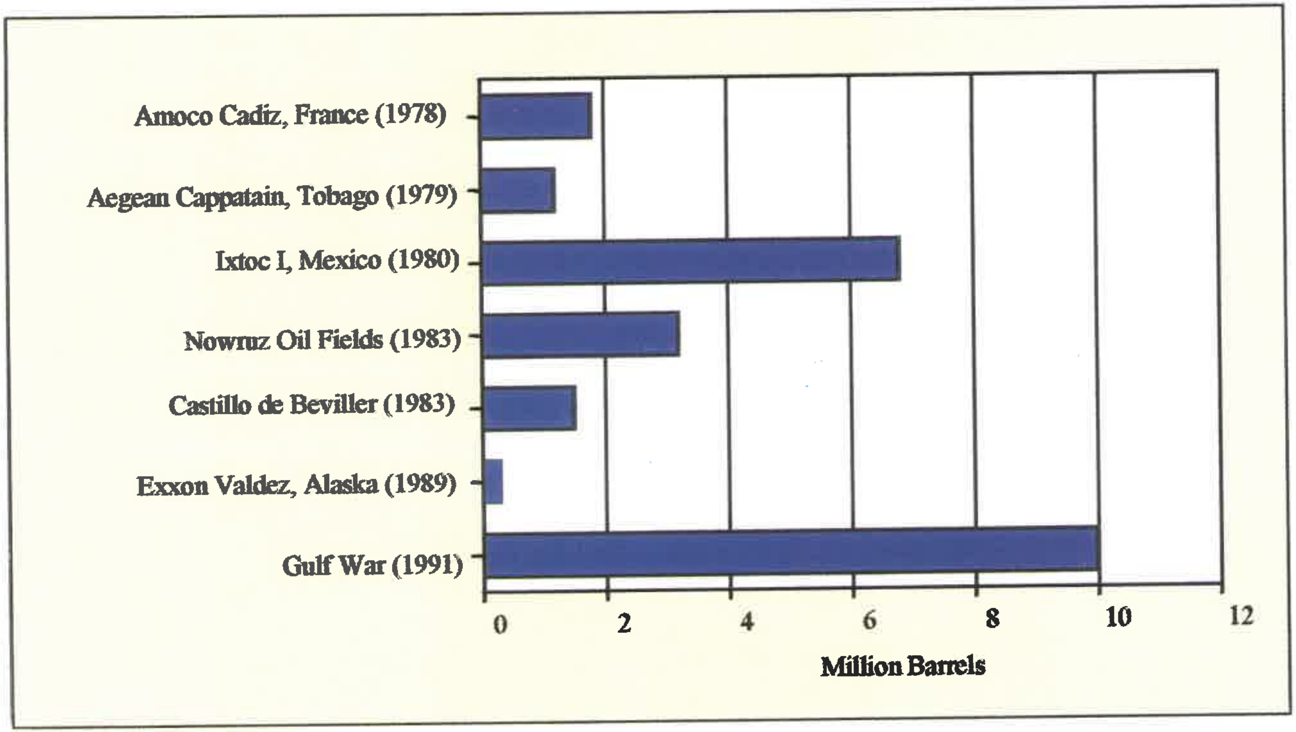


Figure (37): World's major oil spills (Adapted from: US Gulf Task Force,1991).

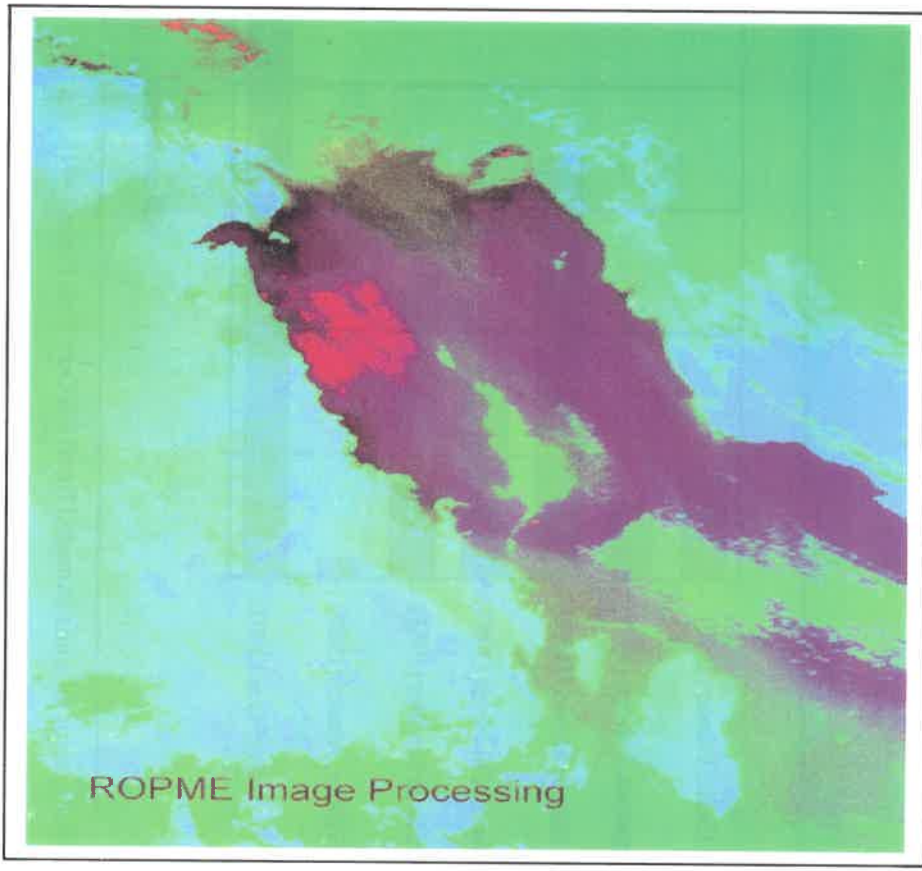


Figure (38): Trajectory of the oil spill, January 1991 (ROPME/PAAC).
NOAA/AVHRR data fragment, spectral analysis, colour composition.

evidence that at least some of that oil had sunk to the bottom. Aerial photography off the Kuwaiti southern borders (May, 1991) showed large patches of sunken oil (Figure 39). Samples taken during the R/V Umitaka-Maru cruise also indicated the presence of sunken oil in the 2000 µg/g range (Al-Majed *et al.*, 1995).

The estimates of the extent of damage to the marine habitats in those areas varied. Early data indicated that at least 30,000 marine birds perished as a result of exposure to oil (excluding those trapped in oil pools formed in the Kuwaiti desert). Some reports showed that approximately 20% of the mangroves on the eastern coast of Saudi Arabia have been oiled and about 50% of the coral reefs have been affected. There was also some indication that hundreds of square kilometers of seagrass beds (feeding grounds for dugongs and turtles) as well as tidal mud flats might have been inundated by oil. The Iranian coast north of Bandar Khomeyni was also affected, but too lesser extent, while the Iraqi coast was only slightly affected. The Kuwaiti coast suffered only relatively light damage while the three coral reef islands off the Kuwaiti coast did not show any significant degree of ecological damage.

Based on observations during the initial surveys, the pollution by oil in the marine environment was not limited to oil spills. Fallout of soot and unburned oil products emitted from the burning oil wells formed slicks on the surface of the water, releasing PAHs and heavy-metal-laden soot particles into the water column (Gerges, 1993).

The above results were preliminary and were based primarily on the initial surveys. It was therefore deemed necessary that the scale of the impact on the massive oil spill on the marine ecosystem, particularly on sensitive habitats, as well as on the fisheries resources (fish and shrimp) of the region as a whole would have to be determined by intensive monitoring and research.

The international and regional efforts to assess the state of the marine environment culminated in the launching, in late February 1992, of a 100-day research cruise in the RSA by the Research Vessel Mt. Mitchell of the National Oceanic and Atmospheric Administration (NOAA) of the United States of America under the auspices of ROPME and the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

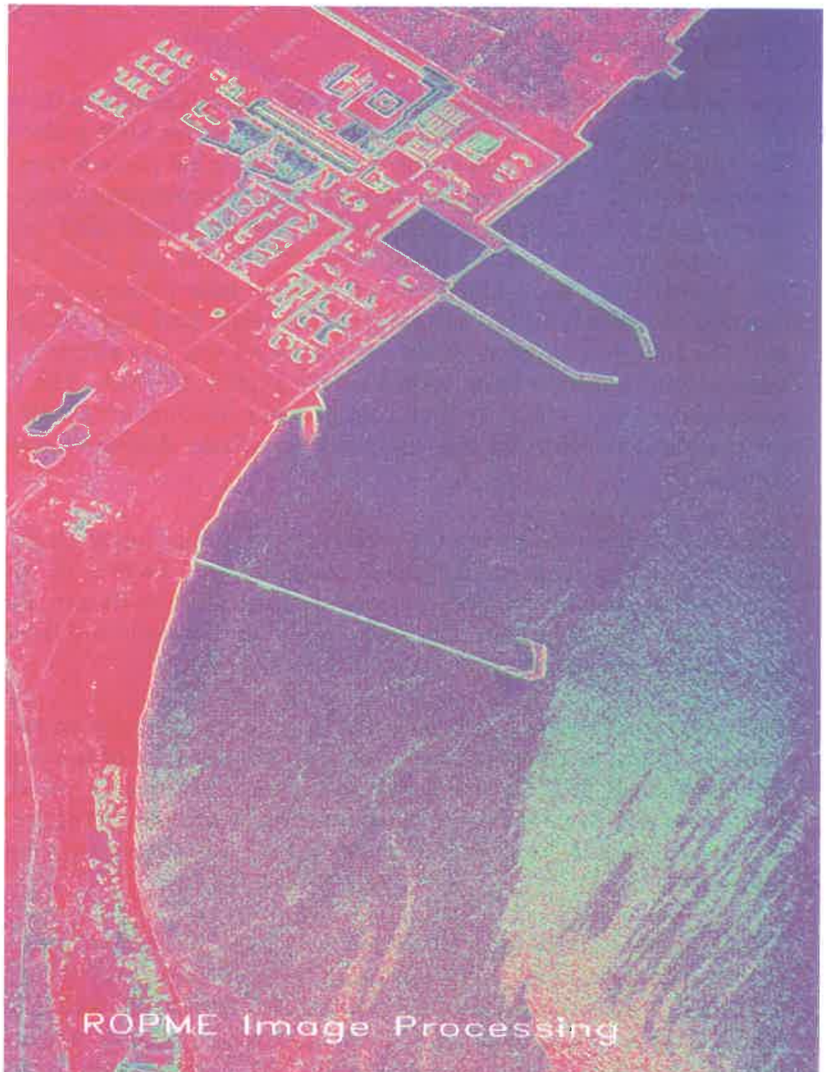


Figure (39): Sunken Oil off Mina AzZoor, Kuwait, May 1991.
Colour IR photography areal surveys texture analysis, colour composition.

The expedition involved a broad range of investigations of the impact of the oil spill, including shoreline and near-shore studies along the most heavily impacted areas of the Saudi Arabian coastline, regional circulation and sediment studies, studies of coral reefs, and investigations of seafood quality. The investigations were carried out at a large number of stations covering almost the entire RSA (NOAA, 1993). The findings and conclusions drawn on the basis of Mt. Mitchell Cruise results were given in several papers published in a special issue of the Marine Pollution Bulletin (1993) and are referred to in the relevant sections of this report.

The Open Sea Cruise of the Mt. Mitchell (1992) and the subsequent cruise of the Tokyo University School of Fisheries research vessel, Umitaka-Maru (1993-1994), in addition to the coastal surveys and national monitoring activities represent the extent of efforts carried out to assess the impacts of war on the marine environment of the RSA. Figure (40) summarize the results of petroleum hydrocarbon analysis (PHCs) in marine sediments before and after the war. Baseline data of the Environment Protection Department (EPD) of Kuwait, suggests that a 5 - fold increase in the PHCs levels occurred in 1991 over 1986, to drop to less than half their value by 1995. Data by Fowler *et al.,* (1993), indicate high levels of PHCs in sediments of Ras Abu Ali in Saudi Arabia, decreasing with distance towards the Strait of Hormuz. Moreover, PHCs levels of over 2000 µg/g were reported off the Saudi sediments (Al-Majed *et al.*, 1995), suggesting the presence of sunken oil.

In their study of sediment toxicity to amphipods, Randolph *et al.* (1996) have shown high mortality rates associated with PHCs concentrations of 1mg/g dry sediment or higher. Out of the 11 sites sampled in Saudi Arabia, 5 proved to be toxic. The data suggests that as the soluble components of oil and the weathering products become available in the water column, toxicity increase. Being lighter than water, these products tend to accumulate at the surface microlayer. About half of the samples of the coastal surface microlayer that were sampled by Hardy *et al.*, (1993) and used in bioassay texts, were shown to be toxic to echinodem larvae.

Around the same period, analysis of metabolites of aromatic hydrocarbons in fish bile carried out on board the Mt. Mitchell identified elevated levels of naphthols, flurorentols and phenanthrols as well as their parent compounds

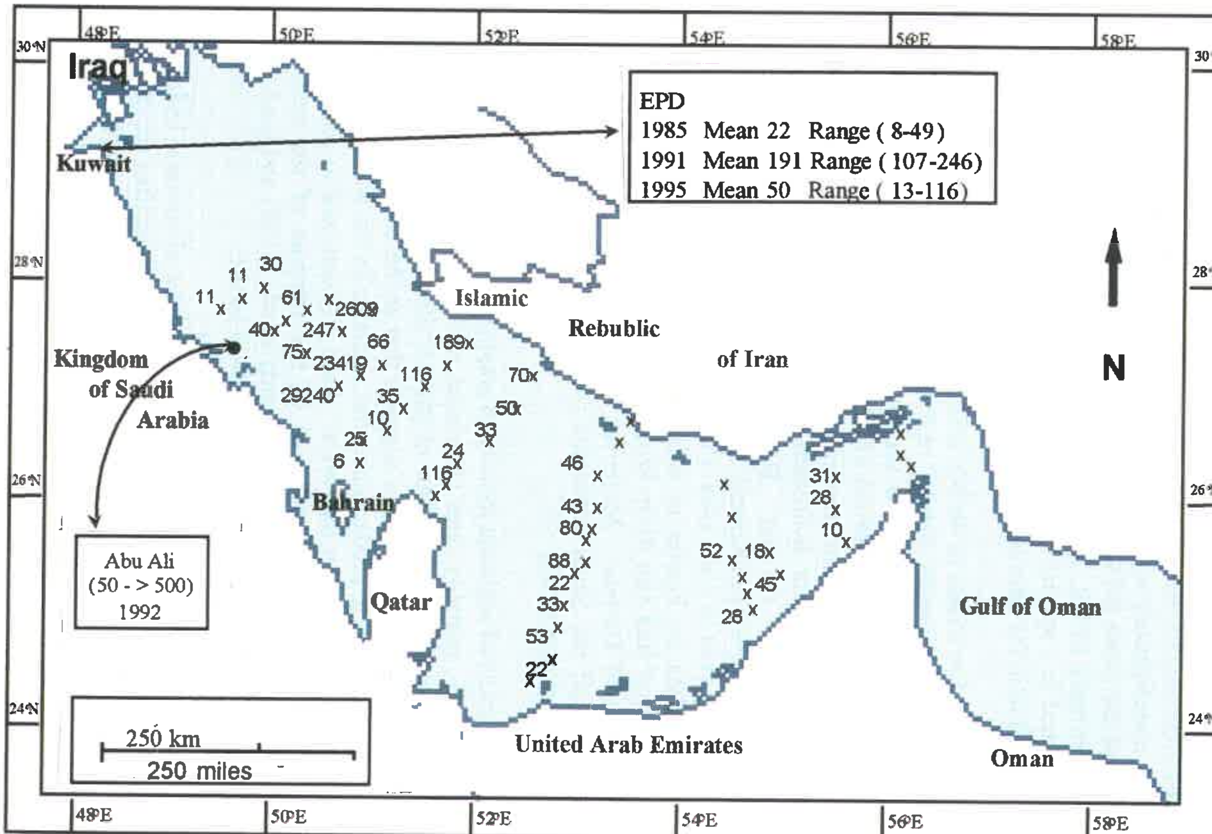


Figure (40): Distribution of PHC's (µg/g dry weight) in sediments before and after the Gulf War. (Adapted from: EPD, 1985;1991;1995; Fowler *et al.*, 1992; Al-Majed *et al.*, 1995) in sediments collected in the RSA (Krahn *et al.*, 1993). The same data showed that dibenzothiophenols reached over 900 μg/g (Figure 41).

Data on the toxicity of the surface microlayer and sediments have lead to a wide spread discussion on the war impacts on fisheries. In an early assessment of the impacts of the war on fisheries, it was estimated that the shrimp populations have collapsed to about 10% of the pre-war levels (IUCN, 1992). Support of this conclusion comes from another study. Price *et al.* (1993) carried out a field study that showed a decrease in penaeid egg and larval abundance in 1992 at Ras Tanura, compared with the years 1975-1978. At Safaniya, a decrease in abundance of both zooplankton and penaeid egg and larval abundance in 1992 compared with data for the 1970s was also apparent (Price *et al.*, 1993). In Kuwait, Siddiqui and Al-Mubarak (1998) have analyzed shrimp landings statistics before and after the war, indicating a large fluctuations in the landings and catch effort over the past few years. A declining trend in landings may be inferred (Figure 42). However, in the absence of reliable regional data and given the stress on the stocks by over-fishing and encroachment on spawning areas, it is difficult to draw a clear picture. Nevertheless, given the indicators of elevated toxicity of sediments and sea surface microlayer, and decline in abundance of zooplankton, the presence of oil on beaches, seabeds and in the intertidal zone and the reduction of incident of light and decrease in sea temperature (Figure 43), it is not unreasonable to assume that the fisheries of the area have suffered severe impacts. Only long-term monitoring along with radical fishery management procedures to halt over-fishing, encroachment on habitats and pollution would help this major natural resource to recover.

6.3 Other Military Activities

6.3.1 Oil well fires and their impacts

Setting fire to the Kuwait oil wells is another episodic event of the 1991 war that had significant environmental impact and adverse effects on not only the surrounding atmosphere but also the marine and terrestrial ecosystems. The United Nations missions to assess the damage inflicted on Kuwait and the environmental consequences of the war in March/April 1991 expressed its deep concern that "The deliberate torching of the oil fields represents Kuwait's most pressing environmental problem of today, beside which all else pales into insignificance. There has never been anything like it in history before" (United Nations, 1991).

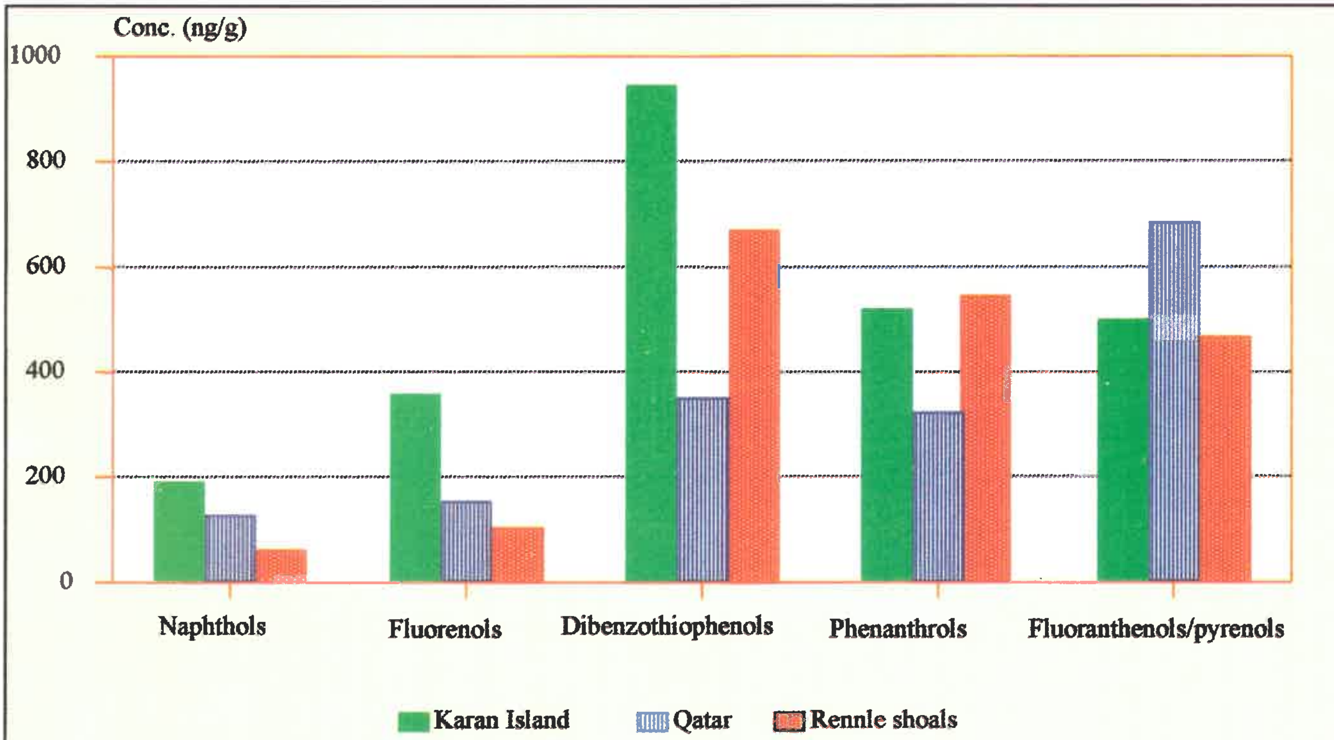


Figure (41): Levels of metabolites of aromatic compounds (ng/g wet wt.) in bile samples of *Lethrinus kallopterus* species, RSA 1992 (Krahn *et al.*, 1993)

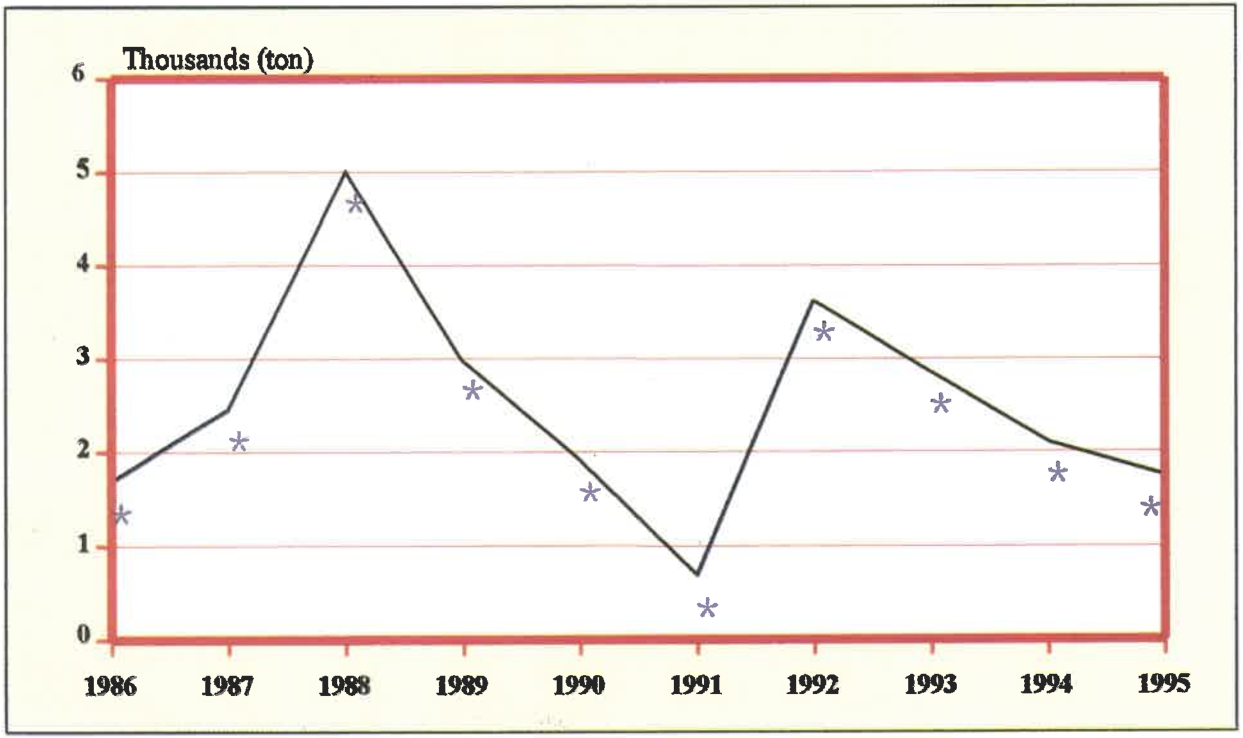


Figure (42): fluctuations of shrimp landing in Kuwait, 1986-1995 (Siddiqui *et al.*, 1998)

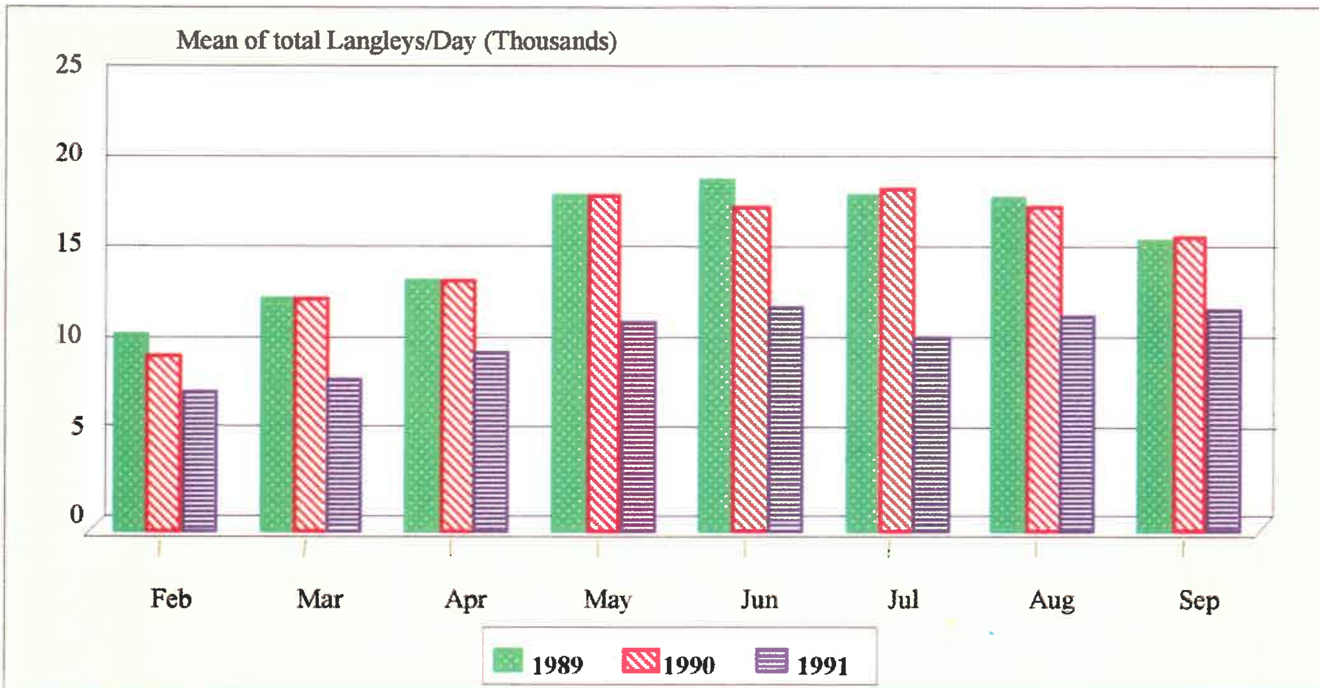


Figure (43): Impact of oil well fires on solar radiation in RSA (Suthers, 1992).

Several reports indicated that out of the 943 Kuwait oil wells, at least 700 wells were either set fire or damaged (United Nations, 1991; Al-Besharah, 1992; Tawfiq, 1992). The official Kuwaiti reports indicated that from the 798 oil wells at which explosives were detonated, 604 wells caught fire and an additional 45 wells only gushed oil to the desert surface (PACC, 1999). Estimates made of the amounts of oil and gas that were burnt every day showed that the best estimate was that provided by the Ministry of Oil in Kuwait which was given after a field survey of the oil wells on fire, the gushing and the damaged wells and the extent of the oil pools formed in the desert around the oil fields, and was based on the previous information about the pressure inside the wells. This estimate put the quantity of oil and gas burnt at 6 million barrels and 100 million^3 per day respectively, generating substantial emissions of sulphur dioxide, hydrogen sulphide and oxides of nitrogen. In addition, incomplete combustion products including carbon monoxide, polycyclic aromatic and other volatile organic hydrocarbons were generated by the fires. Secondary formation of acid aerosols such as sulphuric acid may have also taken place in the atmosphere, although in most cases sulphates were formed instead due to the presence of salt in the aerosols resulting from the release of associated brines and use of seawater in fire fighting (Steven *et al.*, 1992). Figure (44) and (45) show the most dominant plume trajectories over Kuwait and the Region.

The impacts on the marine environment brought about by the Kuwaiti oil well fires is quite evident from both physical and visual observations at the time when the oil wells were still burning and from the analysis of remote sensing data and field observations by several investigators. Particulates from the fires were deposited on both land and sea over wide area. The United Nations Mission, while carrying out an aerial surveys of the coastal area on 20 and 22 March 1991, observed narrow bands of black carbon particles extending over varying distances, obviously resulting from atmospheric deposits of carbon emitted with the soot from the burning oil wells (United Nations, 1991).

Al-Yacoob *et al.* (1993) pointed out that an unknown portion of incomplete combustion products and gases, released from the emissions or ignition of ~500 million barrels of oil during the oil fires, was introduced to the marine environment (Readman *et al.*, 1992). Carcinogenic polycyclic aromatic hydrocarbons (PAHs: products of incomplete combustion and oil genesis) are suspected toxicants to marine organisms (Malins *et al.*, 1984) and can be transported over long distances adsorbed onto airborne and waterborne

Figure (44): Kuwait oil well fire plume, June,1991.
Landsat TM fragment. Low resolution generalisation, colour composition.

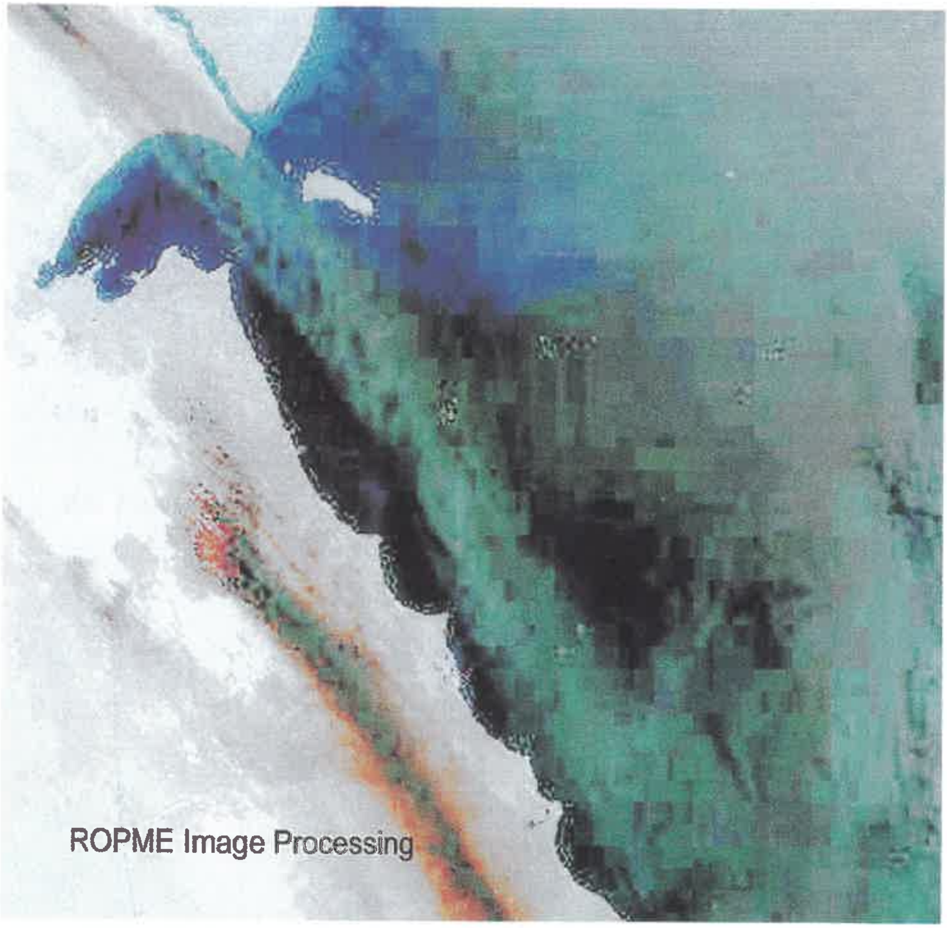


Figure (45): Kuwait oil well fire plume, July 1991.
Landsat TM fragment. Low resolution generalisation, colour composition.

particles. Being hydrophobic, they tend to accumulate in sediments and biota (Govers, 1990). Adsorption onto suspended particles and accumulation on bottom sediments may remove PAHs from the water column and reduce the chance of their photo-decomposition (Literathy *et al.*, 1991).

The composition of the plume analyzed by a UK Meteorology Flight (March, 1992), showed levels smoke of about 500 mg/m^3 (Snashall, 1992). Stevens *et al.* (1992), have also carried out analysis of suspended matter collected from ground level and by an airborne sampling system. Table (15) summarizes the results of their analysis. The black plumes were characterized by a large numbers of carbon chain agglomerates.

Table (15) : Concentrations of selected compounds (μg/m^3) of oil well fire plumes, Kuwait, 1991

Compounds	Black Plume 02/08/91	Black Plume 03/08/91	Black Plume 05/08/91	Mixed Plume 06/08/91	White Plume 07/08/91	White Plume 08/08/91
Na	NDB	6.0 ± 2.9	NDB	3.2 ± 0.6	905 ± 45	6.4 ± 0.6
Al	3.7 ± 3.2	3.5 ± 1.8	8.9 ± 1.3	3.7 ± 0.2	1.9 ± 1.7	0.52 ± 3.7
S	3.0 ± 1.5	18.9 ± 1.7	2.9 ± 0.5	3.9 ± 0.3	95 ± 5	3.2 ± 0.3
Cl	2.2 ± 1.1	7.1 ± 0.9	NDB	5.0 ± 0.3	1820 + 92	9.2 ± 0.5
SO_4	9.3	56	8.7	12	285	9.6
SO_2	133	169	12	49	319	26
Mass	755	955	493	167	4356	22
Volatile Carbon	152	183	NM	37	105	NM
Elemental Carbon	142	443	NM	22	22	NM

NM: Not Measured ; NDB: None Detected Above Filter Blank

(Stevens *et al.*, 1992)

To develop a better understanding of what was being deposited on the marine environment, fluctuations in the levels of petroleum hydrocarbons in daily samples of particulate matter collected at Riqqa south of Kuwait city, closer to the burning oil fields and satellite images taken in the same period were compared. High PHCs level detected on land appears to coincide with the behaviour of the plume (Figure 46). However, the levels of Benzo (a) pyrene associated with the plume measured at ground level are shown in Figure (33). Consistency of the levels of PHCs with the plume behaviour was also evident from the comparison of levels of PHCs monitored simultaneously at the Mansouria station to that monitored by the German Air Quality Mobile Laboratory placed at the Az-Zor Port as shown in Figure (47), (EPC, 1991). Figure (48) shows the regional distribution of the visible part of the plume over several Member States.

Furthermore, physical observations taken in the Sea Area indicated that the smoke plume from the Kuwaiti oil well fires appears to have contributed to the lowering of temperatures in nearshore waters of the western RSA. The mean seawater temperature at Manifa Pier for the period 4 June to 10 December 1991, was 25.9°C. This compare to an overall mean temperatures of 28.4°C for 1986-1990. During the period of recording for 1991, the mean temperature was 2.5°C lower than the overall daily mean for 1986-1990. The maximum difference in mean seawater temperatures between 1991 and 1986-1990 was 6.9°C (McCain *et al.*, 1993).

Downing (1991, 1992) detected a slight reduction in water temperature and assumed to have been caused by a persistent smoke layer above the northern RSA, emanating from the burning oil wells of the Kuwait mainland. Examining the possible effect of the oil well fires on the coral reefs in the region, Downing argued that if a very cold winter followed a summer when sea temperatures were significantly lower than the norm, then the reef corals may be exposed to water temperatures close to or lower than their lethal limit. Secondly, polycyclic aromatic hydrocarbons present in the soot fall-out may have had a toxic effect on the reef biota.

6.3.2 Destruction of coastal infrastructures and habitats

As a defensive measure, the Iraqi military occupying Kuwait laid extensive mine fields all along the coasts, on the intertidal zone and in the deep sea channel approaches to Kuwait. In addition, numerous trenches were dug

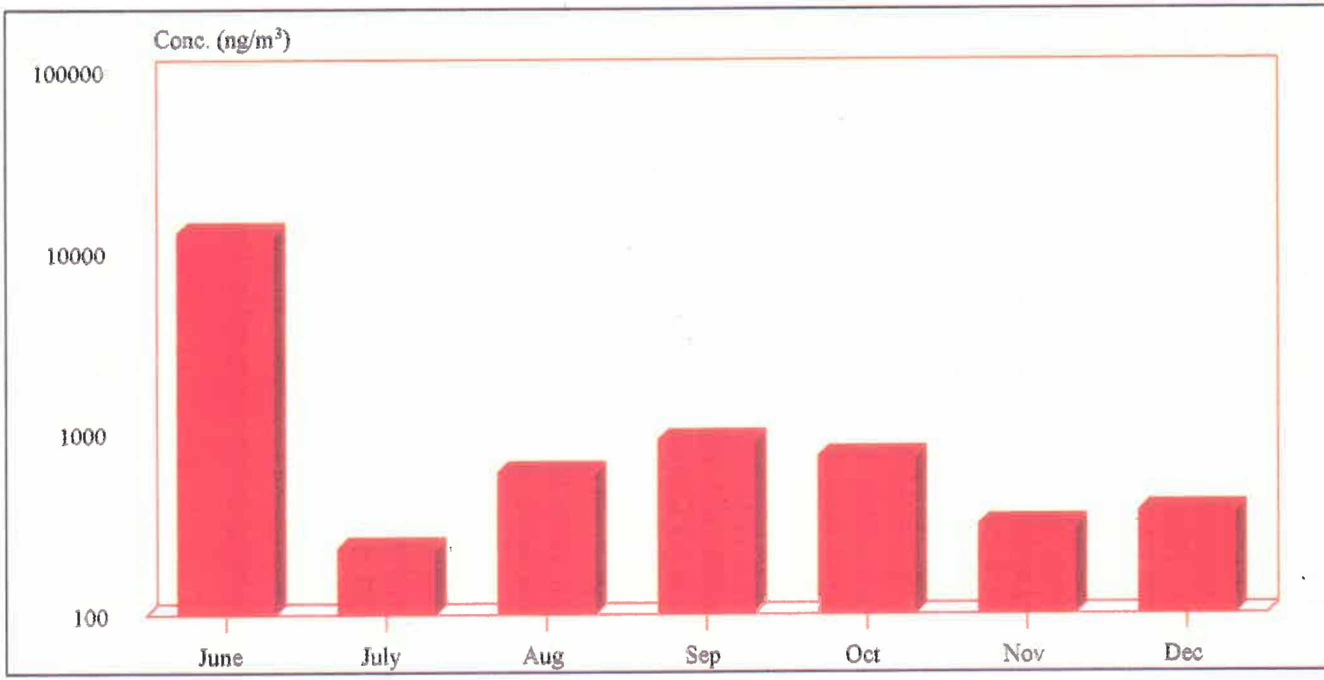


Figure (46): Levels of PHC's (ng/m^3) in PM10 samples collected from Riqqa, Kuwait 1991 (Al-Majed *et al.*, 1995).

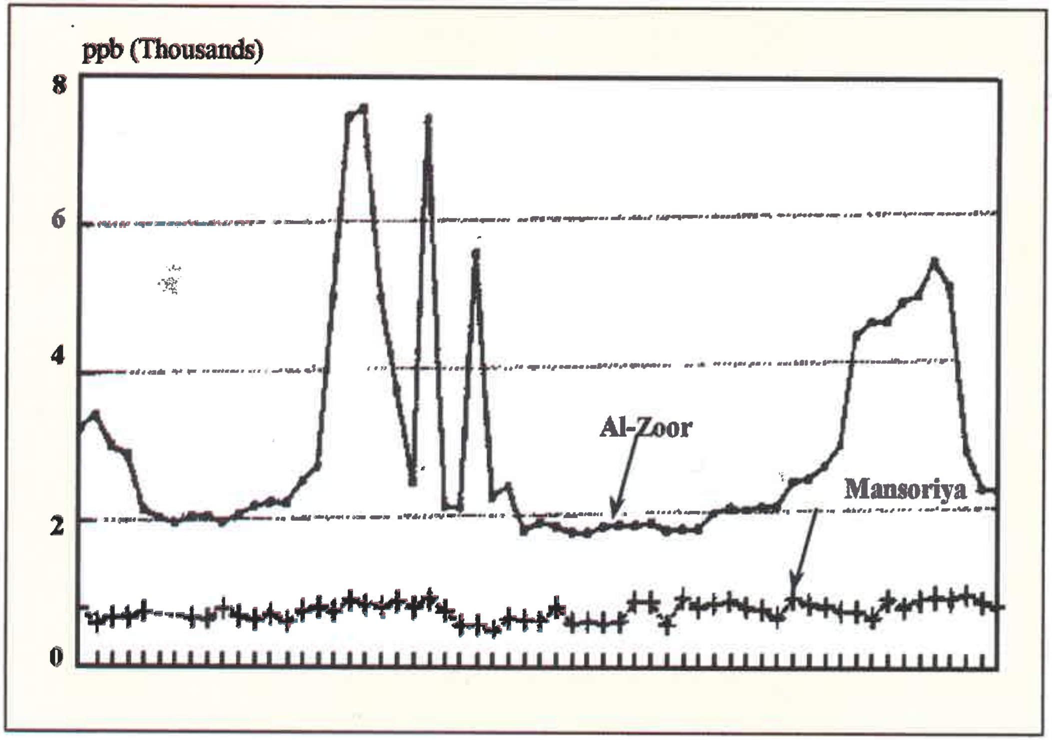


Figure (47): Total hydrocarbons measured simultaneously in Mansoriya and AzZoor, 3-4 August 1991 (EPC, 1992).

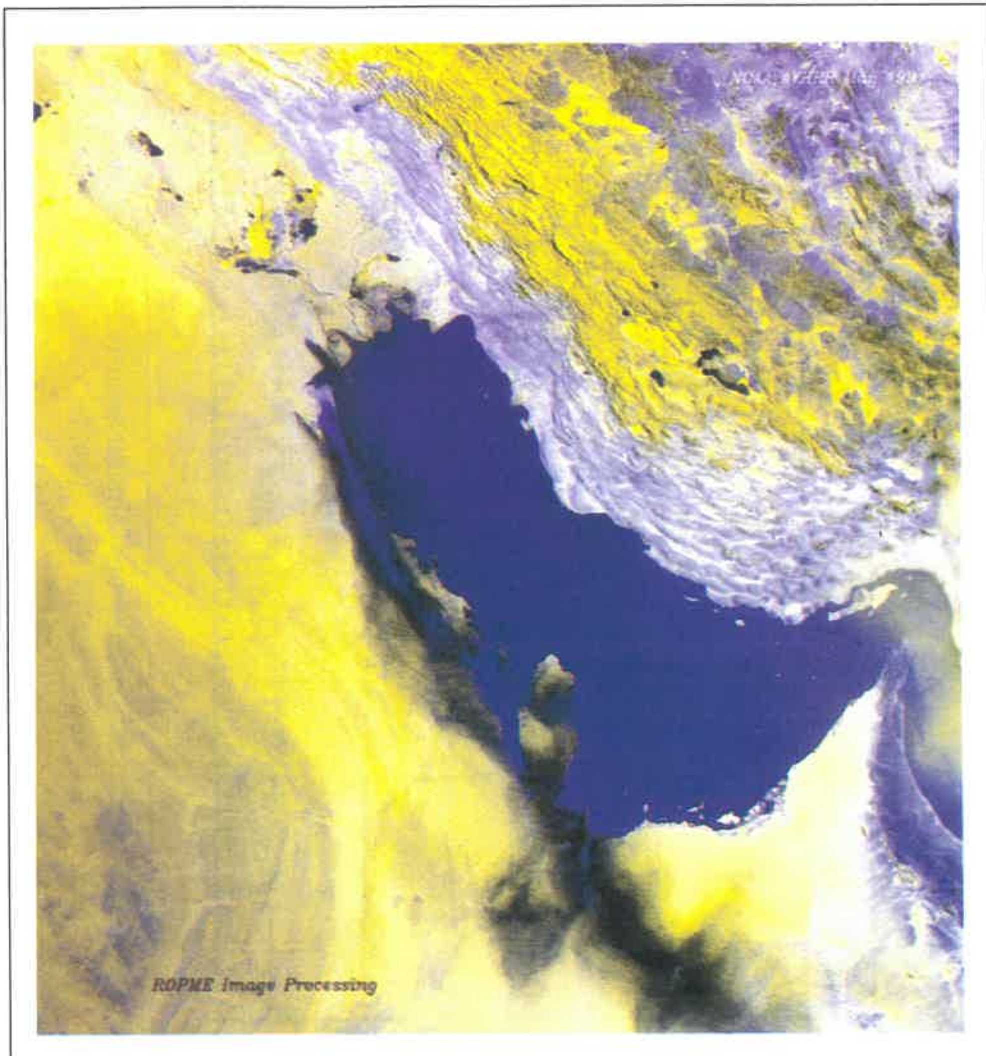


Figure (48): The regional distribution of the oil well fire plume, May 1991. NOAA/AVHRR data fragment, spectral analysis, colour composition (ROPME/PAAC).

along the coast and damage was inflicted on all coastal installations, facilities and infrastructure. These destructive activities in the coastal zone will have negative impact on the marine and coastal environment and will impose serious threat to beach users and fisherman for some years to come (El-Baz & Makharita, 1994).

Another major coastal activity observed in the north-western part of the RSA in the aftermath of the war and which will have negative consequences on the fisheries and the ecology of the area is the drainage of the Iraqi marshes. Iraq, driven by political and military objectives, has reduced the Iraqi marshes (with an estimated area of about 0.5 million hectares (Maltby, 1994) to water channels delivering river water directly into the RSA, with all its sediment loads, agrochemicals, sewage and industrial wastes. This action has deprived the area of a giant "Kidney" that acted as a self sustained mega waste treatment facility and is likely to affect the spawning. grounds of shrimp ,migratory fish at the Shatt Al-Arab delta and Kuwait Bay. Figures (49a, b & c) show the transformation of the once heaven for migratory birds of Europe and a major source of fisheries into an arid, barren land (Abdulraheem, 1998).

6.4 ROPME and UN Initiatives in Times of War

As military operations of the 1991 War started, concern grew over the possible environmental destruction as a result of the hostilities. In a concerted effort by the United Nations agencies, led by UNEP and in cooperation with ROPME, the United Nations Inter-agency Plan of Action, addressing the various aspects of the environmental crisis resulting from the 1991 armed conflict over Kuwait was developed and adopted in March 1991 with two main objectives (a) to assess the environmental consequences of the war on the marine and coastal areas, atmosphere and terrestrial ecosystem and the hazardous waste situation in the region; and (b) to propose a programme for the mitigation of the adverse effects, and for rehabilitation and protection of the environment affected by the conflict. To this effect, multidisciplinary initial surveys and a preliminary assessment of the marine and coastal environment, the atmospheric environment, the inland terrestrial environment and hazardous waste management was carried out in the war-impacted areas, as depicted in Figure (50).

Figure (49a): Iraqi Marshes (September, 1991)

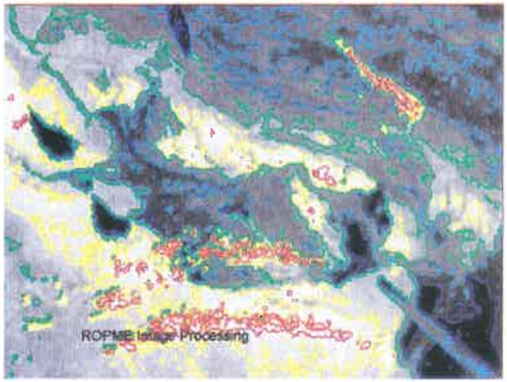


Figure (49b): Iraqi Marshes (September, 1996)

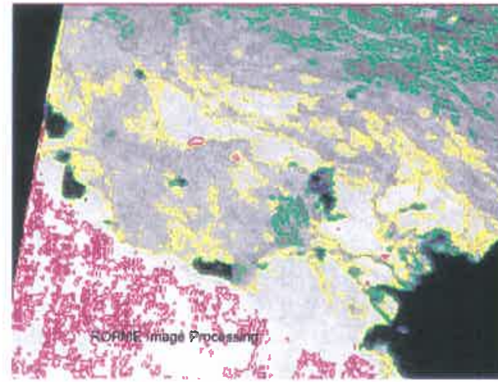
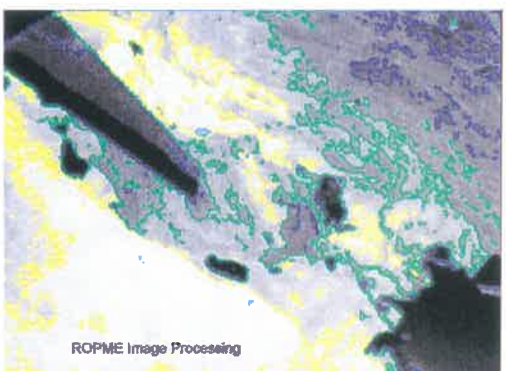


Figure (49c): Iraqi Marshes (September, 1995)



Satellite Imagery Processing Legend

Water: Dark blue
Vegetation 1 (higher biomass concentration): Cyan
Dry soil 1: Yellow
Dry soil 2: Purple (only for Figure c)
Clouds: Red (only for Figure a)

Notes:

1. The north RSA (Kuwait, Bubiyan, Shatt Al-Arab are located in the low right corner of the Figures.
2. Strait dark/grey fragments in the images are part on-board hardware.

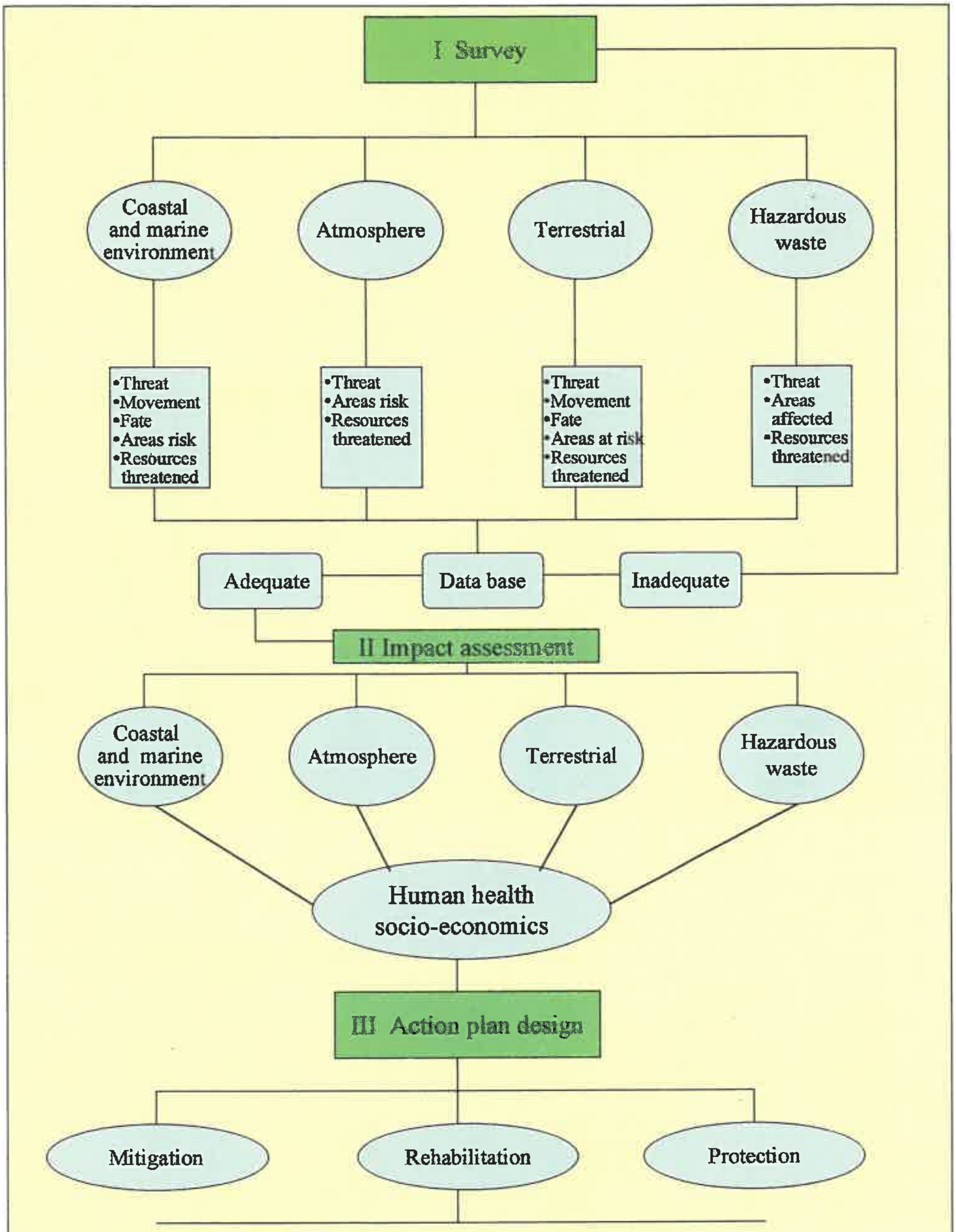


Figure (50): The UN Interagency Plan of Action (Gerges, 1992)

The Iraqi coastal defences, consisting of mines and barbed wire, extended into the sea in order to prevent small boats from landings (Photo Al-Yousifi)

The activities under the Plan of Action started on 20 April 1991 and were completed in 90 days, i.e. on 21 July 1991. They were implemented by some 50 experts from12 United Nations agencies and international organizations, working in collaboration with regional experts to achieve the above objectives of the Plan of Action (Gerges, 1992).

By the completion of the initial surveys and preliminary assessment phases of the above Plan of Action, a meeting of international and regional experts was jointly organized by ROPME and UNEP in Kuwait (28-30 September 1991) to evaluate the results of the Plan of Action and to finalize its draft report. The meeting, which was also attended by representatives from all agencies cooperating in the Plan of Action, reviewed and updated the draft report prepared by UNEP. The revised version of the report was presented to the Fourth Extraordinary Meeting of ROPME Council (Kuwait, 16-17 October 1991) for adoption. The meeting unanimously adopted the report and its conclusions and recommendations. The Council further adopted a set of decisions, which included *inter alia* the following decision:

"Consolidated Rehabilitation Programme (CRP) for ROPME Region, to be prepared with the assistance of the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP), will be presented through UNEP to the UNDP Financing Strategy Meeting in December 1991."

As a follow-up to the above decision ROPME and UNEP in cooperation with UNDP, prepared the required Consolidated Rehabilitation Programme (CRP) including a set of costed and targeted project proposals, taking into consideration the results of the UN Interagency Plan of Action.

Since then, revitalized ROPME took the lead in following up the results of the collective effort exerted by the UN family of agencies and the cooperating international and regional organizations in the aftermath of the war. In this connection the open sea cruises by the American R/V Mt. Mitchell and the Japanese R/V Umitaka-Maru were successfully launched in 1992 and 1993-94 in the RSA. Two Scientific Symposia were organized to discuss the results of the two cruises and formulate some conclusions on the state of the marine environment in the Sea Area after the war. ROPME continues to play its coordinating and leading role in all regional activities, of relevance to the protection of the marine environment in the RSA.

6.5 The Long-Term Impacts of the War on the Marine Environment

6.5.1 Long-term impacts on seawater quality

As stated earlier, most of the countries in the region, rely on de desalination for the production of potable water. The region is producing a total of about 2 billion cubic meter/yr of potable water by desalin releases of PAH from sediment could react with chlorine at the seawater intakes of desalination plants to produce halogenated organic, mostly as bromoform in the volatile fraction (Abdulraheem, 1984).

6.5.2 Long-term impacts on marine organisms

The aromatic hydrocarbons represents principle components of the soluble fraction of oil which could have detrimental long term effects, including genetic changes in marine organisms. This could be especially critical for larval stages which spend most of their lives in the planktonic phase, close to the sea surface where these products are likely to accumulate (Hardy *et al.*, 1993). Thus, the rapid rates of weathering of oil in the RSA may not be as desirable. Increased rates of weathering means greater amounts of soluble weathering products becoming available at the surface microlayer, thus increasing the toxicity to marine organisms. The implications of such scenario, if proven to be true, could spell disastrous future for fisheries in the RSA if sunken oil is not removed and the chronic sources of oil pollution not abated.

Chapter 7

Measures for Prevention and Control of Marine Pollution and Environmental Degradation

Obviously, environmental pollution and degradation should be prevented or controlled. However, problem arises in defining how much effort and financial resources are justified for this purpose. The matter becomes more difficult when there is insufficient basic scientific knowledge on the sources, amounts and fate of contaminants and their interactive relationship with the environment, or when there is inadequate technology available to achieve satisfactory control or prevention (GESAMP, 1990).

With this view, the previous chapters of this report reviewed the current state of the marine environment of RSA in order to understand the physical and ecological features of the Region, the major socio-economic activities as well as the health of the ecosystem. Once such basic facts are established, appropriate policies could then be formulated, suitable prevention and control measures against environmental deterioration are taken and strategies are drawn for the effective management of the marine environment, the coastal areas and their resources. Finally, on the basis of the management approaches adopted, it would be possible to identify a few environmental indicators to be included in the national/regional monitoring and assessment programmes. The present chapter suggests some of these measures and policies for pollution prevention and control and proposes some strategies, which effectively address the prescribed environmental problems of the RSA.

7.1 Policies for Pollution Prevention and Control

Debate continues between those calling for a total ban of the offending activity, or "zero" discharge regardless of costs, and those seeking to improve the control of discharges to the environment of potentially harmful substances. The pragmatist would favour a solution that is effective even if not absolute, rather than one that in practice is difficult to implement.

Over the past century, there has been a gradual development of practical control strategies, at national and international levels. The preferred approach varies with the circumstances of the case, and each has its advantages and disadvantages. However, these approaches have many aspects in common and all have the objective of reducing pollution in an effective and economic way.

A further concept relevant to pollution is that of "sustainable development", as recently outlined in Agenda 21 and the Rio Declaration of the 1992 Earth Summit, the United Nations Conference on Environment and Development (UNCED), and earlier in the Report on the World Commission on Environment and Development (Brundtland Report, 1986). The underlying principle of sustainable development is that the exploitation of resources, the direction of investment, the orientation of technological development and institutional change should be consistent with future as well as with present needs. The irrational use of environmental resources should no longer be acceptable and action is needed to make economic growth compatible with an acceptable environment.

7.1.1 National policies and initiatives

Initiatives to protect the environment at the national level have depended mainly on command and control mechanisms, particularly legislation. The main avenues for the implementation of environmental policy in the region have been national institutions coordinating environmental management and enforcing laws (e.g., ministries, general directorates and the environment protection councils or departments) and the setting of standards and norms through legislation.

Recent socio-economic changes have also brought policy changes that had environmental implications. Unprecedented urban and industrial growth in the ROPME region has resulted in increased demand for natural resources and higher rates of waste generation (both domestic and industrial). In addition, structural adjustment programmes lead the governments of some Member States to suspend many government-supported activities, including environmental planning.

In addition, hostilities in the region over the last two decades have caused large population migrations towards marginal land and water resources.

This, along with the lack of adequate waste disposal and/or treatment in some countries that dispose off their wastes in the Sea Area, has also posed a serious threat to the marine environment and human health in the region.

7.1.2 Regional initiative and policy instruments

Realizing the need for collective action to control pollution and abate the degradation of the marine environment, the eight countries of the Regional adopted in 1978 the Kuwait Regional Convention and the Protocol on Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency. The Convention identified the basic elements of the strategy towards assessment of the marine environment, control and prevention of environmental pollution and development of legal and administrative instruments that allow for the rational exploitation and management of natural resources and other activities.

The Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in cases of Emergency by which the Marine Emergency Mutual Aid Centre (MEMAC) was established (1983). The Protocol has lead to the enhancement of efforts to formulate national oil spill contingency plans and develop legislation towards prevention and control of oil spills in the RSA.

Three other protocols addressing: "Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf"; "Protection of the Marine Environment against Pollution from Land-Based Sources"; and "Control of Marine Trans-boundary Movements and Disposal of Hazardous Wastes and Other Wastes" were signed by the Parties to the Convention in March 1989, February 1990 and March 1998 respectively. These Protocols are expected to further reinforce the efforts towards Prevention and Control of marine pollution and to help setting up relevant national policies.

On the other hand, the development of regional strategy for coastal zone management when adopted is expected to enable the Member States to formulate adequate policies aiming at reducing pollution and ensuring development and management of natural resources on an ecologically sound basis.

7.1.3 Implementation procedures

Various procedures could be developed and adopted by the respective governments to be applied by the concerned authorities to support the implementation of the relevant national policies. The following are examples of such procedures.

7.1.3.1 Environmental Impact Assessment (EIA)

Early planning is the key to development without the occurrence of unacceptable changes in the natural environment. If environmental concerns are considered concurrently with initial technical and economical planning of a major project, and precautions are applied from the outset of the planning process and through the phases of development, it may very well be possible to simultaneously develop a project and at the same time protect the natural resources of an area.

An Environmental Impact Assessment (EIA) will help the decision maker with his task by providing, at an early stage of the decision process, a statement where the consequences to the environment of a proposed programme of action are identified, described and evaluated. Furthermore, the EIA will support efforts aimed at preventing or reducing environmental damage in the short and long term. Thus EIAs provide insight into the nature of the options and trade-off open to the decision maker. At the very least, EIAs are useful reminders of the environmental consequences of taking various actions; at best, EIAs provide quantitative estimates of the magnitudes of these consequences and of the costs of subsequent remedial actions.

The EIA resulted from the raising of environmental awareness during the 1950's and 1960's; during those two decades it became increasingly evident that many industrial and development projects were producing undesirable environmental consequences. In response to these problems, a suitable mechanism was needed to ensure that all major government or private development proposals were subjected to some sort of examination of the total environmental consequences. Governments should therefore enact national environmental policies, which would serve as environmental legislation ensuring systematic and interdisciplinary evaluation of the potential environmental effects of all major actions. EIA legislation has increased worldwide and even certain countries lacking environmental legislation produce EIA selectively.

Worldwide, EIAs are provided for to varying degrees in various international agreements (UNECE, 1984). In the Law of the Sea Convention, Article 206 requires any state which expects an activity to cause "substantial pollution or significant and harmful changes to the marine environment" to asses and report these outcomes. Similarly, the convention for Cooperation in the Protection and Development of the Marine and Coastal Environment of the RSA (the Kuwait Regional Convention, 1978) in its Article XI requires that :

> "Each Contracting State shall endeavour to include an assessment of the potential environmental effects in any planning activity entailing projects within its territory, particularly in the coastal areas, which may cause significant risks of pollution in the Sea Area.
>
> The Contracting States may, in consultation with the secretariat, develop procedures for dissemination of information on the assessment of the activities referred to in paragraph (a) above.
>
> The Contracting States undertake to develop, individually or jointly, technical and other guidelines in accordance with standard scientific practice to assist the planning of their development projects in such a way as to minimize their harmful impact on the marine environment. In this regard international standards may be used where appropriate."

Guidelines on the development and application of EIAs for coastal and marine activities affecting the environment have been prepared by the concerned organizations such as UNEP and the World Bank. Furthermore, a practical approach to EIA was described by Jernelov (1988).

The suggested practical approach to EIA differs from the conventional one in the following ways: (a) it recognizes and utilizes the fact that very few projects are unique in nature or size. Therefore, knowledge about observed environmental effects in analogous cases can be used as a tool in environmental impact assessment; (b) with a monitoring activity as an integrated part of EIA, errors in prediction can be observed and corrected, more knowledge about environmental consequences can be gathered on an on-going basis, and more accurate predictions can be made; and (c) as a consequence of better use of knowledge from analogous cases and monitoring programmes, less time-consuming and costly collection of site-specific data will be required. As a result, in the preparation of EIA one can concentrate on effects known to be of practical relevance and put less emphasis on the theoretical consequences.

The advantages of this practical approach to EIA are that in most cases: (a) it can be based on existing or deducible information; (b) it should be possible to produce within a few months; (c) after initial training, national civil servants, administrators or scientists should be able to prepare it, so that foreign consultants should no longer be needed; and (d) that cost to produce an EIA should be reasonable.

An EIA should be carried out by an organization specializing in that type of work. In cases where the data available for the preparation of an EIA is lacking, it is even more important that the organization, which prepares the EIA, should be a competent one. It is better to prepare an EIA based on partial or incomplete information than not to prepare one at all. The organization which prepares the EIA should use, as much as possible, existing information or analogous information from similar cases. One should always remember that an EIA is only one method or tool among many to be used in the decision making process, and should not be used exclusively.

If the planned project is extensive, and particularly if it involves considerable risk to the environment, it is usually necessary to carry out some type of field study in order to assess the background situation. This may also be needed if the local environment, for some reason, is particularly vulnerable or sensitive. Such a field study may have to be rather extensive. However, in most cases a synoptic analysis, based on existing information supported with a limited amount of new data, will usually be sufficient. Data generated with the EIA are compiled and compared with similar cases.

An EIA should assess possible impacts (type and degree), and the use of technical solutions, such as production technology, anti-pollution measures etc. Based on this assessment, the proposed action may have to be revised and changed to an alternative which will cause less impact on the environment (Jernelov, 1988).

7.1.3.2 Standards and criteria

Emission or source standards and criteria and the limit values associated with them, may control point sources effectively, but they cannot deal with non-point source inputs such as agricultural run-off or atmospheric deposition. By definition, they apply to individual, not to multiple sources. As these standards are based on the "best practicable" or "best available" technology, there is the problem of determining these and of adjusting the respective standards to changing technology. As so far developed, emission standards are generally formulated on the basis of the hazardous properties of particular chemicals, rather than on specific environmental damage (GESAMP, 1990).

For RSA, adaptation of ambient coastal and marine water quality criteria, would provide a better protection of human health, e.g. in recreational beaches and the ecosystem.

7.1.4 Protected areas and marine parks

Because coastal zones and adjacent marine habitats are potentially the sites of extreme resource conflicts, including over-exploitation, mismanagement and pollution from human activities causing environmental degradation, the Kuwait Conventions obligates the Contracting Parties to take all necessary measures to protect the marine and coastal areas and to prevent, abate and combat pollution of the sea areas from the potential sources (e.g. Articles III to IX). Similarly, Article 192(5) of the UN Convention on the Law of the Sea (UNCLOS) stipulates that "States have the obligation to protect and preserve the marine environment." This article not only provides a legal framework for preserving coastal and marine ecosystems, but also suggest that nations will be giving increasing attention to conserving coastal and marine living resources.

In line with above obligations, marine and coastal habitats may be protected through national or regional policies for the establishment of protected areas. The success of these policies depends on the existence of appropriate legal frameworks, general acceptance by local inhabitants, the delineation of areas so that they can be treated more or less as self-contained units, and an effective and well supported managerial system.

Any particular protected area may be designated as such for one or more reasons: (1) it is typical of an important ecosystem or habitat type; (2) it has high species diversity; (3) it is a location of intense biological activity; (4) it provides a critical habitat for particular species or groups of species (Ray, 1976); (5) it has special cultural values (such as historic, religious, or recreational sites); and (6) it facilitates necessary research or determining "natural" baseline conditions.

Marine protected areas must be considered in the broader context of a general programme for coastal and marine resources, that is, an "umbrella programme" for conservation of renewable resources. This umbrella programme should encompass the following:

- Limiting, as necessary, particular exploitative uses of coastal and marine waters and their resources or of linked areas that influence life in these waters, e.g. preventing the mining of living coral reefs to maintain their value to fisheries and to protect the coast from natural hazards.

- Protecting particular vital parts of coastal or ocean ecosystems, especially critical habitats.

- Restoring earlier conditions, by closing areas to enable the recuperation of damaged habitats or depleted stocks, or prohibiting activities that are physically damaging or polluting.

- Obtaining and transferring information through research education and interpretive programmes, Salm, 1984.

Any of these actions may be taken nationally or regionally. They may also be prescribed for specifically defined protected areas. Creating coastal and marine protected areas can help achieve development goals and enhance the benefits of current use. These areas promote sustainable utilization, so that resources may be used, but not used up. Properly designed protected areas provide for a variety of uses and use controls in an integrated resource management. Furthermore protected areas help maintain ecosystem productivity and biological (genetic) diversity, safeguard essential ecological processes and conserve ecosystems that are critical and unique.

7.1.5 Contingency plans and emergency response

The RSA has always been, and will continue to be, under the threat oil pollution incidents by virtue of the handling of oil within the Region, be it through exploration, production and loading operations or through transportation and tanker accidents. In this connection, it is to be noted that the RSA has suffered a number of serious pollution incidents during the last 20 years, but these have mainly been caused by hostilities between neighbouring countries and a few intermediate spills which put the region's marine and coastal ecosystems and the vital coastal installations and infrastructures such as desalination plants at high risk of pollution and damage.

Contingency plans and emergency response arrangements are therefore considered very important for the control of marine pollution in the region, and should be an integral part of the national/regional strategy.

At the national level, most of the ROPME Member States have national contingency plans and stock piles of oil spill response equipment and materials, including that provide by the industry. For example, Saudi Arabia has initiated its National Contingency Plan for Combating Marine Pollution from Oil and other Hazardous Substances in Emergency Cases, and was officially initiated just prior to the 1991 war oil spill. Bahrain, Kuwait and Oman have also operative national contingency planes (Al-Ghamdi, 1998).

Regionally, at the time MEMAC initiated its efforts to develop a regional oil spill contingency plan for the region, the major oil companies operating in seven of the Member States had already in 1972 formed a collective response capability under the umbrella of the Gulf Area Oil Companies Mutual Aid Organization (GAOCMAO). The principal objective of the organization is to provide a coordinated, mutual aid capability through the pooling of the equipment and materials of individual member companies. Today there are 10 operating companies in GAOCMAO, with ROPME trying to foster the inclusion of all oil companies in a regional arrangement covering the entire RSA.

Utilizing the mandate given by the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution and its Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency (1978). The Marine

Emergency Mutual Aid Centre (MEMAC) located in Bahrain, was established to coordinate government activities in the field of oil spill response and promote mutual assistance between ROPME Member States particularly in the cases of emergency. MEMAC's priorities include the finalization of a regional oil spill contingency plan, setup of a regional arrangement to facilitate the lone of personal and equipment between member states during oil special emergencies develop a mechanism for initiating response by member states during an emergency thought the activation of an emergency fund, the finalization of port state control memorandum of understanding among ports of the Region to reduce competition and maintain a high standard of ship safety, maintenance and environmental protection measures. MEMAC is also providing technical input into a regional feasibility study towards the establishment of regional reception facility for oily wastes and other wastes. MEMAC's role in capacity building includes training, organizing oil spill drills and facilitating information exchange.

In an effort to enhance member states ability to detect and track oil spills in the RSA, ROPME is developing its remote sensing capabilities in order to advance the idea of establishing an oil spill detection and response system using satellite observations and modern surveillance and communication technologies. The application of NOAA's Advanced Very High Resolution Radiometer (AVHRR) imagery's have already been used in connection with the 1991 environmental crisis to estimate the extent and behaviour of the oil slicks and the oil well fire plumes, and showed its usefulness and ability to provide an effective tool for emergency response and crisis management.

At the international level: to date five Member States of ROPME have ratified or acceded to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 as amended by Protocols in 1976 and 1984 (FUND Convention); six ratified the International Convention on Civil Liability for Oil Pollution Damage, 1969, as amended by Protocols 1976, 1984 and 1992 (CLC Convention); and only one Member State ratified the International Convention on Oil Pollution Preparedness, Response and cooperation 1990 (OPRC Convention). However, given the increase in awareness shown by governments and industry, this trend seems to be changing.

7.1.6 Precautionary environmental protection policy

The idea that prevention is better than cure and that release should be prevented even before evidence of damage has been propounded for many years. This concept has been developed as the anticipatory protection, or precautionary principle.

The precautionary principle argues that every effort should be made to relieve the potential burden on the environment resulting from the input of foreign substances. It is a part of a policy of risk prevention aiming to reduce progressively the emission levels of all substances introduced by man into the atmosphere, water and soil. On the basis of this principle, rigorous control of contaminants has been applied by some developed countries in certain areas, despite the lack of evidence that environmental deterioration was linked to releases, rather than to other factors, such as natural changes.

Anticipatory environmental protection, as it is evolving, raises an essential issue: are the actions for the protection of the environment. It is taken on the basis of our present knowledge, sufficient, or do we have to assume that the future holds risks which are beyond our knowledge and therefore need to be taken into account in our current pollution prevention strategies (GESAMP, 1990).

In this connection, it is important for example to see how the costs of damage relate to the costs of action to minimize or avoid pollution. Advances have been made in the techniques for analysis of costs incurred as a result of marine pollution and in the evaluation of the benefits of control and abatement. Inevitably, however, the values attributed to a potentially polluting activity and the cost of preventing or cleaning it after it must reflect local conditions and values.

7.1.7 Public awareness

The behaviour of every individual contributes to the nature and extent of environmental damage. In meeting the objectives of pollution control, a high level of environmental awareness in the public is crucial. This can be achieved by provision of relevant information and by the establishment of educational programmes. Environmental public awareness programmes should therefore be an important component of any national policy for environmental protection. Increasing the public awareness of the activities that may have adverse impact on the marine environment will play an essential role in creating positive attitudes towards the environment, and hence in the prevention and control of marine pollution and environmental degradation.

Well-designed programmes and targeted public awareness activities should therefore be developed at both the national and regional levels as part of the adopted policies for marine pollution prevention and control. To this effect, the national authorities concerned should also make research results and scientific report available to the public, and explain them clearly in language, which suits the targeted audience.

7.2 Environmental Legislation

7.2.1 National legislation/regulations

ROPME Member States have passed numerous laws dealing with the environment. In Kuwait, for example, the first law was passed to protect navigable water from oil pollution. Articles 15, 16 and 21 of the constitution of Kuwait were subsequently amended in 1976 and in 1980 to incorporate environmental protection principles and to establish mechanisms to enforce the implementation of environmental laws.

Despite the often fragmented nature of organizational responsibilities for the environment, legislation in the region has been fairly cross-sectoral and all-encompassing since the 1980s. These laws, sometimes known as framework laws, have helped countries reorder fragmented approaches to environmental management.

More recent attempts at harmonization of environmental legislation and institutions have also taken place. The enforcement of existing laws is critical for the protection of the region's environment. Some Member States have imposed new types of liability or increased penalties for environmental offences in order to secure better environmental quality. In Bahrain, for example, any person found guilty of causing oil pollution in the marine environment or of dumping in territorial waters wastes from ships or land-based sources is liable to large fines. Violators are also responsible for the cleanup of the contaminated area within a specific time (UNEP, 1995). Nevertheless, most national environmental legislation and regulations in some countries obviously need updating and revision, particularly to include acceptable and adequate norms and standards.

Furthermore, the question of national legislation concerning civil liability and compensation need more attention by ROPME Member States and further harmonization among the Member States within the region. **Zainal** (1998) indicates that no national legislation enacted so far to deal solely with question of civil liability and compensation. This subject matter has been regulated by secondary legislation in some countries or by general principles of civil law in the others, or by international conventions to which the state in question is a party to.

Naturally all ROPME members are adhered to the ROPME regional legal instruments (Kuwait Convention and various Protocols dealing with different sources of pollution). These contain only very general provisions on the question of civil liability and compensation (Article 13 of the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution of 1978).

7.2.2 The Kuwait Convention and its Protocols

As mentioned earlier, the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978) has four related protocols. ROPME Protocols have been developed in accordance with the recommendations of the Legal Component of the Kuwait Action Plan.

Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency, 1978

The RSA is considered to be an area with one of the highest oil pollution risks in the world. This is mainly due to the concentration of offshore operations and exploitation facilities, tanker loading terminals and the huge volume and density of marine transportation of oil.

The objective of the Protocol, which was signed on 24 April 1978 and entered into force on 1 July 1979, is to provide cooperative and effective preventive and response measures to deal with marine emergencies caused by oil and other harmful substances. Marine emergency means any casualty, incident, occurrence or situation, however caused, resulting in substantial pollution or imminent threat of substantial pollution to the marine environment by oil or other harmful substances and includes, inter alia, collisions, strandings and other incidents involving ships, including tankers, blow-outs arising from petroleum drilling and production activities, and the presence of oil or other harmful substances arising from the failure of industrial installations. The Protocol with 13 Articles and an Appendix on guidelines for reporting marine emergencies enjoys the participation of eight Parties.

- **Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf, 1989**

The Kuwait Regional Convention at Article VII stipulates that the Contracting States shall take all appropriate measures to prevent, abate and combat pollution in the Sea Area resulting from exploration and exploitation of the bed of the territorial sea and its sub-soil and the continental shelf. To this effect, the Protocol was concluded, signed on 29 March 1989, and entered into force on 17 February 1990. Later, the following Guidelines to the Protocol were adopted by the Seventh Meeting of ROPME Council on 21 February 1990:

a) Guidelines on requirements for environmental impact surveys and assessments.
b) Guidelines on the use and storage of chemicals in offshore operations.
c) Guidelines on the conduct of seismic operations.
d) Guidelines on disposal of drill cuttings on the sea-bed,

These Guidelines are to assist Contracting States in developing their specific plans and measures in compliance with the provisions of the Protocol. Also, the application of common standards, criteria and regulations, as well as the harmonization of environmental policies, programmes, administration and legislation of Contracting States for the fulfillment of their obligations under the Protocol, are major objectives to be achieved in the near future.

The objective of the Protocol is to coordinate regional activities towards protection of the marine environment against pollution from exploration and exploitation of oil and gas in the continental shelf. The Protocol with fifteen articles and four Guidelines is a broad framework for developing comprehensive action plans delineating the obligations of Contracting States at the national and regional levels for sound environmental practices in offshore exploration and production (E & P) activities. The Protocol has the same status of participation as the Convention.

Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources, 1990

The Kuwait Regional Convention at Article VI stipulates that the Contracting States shall take all appropriate measures to prevent, abate and combat pollution by discharges from land reaching the Sea Area whether water-borne, air-borne, or directly from the coast including outfalls and pipelines. Also, the development and adoption of a protocol on pollution resulting from land-based sources has been recommended under the Legal Component of KAP. To this effect, the Protocol with 16 Articles and 3 Annexes was finalized in 1989, signed on 21 February 1990 and entered into force on 2 January 1993.

Annex III to the Protocol addresses regional guidelines, regulations and permits for the release of wastes. Accordingly, regional regulations for the waste discharge and/or degree of treatment should be specific for each kind of source and, if necessary, may be different between existing and new sources.

ROPME pursues as a principal approach the development of a Regional Programme of Action to support and reinforce the National Programmes of Action for the implementation of the Protocol. To this effect, ROPME has developed a Regional Programme of Action that is consistent with the Washington Declaration and the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities, which were adopted in Washington in November 1995.

The Regional Programme of Action is to meet the environmental needs and enhance the environmental capabilities of the Region and is aimed primarily towards implementation of the Protocol by way of a coordinated National and Regional process-oriented framework of action.

Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes, 1998

The main objectives of the Protocol are to protect the marine environment of the Protocol Area from detrimental effects of hazardous wastes and other wastes, to assist Contracting States in environmentally sound management of wastes they generate and to enhance cooperation and coordination of action on a regional basis with the aim of controlling the transboundary movements of hazardous wastes and other wastes. To this effect, the transboundary movements of wastes, the dumping of wastes at sea, the ballast water of oil tankers and the wastes of commercial ships are covered by the Protocol.

The promotion of regional cooperation for the establishment and management of reception facilities for the reception and treatment of ballast water and other wastes from ships and for the development of an effective monitoring and surveillance system to detect and control dumping of wastes at sea, are fully addressed in the Protocol.

The Protocol with 16 Articles was signed by six ROPME Member States during the Meeting of the Plenipotentiaries held in Tehran, I.R.Iran on 17 March 1998.

Table (16) gives the status of signature and ratification of the above legal instruments in the RSA as of December 1998.

7.2.3 International conventions and programmes relevant to the protection of the marine environment

7.2.3.1 International conventions

The United Nations Convention on the Law of the Sea (UNCLOS, 1982) is the overarching international convention that deals with almost all matters related to the ocean and seas in the world. Other conventions deal with specific subjects relevant to the prevention of marine pollution from various sources.

The following are the main agreements, conventions and associated legislation relating to the airborne detection of marine pollution by oil:

a) **International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 with Amendments (London Convention) and the 1996 Protocol to Amend the Convention (LC Protocol).** The Convention requires Contracting States to institute a licensing regime for any wastes to be dumped at sea from vessels and aircraft. These regulations exclude operational discharges from vessels which are subject to separate controls under MARPOL 73/78.

Table (16) : Status of signature and ratification of the Kuwait Convention and its Protocols by ROPME Member States

State	Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution and its Protocol (1978)		Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf (March 1989)		Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources (February 1990)		Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes (March 1998)	
	Date of Signature	Date of Ratification	Date of Signature	Date of Ratification	Date of Signature	Date of Ratification	Date of Signature	Date of Ratification
Bahrain	24.04.1978	01.04.1979	29.03.1989	14.08.1990	21.02.1990	02.01.1993	17.03.1998	
I.R. Iran	24.04.1978	03.03.1980	29.03.1989	30.06.1992	21.02.1990	12.09.1993	17.03.1998	
Iraq	24.04.1978	04.02.1979	29.03.1989	17.02.1990	----	----	----	
Kuwait	24.04.1978	07.11.1978	29.03.1989	17.02.1990	21.02.1993	02.01.1993	17.03.1998	
Oman	24.04.1978	20.03.1979	26.04.1989	17.02.1990	02.01.1993	02.01.1993	17.03.1998	
Qatar	24.04.1978	04.01.1979	29.03.1994	17.02.1990	21.02.1990	02.01.1993	17.03.1998	
Saudi Arabia	24.04.1978	26.12.1981	29.03.1995	17.02.1990	21.02.1990	02.01.1993	----	
U.A.E.	24.04.1978	01.12.1979	29.03.1996	16.07.1990	21.02.1990	----	17.03.1998	

b) **International Convention for the Prevention of Pollution from Ships 1973 (MARPOL) and Protocol 1978.** This convention supercedes the International Convention for the Prevention of Pollution of the Sea by Oil 1954 (OILPOL), applies to all tankers over 150 gross tons and other ships over 400 gross tons. It is effective in all sea areas other than those declared by the International Maritime Organization (IMO) as 'Special Areas' which include the Baltic, Black, Red, and Mediterranean seas as well as the RSA. In general tankers may discharge at the rate of 60 litres per hour (roughly 100 ppm) only when on a direct route, 50 miles from the nearest land and on the basis that no more than 1/30,000 of the last cargo carried is in total discharged. For non-tankers discharges are limited to 100 ppm and are not permitted within 12 miles of shore. As a general guide 100 ppm discharged in accordance with these criteria is not visible in the ship's wake - so if oil is sighted in the wake of a ship, that ship is almost certainly in contravention of the legal discharge regulations.

c) **International Convention on Oil Pollution Preparedness, Response and Cooperation 1990 (OPRC).** This Convention requires that parties ensure that:

1) Ships of their flag have a contingency plan on board.

2) They establish an oil pollution reporting procedure involving their vessels and aircraft. and that they inform other states which might thereby be threatened.

3) They identify appropriate responsible national authorities and maintain a national response contingency plan.

Table (17) shows the status of participation of ROPME Member States in the above Conventions as well as other international Conventions not directly dealing with the marine environment but rather related, for example the Conventions on Trade in Endangered Species (CITES), Climate Change, Protection of the Ozone Layer, etc.

7.2.3.2 Global programmes

A Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities was adopted by an Inter-governmental Conference held in Washington, D.C., U.S.A., 23 October –

3 November 1995. The goal of the Global Programme of Action is to prevent degradation of the marine environment from land-based activities, by facilitating the realization of the duty of States to preserve and protect the marine environment. It is designed to assist States to take action individually or jointly within their respective policies, priorities and resources, which will lead to the prevention, reduction and control and/or elimination of the marine environment, as well as to its recovery from the impacts of the degradation of land-based activities.

Implementation of the Global Programme of Action will contribute to maintaining and where appropriate, restoring the productive capacity and biodiversity of the marine environment, ensuring the protection of human health as well as promoting the conservation and sustainable use of aquatic living resources.

ROPME recognizing the importance of the above Global Programme of Action, and building on its previous activities on land-based sources of marine pollution. It took the initiative to develop its Regional Programme of Action on Land-Based Activities (LBA) and has already taken an active and leading role in the implementation of both the Global and the Regional Programme of Action on LBA. ROPME has also prepared its regional overview on LBA and embarked on the preparation of a manual for the implementation of ROPME's Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources that was adopted in 1990 and entered into force in January 1993.

7.3 Institutional Arrangements

7.3.1 National governmental and non-governmental bodies dealing with environmental issues

All ROPME Member States now have environmental ministries or institutions in place, with some countries having restructured these institutions in the recent years, giving them higher political standing. At present, two Member States have ministers of environment in the cabinets, namely, Bahrain (Ministry of Housing, Municipalities and Environment) Oman (Ministry of Regional Municipalities and Environment). I.R. Iran has established the post of a Vice-President for the environment. Kuwait, Saudi Arabia and the UAE have public authorities dedicated for the environment (Table 18).

Table (17): Status of participants of ROPME Member States in international environmental agreements

No.	International Conventions/Protocols
1	United Nations Convention on the Law of the Sea, 1982 (UNCLOS)
2	International Convention for the Prevention of Pollution from Ships, 1973 and Protocol 1978 (MARPOL 73/78); Annex II (1973/85); Amendment to Annex I (1997)
3	International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 with the Amendments 1978/80 (LONDON Convention)
	* 1996 Protocol to Amend the Convention (LC Protocol)
4	International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 as amended by Protocols 1976 and 1984 (FUND Convention)
	* 1992 Protocol to Amend the Convention (FUND Protocol)
5	International Convention on Civil Liability for Oil Pollution Damage, 1969, as amended by Protocols 1976, 1984 and 1992 (CLC Convention)
6	International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualities, 1969 (INTERVENTION Convention)
	* Protocol Relating to Intervention on the High Seas in Cases of Pollution by Substances other than Oil, 1973 (INTERVENTION Protocol)
7	International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990 (OPRC Convention)
8	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1989 (BASEL Convention)
	* 1995 and 1998 Amendments
9	Convention on Wetlands of International Importance, Especially as Waterfowl Habitat, 1971 (RAMSAR Convention)
	* Protocol to amend the Convention, 1982 (RAMSAR Protocol)
10	Convention on the Conservation of Migratory Species of Wild Animals, 1979 (BONN Convention - Migratory Species)
11	Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (WORLD HERITAGE Convention)
12	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973, as amended
13	Convention on Biological Diversity, 1992 (BIODIVERSITY Convention)
14	Framework Convention on Climate Change, 1992 (Convention on CLIMATE CHANGE)
15	Convention for the Protection of the Ozone Layer, 1985 (OZONE LAYER Convention)
	* Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, with Amendments and Adjustments (MONTREAL Protocol)

X Ratified / Acceded to * Signed but not Ratified

Bahrain	I.R. Iran	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
X	*	X	X	*	X	*
		X	X			
	X	*	X			X
X		X	X	X		X
X			X			X
X		X	X	X	X	X
	X	X	X	X		X
	X		X			
*	X					
X	X	X	X	X	X	X
X	X					
X	X					
	X				X	
X	X		X	X	X	
	X	*			X	X
X	X	*	X	X		*
X	X	X	X	X	X	X
X	X	X		X	X	X
X	X	X		X	X	X

Table (18) : Governmental environment institutions and agencies in ROPME Member States

Country	Policy Institutions	Executive Agency
Bahrain	Environmental Affairs	Ministry of Housing, Municipalities, and Environment
I.R. Iran	Environmental High Council	Department of the Environment
Iraq	National Council for the Protection and Improvement of Environment	Ministry of Health
Kuwait	Environment Public Authority (EPA)	Environment Public Authority
Oman	Council of Ministers	Ministry of Regional Municipalities and Environment
Qatar	Council of Ministers (Permanent Commission for Environmental Protection)	Ministry of Municipalities and Agriculture
Saudi Arabia	Ministerial Committee on Environment	Meteorology and Environmental Protection Administration (MEPA)
United Arab Emirates	Council of Federation	Federal Environmental Agency (FEA)

The role of Non-Governmental Organizations (NGOs) is becoming increasingly important, particularly in areas, which require active public participation, and in raising public awareness of environmental issues. In almost all ROPME Member States, environmental NGOs are active and have a wide range of activities, many of which are related to the marine environment.

7.3.2 Overall coordinating bodies

7.3.2.1 At the national level

Recent recognition of the inter-sectoral nature of many environmental concerns has led to an increasing number of Governments developing cross-cutting policy institutions. These commonly take the form of inter-ministerial or interdepartmental committees, and national environmental strategies developed with sector departments.

Only few governments, however, have created high-level, cross-cutting bodies under the direct control of the Head of Government (in Oman for instance), a senior minister or a Vice-President (I.R. Iran, for example) or Deputy Prime Minister e.g. Kuwait and Saudi Arabia.

7.3.2.2 At the regional level

ROPME is the overall regional coordinating body on matters related to the marine environment and coastal areas of its Member States. Since its establishment following the adoption of the Kuwait Regional Convention ROPME was very instrumental in coordinating the national efforts in its Member States in the marine environmental fields. ROPME's Marine Emergency Mutual Aid Centre (MEMAC) coordinates regional activities related to its mandate described above.

On another level, the Heads of States of the Gulf Cooperation Council (GCC) (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and U.A.E.) approved environmental principles in 1985. The GCC Secretariat now encompasses a regional Directorate of Man and Environment that organizes environmental regional surveys, assessments, education, training and information exchange activities at the GCC sub-regional level, as well as with other regional and national institutions.

Another coordinating body under a larger umbrella and wider environmental mandate is the Council of Arab Ministers Responsible for the Environment (CAMRE) which operates under the League of Arab States. CAMRE adopted the Arab Declaration on Environment and Development and Future

Prospects in 1991 and agreed on principles and directives for the protection and improvement of the environment in the region. CAMRE's Technical Secretariat coordinates the implementation of the Arab Programmes for Sustainable Development, which has the marine environment and coastal areas in the Arab region as one of its main components. CAMRE also established the Joint Committee on Environment and Development in the Arab Region (JCEDAR) to enhance cooperation and coordination among Arab regional and national organizations.

There are also many technical organizations dealing with ROPME including: the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA), the Centre for Environment and Development for the Arab Region and Europe (CEDARE), and the Gulf Area Oil Companies Mutual Aid Organization (GAOCMAO) and other Arab specialized organizations. Almost all provide technical assistance and respond to capacity building needs at the regional level. Universities and other research institutions in the region also play a supportive role and often carry out regional activities in cooperation with regional and international organizations.

7.3.2.3 At the international level

Among United Nations bodies and programmes that are active in the region are the United Nations Environment Programme-Regional Office for West Asia (UNEP/ROWA). Seven of the eight ROPME Member States are also served by ROWA. Other relevant regional offices of international organization include the Economic and Social Commission for West Asia (ESCWA), World Health Organization (WHO) and, Food and Agricultural Organization – Regional Near East Office [FAO (RNE)]. The International Atomic Energy Agency - Marine Environmental Studies Laboratory (IAEA-MESL, Monaco) maintains a close relationships with ROPME in the areas of quality assurance training and technical advice. The IOC has also been ROPME's partner in planning for open sea cruises and management of oceanographic date. The IMO has been working closely with ROPME on the issues relevant to MARPOL, reception facilities, port state control (PSC) as well as in training and information exchange.

Chapter 8

Current and Emerging Issues and Challenges

Previous chapters of this report reviewed the present state of the marine environment in the RSA, and the impacts of human activities on the marine and coastal environments. This chapter describes the main current and emerging issues that warrant further attention. Addressing these problems would certainly require continued cooperation in reaching short-term goals through a series of complementary actions at all levels, and key measures to be taken to achieve sustainable development in the RSA as described in the preceding chapter.

As elaborated earlier in this report, the RSA Region has its unique features that include a harsh arid nature and complex ocean dynamics in a small, semi-enclosed and relatively shallow regional sea. The Region also has one of the world's largest oil and gas reserves and has been responsible for the export of more than 50% of the world's oil supplies. This presented the countries of the region with an unprecedented growth in population, industrial and commercial development. Furthermore, the wars witnessed by the Region and their environmental consequences added more to the human pressures on the Region's ecosystems and its resources.

On the basis of the data and information presented and discussed above, it is concluded that the main environmental issues and problems characterizing the RSA could be summarized as follows:

8.1 Current Issues

8.1.1 <u>At the national levels</u>

8.1.1.1 Strengthening national focal points through the provision of technical, administrative and legal support by the governments of the Region is needed in order for them to meet the provisions of regional and global conventions, policies and programmes. This should be done by continuous capacity building and upgrading the status of engagement in the environment.

8.1.1.2 Emphasis should be put on adequate monitoring programmes, supported by quality assurance and quality control regimes, as the most appropriate way to assess the state of the environment and identify major problems and priorities. Implementing rigorous technical training programmes and support of young research students and university graduates is a basic approach to strengthen the manpower base of our NFPs.

8.1.1.3 Addressing the environmental issues of most concern to our societies while maintaining close relationship with the political and social structures and jointly formulating mitigation measures, is a major challenge to our NFPs. Issues of protecting desalination plants from oil releases by establishing reception facilities in our ports, regulating land reclamation and dredging, and the establishment of marine protected areas are likely to accept wide public support and thus meet the political requirements for such actions to be taken. Environmental health is also a major area of concern which should be pursued attentively. Most pollution sources are first and foremost affecting the working environment and are considered a challenge to the occupational health. The next victims are the general population on the vicinity of the pollution sources and the ambient environment.

8.1.1.4 Adopting regional approaches to national problems that are common to other Member States is likely to improve the chances for obtaining support from decision-makers nationally.

8.1.1.5 Insisting on the need to carry out environmental impact assessment as a tool for proper planning is a good preventive approach. This should be an integral part of any environment legislation. Also, other types of control, particularly the pollution pays principle (PPP) are to be effectively applied to ensure maximum compliance with environmental legislation.

8.1.1.6 National procedures, consistent with regional and international procedures, are to be formulated for the determination of liability for damage resulting from pollution and environmental degradation. Recourse is to be available in accordance with national legal systems for prompt and adequate compensation or other relief in respect of damage.

8.1.1.7 Integrated approaches to coastal area management, establishment of new healthy cities and range of agriculture and fisheries resources enable the environment protection authorities to deal with such complex issues.

8.1.2 At the regional levels :

8.1.2.1 Pollution resulting from oil production and transportation

It is evident from the fact that the ROPME region is a major oil producing area of the world, and some 25,000 tankers navigate in and out of the Strait of Hormuz every year, thus making RSA an oil tanker highway. As much as roughly two million barrels of oil are spilled into the RSA's water every year from the routine discharge of dirty ballast waters and tankers slops, and from the region's 800 offshore oil and gas platforms (Hinrischsen, 1996). In addition, in recent years, military activities and the associated massive oil spills have further magnified the problem.

Impacts of contamination by oil could now be observed both in sediment and biota as well as on extended area of the beaches and along the region's coastline in the form of tar balls. It should be noted that unless ROPME Member States decide to take the necessary steps to declare the RSA as a "Special Sea Area" in accordance to MARPOL 73/78, oil pollution from transportation, offshore operations and land-based activities will continue. As the preliminary conclusions of the feasibility study on reception facilities have indicated, meeting the requirements of MARPOL 73/78 does not need expensive or technically difficult. With the ratification of MARPOL 73/78 and joining to other relevant global legislation, e.g. the OPRC, CLC and FUND, our region will have a chance to protect it's marine environment from oil and other forms of marine pollution by enforcing national legislation and imposing fines and compensation on violators.

8.1.2.2 Land-based activities affecting the marine environment

Coastal and marine environment throughout ROPME region are becoming subjected to increasing human pressures, most of which resulted in harmful environmental effects. More acute ecological problems have risen from urbanization and industrial activities in coastal areas of the regions and from loss and degradation of productive habitats, caused by landfill, dredging, sedimentation and related practices. Over 20 major industrial complexes have either been completed or under construction. Other land-based activities include sediment run-off, agriculture and salt water intrusion due to groundwater extraction. These activities are contributing to degradation of the coastal environment.

Dredging and coastal reclamation probably represent one of the most serious impacts on the ROPME environment. Reclamation has been undertaken for residential developments, ports, industrial areas, bridges and causeways, corniche roads, water fronts and other recreation facilities. Favoured areas often have included intertidal flats with mangroves, shallow embayments and other biologically productive areas, whose true bioeconomic value is seldom recognized by developers.

Coastal erosion occurs in several parts of RSA. Some erosion is a natural process and part of the continuing change of the shoreline. However, in many areas, massive and irreversible erosion occurs, primarily because construction activities have not considered impacts on the shoreline. Dams, sea walls and harbours are necessary for economic development but they should be designed to minimize coastal erosion.

These activities led to physical alteration of RSA coasts, sediment mobilization and destruction of habitats. Loss of habitat extends to other parts of the region where considerable proportion of mangrove forests may have been lost over the past 20 years.

8.1.2.3 Pollution resulting from municipal releases

Fresh water in the most valuable commodity in arid areas. Most of RSA countries depend on desalination processes to produce potable water, which is the most expensive water production scheme in man's history. It is a combination of the Region's commitment to development and availability of low cost fuels. However, low cost fuel cannot be a reason for waste. Our Islamic culture has rejected wastefulness even in our daily diet or personal pleasures. Moreover, to produce fresh water at such a cost and fail to recycle it for agriculture and afforestation is another form of waste, or at least a lost opportunity to use a valuable resource. The current percentage of treated effluent re-use of less than 40% must be at least doubled in the next five-ten years. Another reason for setting such an objective is to protect the marine environment from the release of sewage and treated effluents in view of the RSA sensitivity to increased levels of nutrients and in order to protect our beaches (and our infant tourism industry) from contamination with pathogens.

8.1.2.4 Reduction of the impact of the petroleum and the petro-chemical industry

As environmentalists, we must accept the fact that we live in a region that it's development goals and strategies are built around the oil, gas and petrochemical industries. It is our destiny. Thus, it is our challenge to lead the world in proving that this industry can be accommodated with lower health risks to man and the environment. This Region is blessed with extreme aridity and intensive sunlight (UV radiation) which are essential for the breakdown of petroleum hydrocarbons. By insuring that the workers and the general public are properly protected against the emissions vapours generated by these industries, by developing health criteria for the work and the ambient environments and by insisting on cleaner production and reduction of waste, especially hazardous wastes, we would have then achieved most of our objectives. Utilizing our environment to further breakdown oily wastes and render them useful raw materials or as biomass to improve quality of our soils would further fulfill our strategic objective. It may be noted here that ROPME in cooperation with the Harvard School of Public Health has taken the first step in this direction by organizing a seminar in 1997 in which our oil industry was an active participant . The rest is up to the Member States.

8.1.2.5 Loss of RSA fisheries, biodiversity, and ecosystems

It is well established fact in our Region that there is a good potential for our fisheries and tourism industries to contribute significantly to the national economies of the Member States. They can be made sustainable in view of the fact that both rely on renewable resources.

Unfortunately, overfishing continues to be a problem in the Region as a result of lack of season, area and gear regulations on a regional and/or sub-regional levels. Moreover, destruction of habitats by physical alteration and through land-filling, dredging of coastal areas and wide scale drainage of wetlands and marshes have contributed significantly to the loss of nursery grounds of fish, feeding grounds for migratory birds as well as indigenous reptiles, mammals and other ecologically and economically important habitats as mangroves, seagrass beds, oyster banks, coral reefs and tidal flats. In addition to dislocation of large sector of people living there for centuries with special cultural pattern that was a unique system in human civilization.

Another phenomenon affecting the fisheries resources of RSA and coral reefs is that the increased incidence of fish kills and the appearance of invasive species. Fish kill phenomena due to biological, chemical and physical causes need to be addressed and an action plan to be developed for monitoring, diagnosis and prevention of such phenomena. Invasive species that have plagued coral reefs in the Omani and UAE waters are also serious issues. The potential for introducing other species through disposal of ballast water by tankers on through accidental release from aquaculture projects, museums or amateur aquaculture owners remains high in our region. The fact that the RSA has high salinity and wide range of temperature is not enough to prevent hardy species from surviving in this environment. The need for special legislation and public awareness campaign may be emphasized here.

It is obvious that all of the above environmental impacts are inter-linked and all contribute to the loss of RSA fisheries resources which can be enhanced as non-renewable resources and remain the main source of protein for our new generations, given the protection and sound management.

8.1.2.6 Industrial effluents

Marine contaminants such as heavy metals, persistent organic pollutants (POPs) and nutrients are largely originating from industrial sources. The unprecedented high rate of industrial development in the region, and the uncontrolled wastes from industry reaching the marine environment pose a real challenge to the sustainable management of the RSA. The major environmental problems associated with thermal desalination plants are: the disposal of the waste brine into the sea, thermal pollution resulting from brine disposal, pre- and post-treatment chemicals and corrosion products mainly heavy metals (Khordagui, 1997).

8.1.2.7 Industrial emissions

The industrial emissions to the atmosphere that eventually reach the marine environment and their sources are described previously in this report. Setting emission standards and criteria are of prime importance for the improvement and protection of both the atmospheric and marine environment of the region.

8.2 Emerging Issues

8.2.1 The need for designation of marine and coastal protected areas :

Coastal habitats are often susceptible to mismanagement of activities in upland areas. The most serious threat is habitat destruction (Lucas and Synge, 1978; Allen and Prescott-Allen, 1978). This destruction takes many forms: (1) the replacement of entire habitats by settlements, harbours, and other human constructions, by cropland, grazing land, and plantations, and by mines and quarries; (2) the effects of dams (blocking spawning migrations, drowning habitats, and altering chemical and thermal conditions); (3) drainage, channelisation and flood control; (4) pollution and solid waste disposal (from domestic agricultural, industrial, and mining sources); overuse of groundwater aquifers (for domestic, agricultural, and industrial purposes); (5) removal of materials (such as vegetation, gravel, and stones) for timber, fuel, construction, and so on; (6) dredging and dumping; and (7) erosion and siltation.

A major wetland drainage activity in the ROPME region is the recently observed coastal activity in the north-western part of the RSA. Information on the ground and satellite observations indicated that Iraq has embarked on an activity which reduced the marshes in the coastal area of southern Iraq, with an estimated area of almost 0.5 million hectares (Maltby, 1994) to water channels delivering river water directly into the RSA, with all its sediment loads, agrochemicals sewage and industrial wastes. This action will have negative consequences on the fisheries and ecology of the area, and should therefore be vigorously addressed as a major regional challenge. Human suffering of this environmental disaster caused by dislocation of people is tremendous and requires concerted immediate attention.

Designation of coastal and marine protected areas would therefore help maintain ecosystem integrity and productivity, safeguard essential ecological processes by controlling activities that disrupt them or that physically damage the environment. It would also help conserve biological (genetic) diversity and protect ecosystems that are critical and unique.

From the socio-economic point of view, designation of marine protected areas would maintain bioproductivity for fisheries. Continued fish production means continued livelihood for fisherman and for other fishing industry and hence means continued social, cultural, economic and political stability.

8.2.2 River basin management

The issue of river basin management and the implementation of the ROPME's Protocol on the Protection of the Marine Environment from Land-Based Sources in this regard need to be addressed with a view to protect the fisheries of the NW part of the RSA. The quantities of river flow and their load of nutrients are important from pollution control perspective as well as from the need to support spawning and nursery grounds of fish and shrimps. Construction of dams along the river route is a major challenge to the environment, some serious thoughts should be given to this problem.

8.2.3 Harmonization of environmental regulations

In a geographically confined area such as the RSA, and in view of the high density of oil-based industrial development, the need for harmonization of environmental regulations becomes a necessity. Exploration and exploitation of the continental shelf, cooperation in surveillance and combating of oil discharges or spills particularly in cases of emergency, and control over the transport of hazardous wastes represent major areas for regional coordination. The provisions of the Kuwait Regional Convention and its Protocols provide for common standards, criteria and regulations, as well as the harmonization of environmental policies, strategies, programmes, administration and legislation of Contracting States for the fulfillment of their obligations.

One good example of the need for regional harmonization of regulations is the issue of port state control and inspection. In any regional sea, competition between ports over business opportunity could lead to lowering of standards of ships and services, less stringent safety requirements and lack of enforcement of environmental regulations. Failure to standardize safety and environmental regulations could only worsen an already high-risk situation resulting from the frequent use of "Flag of Convenience" ships in the RSA. IMO has recognized the need for harmonization of port state control regulations and has encouraged the signing of 'Memoranda of Understanding' among states sharing regional seas, e.g. the North Sea, the Baltic, the Mediterranean and the Caribbean. In our Region, an understanding has been reached between ROPME and the GCC to adopt such a memorandum of understanding over ship safety and environmental regulations in ports of the RSA. Such a step, with support from the oil industries and port authorities would drastically reduce the number of sub-standard ships, lower the risk of marine pollution and allow ports to upgrade their environmental standards without being engaged in a "fee war" among themselves (Abdulraheem, 1997).

8.2.4 Continuity of regional monitoring programmes and data consistency

With the state of the marine environment in the RSA, and the types, extent and magnitudes of pollution and environmental degradation observed, the need for continued and integrated monitoring programme for the region becomes more evident. This obviously requires close coordination and integration between the Member States of ROPME.

An essential component of such a monitoring programme is the regular collection of data using standard techniques of reference methods as per ROPME's Manual (MOOPAM). Data should be comparable and consistent to enable sound regional analyses and conclusions.

8.2.5 Participation in and follow-up to international conventions

The number of the legally binding international conventions is growing with time. Many of these conventions are directly or indirectly related to the marine environment and to ROPME region in particular. For example, the U.N. Framework Convention on Climate Change, the Convention on Biological Diversity and the Basel Convention on Hazardous Wastes. However, the participation of ROPME Member States in international agreements and conventions has become rather sporadic. Consequently, playing an active role in the large number of meetings related to these conventions at different levels is becoming more and more difficult. It has also been observed that the relatively low level of representation in many international conventions and the low priority given to their implementation is partly due to the shortcomings of domestic legislation. Another difficulty is the large number of professional and administrative expertise and huge amounts of resources needed to implement the complicated legal and administrative requirements of the international conventions.

Nevertheless, regional mechanisms to follow up implementation of these conventions have been initiated, such as Regional Committees for the Montreal Protocol and the Basel Convention. A subcommittee for the Climate Change Convention has also been established in CAMRE, and at the subregional level, for the GCC countries. Such measures should be taken into consideration by ROPME.

It is a real challenge to the ROPME Member States to be able to monitor carefully all the relevant global conventions at the international forums dealing with these issues and to express their unified views and interests. The increased use of existing regional mechanisms would help to streamline positions and provide for exchange of views and experiences within the region as well as with other regions.

Chapter 9

Strategies and Priority Action for Environmental Protection and Sustainable Development

INTROUCTION

High level commitment

Long-term high-level commitment by the Governments of the region is crucial for the effective protection, management and sustainable development of the RSA and its resources. Government support is required to ensure that the regional and global priorities are adequately addressed and are supported through policy measures, effective implementation of the relevant regulations, enforcement of laws and legally binding agreements and protocols, and through capacity building of regional and national institutions and experts. Integration of regional and global conventions and policies into national legislation provides the region with the opportunity to interact, benefit from and influence the development of global programmes and policies.

Regional organization can act as an interface between the global and national concerns. Integrating environmental concerns of the region into the political and socio-economic agenda of member states is at the essence of the Rio Declaration (1992). This chapter identifies some of the priority issues to be included in strategies for environmental protection in the Region.

9.1 Integrated Coastal Area Management (ICAM)

The use of integrated coastal area management plans provides an effective mechanism for sustainable long-term use of the coastal area that forms the interface between land and sea. Throughout the ROPME Region, adoption and implementation of ICAM to support development decisions could significantly decrease unnecessary degradation of coastal and marine environments occurring in many parts of the RSA. The experience of Saudi

Arabia and Oman in carrying out inventories of coastal and offshore habitats and the preparation of integrated coastal area management plans should be reviewed for application elsewhere. It should be noted that a number of practical guidelines and experiences in other Regional Seas of UNEP are also available to support efforts within the Region, the latest of which is being developed on the bases of the Omani experience and which is carried out by ROPME in cooperation with UNEP.

Coastal area management concerns can be addressed in a cost-effective manner through integration into land use planning, preparation of environmental assessments and environmental audits, processes for issuing licenses and permits for activities in the coastal area, decisions on the siting of public and private facilities, and monitoring of development trends and environmental impacts.

National ICAM plans may be developed to provide an overall framework for coastal area management, complemented by more specific plans for urban and industrial areas, areas around industrial ports and free zones, and special plans for management of tourist areas and ecologically sensitive areas including coastal and marine reserves and protected areas, but also keep a regional perspective in mind so as to be complementary and not competitive.

Another planning tool that is complementary to ICAM, but also applies to major development projects and human activities is the environmental impact assessment (EIA) procedures that would help to significantly reduce the degradation of the environment, particularly from land-based activities that have the greatest impact on the marine and coastal environment.

9.2 Conservation Strategies

Because of the increased threats to the marine and coastal environments and their integrity, there is an urgent need for more effective mechanisms to their conservation in a manner that could counteract fragmented decision making. The protection and, where necessary, restoration of coastal and marine habitats is of highest priority for biodiversity conservation. Spawning grounds and critical nursery areas of key species are of particular importance. The integrity of the region must be taken into consideration and areas that are of regional significance should receive special attention. Both national and regional regulatory systems need to be improved to enhance habitat conservation. Conservation strategies both national and regional, being complementary, would be important to develop for key habitats in the RSA, such as coastal wetlands, mangroves, seagrass beds, coral reefs and oyster bank. Island ecosystem represent a unique opportunity to protect a group of habitats and populations that are interactive in a delicate balance that can only be protected in it's entirety and on the bases of a multidisciplinary approach. Mangroves, in view of their value as spawning grounds and nurseries of commercially important fish and shrimp species present another example where a multidisciplinary_approach is required for effective protection and sustainable management. For the same reason, coral reefs need special attention in terms of conservation and protection particularly against the activities that are damaging to coral reef communities including dredging, physical destruction, land-filling, wastewater disposal, and disturbance from excessive tourism activities. Similarly, seagrass beds need conservation because of their value to endangered species of marine mammals (dugongs) and as a host of commercially important fin fish and shellfish, and hence their protection against detrimental coastal activities such as reclamation, dredging and land-filling and illegal shrimp trawling must be a high priority in coastal area management.

Designation of marine and coastal protected areas could also be part of a framework conservation strategy both nationally and regionally. It is important to note that preparing and adopting marine conservation strategy is not an end in itself. It is imperative that any such strategy should be built into the decision-making process in order to fulfill its objectives and achieve the anticipated results of conservation. It is also essential that the strategy will have the necessary support from the government and the public in order to be effective.

Realizing the importance of a regional approach to the conservation of coastal and marine areas and protection of their biodiversity, ROPME in coordination with the EU, UNEP, RAMSAR and the UN Biodiversity Convention Secretariats is preparing for the development of a protocol on protecting biodiversity and the establishment of protected areas in RSA.

9.3 Strengthening the Implementation of ROPME's Protocols

As mentioned above, the Kuwait Regional Convention has four related protocols concerning various aspects of marine environmental protection and management. These protocols have been adopted with the objective to ensure that development and other human activities are controlled and do not cause damage to the marine environment, jeopardize its living resources or cause hazards to human health. Another objective has been the development of an integrated management approach to the use of the marine environment and the coastal areas in a sustainable way, which will allow the achievement of environmental and developmental goals in a harmonious manner.

ROPME Protocols have made the mandate of the Kuwait Regional Convention more specific and play an important role in harmonizing the policies of Contracting States concerning protection of the environment under the national jurisdiction of each State and that of the Region. Meetings of regional/international experts are convened regularly to examine the status of implementation of various programmes in order to ensure that the provisions of the Protocols are complied with. It is generally felt, however, that the implementation of and the adherence to these protocols are far below the desired level, probably due to the non-integration of the convention and the protocols into the national legislation of Member States.

It becomes necessary, therefore, that the implementation of ROPME's protocols be further enhanced and followed up vigorously by the concerned authorities in each Member State, in order to achieve the objectives for which they were prepared. Such strengthening of protocol implementation should be part and parcel of the national strategies of the Member States for the protection and sustainable development of the marine and coastal areas under their jurisdiction.

9.4 Capacity Building

An important factor in achieving the above objectives and effectively addressing the prescribed concerns is building the national and regional capacities which would enable the Member States of ROPME to meet the challenges and honour their obligations. Intensive capacity building programmes should therefore be rigorously pursued both at the national and regional levels and in all areas outlined above. ROPME programmes of in-house training, short courses or visits at qualified laboratories/institutions are to be further encouraged and augmented by establishing a programme of exchange of scientists both within the region and in cooperation with other regions. This requires greater interest in environmental issues by teaching institutes and universities. These issues should be a major part of all the curricula taught in different specialities. Specialist in various fields of the environment should be trained to face the future challenges of the Region.

9.5 Enhancement of Public Awareness, Information Sharing and Networking

As pointed out before, environmental public awareness is an essential component of any national policy for environmental protection. At the regional level, strategies for the enhancement of environmental awareness among the public should be developed and followed-up, making use of the national experiences already available in several Member States of ROPME. In this connection, it has to be noted that the large number of stakeholders involved in the coastal area require multi-level awareness programmes targeting different groups.

On the question of environmental information, there is a general lack of information prevision on the marine environment in most of ROPME Member States. Where information is available in the region, there is a lack of continuity and cohesion in the marine environment monitoring and reporting. Much of the information produced is also under-utilized (UNEP, 1996). At the national level, only a few ROPME Member States have prepared their State of the Marine Environment Report (SOMER). Another common problem in the region is that marine environmental data are scattered among numerous public and private sector institutions, with little or no collaboration or coordination. As a result, there are gaps and duplication in data. It is therefore necessary to regularize the Member States' reporting, harmonize and standardize their information to facilitate information sharing and exchange. Networking is also an effective avenue for dissemination of and accessibility to data and information among Member States should be foreseen as part of our regional strategy on environmental awareness and information.

9.6 Cooperation with Non-Governmental Organizations (NGOs)

A growing number of non-governmental organizations (NGOs) have been established in most countries of the ROPME region. However, their role in planning and implementation needs to be strengthened. In addition, there is a need for capacity building to increase the involvement of NGOs as well as other institutions and the private sector in the environmental policy-making and in taking action in the respective priority area of ROPME's programme. The NGOs themselves also need to ascertain their objectives and role in the development of national policies and provide advice, constructive criticism and assistance to national environmental authorities.

The participation of national and local NGOs will be important for realization of the long-term goals and objectives of ROPME. The cooperation with relevant international non-governmental organizations is also useful in many cases where international expertise or worldwide vision is required for addressing specific problems of regional significance.

9.7 Coordination between Regional and International Organizations

An equally important strategic element is the increased coordination between regional environmental organizations and bodies dealing with the marine environment. An excellent example of such coordination is that existing between ROPME and PERSGA which culminated in the organization of the Sea to Sea Conference in 1995. Cooperation with the GCC on issues such as conducting the study on reception facilities development of port state control and the preparation of regional protocol on biodiversity protected areas is another example of regional cooperation. It should be noted here that ROPME is party in regional efforts to establish a Regional MOU between UNEP (ROWA), CAMRE, PERSGA and ROPME that outlines the terms for regional cooperation with full transparency, evidence of duplication and sharing of experience and information. Similar activities between ROPME and other regional environmental bodies are required and should be encouraged and formulized.

9.8 Harmonization of Legislation

ROPME Member States as members of the international community have collectively a significant role to play at the global arena. However, the process can only be a two way stream, i.e. contributing to global policies, conventions and programmes, and adapting the national policies and legislation to meet the global objectives. Global conventions can only be unfair to our region, if we fail to be present at their development stages. UN conventions are developed by hard negotiations but on the bases of consensus, however, once they enter into force, change becomes even harder.

9.9 Acquisition of New and Cost Effective Monitoring Technologies

As explained earlier, monitoring is the basic element in the process of environmental assessment. However, environmental monitoring of coastal and marine ecosystems requires the commitment of laboratories and well-trained personnel for long periods of time. Equally, coastal surveillance to detect oil and other waste releases in offshore areas or long coastlines, as is the case in Oman, Iran and Saudi Arabia, is complicated and can be very expensive.

ROPME has already exerted efforts to adapt advanced space age-based technologies for the monitoring efforts of ROPME should enable the Region to obtain immediate, accurate and predictive information and data on the location, type and quantities of oil spills almost immediately. Other data such as water quality, coastal morphology changes and information, that would otherwise require monitoring and surveillance programmes will also be obtained. Member States support of this major regional effort would render it a more achievable goal.

9.10 Control and Management of Oil Spills

As evident from this report, pollution by oil is the most significant form of pollution in the RSA for the reasons described in various sections of the report. Oil spills and incidents have long constituted serious threats to the region and have visible and invisible impacts.

In spite of extremely heavy traffic of oil tankers through the RSA, only limited number of reception facilities exist to date in the region, most of which are inadequate to receive and process oily wastes, ballast water or other wastes from transiting ships. This general lack of adequate facilities in the region often leads to illegal dumping of huge quantities of ballast waters and other oily wastes into the marine environment and hence contribute to the observed high level of pollution by oil in the region.

Implementing the recommendations of the Feasibility Study on Reception Facilities, which is expected to be finalized by national and international experts working under the auspices of ROPME, the RSA could be declared as a "Special Area" under MAROL 73/78. This would allow Member States as parties to the MARPOL Convention, to inspect, survey and enforce its provisions on all ships operating in their navigable waters.

Acceding to MARPOL 73/78 and the establishing of reception facilities would also require the adoption of "**Port State Control**" according to which vessels transiting through waters within the Exclusive Economic Zone (EEZ) of a sovereign state could be inspected to ensure that they are complying with international agreements that are in force in the region. The Port State Control standardizes procedures and fees in order not to allow vessels to call at ports where regulations are less stringent and reception facilities are inadequate.

9.11 Control of Land-Based Sources of Pollution

ROPME Member States should expedite the implementation of ROPME's Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources and the associated Regional Programme of Action (RPA). RPA components include survey of land based activities, carrying out a pilot study on persistence organic pollutants (POPs) and development of a river basin management agreement for Shatt Al-Arab and other rivers in the RSA. Such efforts will require the potential cooperation and relationships with countries outside the RSA, the diplomatic skills and the ability to draw support and cooperation of the international and regional organizations concerned.

9.12 Control of Dredging, Reclamation Activities and Modification of Coastal Morphology

Dredging and reclamation activities are an almost permanent feature in many coastal areas in the RSA. As a remedial measure, strict government restrictions on dredging and reclamation activities should be imposed, and where legislation prohibiting these activities exist, they should be enforced and strictly adhered to. It is preferable that such destructive activities be totally avoided, if possible. If not, environmental impact assessments for such operations should be carried out and formal permit obtained prior to the initiation of any small- or large-scale projects requiring dredging or filling, particularly adjacent to environmentally sensitive areas. Furthermore, authorized dredging operations should follow clear operational standards. Impacts of such projects on the adjacent marine and coastal ecosystems should be carefully assessed and monitored. Projects involving land-filling and alteration of coastal morphology of a given State should be evaluated from a regional perspective through ROPME in order to avoid major ecological changes in our Sea Area.

9.13 Restoration of Mangroves and Coral Reefs, Protection of Wetlands

As demonstrated earlier, coastal lagoons, mangroves, seagrass beds and coral reefs represent important components of the ecological systems of RSA and have been rapidly deteriorating. The restoration of damaged ecosystems and re-introduction of lost species or populations by a cooperative effect between research institutions, fisheries and environmental protection authorities is an essential step towards pushing back the tide of destruction and moving towards recovery of our habitats. Meantime, since the restoration projects are extremely costly, governments, development and finance funds/banks and the private sector are all invited to support such a regional effort.

EPILOUGE

The Kuwait Action Plan for the Protection and Development of the Marine Environment and Coastal Areas which was adopted by the Plenipotentiaries of ROPME Member States in April 1978 stipulates that:

> "Environmental Assessment is the one of the basic activities which will underlie and facilitate the implementation of the other components of the Action Plan.
>
> The identification of the present quality of the marine environment and the factors currently influencing its quality and having an impact on human health will be given priority together with an assessment of future trends."

We hope that this Report will be considered as a contribution towards setting our bearings so as to focus on the quality of the marine environment and human health as the ultimate objective of ROPME programmes and activities.

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المنظمة الإقليمية لحماية البيئة البحرية

Regional Organization for the Protection of the Marine environment

سازمان منطقه ای حمایت محیط زیست دریائی

KUWAIT