STATE OF THE MARINE ENVIRONMENT REPORT 2003

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FOREWORD

The Third Edition of the State of the Marine Environment Report (SOMER) is prepared in accordance with the provisions of ARTICLE XVII (d-ii) of the Convention, and Decision CM12/1 of the Twelfth Meeting of the ROPME Council. The First and the Second Editions of SOMER were published in 1999 and 2000 respectively, and were distributed to various regional and international institutions and personalities.

In view of updating SOMER 2000, national state of the marine environment reports were received from NFPs I.R. Iran, Oman and UAE, and a few sets of national data and information from NFPs Bahrain, Kuwait, Qatar and Saudi Arabia. The draft Report of SOMER 2003 then was concluded in December 2003, and was reviewed jointly by a consultant from UNEP and experts from ROPME in February 2004 and subsequently by the NFPs Contact Persons in a meeting convened at ROPME Secretariat in May 2004.

This Report is prepared based on the available data and information from Member States, results of oceanographic cruises, results of ROPME-IAEA Contaminant Screening studies, and the published articles from regional and international scientific literature. The information presented in the Report is the latest on the state of the marine environment of the Region. It covers comprehensive information from various sources together with recommendations of experts, and as such is maintained truly of consensus standards. However, we welcome further contributions and shall be grateful for any comments, amendments and proposals for the improvement of the text.

ROPME has received the support of Member States and the cooperation from regional experts in preparing SOMER 2003. We are grateful to all the contributors and the Member States' designated Contact Persons, Dr. Shaker A.A. Khamdan – Bahrain, Dr. Seyed Mohammad Reza Fatemi and Mr. Mohammad Reza Sheikholeslami – I.R. Iran, Mr. Mohammed G. Abel, Dr. Nahida Bader Al-Majed Bu Tayban and Dr. Bahgat B. Habashi – Kuwait, Mr. Musallam bin Mubarak Al-Jabri – Oman, Mr. Ibrahim Salem Al-Darwish and Mr. Saif Shandhour – Qatar, Mr. Hamdan S. Al-Ghamdi – Saudi Arabia and Dr. Saad Al-Numairy – UAE. We look forward to closer collaboration with Member States for better results in our future endeavour. Special gratitude is extended to Dr. Fatemi, Dr. Al-Numairy and Mr. Al-Jabri in recognition of their efforts in preparing of their national reports, to Mr. Sheikholeslami for his technical review of the manuscript, and to Ms. Katharine Mann-Jackson for the English edit of the text.

The contribution of UNEP/Regional Seas and UNEP/ROWA for arranging the visits of experts, Mr. Dave MacDevette from EASD, Dr. Adel Abdel-Kader (UNEP/ROWA) and Mr. Hassan Partow (UNEP/Regional Seas) during the course of reviewing the draft text of the Report is highly appreciated. Thanks are also extended to UNEP/GPA for the financial support as provided for editing and printing of the Report.

The efforts of Dr. M. Thangaraja, Environmental Specialist of ROPME for incorporating the updated information into the Report is greatly appreciated. He processed certain data, worked with regional and international experts, prepared the final design and gathered published materials for the preparation of the Report.

The constructive contribution of Dr. Hassan Mohammadi, Acting Coordinator of ROPME is particularly noted and valued. He led the regional scientists in their preparation of national reports, procured new data through international organizations, arranged experts review of the manuscript and played the role of chief editor of SOMER 2003.

Captain Abdul Munem Al-Janahi, Director of MEMAC provided updated information on spilled oil, Dr. Peter Petrov, Remote Sensing Expert provided satellite images, and Mr.Ibrahim Hadi, Finance and Administrative Officer provided all necessary facilities for the production of the Report. The neat typing, arranging the figures, tables and text of SOMER 2003 were carried out by Mr. Francis Picardo and the setting and printing by Mr. Basheer Ahmed. To all of them I extend my gratitude.

Finally, my sincere thanks and appreciation are extended to all individuals who provided new data and information and sent their valuable comments and suggestions. SOMER will remain an open book to reflect the current State of the Marine Environment with full transparency to expose all dimensions and concerns of every interested person. We all join hands to make SOMER a truthful reflection of our marine environment. I hope that SOMER 2003 will reach a large audience and inspire them to contribute towards a better and safer marine environment.

Dr. Abdul Rahman Al-Awadi
Executive Secretary of ROPME

INTRODUCTION

This Report is the updated version of the State of the Marine Environment Report (SOMER) of the ROPME Sea Area (RSA) that was published twice in 1999 and 2000. The Report has been supplemented with substantial data and information on the status of the marine environment of the RSA, which includes the results of the ROPME–IAEA Contaminant Screening Project, of recent oceanographic cruises conducted in the RSA and the information obtained from Member States and international scientific literature.

The main objectives of the Report as specified by the ROPME Council Decision are:

- To assess and document the current state of the marine environment of the RSA, giving due attention to recent changes in the environmental conditions and the impacts of human activities on the marine environment and coastal areas;

- To identify current regional concerns and emerging issues which present major challenges; and

- To suggest regional strategies and priority actions commensurate with these concerns and issues to enable the governments and decision-makers to meet these challenges at the national level, as well as in regional and global contexts.

The Report is structured in seven Chapters; Chapter 1 provides a brief background description of the Regional Organization for the Protection of the Marine Environment (ROPME), the ROPME Sea Area, a historical perspective, physical-geographical features, and some socio-economic details about the Region. Chapter 2 describes the general climatic and meteorological conditions prevailing in the Region, as well as the oceanographic, geological, sedimentological, microbiological and biological characteristics of the RSA. The first part of Chapter 3 is devoted to the major marine habitats, including seagrass beds, algal communities, mangroves, coral reefs, mudflats, and protected areas; the second part provides a brief account of the Region's living marine resources including: crustaceans, molluscs, fishes, reptiles, seabirds, and marine mammals. The last part of the Chapter is a short note on non-living resources of the RSA. Chapter 4 discusses the main socio-economic activities and structures in the RSA. More information has been incorporated from national reports on land-based activities, including major domestic and industrial discharges, destruction of marshlands, discharges from rivers, coastal development, physical alterations, as well as exploration and exploitation of living and non-living resources and their impacts. Chapter 5 focuses on specific groups of contaminants (mainly Persistent Toxic Substances) whose observed levels and distribution in the surface and sub-surface water column, sediments and biota are being used as indicators of the health of the marine environment. The Chapter elaborates on the results of the Contaminant Screening Studies conducted by IAEA for ROPME during 1994–2001 as well as the recent studies by Member States which together reflect the status of contamination in coastal waters, and analyses of contaminants in the samples gathered during ROPME oceanographic cruises that provide the data for the basin-wide assessment of contamination in the RSA. Chapter 6 addresses major maritime accidents and natural episodic events. War-related oil spills, tanker incidents, mass mortalities of marine organisms and invasive species are discussed in this chapter. Chapter 7 discusses environmental challenges, prevention and control of marine pollution, and strategies and priority action for sustainable development in the RSA.

This SOMER, which is published by ROPME, has been reviewed by experts from UNEP, ROPME and Member States to provide environmental protection authorities, decision-makers and the scientific community in the Region with a balanced assessment of the current state of the RSA. SOMER provides conclusions and recommendations for action that need to be considered by all those concerned in ROPME Member States when formulating national and regional programme activities in accordance with the provisions of the Kuwait Regional Convention and its Protocols.

SOMER is an open book, subject to review and periodical revision and updating. We sincerely hope that such continuity in the process will provide the necessary information and a better vision of how to protect and sustain marine ecosystems as a vital source of life for present and future generations.

ABBREVIATIONS AND ACRONYMS

AD	Anno Domini
ASA	Annual Statistical Abstract
BAPCO	Bahrain Petroleum Company
BC	Before Christ
BOD	Biochemical Oxygen Demand
CAMRE	Council of Arab Ministers Responsible for the Environment
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
COTS	Crown of Thorns Starfish
DBT	Dibutyltin
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEWA	Dubai Electricity and Water Authority
DO	Dissolved Oxygen
DOE–I.R. Iran	Department of the Environment, Islamic Republic of Iran
E & P	Exploration and Production
ED	Elector-dialysis
EES/FRD	Environment and Earth Sciences Division/Food Resources Division
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EOS	Earth Observing System
EPA–Kuwait	Environment Public Authority, Kuwait
EPD–Kuwait	Environment Protection Department, Kuwait
ERL	Effects Range Low
ERM	Effects Range Medium
ESA	Ecological Society of America
EU	European Union
FAO	Food and Agriculture Organization
FSS	Fisheries Statistical Section
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GEO	Global Environment Outlook

GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
HCH	Hexachlorocyclohexane
IAEA–MESL	International Atomic Energy Agency – Marine Environment Studies Laboratory
ICAM	Integrated Coastal Area Management
IFRO	Iranian Fisheries Research Organization
IHB	International Hydrographic Bureau
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
ISO	International Organization for Standardization
ISQG	Interim Sediment Quality Guidelines
IUCN	World Conservation Union
JICA	Japan International Cooperation Agency
KISR	Kuwait Institute for Scientific Research
LBA	Land-based Activities
MAB–UNESCO	Man and the Biosphere, United Nations Educational, Scientific and Cultural Organization
MAF–Oman	Ministry of Agriculture and Fisheries, Oman
MEMAC	Marine Emergency Mutual Aid Centre
MEPA*	Meteorology and Environmental Protection Administration
MNR	Marine National Report
MODIS	Moderate Resolution Imaging Spectroradiometer
MoU	Memorandum of Understanding
MRMEWR–Oman	Ministry of Regional Municipalities, Environment and Water Resources, Oman
MTBE	Methy Tertiary-butyl Ether
MTC–Oman	Ministry of Transport and Communication, Oman
NASA	National Aeronautics and Space Administration
NFPs	National Focal Points
NGOs	Non-Governmental Organizations
NOAA	National Oceanic and Atmospheric Administration
NODCO	National Oil Distribution Company
NO_x	Nitrogen Oxides
NRC	National Research Council
OLNG	Oman Liquid Natural Gas LLC

*Name changed to: Presidency of Meteorology and Environment (PME)

OPEC	Organization of Petroleum Exporting Countries
OPRC	Oil Pollution Preparedness, Response and Cooperation Convention
PAAC	Public Authority for the Assessment of Compensation
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyl Compounds
PDO	Petroleum Development of Oman
PEL	Probable Effects Level
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
PHCs	Petroleum Hydrocarbons
PM	Particulate Matters
POPs	Persistent Organic Pollutants
QNR	Qurum Nature Reserve
RO	Reverse Osmosis
ROPME	Regional Organization for the Protection of the Marine Environment
RPA	Regional Programme of Action
RSA	ROPME Sea Area
RV	Research Vessel
SBA	Sea-based Activities
SML	Surface Microlayer
SOMER	State of the Marine Environment Report
SO_x	Sulphur Oxides
SPM	Suspended Particulate Matter
SS	Suspended Solids
SSW	Subsurface Water
SWCC	Saline Water Conservation Corporation
TBT	Tributyltin
TC	Thermal Compression
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TPhT	Triphenyltin
TSS	Total Suspended Solids
UAE	United Arab Emirates
UCM	Unresolved Complex Mixture
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea

UNDP	United Nations Development Programme
UNDP/RBAS	United Nations Development Programme/Regional Bureau for Arab States
UNEP	United Nations Environment Programme
UNEP/DEWA	United Nations Environment Programme/Division of Early Warning and Assessment
UNEP/GPA	United Nations Environment Programme/Global Programme of Action
UNEP/ROWA	United Nations Environment Programme/Regional Office for West Asia
US–EPA	United States Environmental Protection Agency
VC	Vapour compression
VOC	Volatile Organic Compounds
WCMC	World Conservation Monitoring Centre
WHO	World Health Organization
WRI	World Resources Institute
WSSD	World Summit on Sustainable Development

EXECUTIVE SUMMARY

1. BACKGROUND

This Report is an updated version of the State of the Marine Environment Report (SOMER) of the ROPME Sea Area (RSA) that was published twice in 1999 and 2000. The main objectives of the Report as stated by the ROPME Council Decision are:

- *To assess and document the current state of the marine environment of the RSA, giving due attention to recent changes in the environmental conditions and the impacts of human activities on the marine environment and coastal areas;*

- *To identify current regional concerns and emerging issues which present major challenges; and*

- *To suggest regional strategies and priority actions commensurate with these concerns and issues to enable governments and decision-makers to meet these challenges at the national level, as well as in regional and global contexts.*

The ROPME Sea Area is the sea area located at the most north-western part of the Indian Ocean, 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 the Plenipotentiaries of the Member States to describe the area covered by the Kuwait Regional Convention of 1978.

The RSA is made up of three parts, each with its own distinct physical and biological characteristics. These include, the inner RSA which extends over 1,000km along the NW/SW axis from the Strait of Hormuz to the northern coast of Iran. This part is in effect a shallow embayment with a mean depth of about 35m and a depth of about 100m near its narrow entrance at the Strait of Hormuz which connects it to the Gulf of Oman and the Arabian Sea.

The middle RSA consists of the Gulf of Oman, which is a deep basin with depths exceeding 2,500 metres along its central channel. On the Iranian side, it extends from the Strait of Hormuz to Chah Bahar at the Pakistani border.

The outer RSA extends from Ra's Al-Hadd to the southern border of Oman. It is an integral part of the Indian Ocean, bounded to the north by the relatively mountainous landmasses of Oman and I.R. Iran, and deepening rapidly to the south with no barriers separating it from the Arabian Sea and the rest of the Indian Ocean.

CHAPTER 1

BACKGROUND

The ROPME Region is home to many valuable natural resources and to a great biodiversity of plant and animal species. Among the treasures of the Region are wetlands, mangroves, fishes, marine mammals, turtles, birds, corals and other forms of life. However, over the years, these valuable resources have borne the brunt of numerous interventions, aggressions and catastrophic incidents, and today they are in urgent need of protection if further degradation is to be prevented and to assist with their restoration and rehabilitation.

Over 25 years ago, between 15–23 April 1978, in recognition of the importance of the coastal and marine environment, a 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. This Conference adopted 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.

The Kuwait Convention entered into force on 1 July 1979 after five instruments of ratification had been deposited. Pursuant to the Convention, that same year the Regional Organization for the Protection of the Marine Environment (ROPME) was also established. It consisted of three main organs namely, the Council, the Secretariat and the Judicial Commission. The ROPME Secretariat was established in Kuwait in January 1982 (Figure 1.1), 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 the Convention and its Protocols. It has also assisted with the implementation of a number of projects, ranging from environmental assessment and environmental management, to public awareness and training.

As part of the process of providing information to support the implementation of the Kuwait Convention, a series of 'state of the marine environment' reports have been produced. These provide information on the state of and trends in the environment, identify emerging issues, and make proposals for further action to ensure the protection of the environment and sustainable development.

Figure 1.1 ROPME Headquarters

1.1 The ROPME Sea Area

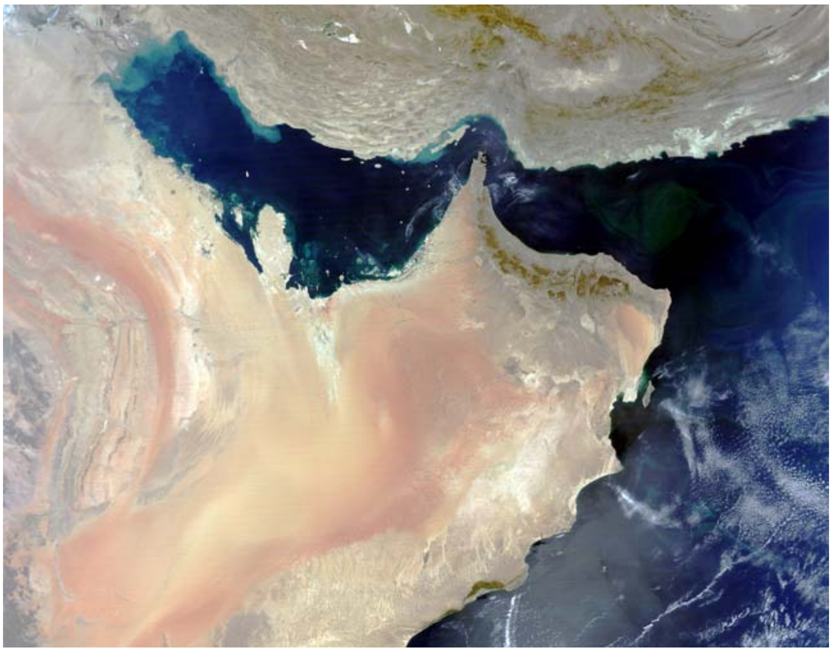
1.1.1 Definition

The ROPME Sea Area (RSA) is the area of sea that is 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 the Plenipotentiaries of the Member States to denote the area covered by the Kuwait Regional Convention of 1978.

Article II of the Kuwait Regional Convention, defines the ROPME Sea Area as the area extending between: 16^{o}39’N, 53^{o}3’30”E; 16^{o}00’N, 53^{o}25’E; 17^{o}00’N, 56^{o}30’E; 20^{o}30’N, 60^{o}00’E; 25^{o}04’N, 61^{o}25’E (Figure 1.2).

1.1.2 Historical perspective

The oldest records of human maritime activity in the RSA bear witness to the evidence of trade between Delmon (Bahrain), Oman and India. For centuries the secrets of navigating the monsoons were closely guarded by the sailors who controlled trade between the Region, and India and Eastern Africa. It was not until the first century BC that the Greeks discovered the monsoons and laid challenge to the Region's sailors. But by the third century AD, as the Roman Empire declined, the Sassanids became the main contenders for marine supremacy in the Region.



MODIS RGB color - composite 1 km resolution (L1, 500m resolution, and color composition channels 1, 4 and 3)

Figure 1.2 Satellite image of the ROPME Sea Area and its surroundings

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

Over time, as the Moslem Empire began to fragment into smaller kingdoms divided by territorial disputes, the outreach of the Moslem fleet shrank. However, it nonetheless remained strong in the Region until the arrival of European naval forces in the fourteenth century. The latter were equipped with bigger, metal-based ships and with maritime and sailing knowledge that they had acquired, but further refined, from Moslem sailors. By 1515 the Portuguese began their campaign to control the area. They were soon followed by the Spanish, Dutch, French and the British. Following stiff resistance by the Quwasims, with their fleet of about 700 ships and over 18,000 men, that lasted until the second half of the 18th century, the British occupied Ras Al-Khaimah. This marked the end of the supremacy of the 'DHOWS' (Price, 1986). Maritime activity in the RSA then became restricted to trade with India and Eastern Africa, pearl diving, fishing and inter-regional trade. This situation lasted until oil was discovered and its exploitation began in the twentieth century.

1.1.3 Physical-geographical features of the RSA

The RSA can be divided into three parts each with its own distinct physical and biological characteristics. These include:

1.1.3.1 *The inner RSA*

The inner RSA consists of the marine area west of 56^oE longitude that extends along the NW/SE axis from the Strait of Hormuz to the northern coast of Iran. It is surrounded by high mountains to the Iranian side and by low-land on the Arabian side. The coastline extends over 1,000km and has a sea surface area of $239,000km^2$. The inner RSA is in effect a shallow embayment with a mean depth of about 35m, and maximum depths of between 90 and 100m at its north-eastern side near the coast of Iran, and about 100m near its narrow entrance at the Strait of Hormuz which connects it to the Gulf of Oman and the Arabian Sea (Emery, 1956; Kasslar, 1973). The Strait of Hormuz is only 56km wide at its narrowest point. It drops to depths of more than 100m through the Strait, and to more than 2,000m less than 200km outside the Strait. The maximum width of this inner part of RSA is 338km. The volume of water is variously estimated to be about $7,800km^3$ by Linden *et al.* (1990) and $8,630km^3$ by Reynolds (1993).

The shallowness of this area means that it is affected by rapid meteorological changes. The presence of a desert landmass on one side and mountains on the other increases the rate of water evaporation and ensures that the exchange of water through the Strait of Hormuz remains quite active (Hunter, 1985). The marine topography of the area is very varied with 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). The bathymetry of the RSA is illustrated in Figure 1.3.

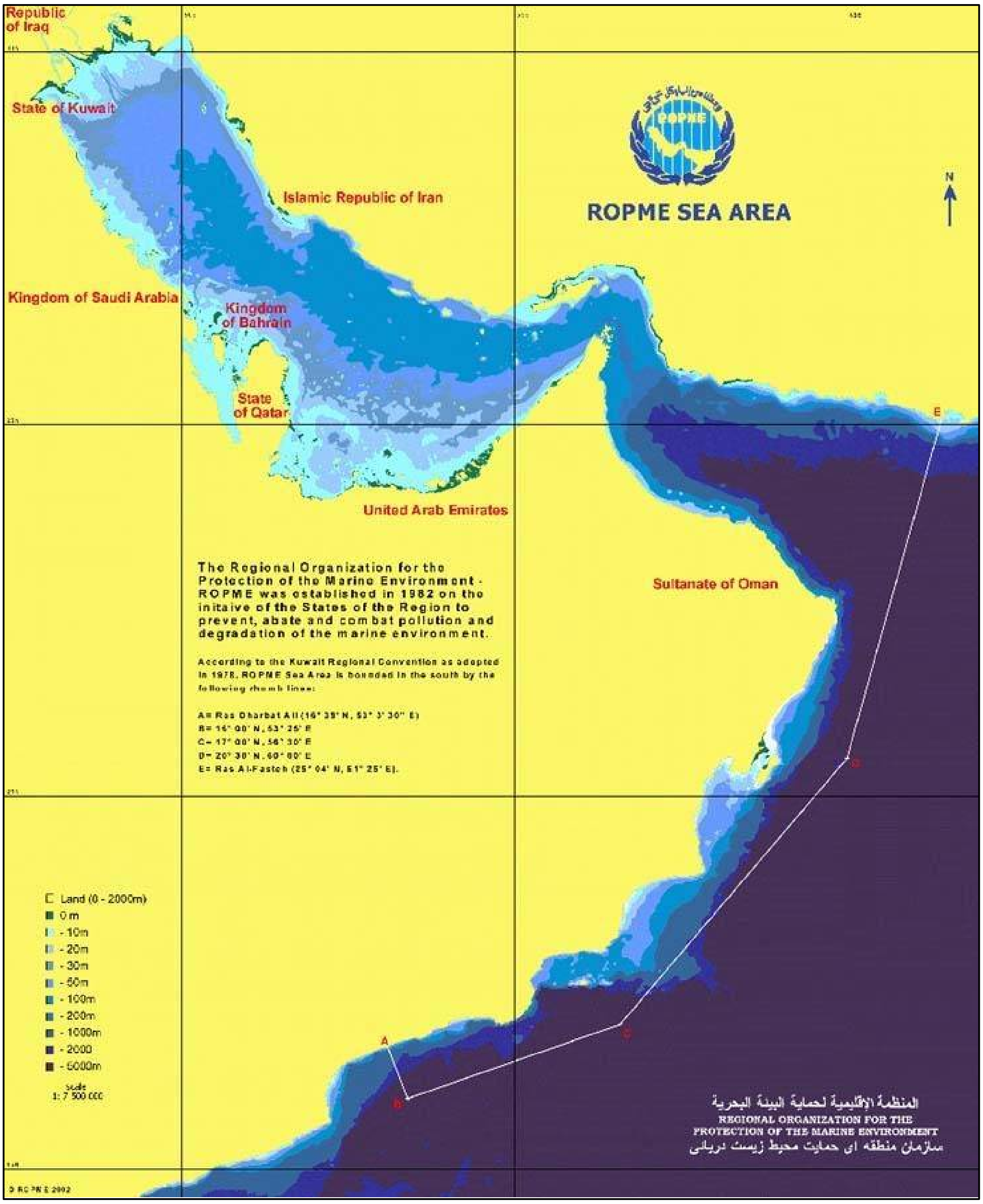


Figure 1.3 Bathymetry of the ROPME Sea Area

1.1.3.2 *The middle RSA*

The middle RSA includes the Gulf of Oman, a deep basin with depths exceeding 2,500 meters along its central channel. It has free access to the Arabian Sea and the Indian Ocean, however, it is not in the monsoon belt. The Middle RSA provides an important link which allows the ambient oceanic waters to flow into the inner part of RSA and its warm saline waters to form a bottom layer that exits via the Gulf of Oman. On the Iranian side, it extends from the Strait of Hormuz to Chah Bahar at the Pakistani border.

1.1.3.3 *The outer RSA*

The outer RSA extends from Ra's Al-Hadd to the southern border of Oman. It exhibits a wide range of habitats ranging from the well-developed sandy shores of the large continental shelf, to the rocky highlands with the 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. It is bounded to the north by the relatively mountainous landmasses of Oman and I.R. Iran, and deepens rapidly to the south where no barriers separate it from the Arabian Sea and the rest of the Indian Ocean.

1.2 Natural Resources

The main natural resources found in all countries of the Region are oil, and associated and non-associated natural gas. In addition to these resources, each individual state has its own unique natural resources including, coal, copper, chromium, iron ore, lead, manganese, zinc and sulphur in I.R. Iran; phosphates and sulphur in Iraq; copper, asbestos, marble, limestone, chromium and gypsum in Oman; and iron ore, gold and copper in Saudi Arabia. However, oil has been the prime mover in the Region, and accounts for 75% to 95% of the export earnings of individual countries. The rapid urbanization and industrialization of the Region are virtually all petroleum and petrochemical driven, and include the use of petroleum for the generation of electricity and desalination of seawater.

1.3 Socio-Economic Aspects

Prior to the discovery of oil, the harsh climate of the RSA offered meagre resources for the survival of the people. The coastal areas were sparsely populated with no significant urban centres. However, the discovery of oil in the early 1930s hailed the start of a new economic and environmental chapter in the region's history. The eastern areas of the Arabian Peninsula and northern Iraq emerged as the main sources of fossil fuel (oil and gas) in the world. With this came a period of rapid socio-economic transformation**,** especially in the 1970s and 1980s. Since then the Region has witnessed unprecedented rates of urbanization, hastily planned industrialization, mass immigration towards the oil-rich states from other parts of the Region, as well as an influx of expatriates from outside the Region. The combined effects of these influences together with rapidly transformed lifestyles and consumption patterns have been overwhelming (GEO, 2000).

The main source of wealth in the region is fossil fuel; and changes in oil prices mean that the region's GDP can fluctuate widely as it did in the 1980s. The GDP per capita in ROPME Member States averaged US$ 12,409 with the lowest in Iraq (US$ 3,197) in 1999 and the highest in Qatar (US$ 20,987) in 1998 (UNDP/RBAS, 2002). The GDP in other Member States was as follows: Bahrain US$13,688 in 1999; Oman US$9,960 in 1998; UAE US$18,162 in 1999 (UNDP/RBAS, 2002); I.R. Iran US$5,326; Kuwait US$16,377; and Saudi Arabia US$11,578 in 2000 (WRI, 2003). However, economic progress during the past 30 years, coupled with increasing coastal population pressures, has led to extensive degradation of the Region's natural resources.

Over the past four decades, the population has increased more than three-and-half fold from just under 33.75 million in 1960 to 121.88 million in 2000. The population growth rate ranges from 1.69% in I.R. Iran to 3.49 in Saudi Arabia (Figure 1.4). Average life expectancy is 70 years, ranging from 58.7 in Iraq to 75.9 in Kuwait (GEO3, 2002). Female life expectancy in the Region generally exceeds that of males (female 72.6 years and male 69.93 years) (UNDP/RBAS, 2002).

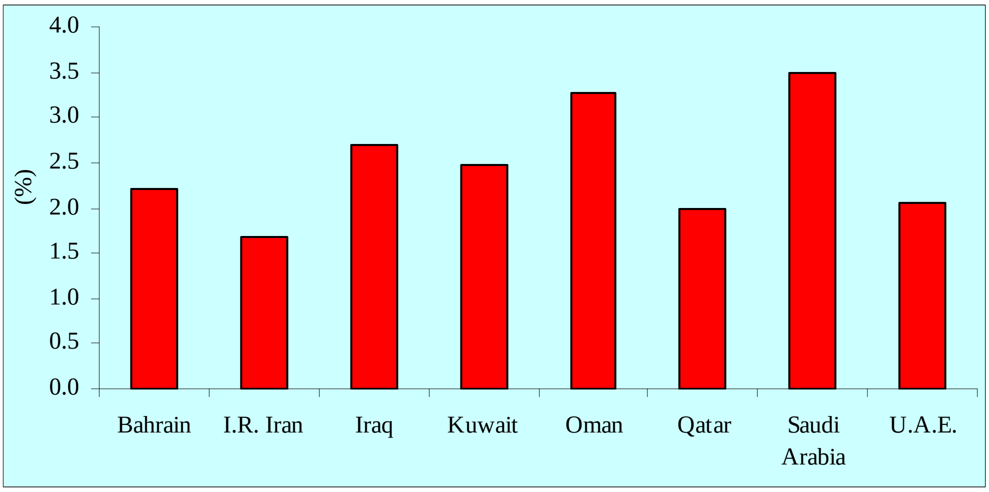


Figure 1.4 Human population growth rate in ROPME Member States between 1995 – 2000

Literacy rates in ROPME Member States ranged from 53.7% (Iraq) to 86.5% (Bahrain) in 1998 (UNDP/RBAS, 2002). Literacy rates in other Member States were: I.R. Iran 78%; Kuwait 85%; Oman 82%; Saudi Arabia 84%; UAE 76% in 2000 (WRI, 2003); and Qatar 80.4% in 1998 (UNDP/RBAS, 2002).

The coastlines of ROPME Member States are: Bahrain – 255km; Iraq – 105km; Kuwait – 756km; Qatar – 909km (GEO3, 2002); I.R. Iran – 1,950km. In the case of I.R. Iran, if the coastal areas of its islands are included it extends to over

2,500km; Saudi Arabia – 790km (SOMER, 1999); Oman – 3,165km (MRMEWR-Oman, 2003); and UAE – 735km (MNR-UAE, 2003). Marine resources have supported coastal populations for hundreds of years, and fostered the development of a maritime and trading culture linking Arabia and Africa with Europe and Asia.

In the past, the major environmental impacts of human development on coastal areas were limited to port areas. Fisheries were mainly small-scale, which left fish stocks relatively undisturbed. However, by the end of World War II the marine environment began to show signs of the impact of urbanization and other coastal development activities. The population continues to encroach on coastal areas. The rate of human settlement within 100km of the coastline has reached 100% in Bahrain, Kuwait and Qatar (GEO3, 2002) (Figure 1.5). Such high population densities place more stress on the marine environment.

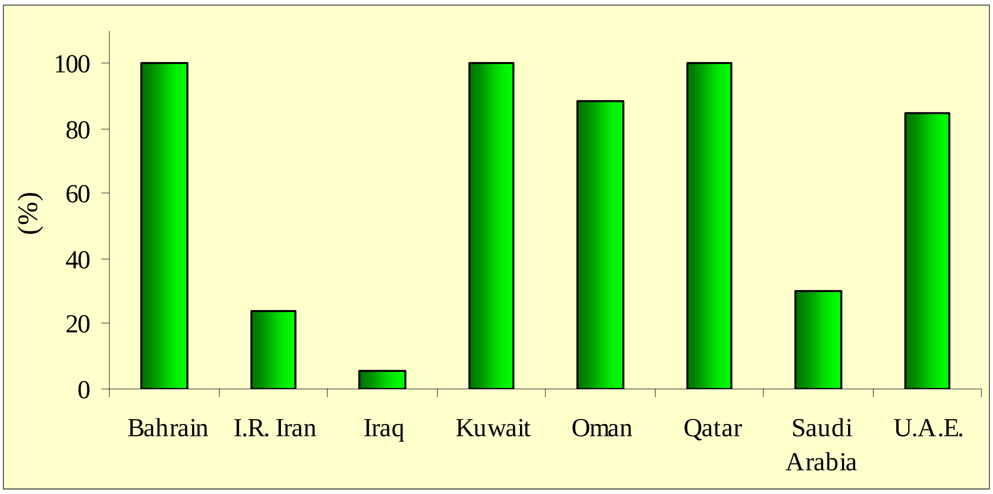


Figure 1.5 Coastal human settlement in ROPME Member States within 100km of the coastline during 1995

The impact of the events of the past 30 years or so on the environment has been considerable. The most pressing environmental concerns are decline of seawater quality, degradation of marine and coastal environments, and coastal reclamation. Other major environmental issues include deteriorating conditions in coastal settlements, the loss of biodiversity, industrial pollution, and inappropriate management of toxic chemicals and hazardous wastes. Power and desalination plants also account for or result in an increase of the temperature in the receiving basins. This will eventually place more stress on the health of ecosystems in the Region.

Rapid and profound changes in this area have led to serious environmental management problems. State environmental authorities are generally young, and experts are needed not only to address current issues but also to study the trends in the depletion of natural resources and the pollution of the environment. Environmental issues are gradually coming to the forefront of national concerns. There are also encouraging signs of an emerging awareness among the public of the need to protect the environment. The past two decades have seen the emergence of environmental NGOs that are beginning to promote popular support for national efforts to protect the environment. The business community has also begun to take its environmental responsibilities more seriously (GEO, 2000).

The major current and emerging environmental concerns in the RSA include: the introduction of various pollutants, physical alteration including destruction of habitats, the use of destructive fishing techniques and overexploitation of marine biological resources, and the introduction of invasive species. These concerns can be summarised as follows:

- Discharges from land-based activities into the sea are mainly from industries such as petroleum, petrochemicals, desalination, cement and construction materials, textiles, ship repairing and food processing. In the north, pollutants and related sources include sewage, organic pollutants, pesticides, trace metals and oil. Population growth and the concentration of the population along the coasts do not match the pace of infrastructure development. Liquid wastes from coastal cities, villages and resort areas are often discharged directly or indirectly into the sea without treatment, causing eutrophication in coastal waters (GEO, 2000). Recreational sites along the coasts may contribute to eutrophication problems along the north-western part of the RSA.

- Major impacts on the marine ecosystem are caused by physical alteration of the coastline and coastal habitats by infilling for coastal reclamation, dredging, increased sewage output, the release of industrial effluents, dumping of oily wastes from tankers and oil-loading terminals, and dumping of litter from both land and sea-based sources.

- Annually around 1.2 million barrels of oil are spilled into the RSA from marine transportation activities (ROPME/IMO, 1996). The level of petroleum hydrocarbons in the area exceeds that in the North Sea by almost three times and is twice that of the Caribbean Sea (GEO, 2000). ROPME Member States generate from 2–8 times more hazardous wastes per capita than does the United States (GEO, 2000).

- Petroleum hydrocarbons from refineries, petrochemical industries, oil terminals, oil spills from ships, and pipeline disposal at sea of oil-contaminated ballast water and dirty bilge, sludge and slop oil. Oil pollution continues to be a problem in various areas of the RSA.

- About 20–30% of the sewage discharged into the sea is estimated to be untreated or only partially treated. This poses a potential threat of eutrophication in confined areas such as bays.

- Sand and dust deposits from the atmosphere as high as 29g/m^2/year have been reported (Gharib *et al.*, 1985).

- Levels of persistent organic pollutants (POPs) are still relatively low but screening of contaminants in marine sediments and biota have revealed low levels of halogenated pesticides, PCBs and organic phosphorous compounds. (IAEA, 1999). PCB concentrations in oyster populations have appeared to decrease over the past two decades, but the concentrations of DDT compounds have varied little over the years (IAEA, 2002).

- Trace metal concentrations are generally low but there are 'hotspots' near the old outfalls of chemical plants where relatively high levels of mercury have been recorded (Al-Majed, 2000). Copper and nickel levels are also relatively high near the outfalls of desalination and power plants (Saeed *et al.*, 1999). Contamination of sediments with high levels of some trace metals, such as nickel, but also with pesticides, suggest that dumping has taken place in certain areas (IAEA, 2002).

- The discharge of concentrated and hot brines from desalination plants is one of the major environmental concerns in the RSA.

- The Region contains only about 8% of the world's mapped coral reefs (GEO, 2000) but almost two-thirds of those in the RSA are classified as at risk, mainly as a result of over-fishing and because more than 30% of the world's oil tankers move through this area every year (Downing and Roberts, 1993).

- Fisheries are an important resource in ROPME Member States. The fish harvest is decreasing because of coastal pollution, over-fishing, the use of destructive fishing techniques, and inadequate fisheries management (GEO, 2000).

- The high mortality rates of marine organisms recorded in RSA are the result of a variety of environmental factors. The causes of marine mortality in RSA have been identified as pollutants, sudden changes in the physico-chemical processes of the sea, the outbreak of bacteria, viruses, fungi and parasites, harmful algal blooms and red tides.

- Invasive marine species constitute a potential threat to the marine environment of the RSA. An in-depth scientific study is necessary to identify the invasive species of the RSA and possible ways to reduce their numbers.

- The Region has witnessed three wars with devastating effects on the environment from the late 1980s to early 2003. Subsequent reconstruction has resulted in substantial development along the shores of the affected countries. The uncontrolled expansion of coastal cities, in which much of the Region's population lives, during the 1990s put even more stress on the marine and coastal environment.

- The three wars in the Region have caused extensive damage to the environment of the Sea Area. The Iraq-Iran War, which lasted eight years, targeted refineries, oil terminals, offshore oil fields and tankers; however, the 1991 War exceeded all other environmental disasters of the past four decades. Over 9 million barrels of oil were released into the marine environment (PAAC, 1999). Environmental recovery after an oil spill remains rather slow (IAEA, 2002). Fallout from burning oil products produced a sea surface micro-layer that was toxic to plankton and the larval stages of marine organisms. The long-term impacts of these wars on fisheries and the marine environment in general have yet to be assessed. Several projects to assess the long-term impact of the 1991 environmental catastrophe on Kuwait and nearby Member States’ ecosystems including, terrestrial, marine and fishery have been conducted in the respective countries since 1991. Respiratory problems and other illnesses related to the crises are also included in these studies (KISR/PAAC, 1998). The recent war in Iraq (March/April 2003) also had considerable environmental impacts in the Region. Moreover the accumulation of hundreds of ship wrecks in the waterways of Iraq and Kuwait poses a continuous threat to the marine life and environment, to navigation and to public health (ROPME/UNDP, 2004).

2. MAJOR ENVIRONMENTAL ISSUES IN THE ROPME SEA AREA

The impact of the events of the past 30 years or so on the RSA marine environment has been considerable. The most pressing environmental concerns include the decline of seawater quality, degradation of marine and coastal environments, and coastal reclamation. Other major environmental issues include deteriorating conditions in coastal settlements, the loss of biodiversity, industrial pollution, and inappropriate management of toxic chemicals and hazardous wastes. Power and desalination plants also account for or result in an increase in the water temperature in the receiving basins. This will eventually add more stress to the health of ecosystems in the Region.

Rapid and profound changes in this area have produced serious environmental management problems. State environmental authorities are generally young, and experts are needed not only to address current issues but also to study trends in the depletion of natural resources and the pollution of the environment. Environmental issues are gradually coming to the forefront of national concerns. There are also encouraging signs of an emerging awareness among the public of the need to protect the environment. The past two decades have seen the emergence of environmental NGOs that are beginning to promote popular support for national efforts to protect the environment. The business community has also begun to take its environmental responsibilities more seriously.

Broadly speaking, the most pressing current and emerging environmental issues in the RSA include, the introduction of various pollutants, physical alteration, including destruction of habitats, the use of destructive fishing techniques and overexploitation of marine biological resources, and the introduction of invasive species. These can be summarized as follows:

- *Discharges from land-based activities into the sea are mainly from industries such as petroleum, petrochemicals, desalination, cement and construction materials, textiles, ship repairing and food processing. In the northern part, pollutant-related sources include sewage, organic pollutants, pesticides, trace metals and oil. Population growth and the concentration of the population along the coasts have not matched the pace of infrastructure development. Liquid wastes from coastal cities, villages and resort areas are often discharged directly or indirectly into the sea without treatment, causing eutrophication in coastal waters. Recreational sites along the coasts may contribute to eutrophication problems along the north-western part of the RSA.*

- *The major impacts on the marine ecosystem are caused by physical alteration of the coastline and coastal habitats, by infilling for coastal reclamation, dredging, increased sewage output, the release of industrial effluents,* *dumping of oily wastes from tankers and oil-loading terminals, and dumping of litter from both land and sea-based sources.*

- *Annually around 1.2 million barrels of oil are spilled into the RSA from marine transportation activities. The level of petroleum hydrocarbons in the area exceeds that in the North Sea by almost three times and is twice that of the Caribbean Sea. ROPME Member States generate from 2–8 times more hazardous wastes per capita than does the United States.*

- *Petroleum hydrocarbons from refineries, petrochemical industries, oil terminals, oil spills from ships and the disposal at sea through pipelines of oil-contaminated ballast water and dirty bilge, sludge and slop oil are a major concern. Oil pollution continues to be a problem in various areas of the RSA.*

- *About 20–30% of the sewage discharged into the sea is estimated to be untreated or only partially treated. This poses a potential threat of eutrophication in enclosed areas like bays.*

- *Sand and dust depositions from the atmosphere as high as 29g/m^2/year have been reported.*

- *Levels of persistent organic pollutants (POPs) are still relatively low but the screening of contaminants in marine sediments and biota has revealed low levels of halogenated pesticides, PCBs and organic phosphorous compounds. PCB concentrations in oyster populations have appeared to decrease over the past two decades, but the concentrations of DDT compounds have varied little during the years.*

- *Trace metal concentrations are generally low but there are hotspots near the old outfalls of chemical plants where there are relatively high levels of mercury. Copper and nickel levels are also relatively high near the outfalls of desalination and power plants. Contamination of sediment with high levels of some trace metals, such as nickel, but also with pesticides, suggest that dumping activities have been taking place in certain areas.*

- *Discharges of concentrated and hot brines from desalination plants constitute some of the major environmental pressures in the RSA.*

- *The Region contains only about 8% of the world's mapped coral reefs but almost two-thirds of those in the RSA are classified as at risk, mainly as a result of over-fishing and because more than 30% of the world's oil tankers move through this area every year.*

- *Fisheries are an important resource in ROPME Member States. The fish harvest is decreasing because of coastal pollution, over-fishing, the use of destructive fishing techniques, and inadequate fisheries management.*

- *Marine organisms in the RSA are dying as a result of various environmental factors. The causes of marine mortality in the RSA have been identified as pollutants, sudden changes in the physico-chemical processes of the sea, outbreaks of bacteria, viruses, fungi and parasites, harmful algal blooms and red tides.*

- *Invasive marine species are a potential form of threat to the marine environment of the RSA. An in-depth scientific study is necessary to identify the invasive species of the RSA and possible means for their abatement.*

- *The Region has witnessed three wars with devastating effects on the environment from the late 1980s to early 2003. Subsequent reconstruction resulted in substantial developments along the shores of the affected countries. The uncontrolled expansion of coastal cities, in which much of the Region's population lives, during the 1990s put even more stress on the marine and coastal environment.*

- *The three wars in the Region have caused extensive damage to the environment of the Sea Area. The Iraq-Iran War, which lasted eight years, targeted refineries, oil terminals, offshore oil fields and tankers; however, the 1991 War exceeded all other environmental disasters of the past four decades. Over 9 million barrels of oil were released into the marine environment. Environmental recovery after an oil spill is a slow process. Fallout from burning oil products produced a sea surface micro-layer that was toxic to plankton and the larval stages of marine organisms. The long-term impacts of these wars on fisheries and the marine environment in general have yet to be assessed. Several projects to assess the long-term impact of the 1991 environmental catastrophe on Kuwait and nearby Member States' ecosystems including, terrestrial, marine and fisheries have been carried out in the different countries since 1991. Respiratory problem and other illnesses related to the crises have also been included in these studies. The recent war in Iraq (March/April 2003) also had a considerable environmental impact in the Region. Moreover the accumulation of hundreds of ship wrecks in the waterways of Iraq and Kuwait poses a continuous threat to the marine life and environment, navigation and public health.*

3. ENVIRONMENTAL CHARACTERISTICS OF THE ROPME SEA AREA

The ROPME Sea Area is located in the north temperate tropical region. It is hot and dry in summer and relatively cool in winter with small amounts of rainfall in winter and spring. The winter (December to January) season in the Region is short and often, spring, which occurs in March or April only lasts for a month.

The Arabian Peninsula and the ROPME Region are considered to be one of the hottest areas in the world. Temperatures in excess of 49^{o}C have frequently been recorded at some measuring stations in the Region in summer especially in the northern part of the RSA. Winter is characterized by mean daily temperatures below 20^{o}C with temperatures sometimes dropping to lows of around 0^{o}C in the north-western part of the RSA.

In the ROPME Region four types of wind prevail in a year. These include the Shamal (Shamal is an Arabic word that means “North”); the Kaus (a local term used to describe a wind, taken from the word for south-east); the sea breezes of coastal areas; and the Monsoon.

The Shamal wind is the most common and blows down the axis of the RSA from the north-west in both summer and winter. The summer Shamal can reach speeds of 153 kilometres/hour, causing dust storms and haze. The Kaus blows from south-south-east ahead of an approaching cold front. A strong sea breeze occurs along the entire coastline, especially along the Arabian Peninsula. Wind patterns in the middle and outer RSA are strongly influenced by tropical circulation of the Arabian Sea with south-west monsoon winds during the summer and north-westerlies in the winter months.

Dust and sand storms are among the most important weather phenomena in Kuwait, southern Iraq and I.R. Iran. Dust storms can deposit up to 1,002.7t/km^2 of sediment in the inner RSA in the month of July alone. The dust storms passing over the northern part of the RSA are a major source of marine sediments.

The amount of precipitation in the Region varies greatly, but the general trend is for decreasing precipitation as one goes from north to south, it varies from 48mm in Doha, Qatar to 275mm in Bushehr, I.R. Iran. The average precipitation in the RSA over a period of 17 years has been calculated at about 78mm/yr, which corresponds to $1.9 \times 10^{10} m^3$/yr.

Evaporation from the open water of the RSA has been estimated at 144cm/yr. Maximum and minimum mean monthly evaporation from the coastal and the central regions of the RSA have been estimated at 29.3cm in June and 8.1cm in February, respectively.

River flow into the RSA occurs mainly in the north (Tigris, Euphrates and Karun) and primarily on the Iranian side. The Tigris (Dijlah) and Euphrates (Al-Furat) rivers together provide an annual average of 708m^3/sec; and the Karun adds 748m^3/sec. Thus, the total average outflow from the Shatt Al-Arab is 1456m^3/sec.

The sedimentary nature of the RSA is the result of heavy rainfall that occurred during the Pleistocene era and 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 dry Al-Batin river from the highlands of the west central part of the Arabian Peninsula. Riverine input is reflected in the composition of sediments on the bottom. It should also be noted that relatively large amounts of sand are deposited by the prevailing NW winds blowing across the axis of the RSA. It is estimated that as much as $100t/km^2$ of sand are deposited annually in the inner RSA. Fine (mud) sediments predominate in the north-western part of the RSA and reflect the influence of the river inputs into the area. Much of the RSA floor is made up of biogenic sediment, produced mainly from micro-organisms, 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 UAE coast, whereas, on the Iranian side these are mixed with a greater proportion of terrigenous sediments from the wind, and numerous small riverine inputs.

The surface water temperature of RSA varies between 12^oC in winter and $>35^oC$ in summer.

Tides in the RSA are complex and vary from semi-diurnal to diurnal. The tidal range is large with values greater than 1m everywhere. The tidal range varies in the inner RSA from about 1.4m near Qatar to 3m in the extreme north-west and to 2.8m in the extreme south-east. The tidal regime in the Omani coastal waters (middle and outer RSA) is predominantly of the mixed, prevailing semi-diurnal type. Average ranges around the Omani coast are between 1.5m and 2m, with a high of about 3m.

The schematic circulation model of the RSA devised by Hunter (1983) indicated that 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 the entire southern coast of the RSA. The flow stagnates east of Qatar, where high evaporation and sinking forms a dense, bottom flow to the north-east and out of the Strait of Hormuz. The inflow from the Strait of Hormuz is stronger (about 20cm/sec) in summer and weaker (about 10cm/sec) in spring and autumn. The circulation pattern of the inner RSA has also been classified as one of both high- and low-salinity water exchange in the Strait of Hormuz; density-dominated circulation in the central and southern inner RSA; a frictional balanced, wind-dominated regime in the NW inner RSA; and evaporation-induced bottom flow.

The concentration of nutrients in seawater varies over space and time. Measurements of nutrients indicated that the surface nutrient content in the middle and outer RSA is much higher than in the inner RSA. High phosphate surface water (> 1μmol/l) from the outer RSA rapidly loses phosphate through mixing and biological stripping as it moves north to the inner RSA (<0.1μmol/l) and the nitrate concentrations (2 to >10μmol/l) frequently drop below detectable limits. This may be taken as circumstantial evidence that nitrates are a limiting nutrient in the inner RSA during winter-time.

Salinity gradually increases from southern to northern parts as a result of higher evaporation, with lower salinity along the Iranian side. In summer, the surface salinity varies from 34‰ (June) on the southern Omani coast on the Arabian Sea to 38.9‰ in the northern part of the Gulf of Oman and increases up to 42‰ just off Bahrain. Very high water salinity, 70‰, has been reported in the Gulf of Salwah at its southern extremity. In winter, salinity is somewhat higher than in early summer in the upper NW of the RSA, apparently due to the variation of fresh water influx from Shatt Al-Arab and meteorological effects, particularly evaporation.

Surface layer dissolved oxygen is normally saturated with a concentration of 6mg/l or higher depending on the temperature and salinity of the water. Depletion of dissolved oxygen occurs in certain shallow waters as a result of nutrient enrichment.

Surface pH in the middle and outer RSA (8.130–8.214) is in general lower than in the inner RSA (8.210–8.320). The pH drops with depth and might reach 7.454 at about 800–900m depth in the Gulf of Oman. Seawater is naturally a buffered solution so there is little variation in pH between the surface and bottom waters. This is evident in the waters of the RSA.

Bathing in sewage-contaminated seawater with microgerms poses significant risks of gastrointestinal disease; and consumption of contaminated seafood causes hepatitis diseases worldwide.

Chlorophyll analyses and phytoplankton cells counts have shown that phytoplankton production is limited to certain areas and does not occur throughout the whole RSA. Chlorophyll-*a* levels ranging from 0.2 to 0.86mg/m^2 have been reported in the inner RSA, while measures of 0.5 mg/m^3 have been reported in the Arabian Sea. A recent estimate made during the Ghods Cruise in summer 2001, showed ranges of phytoplankton of 0.11 to 1.46μg/l at the surface waters of the inner RSA. A total of 147 taxonomic entities of phytoplankton were recorded from the samples gathered by the cruise in the inner RSA and the number of species found at each measuring station ranged from 17 to 62. Relatively limited information is available about the microbiological characteristics and primary productivity of the RSA, thus further research is needed to fill the lacunae.

Zooplankton production in RSA varies over time and space, and estimates have been made through different types of analyses, therefore, comparison of the production levels is difficult. Maximum levels of zooplankton biomass were found in the north-east of the RSA where seawater with high temperatures, low salinity and high concentrations of nutrient and chlorophyll-*a* was recorded. Abundance of zooplankton estimated during the Umitaka-Maru cruises indicated a mean value of 2064.5 ±3282/m^3. Among the species studied, copepods dominated with a mean of 10680 ± 1383/m^3. Copepods are consistently the most abundant constituents with an average of 48.93% of the total zooplankton in Muscat waters as well. In Kuwaiti waters, zooplankton biomass varied from 4.8mg/m^3 (dry/wt.) to 288mg/m^3 with a mean of 186.7mg/m^3. In Qatari waters, it ranged from 100–500mg/m^3. In the Gulf of Oman, the mean overall biomass was found to be 84681mg/100m^3 (wet wt.), whereas on the Arabian Sea coast of Oman it was 62,645mg/100m^3. The Arabian Sea biomass was less than the biomass of the Gulf of Oman by a factor of 1.35. Seasonal variations in zooplankton abundance have indicated that its biomass was higher in winter than in summer. In the inner and middle RSA during winter, zooplankton biomass was 3–3.5 and 2.27 times respectively, higher than in summer.

Most of the marine fishes spawn in the open sea and produce pelagic eggs and larvae, known as ichthyoplankton. Those areas with the highest density of fish eggs and larvae are looked upon as spawning grounds for a number of fish species, and if need be, are closed to fishing, as a conservation and stock replenishment measure. In the inner RSA, the predominant families of eggs belong to the Engraulidae and Clupeidae families, which account for 45.4% of all eggs, whereas the larvae are Engraulidae, Clupeidae and Gobiidae and account for 42.5% of all larvae. A total of 53 families of fish larvae have been identified in the inner RSA. However, in the middle and outer RSA, 54 species of fish eggs and 93 species of fish larvae have been recorded. Comparative studies of the middle and outer RSA have indicated that the Arabian Sea has 20 times greater egg abundance than the Gulf of Oman, whereas the Gulf of Oman has 2.6 times higher larval abundance than the Arabian Sea. Sardines and mesopelagic larvae dominate in the Gulf of Oman. The eggs and larvae were found in higher concentrations in summer, which is the peak spawning period in the RSA.

Benthic faunal analyses of samples gathered from a recent cruise indicated the presence of 304 taxonomic entities in the inner RSA. The greatest abundance of benthic invertebrates was recorded near the coast of Qatar, while the smallest number was recorded in waters adjacent to the Kuwait and Iraq coastline. The mollusc population was higher in the offshore waters of Qatar, whereas Echnoid concentration was higher in the waters of UAE. Crustacean and Annelid abundances were higher in Qatar and I.R. Iran waters respectively. This study is to be extended to other areas in future.

4. MARINE RESOURCES OF THE ROPME SEA AREA

The marine environment provides the largest inhabitable space for marine fauna and flora. The marine habitat ranges from exposed beaches to the open sea environment which includes the benthic deep and shallow subtidal habitats, intertidal habitats; rocky, sandy and muddy shores; pelagic, mesopelagic and demersal habitats and so on. Of these, certain habitats are in a critical situation, among them the mudflats, which provide shelter to varieties of organisms. The marine habitats of the RSA are listed and over 85 sites are marine protected areas.

Seagrasses and seaweeds are an important food source as well as good substrates and provide shelter to a number of marine organisms. Seaweeds are commercially important, exploited for alginates, agar and carrageenan. They are often used directly as food for human consumption and organic manure. Marine algae are rich in protein, vitamins A, B, C and E, minerals, folic acids, phenolic compounds, sterols, terpenoids and hologenated substances, used for the preparation of drugs. The seaweeds, Phaeophyta (brown algae), Rhodophyta (red algae) and Chlorophyta (green algae) are harvested worldwide. Four species of seagrass are commonly found in the RSA. Of these, *Halodule uninervis* and *Halophila ovalis* are the most common. The seagrasses of Masirah form an important part of the diet of the Green turtle, *Chelonia mydas*. A recent study revealed that there are 232 taxa of seaweeds in Omani waters. Dense subtidal beds of seaweeds on the Dhofar coast of Oman form the basic food for several herbivores such as the abalone, *Haliotis mariae*; rabbitfish, *Siganus* spp.; parrotfish, *Scarus* spp.; and the Green turtle, *Chelonia mydas*.

Mangroves are found on the mudflats, and provide living space for more than 2,000 species of marine organisms. In the RSA, because of severe climatic conditions and limited habitats, there is only one species of scattered population of mangrove, the *Avicennia marina*. Because the air temperature drops to freezing in winter over the extreme NW part of the inner RSA, mangrove trees are not found in Kuwait and most of the NE coasts of Saudi Arabia. On the Iranian coast, about 10,000 hectares of *Avicennia marina* plants are found. Along the Oman coasts and islands mangroves are scattered over more than 20 sites with faunal assemblages of many species of fish, crabs, shrimps and clams, over 200 bird species, three species of turtles and four mammal species. In Qatar, mangroves are found on the north-eastern coast. The standing biomass of the UAE coast has been estimated between 70 and 110t/ha.

Coral reefs are the jewels of the sea. Their presence in the RSA is a unique example of the adaptation of marine organisms in such extreme environmental conditions. There are many patch reefs in the RSA, with coral islands representing the peak of their development. About 55–60 zooxanthellate species have been identified in the RSA. Coral reefs in the inner RSA live in an environment charaterized by great extremes of temperature and salinity, and high turbidity. However, no coral species occur in places with >46‰ salinity. Coral survival is limited where physical conditions are more extreme.

The numbers of coral species distributed among ROPME Member States' coastal waters are: 31 species in Bahrain; 19 species in I.R. Iran; 26 species in Kuwait; 91 species in Oman; 8 species in Qatar and 34 species in UAE. Coral bleaching has been reported in Bahrain, Oman, Saudi Arabia and UAE because of high temperatures. Coral reefs are extensively destroyed by Crown of Thorns Starfish (COTS) in Oman and UAE. Manual removal of COTS from infected coral reefs prevents mass destruction of coral reefs in the RSA.

Shrimp is one of the most important seafood commodities in the RSA. The richest shrimp resources are found in I.R. Iran and Kuwaiti waters, with smaller catches in Bahrain, Oman, Qatar and Saudi Arabia waters. The main species used for commercial exploitation in Kuwait are *Penaeus semisulcatus* and *Metapenaeus affinis*. In Omani waters, although 12 known species occur, four species are used in commercial fisheries, namely *Penaeus indicus*, *P. semisulcatus*, *Metapenaeus monoceros* and *M. stebbingi*. In Bahraini waters, of the seven penaeid species that exist, commercial landings are from a single species, *P. semisulcatus*.

Among lobsters, two species of spiny lobster, *Panulirus homarus* and *P. versicolor* are commercially exploited in the middle and outer RSA. The shovel nose lobster, *Thenus orientalis* is exploited as shrimp by-catch in Bahrain, whereas *Scyllarides squammasus* is commonly caught in traps in Oman. Crabs are found in different habitats in RSA. The families Grapsidae and Ocypodidae are the dominant faunal species of the intertidal flats and mangroves of the Region, where six species of grapsid and 21 taxa of ocypodid crabs are known to occur. The crabs, *Portunus pelagicus* and *Scylla serrata* are commercially important species in the RSA.

Among molluscs, the abalone, *Haliotis mariae* is found only in outer RSA, restricted to the Dhofar coast of Oman. It is commercially exploited. Pearl oysters belonging to the *Pinctada* species are found in the RSA. The species, *Pinctada radiata* is abundant in Bahraini waters, and also common in Kuwaiti and Saudi Arabian waters. However, *P. margaritifera* is abundant along the Iranian coast. Interestingly, both of these species are found along the Oman coast in the Gulf of Oman. Among cephalopod molluscs, squids, cuttlefish and octopus are the commercially important groups occurring in the RSA. The Pharaoh cuttlefish, *Sepia pharaonis* is also an important commercial species in the RSA.

The inner RSA has >500 species of fish which live in pelagic, demersal and coral reef habitats. Of these species, about 130 species occur in Kuwait, 71 species in Bahrain and 106 species in Saudi Arabia. In the middle and outer RSA off Oman, about 1,138 species of fish are known to occur. Environmental extremes in the inner RSA have restricted the distribution of many species of fish. On the other hand, the high species diversity of Oman's fish fauna is a result of the diversity of coastal habitats, a wide climatic spectrum and the geographic location in the north-western upwelling region of the Indian Ocean.

Marine turtles have a prominent place among the fauna of the RSA. All five species of sub-tropical sea turtle are known to occur in the Region, where the females come to the beach for nesting. Although turtles nest on the beaches and certain islands of Bahrain, I.R. Iran, Kuwait, Qatar and Saudi Arabia, three of the turtle nesting locations in Oman are of international significance. Masirah Island has the largest nesting population of Loggerhead turtles, while Ra's Al-Hadd supports the largest nesting aggregation of Green turtle known in the northern Indian Ocean, and Damaniyat Islands support extensive Hawksbill turtle nesting. Sea bird *Sterna* spp. and Ghost crab, *Ocypode rotundata* are the major predators of turtle hatchlings.

Sea snakes are the most venomous snakes in the world. Nine species of sea snake are known to occur in the RSA. Of these, the hook-nosed or beak-nosed sea snake, *Enhydrina schistosa* and the annulated sea snake, *Hydrophis cyanocinctus* are the most dangerous species in the Region. The *Hydrophis* is the most common species in the Region, found in muddy, warm waters and its preferred habitat is the soft substrate of the inner RSA.

The RSA has a diverse marine bird community of great international importance. A large number of seabirds breed on the offshore islands, especially the Socotra cormorant and the terns Sterninae. The intertidal zone of the RSA is estimated to support up to four million waders during winter, making RSA one of the five most important regions of the world for wintering waders. The subtidal zone is also internationally important during migratory seasons for populations of about 20 other species of water birds including grebes, cormorants, herons, flamingos, gulls and terns.

Marine mammals, dugongs, dolphins and whales inhabit the RSA. The estimated population of dugongs in the RSA is 7,310, making the RSA the most important area for this species in the western part of its range and second in global importance only to Australia. Altogether, about twenty dolphins and whale species are known to occur in the RSA.

Of the living marine resources of the RSA, certain species are dangerous to human beings, and cause injury or intoxication during direct encounters. Species of dangerous organisms of the Region belong to both invertebrate and vertebrate groups, from Phylum coelenterata (Jellyfish) to vertebrata (sea snakes) are listed. Many serious incidents can be avoided through raising public education and awareness, since it is important for the general public to know about the dangerous organisms which pose threats to human beings in the Region.

5. SOCIO-ECONOMIC ACTIVITIES AND STRUCTURES AFFECTING THE ROPME SEA AREA

Prolific socio-economic activities of ROPME Member States along the coastal stretch and the sea have considerably affected the environment of the Region. The substances from land and sea-based activities such as domestic sewage, industrial effluents, toxic substances, petroleum hydrocarbons, nutrients, and litter pose a major threat to the environment and should be controlled region-wide.

The heavy industries of the Region, which include petroleum refineries, petrochemical industries, desalination and power plants, food, agriculture and livestock industries are the main sources of organic carbon load. The pollution load from each industry varies according to the production capacity and the type of product of the industry. For example, petrochemical plants produce a wide range of products namely, methanol, ethanol, ethylene chloride, ethylbenzene, styrene, chloride, caustic soda, formaldehyde, polyethylene, ethylene, nitrogen, oxygen gases, urea, ammonia, etc. All these products have their own detrimental impacts on marine life.

The cooling water and brine discharges from power and desalination plants contain the pollutants of residual chlorine and thermal loads. Desalination plants discharge heated brine into the sea which leads to changes in the physico-chemical and biological characteristics of the local marine ecosystem.

Effluents from oil refineries contain liquid hydrocarbon, phenol, sulphides and dissolved solids. In addition, heavy loads are added from fertilizers and petrochemical industries, and gas and fuel production industries of the RSA. Oil sludge is the main solid industrial waste found in the RSA. The solid wastes generated from various industries affect the environment considerably if they are not managed properly.

The atmospheric emission loads to the RSA from land-based industries eventually reach the marine environment. The major sources of emissions are oil refineries, petrochemical and fertilizer plants, power plants, motors vehicles, etc. Rapid increases in the number of motor vehicles have contributed significantly to air pollution. Emissions from industries contaminate the atmosphere with sulphur oxides, CO, nitrogen oxides and hydrocarbons. Particulate matters from industrial emissions cause more stress for the marine environment.

Sewage discharges from urban and rural areas into the coastal and marine environment of the RSA are another source of pollution. These are either partially treated or untreated. The combined sewage treatment plant capacity in the region is more than 2 millions m^3/day. However, greater volumes of untreated sewage are continuously entering the RSA causing degradation of the marine environment. The sewage treatment capacity of Member States varies, and certain effective steps are being taken by Member States to mitigate contamination. Treated sewage water is mainly used for irrigating landscape areas, parks, recreation facilities, highways and golf courses.

Development activities of certain Member States in river basins, such as dam construction, water diversion, etc. have significantly affected the marine ecosystem of the RSA. They have caused considerable changes in normal river hydrological regime and flow patterns, and changes in the quality and quantity of water entering the RSA. The impacts are enormous in the Shatt Al-Arab ecosystem and also for the fisheries resources of the NW part of the RSA. The reduction in river water flow into the RSA causes various ecological problems in the Region, which require cooperation among the countries for continuous monitoring and arrangements for regional river basin management.

Physical alteration for coastal development is a major threat to the marine environment of the RSA. Coastal development requires extensive dredging and land reclamation, or increasing the land area by land filling for future development. These activities include various construction activities for the development of industries, residential areas, sports complexes, causeways, fishing ports, commercial ports, harbours, etc. Physical alteration along the coastline damages the spawning grounds of a number of marine species, and destroys the seagrass beds and mudflats. It also increases siltation and water turbidity which irritates or clogs fish gills, inhibits photosynthesis of marine flora and creates coastal erosion. Rapid and continuous coastal zone development activities in the RSA require strategic impact assessment, well-defined management plans and monitoring.

The fast rate of development of recreational and tourism facilities along the coast poses a great threat to the environment of the Region. Marinas, water sports, sport fishing, marine parks and beach camping facilities are all being developed. The adverse impact of these facilities should be carefully monitored and mitigated to protect the coastal area against further degradation.

Environmental degradation of the RSA by various man-made activities has affected the marine living resources. The destruction of nursery and spawning grounds of many marine species by coastal reclamation and the reduction of the outflow of freshwater resources from Shatt Al-Arab have had a significant impact on the living resources of the RSA. In addition to this, destructive fishing methods cause severe impacts to the fisheries and the marine ecosystems of the Region. Over-exploitation of targeted species, has considerably affected the stocks of many commercially important species. These problems could be tackled effectively by the introduction of regulations and enforcement such as restriction of fishing efforts, fishing net mesh size, determining the capture size and the introduction of closed fishing seasons and areas.

Non-living marine resources, oil and natural gas, are exploited from offshore deposits by Member States and seawater is used for desalination, cooling and steam production to generate electricity. The sand and gravel from coastal waters are also exploited for various uses. Offshore exploitation and production of oil and gas cause chronic environmental problems in the Region. Discharges of chemicals and enormous volumes of water produced from offshore fields, increase the magnitude of environmental impacts, and are of major concern.

Dredging activities are undertaken on a wide scale in the coastal stretch of the RSA, particularly for land reclamation, de-silting of harbours, etc. The dredged materials contain varieties of substances which may contaminate the environment. Suitable techniques should be adopted to dispose of the dredged materials without causing adverse environmental impacts. The oil spill, ballast water, sewage, tar ball deposits along the coast and garbage from tankers should be restricted as they are continuously contaminating the entire RSA waters. The large network of pipelines lying on the sea floor of the RSA is another source of oil pollution which frequently causes environmental hazards on account of pipe ruptures and oil leakage.

6. CONTAMINATION OF THE ROPME SEA AREA

Although the coverage of surveys carried out in some areas of the coastal waters has not been comprehensive during the contaminant screening survey, several pertinent findings and general conclusions can nonetheless be highlighted based on the screening results from the four Member States surveyed in 2000 and 2001, as well as on previous data for the Region generated through surveys using similar sampling sites, sample preparation techniques, analytical methodologies, quality assurance measures and analyses.

Oil pollution continues to be a problem in various parts of the RSA. Approximately six years after a severe oil spill occurred in the Gulf of Oman off the east coast of UAE, relatively high petroleum hydrocarbon concentrations were still noted in the sediments and oysters around Akkah Head. The existing concentrations in sediments are much lower than those measured just after the spill, but nevertheless, attest to the slowness of the process of environmental recovery from acute oil spills in the Region. Interestingly, sediments from this area also contained extremely high levels of trace metals (e.g., nickel) and high concentrations of certain organochlorine pesticides. In contrast, trace metal levels in oysters from Akkah Head and Akkah Beach were not particularly high suggesting that contaminant trace metals in sediments may act more as a sink than a source of contamination to the bivalves living near them. The source of the varied mixture of contaminants found at Akkah Head and Akkah Beach is not known, but it is likely that it is not a directly result of the 1994 oil spill. Regular monitoring of the area and more specific analyses are required to determine if any dumping activities have taken place in this area.

Moreover, it has been over three years since the last time-series measurements of petroleum residues and related contaminants were made in specific areas of north-western Saudi Arabia and Kuwait which were heavily affected by the 1991 War oil spill. In order to achieve a high resolution time-series data set which will allow better assessment of the ecosystem recovery potential in this affected region, further screening measurements should be undertaken at the same locations in the near future. Such screening surveys in all the above-mentioned areas will continue to pinpoint local ‘hotspots’ as well as ensure the capture of data with more synoptic coverage of spatially and temporary determined contaminant levels in the RSA.

Another location where chronic pollution involving a mixture of contaminants has occurred is off the BAPCO industrial complex in Bahrain. The highest concentrations of a variety of toxic substances were found there, and the extremely high levels of benzo(a)pyrene recorded off BAPCO and at Askar should be viewed with concern and warrant continued monitoring.

In particular, the new results on organochlorine compounds have proven useful in expanding the existing time-series data sets for the Region. Whereas PCB concentrations in oyster populations have appeared to decrease over the last two decades, concentrations of DDT compounds have varied little during this time. Such data sets are unique and should be extended to coastal water sediments in well-defined locations so that the countries can better evaluate temporal changes and recovery potential in areas that have been heavily contaminated, such as Akkah Beach in UAE and off BAPCO in Bahrain.

The origins of high trace metal and organotin compound levels in rock oysters from certain locations on Masirah Island are not obvious, but the high trace metal concentrations may be a result of natural geochemical and oceanographic processes. Likewise, the interesting observation of very high Cd concentrations in the livers of some fish from southern Oman may result from the bioaccumulation of high Cd levels in the food chain, brought into the productive surface waters by the natural upwelling processes that occur in this region. Only more detailed spatial and temporal sampling will help resolve these unexplained observations.

Detailed sampling of fish (liver) in the south of Oman should be continued to try to explain the high concentrations of Cd observed in the samples (food chain bioaccumulation through natural upwelling, or other source).

Mercury concentrations generally continue to be very low in sediments, and total Hg levels in top predator fish commonly consumed in the RSA were found to be below the 0.5µg g^{-1} wet threshold value set by many Member States and were similar to levels measured in the same species during earlier years.

Most interesting, and as yet unexplainable, is the observation of very high arsenic concentrations in certain bivalve species from the RSA when compared to those from other regions in the world. Again, it is not clear whether this is related to point sources of contamination (unlikely) or to natural biogeochemical processes in the Region (more likely). It is evident that to properly interpret sources of possible metal contamination, it is imperative to understand the natural bioaccumulation potential and naturally occurring levels of elements like As in the species under study since content and ratios of trace metals vary greatly among the bioindicator species (particularly bivalves) used in the RSA.

Aside from the specific aspects mentioned above which should be given attention in future monitoring work, we still have gaps in our knowledge of the spatial (and local) distributions of some of these key contaminants in the coastal waters of the RSA. Most of the reliable existing data that have been obtained relate to the north-western region of the RSA. Areas around the north-eastern Shatt Al-Arab have been little surveyed as have many locations along the eastern and south-eastern shores of the RSA. Because the Shatt Al-Arab drainage system is the most likely source of the large-scale input of agrochemicals and many other industrial and urban contaminants in the RSA, this is a critical area to screen for POPs as well as other potential contaminants originating from land-based sources.

It should be also noted that the last screenings carried out in Kuwaiti and Saudi Arabian coastal waters were made in 1998, over 5 years ago. These countries were heavily affected by the 1991 War oil spill. In order to achieve a high-resolution time-series data set that will allow a better assessment of ecosystem recovery potential in this affected region, further screening measurements should be undertaken at the same locations in the near future.

Neither faecal sterols from sewage inputs nor organotin compounds arising from biocide use appear to be major problems in the areas screened in these surveys. The environmental levels of organotins found in coastal sediments from the RSA were relatively low by global standards. Similarly, the organotin content of the marine biota is comparatively low and does not pose any immediate public health problems.

The basin wide contaminants study of the sediment samples gathered by the Oceanographic Cruise – Summer 2001 revealed that the open RSA has naturally occurring hydrocarbons derived from a mixture of autochthonous and terrestrial origins, and low levels of anthropogenic input of degraded petroleum hydrocarbons. Since the high concentration and widespread distribution of the C_{12}-C_{22} n-alkanes with a strong even carbon number masked almost all evidence of spilled oil, a continued watch should be maintained on the area in order to track any changes in the aliphatic distribution.

With the exception of a few stations used during the Oceanographic Cruise – Summer 2001, the concentrations of total DDTs, total HCHs, and total PCBs were relatively uniform. The only stations where comparatively high concentrations were recorded were Station 20 for total DDT, Station 56 for total HCHs, and Stations 27 and 78 for Total PCBs. Overall, the concentration of organochlorinated compounds in sediments in the inner RSA is relatively low by global standards.

Local sources affect the strengths and propensity of fine-grained material to accumulate and influence the distribution of metallic contaminants in sediments of the inner RSA. Trace metal concentrations are strongly correlated to the aluminium concentration, a good proxy for terrigenous material and the amount of fine-grained material present. Several trace metals (As Cr, Ni) exhibit sufficiently high concentrations to exceed sediment quality guidelines. Such trace metals, at least in the case of Cr and Ni, undoubtedly have a high natural occurrence in this mineral-rich Region. However, anthropogenic activities, notably mining, may have further increased the trace metal burdens in the sediments of the RSA, which could explain the presence of an apparent hotspot for zinc in one region. Several trace metals (Ag, Cd, Pb) have relatively low levels that pose no environmental concerns.

7. <u>MAJOR ACCIDENTS AND EPISODIC EVENTS</u>

This Region is the most crowded shipping route in the world, with some 25,000 tankers carrying about 60% of the world's total crude oil exports by sea. Annual oil spills in the RSA are the equivalent of about 1.2 million barrels. Transportation and tanker accidents are the main source of oil released into the sea in comparison with inputs from natural seepage, atmospheric fall-out and urban run-off.

The most dramatic environmental impact in RSA has been caused by wars. The Iraq-Iran War and the blowout of the Nowruz offshore oil wells off the Iranian coast, which spilled over 2 million barrels of crude oil into the marine environment was the first environmental catastrophe of its kind. During the 1991 War, the quantity of oil discharged and spilled from various sources into the RSA exceeded 9 million barrels which caused tremendous environmental stress to the entire ecosystem. This oil spill has had a significant impact on the onshore and offshore areas of Kuwait and Saudi Arabia. The setting of fire to more than 730 Kuwait oil wells was another episodic event of the 1991 War. Oil well fires caused serious air and water pollution as well as health problems in human beings and other organisms.

The 1991 oil spill has damaged the marine environment and affected the habitats of many organisms in the RSA. The water currents dispersed the oil into all coastal areas and islands in Kuwait and the eastern parts of Saudi Arabia and Qatar. The oil deposited on the bottom of the sea affected the growth of the coral reefs and other benthic organisms. Enormous numbers of land mines were laid in the coastal zone during the war and have had negative impacts on the marine and coastal environment as well as posing a serious threat to the lives of beach users and fishermen.

Mortality of marine organisms in the RSA is the result of various environmental factors. The causes of marine mortality in the RSA have been identified as pollutants, sudden changes in the physico-chemical processes of the sea, outbreaks of bacteria, viruses, fungi and parasites, harmful algal blooms and red tides. The marine mortality incidents in the RSA between 1986–2001 are documented and the causes of mortality are also explained.

Invasive marine species constitute a new form of threat to the marine environment, where they could destroy rare native species by preying them, competing with them for shelter, food or both, introducing harmful germs and parasites, and finally changing the normal function of the affected marine ecosystem. An in-depth scientific study is necessary to identify invasive species in the RSA and the possible ways to bring about their abatement. This is a difficult task which requires thorough long-term planning along with regional and international cooperation.

8. MARINE POLLUTION CONTROL, EMERGING ISSUES AND STRATEGIES FOR SUSTAINABLE DEVELOPMENT

This Chapter provides a summary of the information on the measures, policies and strategies for sound environmental management and sustainable development of the RSA and includes information on environmental challenges, Mechanisms for Prevention and Control of Marine Pollution and Strategies, and priority action for Sustainable Development.

Based on current and emerging environmental issues, the specific environmental challenges that face the Region can be described as follows:

- ***Conservation and restoration of marshlands of Mesopotamia.*** In this connection a river basin management programme should be developed for the Shatt Al-Arab and its entire basin. ROPME could provide an important forum for transboundary cooperation to rehabilitate the Mesopotamian Marshlands, but there is also need for international support and UNEP to assist in facilitating a process of regional dialogue between Member States to pursue a successful programme to address this environmental disaster.

- ***Pollution from land-based activities.*** Over the last three decades the ROPME Region has witnessed one of the highest rates of economic growth in the world. The rise in industrialization together with high population growth and rapid urbanization, have resulted in ever-increasing environmental problems in the Region. In order to deal with these problems ROPME has developed guidelines on Integrated Coastal Area Management to harmonize development activities in the coastal zone. Member States are also taking appropriate measures to develop ICAM plans, and to prevent, abate and combat pollution from land-based activities.

- ***Pollution from ships.*** The RSA is an area with one of the highest oil pollution risks in the world from various sources such as, offshore installations, tanker-loading terminals and the huge volume and density of marine transportation of oil. Smaller scale oil pollution incidents such as submarine pipeline rupture and well blowout are more frequent in the RSA. ROPME is supporting every effort to encourage the ratification of the MARPOL Convention and meet the requirements for the construction of adequate reception facilities in the Region in order that the RSA be declared a Special Area with the assistance of Member States, regional and international organizations and oil companies.

- ***Pollution from offshore operations.*** The impact of offshore operations on the marine environment especially in shallow waters or near to ecologically sensitive areas is more noticeable. The high salinity, temperature and oil content of produced water by offshore oil wells are among the main causes of stress to marine life. To this end, ROPME is making every effort to address all aspects of produced water in a comprehensive way so as to minimize its detrimental impact on the marine environment.

- ***Conservation of biodiversity.*** Marine mortality episodes are familiar phenomena in the Region and their toll on fish, dolphins, dugongs, whales, waterfowl, algae and corals has reached record levels in the past two decades. The mortality phenomena have been attributed to high levels of anthropogenic contaminants, unseasonably warm temperatures, disease agents, biotoxins and changes in food supply. ROPME has initiated a Plan of Action on Marine Mortality (PAMM) and has established a permanent Regional Group of Experts to address these mortality events. Preparation of a Protocol concerning the Conservation of Biological Diversity is underway by ROPME and several Legal/Technical Expert Meetings have been conducted to review the draft text of the Protocol. Ratification of this protocol by Member States will hasten regional efforts for conservation of RSA Biodiversity.

  The mechanism for prevention and combating marine pollution starts from the adoption of policies and preventive measures, the establishment of environmental legislation and the development of necessary institutional arrangements for implementation and enforcement.

- ***Policies for pollution prevention and control.*** Policies for pollution prevention and control address national policies and initiatives, regional initiatives and policy instruments, protected areas and marine parks, contingency plans and emergency response, precautionary environmental protection policy, public awareness and implementation procedures. The latter include an overview of Environmental Impact Assessment (EIA) procedures and the necessity to adopt the ambient coastal and marine water quality criteria.

- ***Environmental legislation.*** Environmental legislation includes principal issues such as, national legislation/regulation, the Kuwait Regional Convention and its Protocols, and the international conventions and programmes relevant to the protection of the marine environment. The Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978) has four related protocols that were developed in accordance with the recommendations of the Legal Component of the Kuwait Action Plan. ROPME countries also are members of international conventions and agreements. However, most national environmental legislation and regulations in some countries of the Region obviously need updating and revising, particularly those sections that relate to acceptable and adequate norms and standards.

- ***Institutional arrangements.*** Institutional arrangements are made at the regional level, as well as the national level, in the form of government and non-governmental bodies dealing with environmental issues or through follow-up with the overall coordination bodies. Some of the countries in the RSA have restructured these institutions in the recent years, giving them higher political standing. The role of non-governmental organizations (NGOs) is becoming increasingly important particularly in areas that require active public participation, and in raising public awareness of environmental issues. In almost all ROPME Member States, environmental NGOs are operational and have a wide range of activities, many of which are related to the marine environment.

  As far as strategies and priority action for Sustainable Development are concerned, a 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. 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. ROPME can act as an interface between 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). The following priority issues should be included in strategies for environmental protection in the Region.

- ***Integrated Coastal Area Management (ICAM).*** National ICAM plans may be developed with a regional perspective to provide an overall framework for coastal area management, complemented by more specific plans for different coastal development.

- ***Environmental impact assessment.*** Another planning tool that is complementary to ICAM is the environmental impact assessment (EIA) procedures that would help to significantly reduce the degradation of the environment, particularly from land-based activities in all Member States.

- ***Conservation strategies.*** 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. National and regional conservation strategies are complementary and should be developed for key habitats such as coastal wetlands, mangroves, seagrass beds, coral reefs and oyster banks in the RSA.

- ***Strengthening the implementation of ROPME Protocols.*** As mentioned above, the Kuwait Regional Convention has four related Protocols dealing with various aspects of marine environmental protection and management. These protocols have been adopted to further specify the mandate of the Convention. In order to achieve the objectives set for these important legal instruments, strengthening of Protocol implementation should be part and parcel of the national strategies of Member States for the protection and sustainable development of the marine and coastal areas under their jurisdiction.

- ***Capacity building.*** The efforts aimed at ROPME capacity building such as in-house training, short courses, or visits to qualified laboratories/institutions are to be further encouraged and increased through the establishment of 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 specialties in order to train specialists in various fields of the environment to face the future challenges of the Region.

- ***Enhancing public awareness, information sharing and networking.*** 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 ROPME Member States. In this connection, it has to be noted that the large number of stakeholders involved in the coastal area requires multi-level awareness programmes targeting different groups.

- ***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.

- ***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. In this connection, the ROPME's efforts to collaborate with regional, international and related stakeholders such as FAO, IAEA, IHB, IMO, IOC, ISO, IUCN, OPEC, GCC, UNEP, UNDP, UNESCO and WHO should be mentioned.

- ***Harmonization of legislation.*** ROPME Member States as members of the international community collectively have a significant role to play in the global arena. But the Member States should realize that the role of ROPME is to be involved in the development of global conventions to ensure that they take into consideration the needs and opportunities afforded by the Region.

- ***Environmental assessment and monitoring.*** Although much progress has been made since 1999 in the development of regular state of the environment assessments and monitoring systems, a strengthened monitoring and assessment programme is required to address new challenges in the Region. This programme will be integrated with larger global assessments such as the United Nations Global Marine Assessment and the Global Environment Outlook process and will be developed with regional and international scientific institutions and with relevant United Nations agencies. ROPME capacity for remote sensing application combined with harmonized efforts by Member States would help to achieve better environmental assessments and monitoring of the region in future.

- ***Control and management of oil spills.*** As mentioned, oil pollution is the most significant form of pollution in the RSA. Only limited numbers of inadequate reception facilities exist in the Region. 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. Acceding to and implementation of MARPOL 73/78, and adoption of Port State Control procedures by all Member States are the main instruments for controlling oil pollution in RSA.

- ***Control of land-based sources of pollution.*** ROPME Member States should seriously pursue 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), particularly the integrated management of the Shatt Al-Arab river basin and the management of Municipal Wastewater. ROPME has expressed willingness and begun cooperating with UNEP/GPA in their Strategic Action Plan on Municipal Wastewater.

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- ***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. 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 permits obtained prior to the initiation of any small- or large-scale project requiring dredging or filling, particularly those adjacent to environmentally sensitive areas. Furthermore, authorized dredging operations should follow clear operational standards.

- ***Restoration of mangroves and coral reefs, protection of wetlands.*** Mangroves, coastal lagoons, seagrass beds and coral reefs represent important components of the ecological systems of the RSA and have been subject to rapid deterioration. The restoration of damaged ecosystems and re-introduction of lost species or populations through the cooperative efforts of research institutions, fisheries and environmental protection authorities are essential steps to push back the tide of destruction and move towards the recovery of these habitats. In the meantime, since the restoration projects are extremely costly, governments, development and finance funds/banks and the private sector should support such important regional efforts.

- ***Development of an Environmental Information System and reporting programme.*** There is an urgent need for the development of an environmental information system with GIS capabilities. Such an information system can be extensively used and benefited from by all concerned scientists and authorities. To this end, ROPME's environmental reporting capacity needs to be strengthened and its reporting outputs disseminated in printed and electronic formats, including through the upgrading of its Website.

CHAPTER 2

ENVIRONMENTAL CHARACTERISTICS OF THE ROPME SEA AREA

2.1 Climatic and Meteorological Characteristics

The ROPME Sea Area is located in the north-temperate tropical region. This region marks the boundary between the tropical cellular circulation and the synoptic weather systems of the mid-latitudes. Sinking dry air in these latitudes produces clear skies and arid conditions (Reynolds, 1993). The local climate is strongly influenced 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 travel in a north-west to south-east direction along the axis of these mountain ranges.

The climate of the RSA is 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 short. Winter tends to last no more than two months and occurs in December and January, and spring, which occurs in March or April, often lasts no more than one month (Ali, 1994).

2.1.1 Atmospheric temperature

During the winter the air temperature in the northern part of the RSA is lower than in the southern part. Winter is characterized by mean daily temperatures below 20^{o}C with lows of around 0^{o}C in the north-western part of the RSA (Reynolds, 2002). During the summer, mean daily air temperatures are consistently higher than 30^{o}C.

The Arabian Peninsula and the ROPME Region are among the hottest areas in the world (Takahasi and Arakawa, 1981). Temperatures in excess of 49^{o}C have frequently been recorded at some weather stations in the Region especially in the northern part of the RSA (Safar, 1985; MEPA, 1989; Qatar, 1990; Al-Kulaib, 1990). In 1997 a record temperature of 84^{o}C in the sun and 52^{o}C in the shade was reported in the open desert of Kuwait. Air temperature extremes in Oman have ranged from 47.8^{o}C in June 2002 to as low as 5.4^{o}C in February 2002 (MRMEWR–Oman, 2003). These large variations of temperatures mean that terrestrial and marine flora must be endowed with special adaptation capabilities.

2.1.2 Winds

In the ROPME Region four types of wind prevail. The Shamal ("Shamal" is an Arabic word that means "North") during the winter and summer; the Kaus (a local term taken from the word "south-east"); coastal winds brought by sea breezes (Ali, 1994); and the monsoon winds that prevail during the south-west and north-east monsoon periods in summer and winter respectively.

The most prominent weather phenomenon is the Shamal wind that blows down the axis of the RSA from the north-west in both summer and winter. The summer Shamal can reach speeds of 153 kilometres/hour, causing dust storms and haze. The winter Shamal usually rises with great abruptness and force between November and March, but seldom exceeds speeds of more than 10 metres/second. The Shamal brings with it some of the strongest winds and highest seas of the season, albeit relatively rarely. It should be noted that the Shamal blows on the NW part of RSA and gathers humidity as it blows down the axis of the RSA.

The Kaus blows from the south-south-east ahead of an approaching cold front. Kaus winds increase in intensity as the front approaches, building up to gale force strength. The Kaus increases in force as it blows towards the north-west, bringing with it more humidity during the summer months.

A strong sea breeze occurs along the entire coastline, especially along the Arabian Peninsula. Driven by the intense difference in temperature between the land and water surfaces, the sea breeze affects the movement of air on land with the result that the winds drive floating pollutants to the beach much faster than they would otherwise be transported. Wind patterns in the middle and outer RSA are strongly influenced by the tropical circulation of the Arabian Sea, with south-west monsoon winds blowing during the summer and north-westerly winds blowing in the winter months.

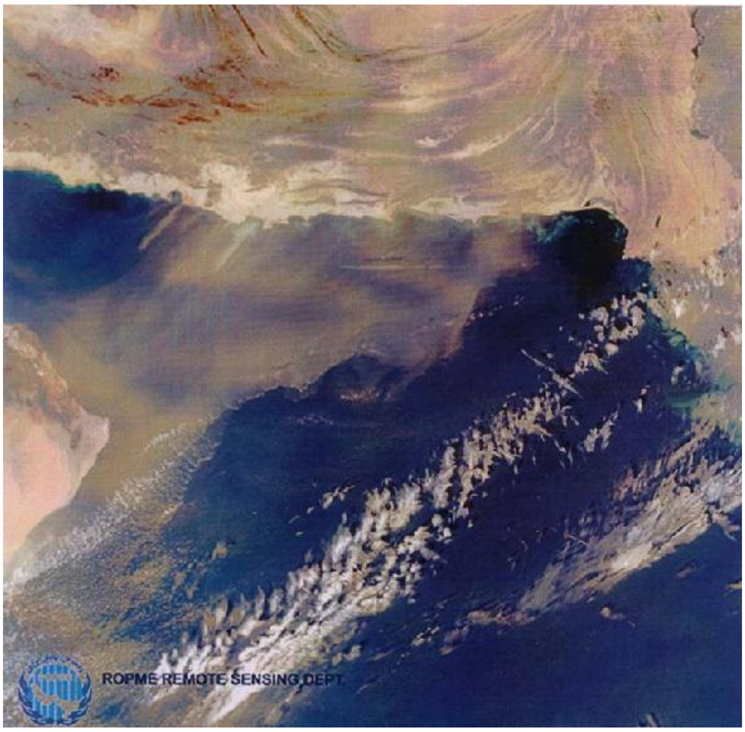
2.1.3 Dust and sand storms

Dust and sand storms figure among the important weather phenomena in Kuwait, southern Iraq and I.R. Iran. This area is particularly susceptible to these storms on account of its low topographic relief, scanty vegetation cover, light-textured topsoil and recurring strong and turbulent winds. Dust storms deposit up to 1002.7t/km^2 of sediment in the inner RSA in the month of July (Khalaf and Al-Ajmi, 1993). These storms have widespread adverse effects on the environment, the economy and the quality of life.

The dust storms through the northern part of the RSA are a major source of marine sediments (Khalaf *et al.*, 1982; Al-Bakri *et al.*, 1984). The dust fallout in the area has an effect on the movement and destiny of oil spills on the sea surface, acting as a sinking mechanism for oil droplets (Foda, 1984). It also acts as a carrier for various types of pollutants, especially pesticides, by adsorbing them as suspended particles in the water column and transporting them to remote areas (Risebrough *et al.*, 1968). Suspended dust can be carried over distances of up to several thousand kilometres (Darwin, 1846; Delany *et al.*, 1967; Prospero *et al.*, 1970) and eventually be partially deposited in the Sea Area.

Between April 1979 and March 1980, the amount of dust fallout recorded in the coastal area of Kuwait ranged from 9.8t/km^2 in November to 1002.7t/km^2 in July (Khalaf *et al.*, 1980). However, during 1998 the concentration of dust fallout varied from 9.4t/km^2 to 145t/km^2 with an overall mean of 40.2 ± 42.3t/km^2 in Kuwait (EPA–Kuwait, 1999).

Satellite remote sensing observations have indicated that most storm-generated particulate matter comes from exposed desert surfaces or dry irrigated lands located in the path of the prevailing wind. Remote sensing observations in March 2003 showed a large dust storm spreading over the northern RSA covering the arid landscape across the deserts of Saudi Arabia. An observation made on 25 November 2003 by MODIS/Aqua shows the prevailing dust storm over the southern coast of I.R. Iran and the middle and outer part of the RSA (Figure 2.1). In this Figure, the large dust cloud observed over the Gulf of Oman during this period resulted in a significant decrease in the contrast of the coastline boundaries.



The dust storm is seen as greyish white or light grey haze present over the sharper light greyish colors of the underlying arid landscape and over the Gulf of Oman and Arabian Sea. The spots of green and bluish green indicate the chlorophyll concentration, presence of algae or phytoplankton patches (visible under dust layer). The very thin line of clouds, whiter and brighter than the dust, is running southeastward over the Gulf of Oman and demarcating the edge of the front.

Figure 2.1 Satellite image of dust storm in the south-eastern part of the RSA, southern coast of I.R. Iran and middle and outer part of the RSA in November 2003 (MODIS/Aqua [500m resolution, colour combination channels 143])

Sources of dust include inland and coastal areas. The dust storm that blew over Kuwait City on 26 March 2003 is shown in Figure 2.2. As a general rule, dust clouds (air-borne suspended particulates) last for a few days, and later spread (dissipate) over the sea surface where they settle. The main fall-out from the dust cloud occurs over the sea, creating a major source of seabed sediment.

Figure 2.2 A high-density yellowish dust storm blew over Kuwait City on 26 March 2003

2.1.4 Water balance

2.1.4.1 *Precipitation*

The amount of precipitation in the Region varies greatly, but increases as one moves from south to north. It varies from 48mm in Doha – Qatar (in the south) to 275mm in Bushehr – I.R. Iran (in the north). The annual precipitation in the RSA fluctuates considerably but the average precipitation recorded over a 17-year period was 78mm/yr, which corresponds to 1.9 x $10^{10}m^3$/yr (Hassan and Hassan, 1989). However, there is a large degree of variability from year to year, even within the same country. More detailed data from I.R. Iran showed that in 1995, the maximum annual precipitation reported was 587.8mm in Bushehr city and the minimum was 94.1mm in Ahwaz city. Average precipitation recorded during 1996 was 168mm (LBA–I.R. Iran, 1999). However, from 1961–1990 the overall average rainfall ranged from 59mm in Saudi Arabia to 227.6mm in I.R. Iran (GEO3, 2002) (Figure 2.3).

2.1.4.2 *Evaporation*

Evaporation from the open water of the RSA has been estimated at 144cm/yr (Privett, 1959). Meshal and Hassan (1986) estimated evaporation from the coastal and the central region of the RSA and found that the monthly mean evaporation from the coastal waters of the Region reaches its maximum value of 29.3cm in June and its minimum of 8.1cm in February, with a total evaporation rate of 202.6cm/yr. Accordingly, evaporation from the whole RSA may be taken as the mean of these two values i.e., 172cm/yr (Said, 1998).

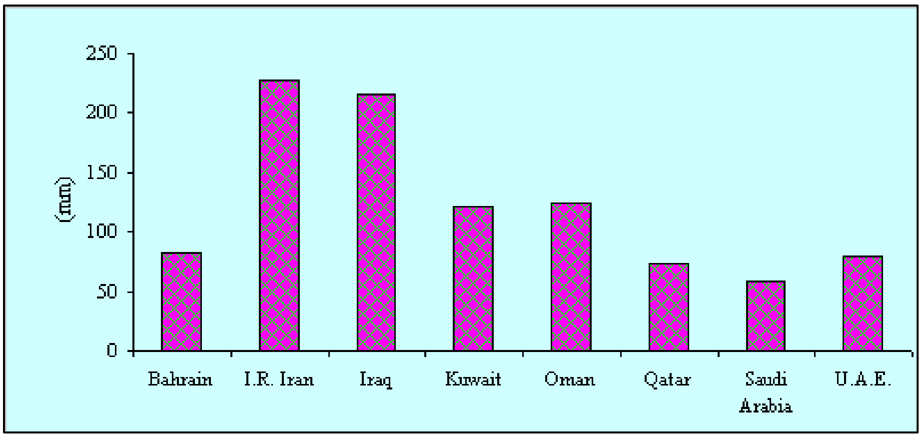


Figure 2.3 Average rainfall in ROPME Member States from 1961 – 1990

2.1.4.3 *Land run-off*

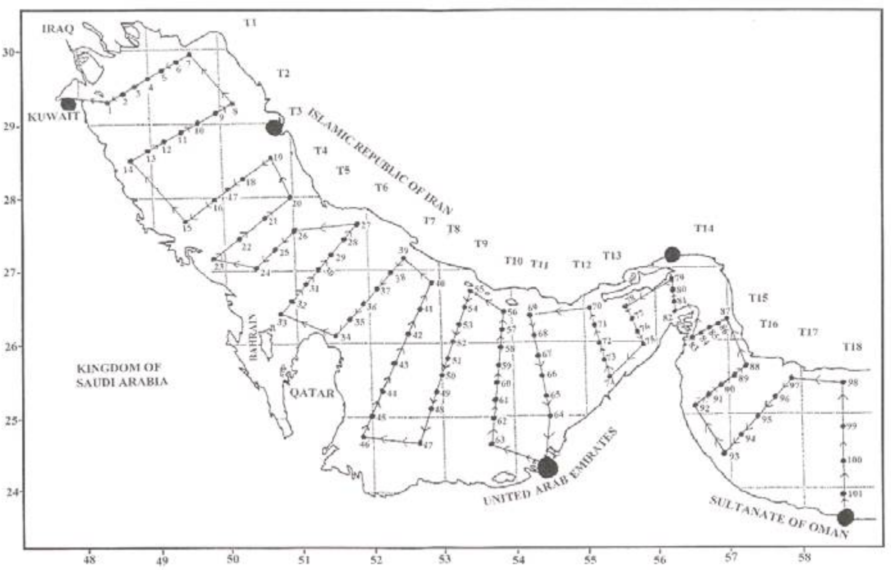
Run-off from rivers into the RSA occurs mainly in the north (Tigris, Euphrates and Karun) and primarily on the Iranian side. The Minab, Kahir, Kajoo and Bahookalat rivers flow into the Gulf of Oman. Shatt Al-Arab forms the nexus of three major rivers; the Tigris (Dijlah) and Euphrates (Al-Furat) rivers together provide an annual average run-off of 708m^3/sec; and the Karun adds a further 748m^3/sec. Thus, the total average outflow of the Shatt Al-Arab is 1456m^3/sec (Reynolds, 1993). Other major rivers are the Hendijan (203m^3/sec), the Hilleh (444m^3/sec), and the Mond (1387m^3/sec) which combine to give an annual average run-off of 110km^3/yr. This is greater than earlier estimates, which put the figure at 5 to 100km^3/yr (Ahmed and Sultan, 1991). Industrial and agricultural developments have a pronounced effect on the outflow from the Shatt Al-Arab, where annual run-off has decreased substantially over the past 20 years (Reynolds, 1993; UNEP, 2001).

2.2 Oceanographic Characteristics

Comprehensive information on the hydrographic structure of the RSA can be found in the results of three basin-wide investigations carried out by different open sea cruises in this area. 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 II from Woods Hole Oceanographic Institution USA, and Reynolds (1993) reported on a 1992 100-day oceanographic cruise by the NOAA Research Vessel Mt. Mitchell, USA. Following the Mt.

Mitchell cruise, three cruises were carried out by a Tokyo University School of Fisheries research vessel, the Umitaka-Maru from 1993–1994.

In recent years, I.R. Iran's training vessel 'Ghods' has been used twice by ROPME (ROPME Oceanographic Cruises) to conduct oceanographic cruises in the inner RSA during the 2000 and 2001 summer seasons. The cruise track and sampling stations of the ROPME Oceanographic Cruises are shown in Figure 2.4, and the results are reported in different sections of this chapter. Several investigations of coastal water circulation patterns have also been carried out by individual Member States.



Note : All stations selected are beyond 12 mile zone for each country

Figure 2.4 Cruise Track and Sampling Stations of ROPME Oceanographic Cruises

2.2.1 Physical oceanographic characteristics

2.2.1.1 *Sea surface temperature*

The surface water temperature in the RSA varies between 12^{o}C in winter and >35^{o}C in summer. The temperature difference between summer and winter is greatest (>20^{o}C) in the north-west and smallest (<11^{o}C) at Hormuz. The temperature of the inward surface flow from the Strait of Hormuz to the inner RSA varies between >28^{o}C in summer and >20^{o}C in winter. The annual seawater temperature variations in the area, where the sea reaches depths of 20m in May and plunges to deeper depths in February, could be explained by the air temperature and the vertical mixing intensity. Strong mixing in February leads to a vertical homogeneity with changes being extended to greater depths (Reynolds, 1993). In May, the thermocline acts as a barrier and limits the variation to the upper 20m of the area (Reynolds, 1993). A recent study conducted during a summer cruise in August 2001 showed that the temperature of the surface waters of the inner RSA ranged from 30.15^{o}C (Strait of Hormuz) to 35.81^{o}C (Iranian coast).

The surface water temperature of the middle RSA varied from 22.08^{o}C to 31.74^{o}C. The lowest temperature (22.08^{o}C) was recorded in the Strait of Hormuz in January, while the highest recorded temperature (31.74^{o}C) was on the Batinah coast in May.

In the outer RSA, the surface temperature varied from 20.07^{o}C to 27.59^{o}C. The lowest temperature (20.07^{o}C) was recorded close to Ras Sharbithat in September, while the highest (27.59^{o}C) was recorded at Raysut on the Dhofar coast in December (Thangaraja, 1995).

2.2.1.2 *Tidal movement*

The tidal range varies in the inner RSA from about 1.4m near Qatar to 3m in the extreme north-west and to 2.8m in the extreme south-east. When onshore winds are strong, the level of coastal waters, especially the southern part may rise by 2.4m above tidal levels and cause extensive flooding on the low sabkhas. Tidal currents are strong (1m.s^{-1}) near the western end of the Strait of Hormuz, but in other areas, except between islands or in estuaries and lagoon entrances, rarely exceed 0.2–0.4m.s^{-1} (Reynolds, 2002). The tidal range is lowest in the central basin of the area, ranging from about 1 to 2 metres in Bahrain.

The tidal regime in the Omani coastal waters (middle and outer RSA) 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 3m (WIMPOL, 1986).

Tides in the RSA are complex and vary from semi-diurnal to diurnal. The tidal range is large with values greater than 1m recorded everywhere (Lehr, 1984). Another important and interesting feature observed at some locations off the coast, for example in Kuwait, is that the semi-diurnal nature of the tides may create a complex air exchange in the region as wind speed, wind direction and coastal morphology interact, affecting both the flow of air and seawater. In the north-west, at Shatt Al-Arab delta, tides are normally in the region of about 2.5metres, and in the south (in the Gulf of Oman), about 2 metres. In Dubai (UAE) and Lengeh (I.R. Iran) ranges of 3 to 4 metres have been observed (Hartman *et al.*, 1971; Linden *et al.*, 1990).

2.2.1.3 *Water circulation*

Water circulation studies carried out 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 the prevailing Shamal winds, water of relatively low salinity from the Arabian Sea enters the inner RSA through the Strait of Hormuz, diluting the hyper-saline water of the inner RSA. As it enters, it evaporates, becomes denser and sinks, after which it leaves the inner RSA waters as a high salinity undercurrent moving through the deeper part of the Strait of Hormuz (Al-Hajri, 1990). This circulation is called 'reverse estuary flow'.

The inflow from the Strait of Hormuz to the inner RSA is stronger (about 20cm/sec) in summer and weaker (about 10cm/sec) in the spring and autumn (Hunter, 1982). The circulation pattern of the inner RSA has also been variously classified as high- and low-salinity water exchange in the Strait of Hormuz; density-dominated circulation in the central and southern inner RSA; frictional balanced, wind-dominated regime in the NW inner RSA; and evaporation-induced bottom flow (Hunter, 1983).

The schematic circulation model for the inner RSA produced by Hunter (1983) indicated that the flow is predominantly density-driven with a surface flow travelling inward from the Strait of Hormuz and adjacent to the Iranian coast. A southward coastal flow is to be found along the entire southern coast of the inner RSA. The flow stagnates east of Qatar, where high evaporation and sinking forms a dense, bottom-flow to the north-east which eventually flows out of the Strait of Hormuz.

Along the Iranian coast of the inner RSA, the flow persists at a speed of 10cm/sec almost as far as the Qatar peninsula. Near the bottom in this region, there is an opposite outflow towards the Strait of Hormuz. On the Emirates side of the inner RSA, the flow is strongly dominated by the wind, which generates an easterly surface flow of the magnitude of 12–15cm/sec. This flow drags the bottom flow with it in the same direction. The pattern of surface velocities around the northern coast of I.R. Iran is anti-clockwise, although it is quite small (<4cm/sec) (Lardner *et al.*, 1993).

The energy which drives water circulation in the middle and outer RSA comes from three processes including tidal forces, wind forces and differences in water density. The tides in the middle RSA (Gulf of Oman) co-oscillate with those of the Arabian Sea, and are semi-diurnal, with a range of 1.7 to 2 metres. 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 wind force in Oman (middle and outer RSA) is related to the seasonal monsoons. The summer monsoon from May to September is dominated by wind from the south and south-west, while north-east winds dominate during the winter months from November to February. Waves arrive as swells, with a long wavelength, low amplitude waveform from distance storms. Local wind creates small waves of 0.2m in height during the months of April and

May, whereas more energetic waves during winter from November to February result in high waves in December with wind speeds of over 15m/s.

2.2.2 Chemical oceanographic characteristics

2.2.2.1 *Nutrients*

Consistent basin-wide measurements of nutrients made over entire the RSA by the Woods Hole Oceanographic Institution in March 1977 (Brewer *et al*., 1978) indicated that the surface nutrient content in the middle and outer RSA is much higher than in the inner RSA. High phosphate surface water (> 1µmol/l) from the outer RSA rapidly loses phosphates through mixing and biological stripping as it moves north to the inner RSA (<0.1µmol/l); while nitrate concentrations (2 to >10µmol/l) were frequently below the detection limit. This may be interpreted as circumstantial evidence that nitrates are a limiting nutrient in the inner RSA during winter time.

The results of the survey carried out by the Umitaka-Maru Cruises (1993–1994) in the inner RSA between the latitudes 28^{o}N and the Strait of Hormuz showed higher concentrations of nitrates in certain parts of the RSA. The overall mean ammonium ion concentrations varied from 0.75µmol/l (December 1994) to 1.91µmol/l (January 1993), nitrates from 1.07µmol/l (December 1994) to 2.10µmol/l (December 1993), phosphates from 0.34µmol/l (December 1993) to 0.51µmol/l (December 1994), and silicates varied from 1.93µmol/l (January 1993) to 4.74µmol/l (December 1993). The maximum values of nitrates, phosphates and silicates were observed in water samples near the Iranian coast (Hashimoto *et al.*, 1995). In shallow estuarine areas, e.g., Kuwait Bay, the levels measured by EPD–Kuwait, ranged from 29.6 to 76.1µg/l (0.48-1.3µmol/l) for nitrates, from 16.4 to 24.1µg/l (0.17-.025µmol/l) for phosphates and from 397 to 590µg/l for silicates (6.6–9.8µmol/l-SiO_2) (EPD–Kuwait, 1994).

In Bahrain, sampling was carried out twice a year (August and December) at four stations. The results showed that the concentrations of nitrites, nitrates, ammonia, phosphates and silicates ranged from 0.02–0.11, 0.38–0.77, 0.04–16.60, 0.04–0.23 and 0.8–64.7µg/l, respectively (MNR–Bahrain, 2000).

Recently in Kuwait, as a part of a marine monitoring programme, nutrient studies were conducted monthly at 13 stations to determine the level of nutrients. The reported mean concentrations were as follows: 7.1µg/l (0.15µmol/l) for nitrites, 19.6µg/l (0.32µmol/l) for nitrates, 4.9µg/l for ammonia (0.27µmol/l), 10.7 µg/l (0.11µmol/l) for phosphates and 349µg/l for silicates (5.8µmol/l-SiO_2 (MNR-Kuwait, 1999). These values are somewhat higher, but still lower than those recorded in the middle and outer RSA.

As mentioned above, in Oman, the levels of nutrients were found to be higher in the surface waters of the Gulf of Oman during monsoon upwelling, with surface water phosphate levels >1.0µmol/l and nitrate levels > 8µmol/l in February and March (Brewer *et al.*, 1978). In the Arabian Sea, along the Dhofar coast during the south-west monsoon upwelling, nutrient levels increased to over 20µmol/l nitrate-nitrogen and about 2µmol/l phosphate-phosphorus during the period July to mid-October (Savidge *et al.*, 1990).

In Qatar, sampling was carried out twice (January and June) in 2001 at 25 stations. The results showed lower concentrations of most of the measured nutrients compared to the previous study. For nitrates, the concentration level was too low so it was undetectable in all samples, whereas silicate levels varied from 2.45–270.99µg/l (0.04-4.5µmol/l) in January and 2.99–342.8µg/l (0.05-5.7µmol/l) in June (MNR–Qatar, 2003). Fluctuations in the nutrient concentrations could be attributed to the sampling locations, the 25 stations are distributed over the long coastline of Qatar.

The same pattern of nutrient concentration was found in UAE coastal waters during October 1993–September 1994 and showed that concentrations of ammonia went from undetectable levels to 15.32 µg/l, nitrites also rose from undetectable levels to 5.18µg/l, nitrates varied between 0.07–14.32µg/l, and silicates varied from 0.4–26.5µg/l. The patterns of distribution indicated an insignificant difference between the surface and bottom layers on account of the shallowness of the area, turbulence of the water column and the effects of sewage wastewater. However, with the exception of nitrates, the highest concentration levels were observed in the winter season. At Sharjah, most of the nutrients decreased in a seaward direction due to the presence of effective sewage pollution sources inside the creek. From this, it was concluded that the discharge of sewage and industrial wastes have affected the quality of seawater inside some semi-enclosed areas, especially Sharjah creek, as indicated by rises in the concentrations of nutrients (Shriadah and Al-Ghais, 1999).

Recently, basin-wide nutrient levels were measured in the inner RSA (see Figure 2.4) during the Oceanographic Cruise that took place during August in the summer of 2001. In general, the surface concentrations of nitrites were very low, ranging from undetectable to a maximum of 15.63µg/l (0.34µmol/l) in the bottom waters of the Strait of Hormuz. However, the nitrite levels on the bottom were higher that in the surface waters at all stations with ranges of 0.03 to 170.97µg/l (0–3.7µmol/l). The maximum recorded was in the offshore waters of UAE. In the case of nitrates, the minimum and maximum levels at the surface waters were very low 0–5.3µg/l (0–0.1µmol/l). The minimum and maximum concentrations of nitrates in bottom waters were 270.97–804.13µg/l (4.4–13µmol/l). The minimum level of surface nitrates was recorded in the open sea area before the waters reached the Strait of Hormuz, while the maximum surface and bottom nitrate levels were recorded at the same location, in the offshore waters of UAE.

The phosphate concentrations in the surface waters of the inner RSA were low and varied from 0.17–2.67µg/l (0–< 0.03µmol/l) while concentrations on the bottom were significantly higher, 247.3–448µg/l (2.6–4.7µmol/l). Phosphate levels were highest at the surface of Iranian waters.

Ammonia levels in the waters of the inner RSA ranged from 0.45µg/l to 38.07µg/l (0.02–2.1µmol/l) in the surface waters, and from 0.57µg/l to 25.37µg/l (0.03–1.4µmol/l) in the bottom waters. The maximum level of ammonia was recorded in the surface waters offshore in the centre of the inner RSA, between I.R. Iran and Saudi Arabia. Silicate levels in the surface water varied from 0.17µg/l (<0.003µmol/l) (close to Strait of Hormuz) to 303.77µg/l (5.05µmol/l) (Kuwait), whereas at the bottom silicate levels varied from 2.87µg/l (0.05µmol/l) (mid north) to 324.43µg/l (5.4µmol/l (Kuwait). The overall results disclosed that Kuwaiti waters had maximum concentrations of silicates both at the surface and at the bottom.

2.2.2.2 *Salinity*

Salinity gradually increases from south to north due to higher evaporation, with lower salinity being found along the Iranian side. In summer, the surface salinity varies from 34‰ (June) on the southern Omani coast of the Arabian Sea to 38.9‰ in the northern part of the Gulf of Oman, and increases up to 42‰ just off Bahrain. Very high water salinity, 70‰, has been reported in the Gulf of Salwah at its southern extremity. In winter, salinity is somewhat higher than in early summer in the upper NW of the RSA, apparently on account of variations in the fresh water influx from Shatt Al-Arab and meteorological effects, particularly evaporation.

Surface water with low salinity, about 37‰, enters the inner part of the RSA through the Strait of Hormuz during the summer season. This same flow, with a salinity of 39‰, has also been observed in the winter (Reynolds, 1993).

A basin-wide measurement of the surface and surface to bottom water salinity profile was carried out in the inner RSA during the Oceanographic Cruise investigation of August 2001. During that period, the surface salinity of the water of the inner RSA ranged from 36.98 to 41.07‰, of which the minimum and maximum salinity levels were recorded at stations in the Strait of Hormuz and Kuwaiti waters respectively. Salinity on the bottom was higher than in the surface waters at all stations and an overall maximum bottom salinity of 41.35‰ was recorded in Kuwaiti waters.

The distribution of salinity in the surface waters of the Gulf of Oman from the Strait of Hormuz in the Musandam peninsula to Ra’s Al-Hadd at the entrance to the Gulf of Oman varies from 36.5 to 38.9‰.

In the Arabian Sea (from Ra's Al-Hadd to the southern most part of the Sultanate) (outer RSA), surface salinity variation is found to range from 35.50 to 37.70‰.

The variation in salinity in the surface to bottom water column of the Gulf of Oman and the Arabian Sea is samll, which indicates a thorough mixing of waters. In most of the sites of the middle and outer RSA, the surface and the bottom readings are either the same or differ by one or two parts per thousand. Various time-series studies conducted in three geographically important areas in the middle and outer RSA in different periods revealed that in the Khasab waters in the Strait of Hormuz, surface salinity remains high, ranging from 37.80 to 40.30‰. A maximum of 40.30‰ was recorded in October. However, a one year study in Muscat waters showed that salinity levels varied between 33.10–39.00‰, the lowest being in January and the highest in November. Monsoon rain reduces the salinity levels considerably in the coastal waters of Dhofar (Thangaraja, 1995).

2.2.2.3 *Dissolved oxygen*

The level of dissolved oxygen (DO) in the surface waters of the inner RSA ranged from 4.05 to 6.8mg/l at the time of summer 2001 Oceanographic Cruise. The distribution of dissolved oxygen in the surface waters in various parts of the middle and outer RSA in Omani waters was recorded on different occasions. In the Gulf of Oman, it ranged from 4.37 mg/l to 11.2mg/l. The minimum level of dissolved oxygen, 4.37mg/l, was found in the inshore waters of Ra's Al-Hadd on 15 September 1990, while the maximum (11.2mg/l) was recorded in the offshore waters of Sur on 27 August 1990. The oxygen level in the bottom waters ranged from 0.04mg/l to 9.49mg/l. The minimum DO (0.04mg/l) was measured at a depth of 108.6m in the offshore waters of Muscat on 29 January 1990 and the maximum level of DO (9.49mg/l) was recorded at a depth of 18m in the inshore waters of the Batinah coast on 23 May 1990.

In the Arabian Sea (outer RSA), the surface oxygen level varied from 2.62 to 9.13mg/l. The minimum oxygen level (2.62mg/l) was recorded close to Sharbithat in the Madrakah Bay on 29 September 1990, and the maximum (9.13mg/l) was recorded in the Masirah Bay, on 20 September 1990. The oxygen level in the bottom layers of water ranged from 0.12 to 6.91mg/l. The lowest level (0.12mg/l) of oxygen was found at a depth of 160m on the North Sharquiyah coast, on 16 September 1990, while the highest oxygen level (6.91mg/l) was measured at a depth of 15m in the inshore waters of Ras Al Madrakah on 10 December 1989.

The time series studies conducted in waters off Muscat at different periods have indicated slight variations over the years. The DO ranged from 3.22 to 8.74mg/l, with the minimum in February and the maximum in March during the period of September 1987 to October 1988. However, it rose to between 4.07 and 9.69mg/l during the period from January to December 1992.

In both the middle and outer RSA, the surface water column had higher levels of dissolved oxygen in normal sea conditions. Oxygen levels dropped with an increase in depth. In most of the sites measured, beyond 75m depth, the DO level was <2mg/l (Thangaraja, 1995).

2.2.2.4 *Hydrogen ion concentration*

The measurement of pH levels during the Oceanographic Cruise in August 2001 revealed a slight variation between surface and bottom pH levels in the inner RSA. At all measuring stations, the pH level at the bottom was a little higher than that in the surface waters. The surface pH ranged from 7.92 to 8.23.

Basin-wide and consistent pH measurements conducted by the Woods Hole Oceanographic Institution in March 1977 (Brewer *et al*., 1978), revealed that the surface pH in the middle and outer RSA (8.130–8.214) is, in general, lower than in the inner RSA (8.210–8.320). The pH drops with depth and might reach 7.454 at about 800–900m depth in the Gulf of Oman. However, the pH of the bottom water in the inner RSA was never lower than 8.160 throughout this survey.

2.3 Geological and Sedimentological Characteristics

2.3.1 Geology

The RSA has evolved as a result of the interaction of the African and Eurasian plates. The Arabian Plate has been gradually moving north-eastward, under the Eurasian Plate, 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 10,000m, has accumulated.

In the north-west the closure of the ancient seaway has been completed, and today the former marine area is covered by the flat alluvial lands of the fertile crescent of Iraq and I.R. Iran. This lowland has been formed by the deposition of sediments from the Tigris-Euphrates-Karun alluvial system in the depression between the stable Arabian Shield and mobile fold belt of I.R. Iran, a composition of major river systems.

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 development of the Oman mountain range on the Arabian side of the depression.

The inner RSA is a flooded-valley and estuary. Evidence of 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 that they originated in shallow waters (e.g., shallow water oolitic sands). Fauna bearing characteristics of species found in shallow waters have been found in sediments at depths well below their original levels of formation. The inner part can be considered geologically young in view of the fact that marine life was only recently re-established during the Holocene transgression (Sheppard, 1993).

The western coast of the RSA is generally low, flat and sandy. Often a sandbar covered by dunes isolates large lagoons that are flooded in winter but dry and covered by salt or gypsum for the rest of the year. Extensive algal and intertidal flats occur south of the Bahrain archipelago. The coast of the United Arab Emirates is characterized by a number of broad, sandy flats and lagoons, and edges with barrier and fringing reefs. At the northern end of the RSA lies the vast deltaic plain of the Euphrates, Tigris and Karun rivers that is made up swamps, sandbars, spits and islands with fluctuating boundaries. The eastern coast is a region of extensive continental sedimentation. It is flat and low as far as Bushehr, then rocky and precipitous. In front of Ras Musandam the coast forms a large recess at the Strait of Hormuz, with two main islands, Qeshm and Hormuz. Along the north shore, cliffs and deltaic plains alternate (Chiffings, 1998).

The open, oceanic coast of Oman includes sandy and rocky stretches with ragged cliffs. The rocky shores are a major feature of the Gulf of Oman. The southern coast is composed of rocky headlands with cliffs alternating with shores of fine sands buffeted by oceanic swells (Chiffings, 1998).

2.3.2 Sedimentological characteristics

The sedimentary nature of the RSA is the result of heavy rainfall during the Pleistocene era 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 dry Al-Batin river from the highlands of the west central part of the Arabian Peninsula. The riverine input is reflected in the composition of the bottom sediments (Figure 2.5).

Fine (mud) sediments predominate in the north-western part of the RSA and reflect the influence of the river inputs in the area. Much of the RSA floor is biogenic sediment, produced by micro-organisms, 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 UAE 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 that blow across the axis of the RSA. Khalaf *et al.* (1986) estimated that as much as 100t/km^2 of sand are deposited annually in the inner RSA.

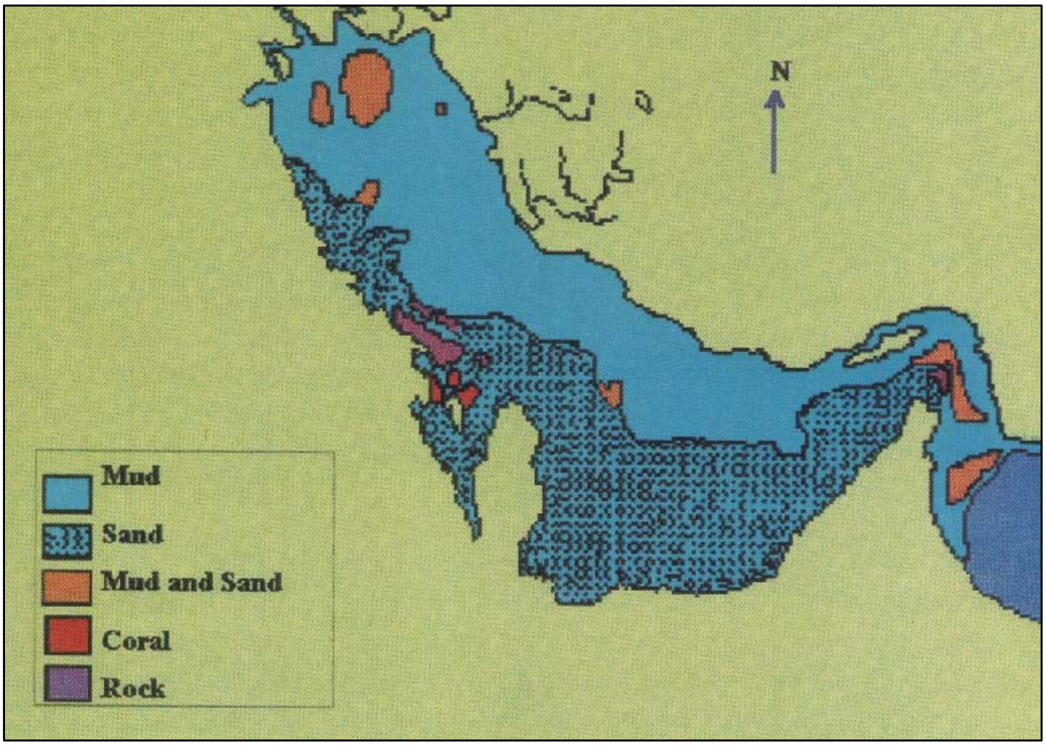


Figure 2.5 Sediment types in the RSA

2.4 Microbiological and Biological Characteristics

2.4.1 Microbiological characteristics

Microbiological measurements are one indicator of sewage pollution in the marine environment. Among the Member States, microbiological data are only available from Kuwait and UAE, and are not sufficient to draw an accurate picture of the status of the marine environment in the RSA. The results measured in Kuwait at 12 permanent locations indicate that the median concentration varies from 214–500 colonies/100ml for total coliform, from 1,247 colonies/100ml for faecal coliform and from 63,180 colonies/100ml for faecal streptococci in the coastal waters (MNR–Kuwait, 1999).

Regular monitoring of the recreational bathing areas at eight locations around Abu Dhabi during the period January to November 2002 revealed that the levels of total coliforms ranged from 4–1,100cfu/100ml (permitted level 2,000cfu/100ml) and *Streptococcus* from ND–400cfu/100ml (permitted level 400cfu/100ml). The measurements undertaken on *E. coli* and total coliforms at ten locations along the Dubai Creek during 1999 and 2000 indicated that they were within the permitted levels as shown in Figure 2.6 (MNR–UAE, 2003).

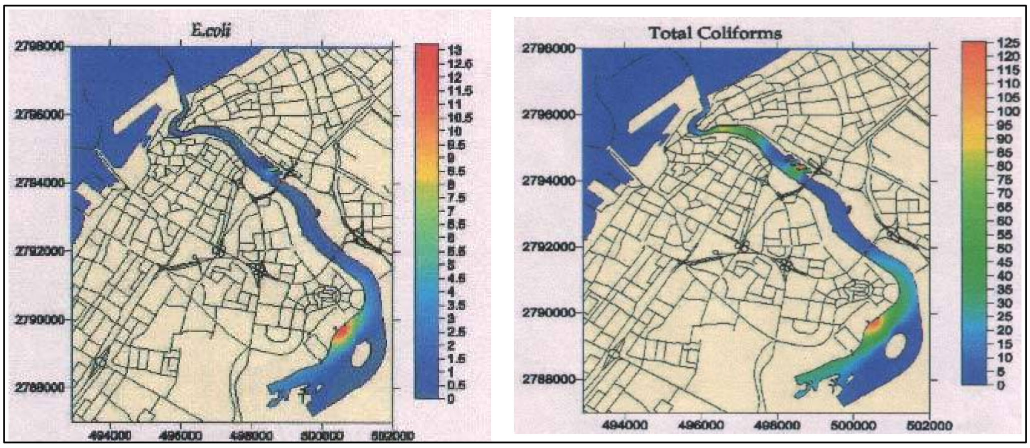


Figure 2.6 Distribution of *E. coli* (1999) and Total Coliforms (2000) along Dubai Creek (cfu/100ml)

2.4.2 Biological characteristics

2.4.2.1 *Primary productivity*

The studies conducted in the RSA to estimate phytoplankton primary productivity from total counts of phytoplankton cells and chlorophyll analyses have been confined to a limited area. Measurements of chlorophyll-*a* ranging from 0.2 to 0.86mg/m^3 have been reported in the ambient marine environment of the inner RSA (Sheppard, 1993) which is not particularly high, whereas values around 0.5mg/m^3 and greater have been reported from the Arabian Sea waters (outer RSA). Measurements recorded during the R/V Umitaka-Maru cruises (January 1993, December 1993 and December 1994) ranged from 0.44–2.84mg/m^3 in a homogenous vertical distribution (Hashimoto, *et al.*, 1995). The mean daily primary productivity in the area studied was estimated to be 0.51gC/m^2/day (ranging from 0.12–1.27gC/m^2/day) (Hirawake *et al.*, 1998). They showed that the highest primary productivity value was observed in the waters off Henorabi Island (eastern RSA Coast, off I.R. Iran). They also demonstrated that primary production was higher in the waters off the coast of I.R. Iran near the entrance to the inner RSA, while the waters from the Qatari Peninsula to the United Arab Emirates were less productive. Based on the data available, the distribution of productivity in the inner RSA is shown in Figure 2.7.

Chlorophyll-*a* concentrations in Bahrain varied from 4–6mg/m^3 whereas in Kuwaiti territorial waters it ranged from 0.56 to 10.76mg/m^3 with a mean concentration of 2.23mg/m^3 (MNR–Kuwait, 1999). Al-Yamani *et al.* (1997b) reported average primary production rates of 152.89mg Cl^{-1} d^{-1} with a minimum of 11.40mg Cl^{-1} d^{-1} and a maximum of 610mg Cl^{-1} d^{-1} in Kuwaiti waters. During

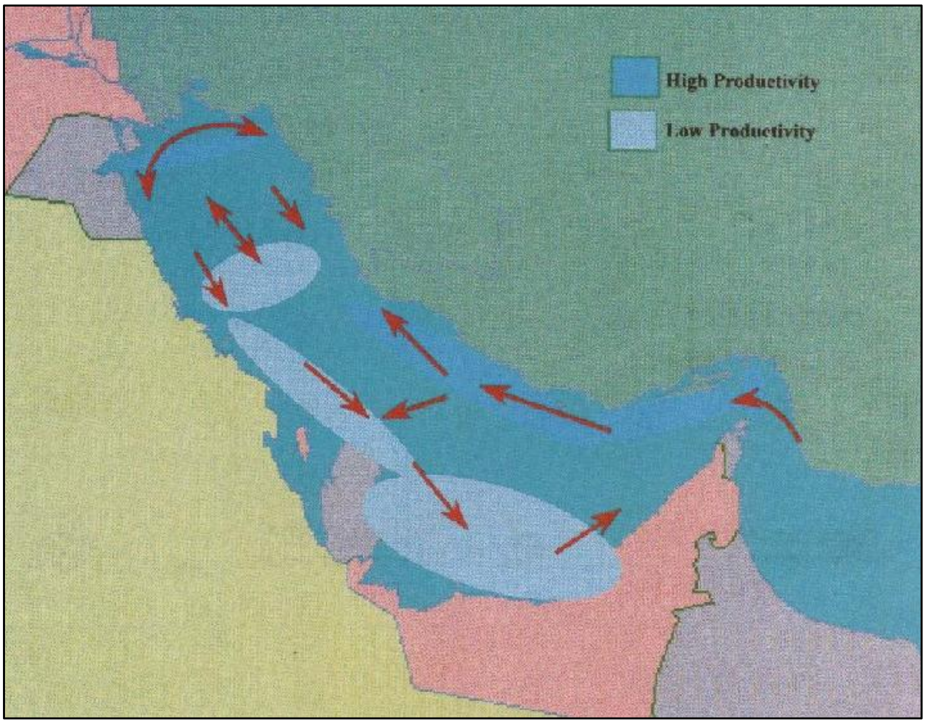


Figure 2.7 Distribution of productivity in the inner RSA

the red tide phenomenon in Kuwait, daily production of phytoplankton ranged from between 6,094 and 6,855mg Cl^{-1} d^{-1} (Rao and Al-Yamani, 1999). Phytoplankton production in terms of biomass is estimated to be >4mg m^{-3}, but reaches 15–18 >4mg m^{-3}, in the north-west of the RSA (Jamal and Pavlov, 1979; Al-Yamani *et al.*, 1997a, b). Phytoplankton production reached 60–90% of total biological biomass in areas where plankton biomass is >500mg m^{-3}. In the inner RSA, three high plankton biomass areas were identified, i.e., off the Kuwaiti coast; off the Qatar peninsula; and in the Strait of Hormuz on the south-eastern side and the Kuwait Bay (Jamal and Pavlov, 1979).

The concentration of chlorophyll-*a* pigments at the surface water was measured at 76 stations in the inner RSA during the summer 2001 Oceanographic Cruise (see Figure 2.4). The chlorophyll-*a* concentration in the surface water ranged from 0.11 to 1.46µg/l with a mean of 0.38µg/l. The minimum level (0.11µg/l) of chlorophyll-*a* concentration was recorded at Station 67 in offshore waters between I.R. Iran and UAE, whereas the maximum (1.46µg/l) was recorded at Station 1 in Kuwaiti inshore waters (Figure 2.8).

In the Gulf of Oman, the maximum sub-surface chlorophyll was found at a depth of 20–40m during two seasons (SW monsoon in September and inter-monsoon period in November/December). During the inter-monsoon season, total chlorophyll-*a* concentration was generally half that measured in September. The highest level of chlorophyll (1.170mg/m^3) was found in the shelf waters (Barlow *et al.*, 1999).

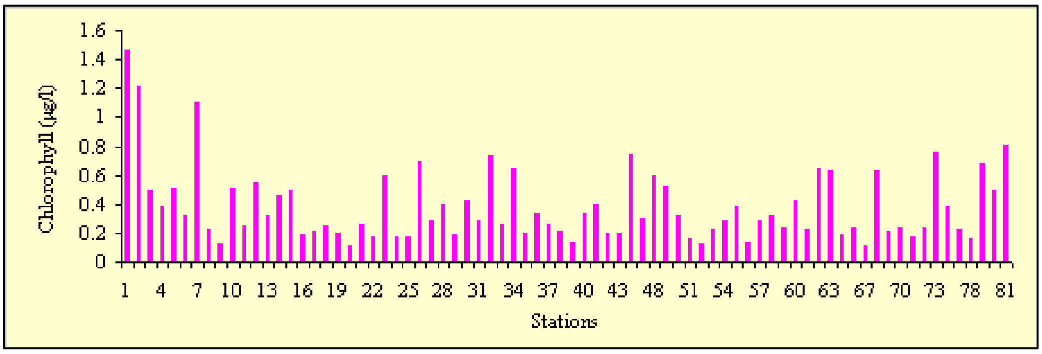


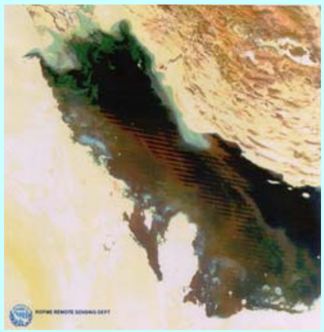
Figure 2.8 Concentration of Chlorophyll-*a* pigments in the surface waters of the inner RSA measured during the Oceanographic Cruise – Summer 2001

Chlorophyll concentrations were estimated in the RSA utilizing satellite remote sensing techniques. Observations during September 1999 over two periods (7–13 September 1999 and 14–21 September 1999) indicated the presence of high concentrations of chlorophyll in the southern part of RSA (west coast of the Gulf of Oman) during the second period, ranging from 7.5–10mg/m^3, which could be attributed to upwelling in this area. The analysis also showed relatively higher concentrations in the shallow and coastal areas (4–5mg/m^3) with concentrations decreasing (0.2–0.3mg/m^3) as the depth increased (open sea area).

Recent satellite remote sensing observations made of the bio-physical properties of the inner and outer RSA show the variations in phytoplankton productivity over space and time. Patches of phytoplankton blooms were recorded in the coastal waters of the inner RSA as well as in the coastal and offshore waters of the outer RSA during the month of October 2003. A remote sensing image taken on 6 October 2003 shows the occurrence of phytoplankton blooms in greenish patches in the shallow coastal waters around the northern end of the RSA near Shatt Al-Arab delta (I.R. Iran, Iraq and Kuwait). Similar patches are also seen near the outlet of the Mond River and the coastal waters of Bahrain, Qatar, Saudi Arabia, UAE and the Strait of Hormuz (Figure 2.9).

In the meantime, in the outer part of the RSA in Omani waters, patches of phytoplankton blooms can be seen in the areas round the eddies. The observed phenomenon covers hundreds of kilometres. The satellite images suggest that a near-shore jet develops and quickly moves offshore, developing meanders that extend hundreds of kilometres from the coast. Eddies are also found in association with the surface jets. The eddies and meandering surface jets create the plankton filaments which are seen as greenish in the images. Multiple filaments are found in some cases, which suggests that the flow field is more complex (Figure 2.10). Bio-physical observations made using satellite remote

(A) Sites of phytoplankton blooms (06 October 2003, MODIS)

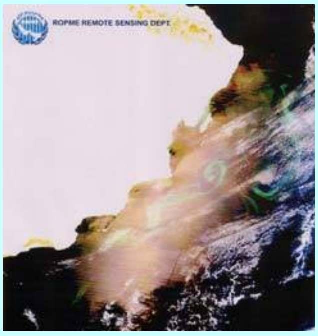


(B) Enhancement of phytoplankton bloom sites (06 October 2003, MODIS)

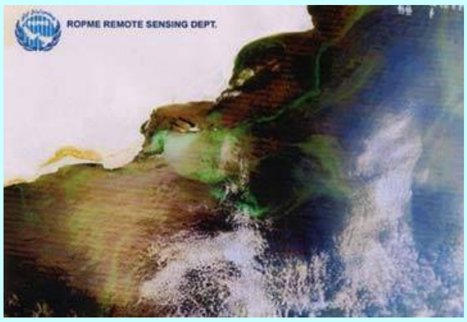
Figure 2.9 Satellite images of the inner RSA showing phytoplankton bloom patches in October 2003 (L2, 500m resolution, colour combination channels 143)

(A) Areas of eddies and patches of phytoplankton blooms (05 October 2003, MODIS / Terra1)

(B) Complex flow fields with multiple eddies, meanders and their filaments with rich phytoplankton blooms (06 October 2003, MODIS)



(C) Convoluted patterns of phytoplankton blooms (12 October 2003, MODIS)



(D) Movement of phytoplankton blooms in the outer RSA (19 October 2003, MODIS)

Figure 2.10 Satellite images of phytoplankton blooms in the outer RSA in October 2003 (L2, 500m resolution, colour combination channels 143) sensing in the outer part of the RSA indicated that on 5 October 2003, the eddies moved offshore from the coast where the dense patches of phytoplankton blooms can be observed as greenish patches between the entrance of the Gulf of Oman (Ra's Al-Hadd) and Ra's Sharbithat Bay. Rich blooms occur along the Masirah channel and Ra's Al-Madrakah Bay (Figure 2.10A). The flow field is more complex with multiple eddies, meanders and their filaments with rich plankton blooms being observed on 6 October 2003 (Figure 2.10B). Similar bio-physical activities were also noticed on 12 October 2003 (Figure 2.10C). Further developments of the rich phytoplankton bloom field can be seen moving towards the south of Oman covering the whole outer part of RSA on 19 October 2003 (Figure 2.10D). It seems that the dynamic water circulation feature of a large eddy which occupies the entrance to the Gulf of Oman is one of the major suppliers of nutrients which induces the enormous production of phytoplankton in late summer and early autumn in the RSA.

2.4.2.2 *Phytoplankton species occurrence and abundance*

Phytoplankton species diversity and abundance were recorded twice during the summer 2000 Oceanographic Cruise (17 August to 4 September, 2000) and the summer 2001 Oceanographic Cruise (August 2001). During the summer 2000 cruise, a total of 17 taxa of phytoplankton belonging to four dinoflagellates, eleven diatom and two blue green algae were recorded from 46 phytoplankton samples. The dinoflagellates, *Ceratium* and *Pyrodinium,* were the most frequently occurring taxa and were recorded in 91% and 98% of all samples respectively. Other important phytoplankton belonging to the diatom taxa *Synedra* and *Coscinodiscus* were identified. The majority of samples (71%) were dominated by dinoflagellate, notably by *Pyrodinium* and *Ceratium*, and the remaining samples were dominated by the common diatoms, *Synedra*, *Pleurosigma* and *Coscinodiscus*. The species of *Pyrodinium* and *Ceratium* are considered toxic or nuisance algae. Other species recorded in the samples included *Prorocentrum*, *Dinophysis*, *Thalassiothrix*, *Biddulphia*, *Chaetoceros*, *Navicula*, *Nitzschia*, *Rhizosolenia*, *Corethron*, *Detonula*, *Phormidium*, and *Lyngbya*. However, during the summer 2001 Oceanographic Cruise, a total of 147 taxonomic entities of phytoplankton species were recorded. These are illustrated in Table 2.1.

The potentially toxic or nuisance species found among the list of 147 are *Pyrodinium bahamense, Dinophysis caudata*, *D. tripos*, *D. miles*, *Prorocentrum triestinum*, *P. minimum* (Figure 2.11), *Phalaeroma pulchella, P. rotundata, Pseudonitzschia* spp. and *Anabaena* spp.

Two sets of phytoplankton samples were collected during the summer 2001 Oceanographic Cruise using a Rosette sampler and Bongo net. These sets of samples were analysed separately for comparative analyses of species abundance and diversity.

Table 2.1 Phytoplankton species found in samples collected during the Oceanographic Cruise – Summer 2001 from the inner RSA

DIATOMS	*Rhizosolenia hebetata* var. *semispina*	small *Gymnodinium* sp.
Asteromphalus cf. *hookeri*	*Rhizosolenia imbricata*	medium *Gymnodinium* sp.
Azpeitia spp.	*R. imbricata* (1/2 valve)	*Gymnodinium* cf. *sanguineum*
Bacillaria paxillifera	*Rhizosolenia setigera*	*Diplopsalis* sp.
Bacteriastrum spp.	*Rhizosolenia styliformis*	*Gonyaulax* spp.
Bacteriastrum furcatum	*Thalassionema nitzschioides*	*Gonyaulax digitalis*
Bellerochea sp.	*Thalassionema* sp.	*Katodinium glaucum*
Cerataulina pelagica	*Thalassiothrix* sp.	*Lingulodinium polyedra*
Chaetoceros cf. *affinis*	*Triceratium* cf. *favus*	*Mesoporos perforatus*
Chaetoceros compressus	small centric *Cyclotella* ?	*Ornithocercus steinii*
Chaetoceros decipiens	small *Thalassiosira* spp.	*Oxytoxum* cf. *laticeps*
Chaetoceros diversus	short *Pseudonitzschia* spp.	*Oxytoxum* spp.
Chaetoceros cf. *eibenii*	short thin *Pseudonitzschia*	*Peridiniopsis asymmetrica*
Chaetoceros laciniosus	(*delicatissima* ?)	*Phalacroma pulchella*
Chaetoceros messanensis	long *Pseudonitzschia* spp.	*Phalacroma rotundata*
Chaetoceros peruvianus	*Cylindrotheca closterium*	*Pronoctiluca* cf. *spinifera*
Chaetoceros spp.	small medium centric *Thalassiosira*	*Pronoctiluca* spp.
Coscinodiscus asteromphalus	unid. diatom a (possibly *C. affine*)	*Prorocentrum gracile*
Coscinodiscus concinnus	unid. diatom b (*Eucampia/Ceraulina*	*Prorocentrum micans*
Coscinodiscus granii	spp.?)	*Prorocentrum triestinum* ?
Coscinodiscus cf. *jonesianus*		*Prorocentrum minimum* ?
Coscinodiscus oculis-iridis	**CYANOBACTERIA**	small *Prorocentrum* spp.
Coscinodiscus radiatus	*Anabaena* spp.	*Podolampas bipes*
Coscinodiscus spp.	*Trichodesmium* spp.	*Protoperidinium bipes*
Dactyliosolen cf. *fragilissimus*	**Monad flagellates**	*Protoperidinium conicum*
Detonula pumila		*Protoperidinium depressum*
Fragilariopsis spp.	**DINOFLAGELLATES**	*Protoperidinium divergens*
Guinardia delicatula	*Alexandrium* spp.	*Protoperidinium globulus*
Guinardia striata	*Amphidinium* spp.	*Protoperidinium granii*
Hemiaulus hauckii	*Ceratium furca*	*Protoperidinium oceanicum*
Hemiaulus cf. *sinensis*	*Ceratium fusus*	*Protoperidinium steinii*
Lauderia annulata	*Ceratium horridum*	*Protoperidinium* cf. *subpyriforme*
Leptocylindris danicus	*Ceratium lineatum*	*Protoperidinium* spp.
Naviculoids sp.	*Ceratium longipes*	*Pyrocystis* cf. *robusta*
Odontella cf. *mobiliensis*	*Ceratium macroceros*	*Pyrodinium bahamense*
Odontella mobiliensis	*Ceratium tripos*	*Pyrophacus steinii*
Paralia sulcata	*Ceratium vultur*	*Scrippsiella trochoidea*
Planktonella sol	*Ceratium* spp.	*Scrippsiella precaria*
Pleurosigma sp.	*Ceratocorys horrida*	small *Peridinales* sp.
Proboscia sp.	*Cochlodinium* spp.	medium *Peridinales* sp.
Pseudosolenia calcar-avis	*Dinophysis caudata*	large *Peridinales* sp.
P. calcar-avis (1/2 valve)	*Dinophysis tripos*	Dinoflagellate cysts(unid.)
Rhizosolenia spp.	*Dinophysis miles*	*Zygabkodinium lenticulatum*
Rhizosolenia bergonii		

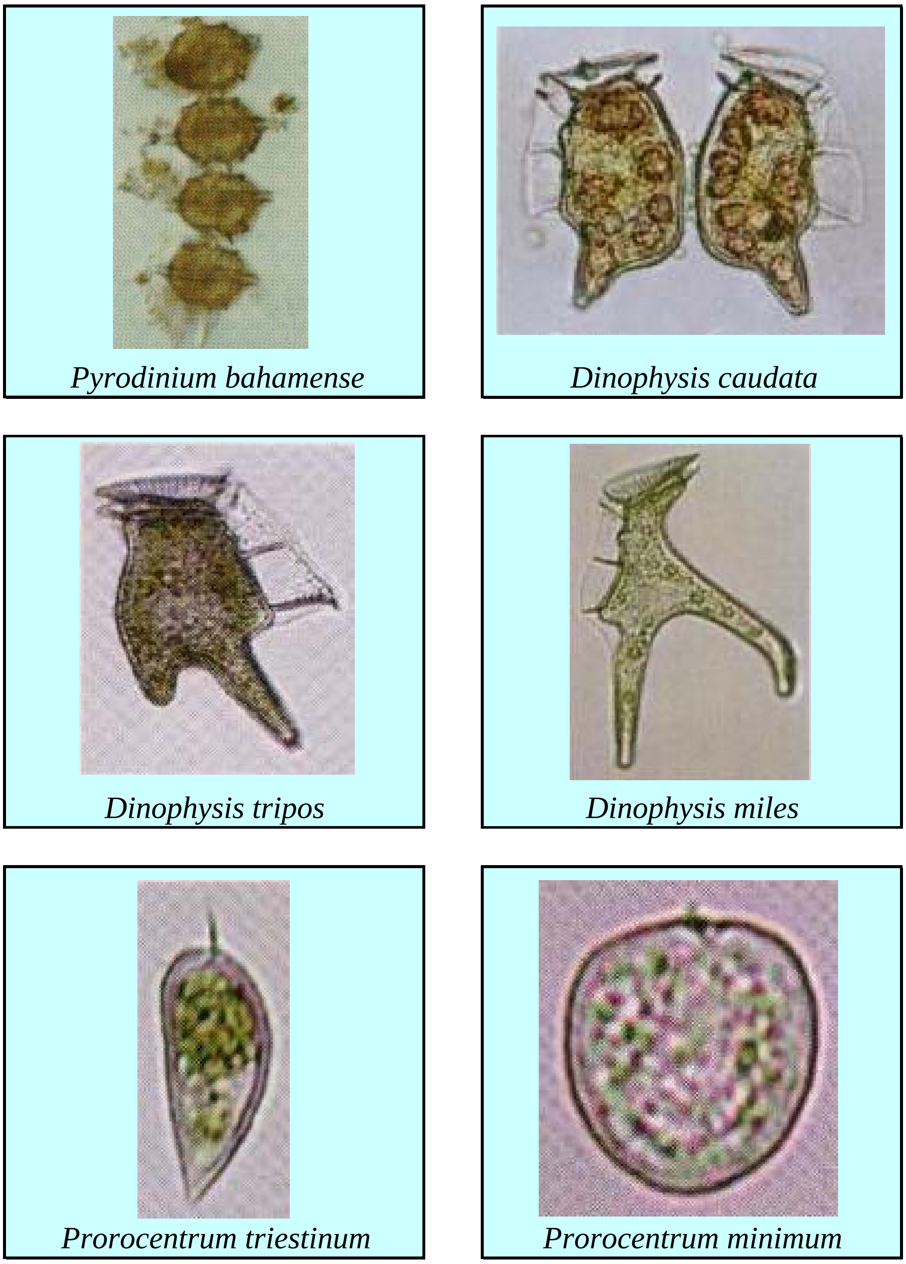


Figure 2.11 Some of the potentially toxic species found in the samples of the Oceanographic Cruise – Summer 2001

The distribution of phytoplankton taxonomic classes revealed that concentrations of total phytoplankton counts vary between the two sets of samples analysed. It can be seen from Figures 2.12 and 2.13 that concentrations of phytoplankton are an order of magnitude higher in the samples collected with the rosette sampler and preserved in lugol's iodine than those collected with the 'Bongo' nets and preserved in formalin. However, in both sets of samples, the highest concentrations were those recorded by the northern stations (see Figure 2.4) located adjacent to the Iraqi coastline.

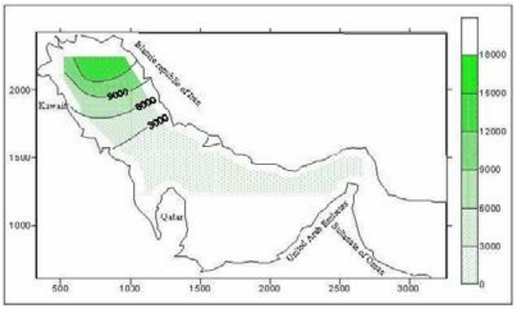


Figure 2.12 Concentrations of phytoplankton (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Net-tows and formalin fixed)

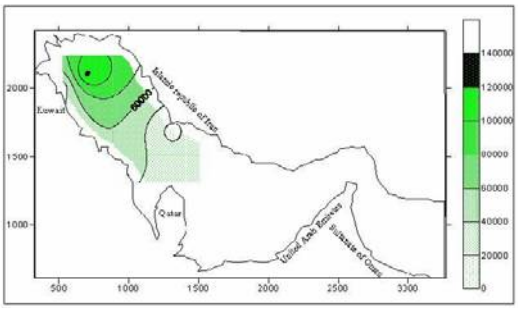


Figure 2.13 Concentrations of phytoplankton (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Rosette sampling and lugols fixed)

Concentrations of diatoms resemble those of the total phytoplankton shown in Figures 2.14 and 2.15. It can be seen from these figures that there is again a disparity between the two sets of samples with lugol's preserved/rosette collected material showing higher concentrations of organisms. The highest concentrations of diatoms are found in the northern-most sites analysed. This disparity between the two methods of collection and preservation is also true of the remaining two classes of phytoplankton, the dinoflagellates and cyanobacteria with higher concentrations recorded from the rosette collected/lugol's fixed material.

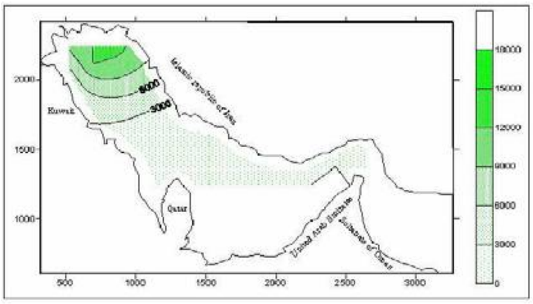


Figure 2.14 Concentrations of Diatoms (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Net-tows and formalin fixed)

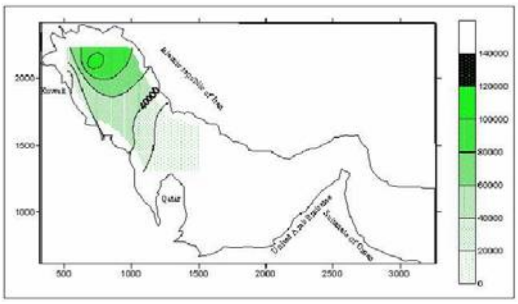


Figure 2.15 Concentrations of Diatoms (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Rosette sampling and lugols fixed)

The dinoflagellates generally follow the same trend as the total phytoplankton and diatom results with the highest concentrations being found in the north of the Region (Figures 2.16 and 2.17). Cyanobacterial concentrations conversely, appear to increase towards the south-east of the Region (Figure 2.18) although samples collected using the Bongo Nets showed highest concentrations to the south-east and in coastal waters to the north of the Region (Figure 2.19).

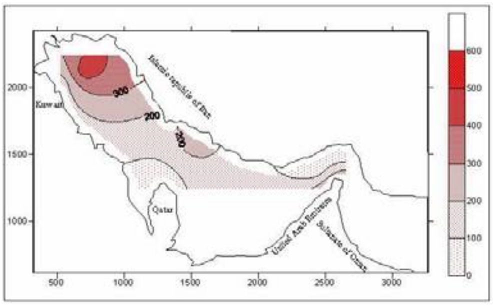


Figure 2.16 Concentrations of Dinoflagellates (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Net-tows and formalin fixed)

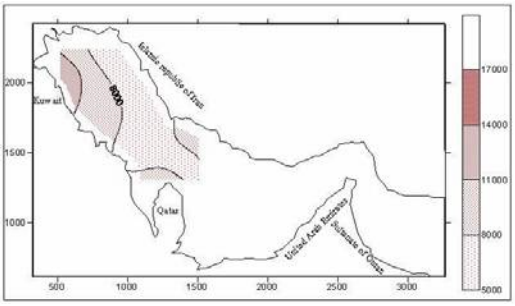


Figure 2.17 Concentrations of Dinoflagellates (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Rosette sampling and lugols fixed)

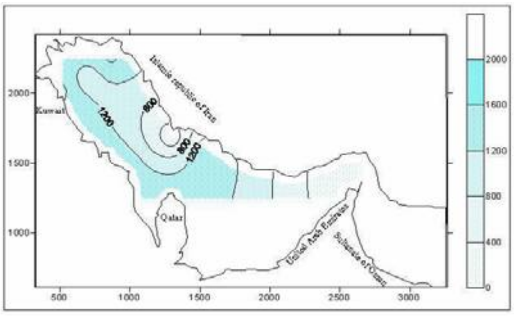


Figure 2.18 Concentrations of Cyanobacteria (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Net-tows and formalin fixed)

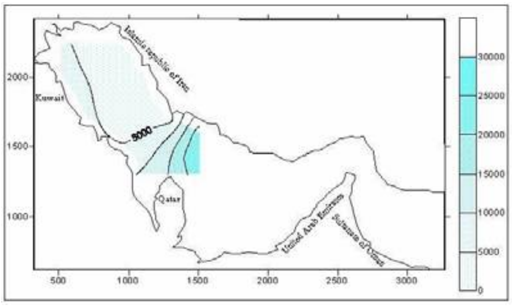


Figure 2.19 Concentrations of Cyanobacteria (cells/l) during the Oceanographic Cruise – Summer 2001 (Method: Rosette sampling and lugols fixed)

2.4.2.3 *Zooplankton*

Major zooplankton groups from the inner RSA were identified and enumerated during the Umitaka-Maru cruises. Mean abundance of zooplankton was 2,064.5 ± 3,282/m^3. Copepods were the most dominant group with a mean of 10,680 ± 1,383/m^3. Total zooplankton composition abundance ranged from 41.3% to 62.7%. Calanoids and Cyclopoids were equally abundant at all sampling stations, whereas Ostracods were more abundant along the eastern coast of RSA (Al-Yamani *et al.*, 1998).

The zooplankton biomass production estimated in terms of dry weight varied between 4.8 and 288.0mg/m^3 in the inner part of Kuwait Bay and the southern area of Kuwaiti territorial water (Ras Az-Zor) respectively, and the overall mean was 186.7mg/m^3 (MNR–Kuwait, 1999).

The plankton biomass in the northern, eastern and south-eastern parts of Qatari waters was estimated at 100–500mg/m^3, 200–500mg/m^3 and 150–200mg/m^3 respectively. These quantities indicate the high productivity of the water around Qatar (UN, 1997). The copepod population numerically dominated the zooplankton community along the coastal waters of Qatar, accounting for 76% with an average of 1,897Ind/m^3 during October, December 1994 and April 1995 (Nehad and Ghobashy, 1999).

Recently, analyses of zooplankton occurrence and abundance were made from the samples from the inner RSA collected during the oceanographic cruises conducted in summer 2000 and summer 2001. During the summer 2000 cruise, the samples contained zooplankton with 65 genera. The kinds of zooplankton recorded from the samples are: Foraminifera, Radiolaria, Hydrozoa spp., Medusae, Siphonophores, Ctenophores, Chaetognaths, Polychaete larvae, Cirriped nauplii, Ostracods sp., *Penilia* sp., Calanoid spp., Copepod nauplii, *Undinula* sp., *Canthocalanus* sp., *Eucalanus* sp., *Clausocalanus* sp., *Paracalanus* sp., *Acrocalanus* spp., *Euchaeta* sp., *Centropages* sp., *Temora* sp., *Candacia* sp., *Calanopia* sp., *Labidocera* sp., *Pontellopsis* spp., Pontellidae sp., *Acartia* sp., Harpacticoid sp., *Microsetella* sp., *Macrosetella* sp., *Clytemnestra* sp., *Euterpina* sp., *Oithona* sp., *Oncaea* sp., *Corycaeus* sp., *Copilia* sp., *Sapphirina* sp., Mysids, Amphipods, Hyperiidae spp., Isopoda sp., Euphausid sp., Brachyuran zoea, Caridean larvae, Decapoda sp. (Megalopa larva), Decapoda spp. (Zoea larva), Penaeid larvae, Jaxea spp. larvae, *Lucifer* adult, *Lucifer* (Zoea larva), Gastropoda spp. larvae, Heteropods sp., *Creseis* sp., *Limacina* sp., Bivalve (Veliger larva), Cyphanautes larvae, Asterina spp. larvae, Echinoderm larvae, Doliolids, Larvaceans, Salps, Urochordata spp., fish eggs and fish larvae. Among them, the dominant groups of zooplankton were small crustacean copepods, particularly cyclopoid and calanoid copepods and also chaetognaths.

In contrast, the zooplankton found in the samples gathered during the summer 2001 cruise belonged to 71 taxanomic entities and were as follows: *Tintinnopsis* sp., *Codonellopsis* sp., Tintinnids sp., *Globigerina* sp., *Acanthometron pellucidum,* Anthomedusa, Leptomedusa, Diphyes, Siphonophora sp., Siphonophora (Planula & Cormidium), Nemertea, Nematoda , Trochophore larva, Spionid larva, Chaetopterus larva, Nereid sp., Polychaete sp., *Sagitta setosa, Sagitta maxima, Sagitta* sp., Barnacle (Nauplii & Cypris), *Conchoecia* sp., Ostracoda sp., *Evadne* sp., Crustacea larvae (Nauplius & Metanauplius), *Calanus finmarchicus,* Calanoid sp., *Rhincalanus nasutus, Pseudocalanus elongatus, Paracalanus parvus, Acartia* sp., *Oithona spinorostris, Oithona* sp., Cyclopoid sp., *Microsetella norvegica, Tigriopus* sp., Harpacticoid sp., *Squilla* sp. (Alima larva), *Neomysis integer,* Mysidacea unid. sp., *Thysanoessa* sp., Euphausiacea (Zoea larva), Caridea shrimp (Zoea larva), Penaeidea shrimp (Zoea larva), Paguridea crab (Zoea larva), Brachyuran crab (Zoea larva), Chiton sp. (larva), *Mangelia nebula* (Veliger larva), *Nassarius* sp. (Veliger larva), Gastropoda sp. (Veliger larva), *Cerithiopsis* sp. (shells), Nudibranchia larva, Bivalvia (shells unid. sp.), *Asterias rubens*, *Amphiura filiformis*, *Echinocardium* sp., *Ophothrix fragilis*, *Phoronis* sp., Pentacula larva, Echinopluteus larva, *Oikopleura* sp., *Fritillaria* sp., Ascidian larva, Salps, Doliolids, fish Eggs – Clupeiformes, fish eggs unid. sp., Clupeidae larvae, Engraulidae larvae, Sparidae larvae and fish larvae unid. sp. (DOE–I.R. Iran, 2003).

The zooplankton biomass estimated in the Gulf of Oman from vertical hauls ranged from 3,602 to 386,067mg/100m^3 (wet wt.) with an average of 71,006mg/100m^3, whereas the surface water zooplankton biomass ranged from 2,082 to 690,800mg/100m^3 with an average of 95,066mg/100m^3. The overall average biomass from the Gulf of Oman was found to be 84,681mg/100m^3 (wet wt.).

In the outer RSA (Arabian Sea off Oman), the biomass estimated from vertical tows ranged from 6,614 to 604,129mg/100m^3 (wet wt.) with an average of 94,248mg/100m^3, whereas the surface zooplankton biomass ranged from 1,567 to 135,122mg/100m^3, with an average of 39,197mg/100m^3. The overall average biomass in the Arabian Sea was found to be 62,645mg/100m^3. The zooplankton biomass of the Arabian Sea was approximately 1.35 times less than that of the Gulf of Oman.

Seasonal variation of zooplankton biomass was observed in the middle and the outer RSA. The Gulf of Oman has two prominent seasons – the summer and the winter. Summer lasts from May to September and winter from November to March. The various physico-chemical changes that occur in the Gulf of Oman waters due to the monsoonal circulation in winter stimulate the higher zooplankton production. The estimated average zooplankton biomass in winter was 113,783mg/100m^3, whereas in summer it was 50,061mg/100m^3. This showed that the zooplankton biomass in winter was approximately 2.27 times higher than that of summer. Michel *et al.* (1986) recorded 3.0 to 3.5 times greater zooplankton biomass at the Strait of Hormuz in Musandam waters than in other Kuwaiti and adjacent Saudi Arabian waters in the period from February to March 1980.

In the middle RSA, especially along the inshore waters near Muscat, considerably more zooplankton were found in the four months from November to February with a peak in November (42,838/100m^3). From March to June, the zooplankton population declined sharply with lowest levels of 1,435/100m^3 recorded in May. July to October was considered to be the recovery period with two minor peaks in July and September and two sharp falls between the minor peaks, in August and October (Thangaraja, 1995).

Among the total zooplankton, copepods were consistently the most abundant form with an average of 48.93%. The cladocera was in second position, with an average of 21.14% followed by chaetognatha (8.27%), lower chordata (7.77%), cirripedia (4.37%) and decapoda (3.87%). At some stations, other zooplankton groups such as the ostracods, molluscs and coelenterates occurred in considerable numbers on a few occasions, but on average, these species formed a very small percentage. Annelids, Amphipods, Cumaceans and Echinoderms constituted a very small share of the total zooplankton found in the waters off Muscat (Thangaraja, 1995).

Common species contributing to the secondary production of the Gulf of Oman were: radiolarians; medusae such as anthomedusae, leptomedusae, limnomedusae, trachymedusae, nacromedusae and siphonophora; polycheate larvae; *Sagitta* spp.; copepods such as calanoida, harpacticoida and cyclopoida; cladocera such as *Penelia avirostris* and *Evadana* sp.; Nauplius and cypris larval stages of *Balanus* sp.; *Lucifer* spp.; zoea and magalopa larval stages of crabs; mysis and postlarval stages of shrimps. Other decapods such as mysids, euphousids and amphipods; veliger larvae of gastropod and bivalves; planktonic molluscs, *Creseis virgula* and *Clio acicula*; ophiopluteus larvae of starfish; *Doliolum* spp. and *Oikopleura* spp. of chordates and various species of fish eggs and larvae.

In the outer RSA, especially the southern part of Oman, the biomass of zooplankton was found to be 40,102mg/100m^3 (September to October) and 70,190mg/100m^3 (December to February). This revealed that in the Arabian Sea, zooplankton biomass started increasing at the end of south-west monsoon season (September to October) and attained a peak in December to February. This could be expected year after year in the southern part of Oman, which is influenced by the prevailing upwelling phenomenon that occurs at the time of the south-west monsoon.

2.4.2.4 _Ichthyoplankton_

In general, there is a paucity of information on marine ichthyoplankton. This is especially true in the RSA where only a few works by Nellen (1973a, b), Houde *et al.* (1986), Thangaraja (1998b) and Thangaraja and Al-Aisry (2001) are known. Nellen (1973a, b) worked on the different kinds and abundance of fish larvae in the Arabian Sea and the RSA as part of a large Indian Ocean Survey. Houde *et al.* (1986) studied ichthyoplankton abundance and diversity in the western RSA, in the waters of Kuwait (inner RSA) and Thangaraja (1998b) in the Oman waters (middle and outer RSA).

In the inner RSA, a total of 214 ichthyoplankton samples were collected during eleven cruises on RV Oloum I at stations in Kuwaiti waters and from stations off Saudi Arabia and in the southern RSA during two other cruises. There were 94,392 larvae and 152,632 eggs in the collections. The predominant families of larvae were Engraulidae, Gobiidae and Clupeidae which accounted for 42.5% of all larvae. Egg catches were dominated by Engraulidae and Clupeidae, which accounted for 45.4% of all eggs. A total of 53 families of fish larvae were identified. Forty-one genera, 24 species and 84 specific types of larvae were found (Houde *et al.*, 1986).

Between 1989 and 1990, fish eggs and larvae were collected at 134 stations in the Gulf of Oman (middle RSA) and the Arabian Sea (outer RSA) by the FAO ship, R/V Rastrelliger. A total of 54 species of fish eggs and 93 species of fish larvae occurred in the samples. The overall fish eggs and larval abundance estimate disclosed that the Arabian Sea had a 20 times greater egg abundance than the Gulf of Oman, whereas the Gulf of Oman had 2.6 times higher larval abundance than the Arabian Sea.

The highest larval abundance was recorded in the Gulf of Oman where sardines (*Sardinella longiceps* and *S. gibbosa*) and mesopelagic larvae (*Benthosema pterotum*) dominated. For the first time the larvae of kingfish, *Scomberomorus commerson* (Figure 2.20) were collected from Masirah Bay (outer RSA) in September 1990. This finding revealed that the kingfish, which is a highly commercially important fish of RSA, spawns in Omani waters following the south-west monsoon. The spawning ground is in Masira Bay and its neighbouring waters in the Arabian Sea. Tuna also spawns in Omani waters following the south-west monsoon. Tuna larvae of the *Auxis thazard* were found in the Gulf of Oman (offshore of Muscat) and in the Arabian Sea (offshore of Ras Sharbithat) in August and September (Thangaraja, 1998b).

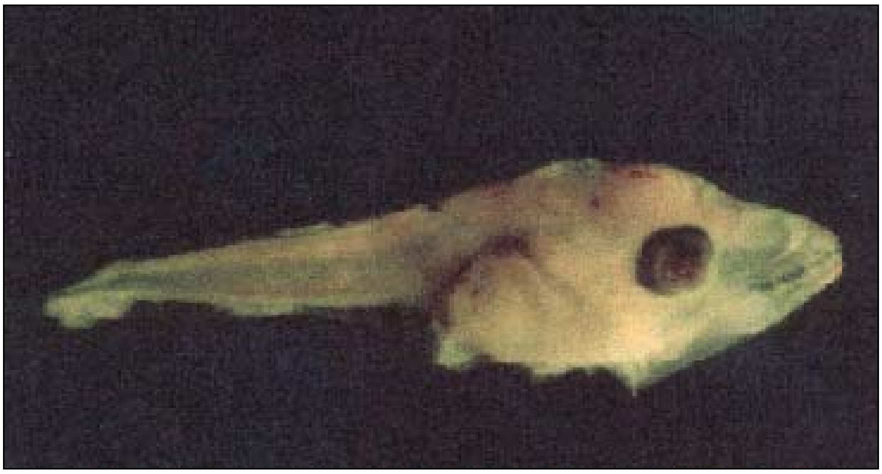


Figure 2.20 Microscopic view of post-larva (4.9mm size) of kingfish, *Scomberomorus commerson*

Time series regional surveys on ichthyoplankton are vital because by conducting regular collection of planktonic fish eggs and larvae, it is possible to map the marine areas to determine patterns of the breeding of fishes and the relative abundance of ichthyoplankton of commercial fish stocks. This information could be used as an index of fish abundance or for predicting year/class strength. Areas where the maximum density of eggs or larvae are recorded can be looked upon as possible spawning grounds for a good number of species of fishes, and if need be, closed to fishing, as a conservation measure. Eggs in very early stages of embryonic development are likely to be nearer to the spawning grounds than those in the advanced stages. Ichthyoplankton studies help stock assessment, location of spawning grounds, conservation of recruits and aquaculture (Thangaraja, 1998b).

2.4.2.5 *Benthic fauna*

More than 270 species of macrobenthic fauna were recorded at 19 stations located in the EEZ of Qatar in the inner RSA. Of the benthic fauna, Molluscs are the predominant group (201 species), followed by Crustacea (26 species), Echinodermata (17 species), Annelida (14 species), Ascidiacia (6 species) and Hydrozoa (4 species). The faunal diversity index showed a small variation between the stations (Al-Khayat and Al-Khayat, 2000).

Benthic samples collected by Van Veen Grab from the inner RSA during the summer 2001 Oceanographic Cruise were analysed for species occurrence and abundance. A total of 304 taxonomic entities were recorded from the samples analysed and are depicted in Table 2.2.

High numbers of foraminifera shells were present in all the samples but none have retained the rose Bengal colour, this is an indication that they were already dead prior to collection and as such were not included in the counts. Maximum abundances of benthic invertebrates were recorded from sampling stations close to the coast of Qatar (see Figure 2.4) where concentrations of ~15,000 individuals/m^2 were recorded. Abundances were lowest in waters adjacent to the Kuwaiti and Iraqi coastlines and in waters to the east of the sampling grid (Figure 2.21). Mollusc abundances were highest in waters off the Qatar coast and reached concentrations of ~3,000 individuals/m^2 (Figure 2.22). Echinoid concentrations were greatest (~600 individuals/m^2) in waters to the east of the Region and in the waters off the United Arab Emirates (Figure 2.23). Crustacean abundances were highest in waters to the north of Qatar where concentrations of up to 10,000 individuals/m^2 were recorded (Figure 2.24). Annelid concentrations were highest in the waters off the southern coast of the I.R. Iran where concentrations of ~3,000 individuals/m^2 were recorded (Figure 2.25).

Table 2.2 List of benthic fauna and their occurrence in the inner RSA, recorded from samples collected during the Oceanographic Cruise – Summer 2001

PROTOZOA	*Galathowenia ?* sp.	Polynoinae sp.
Folliculinidae sp	*Glycera convoluta*	*Potamilla ehlersi*
	Glycera rouxi	*Potamilla* sp. 1
PROIFERA	*Glycinda* cf. *capensis*	*Prionospio (Minuspio)* sp. 1
Porifera sp.	*Goniada emerita*	*Prionospio* sp. indet. (damaged)
	Goniada maculata ?	*Prionospio ehlersi*
CNIDARIA	*Goniadella* sp.	*Prionospio malmgreni*
Virgularia sp.	*Gyptis capensis*	*Prionospio pinnata*
Edwardsiidae sp.	*Halosydna* cf. *Alleni*	*Prionospio queenslandica*
	Harmothoe cf. *dictyophora*	*Prionospio sexoculata ?*
NEMATODA	*Heteromastus filiformis*	*Prionospio* sp. 1
Nematoda spp.	*Hydroides homocerous*	*Prionospio steenstrupi*
	Isolda albula	*Prionospio tridentata*
NEMERTEA	*Kefersteinia cirrata*	*Procerastea perrieri*
Nemertea spp.	*Laonice cirrata*	*Protodorvillea egena*
	Leocrates sp.*?*	*Protomystides* sp.
ANNELIDA	*Leonnates persica*	*Pseudoeurythöe hirsuta*
Polychaeta	*Lepidonotus* sp.	*Rhodine* sp.
Aisychis disparidentata	*Leptonereis* sp.	*Sabellaria spinulosa* var. *alcoki*
Amphiglena quadrioculatum	*Loandalla* sp.	*Samytha (=Amage)* cf. *bioculata*
Amphinomidae sp 1	*Loimia medusa*	*Schistomeringos neglecta ?*
Ancistrosyllis constricta	*Lumbrinereis* cf. *bifilaris*	*Sclerocheilus* cf. *minutis*
Ancistrosyllis parva	*Lumbrinereis gracilis*	*Scolelepis indica*
Ancistrosyllis rigida	*Lumbrinereis heteropoda heteropoda*	*Scoloplos chevalieri*
Ancistrosyllis sp.	*Lumbrinereis latreilli*	*Sphaerodoridium* sp. 2
Aonides oxycephala	*Lumbrinereis* sp. 1	*Sphaerodorum* sp.
Aphrodite sp. juv.	*Lumbrinereis* sp. 2	*Sphaerosyllis capensis*
Arabella mutans	*Magelona* cf. *alleni*	*Sphaerosyllis* sp.
Aricidea cf. *longobranchia*	*Magelona* cf. *cornuta*	*Spiofilicornis*
Aricidea jeffreysi	*Magelona cincta*	*Spiochaetopterus vitrarius*
Aricidea sp. 1	*Magelona* sp. indet.	Spionidae sp. indet.
Asychis disparidentata	*Marphysa macintoshi*	*Spiophanes bombyx*
Augneria sp.	*Mediomastus* sp. 1	*Spiophanes* cf. *kroeyeri*
Brada villosa	*Melinna palmata*	*Spiophanes japonicum*
Brania sp. 1	*Mesochaetopterus minutus*	*Sternaspis scutata*
Caulleriella bioculatus	*Microneries* sp.	*Sthenolepis japonicus*
Chone filicaudata	*Nephtys (Micronephtys) sphaerocirrata*	Syllidae sp. indet.
Chone sp.1	*Nephtys lyrochaeta*	*Syllis (Langerhansia) cornuta*
Chrysopetalum (= Paleanotus) ehlersi	*Nephtys paradox ?*	*Syllis (Langerhansia)* sp.
Cirratulus filiformis	*Nephtys tulearensis*	*Syllis gracilis*
Cirriphorous cf. *branchiata*	*Nereis (Nereis) persica*	*Syllis spongicola*
Cossura coasta	*Nerimyra* sp. 1	*Terbeliides stroemi*
Dasybranchus sp.	*Notomastus* sp.	*Terbella ehrenbergi*
Diopatra cuprea punctifera	*Onuphis eremita*	Terbellidae sp. indet.
Diplocirrus cf. *capensis*	*Onuphis investigatoris*	*Thalenessa (=Euthalenessa) djiboutiensis*
Dorvillea sp.	*Ophelina acuminata*	*Tharyx filibranchiata*
Drilognathus sp.	*Owenia fusiformis*	*Tharyx marioni*
Drilonereis filum	*Paradonides lyra*	*Tharyx* sp. juv.
Eteone (Mysta) siphodonta	*Paralacydonia paradox*	*Trichobranchus* sp.
Euchone cf. *capensis*	*Paraonis gracilis gracilis*	*Vermiliopsis acanthophora*
Euclymene luderitziana	*Pectinaria (Amphictene) crassa ?*	
Euclymene sp. indet.	*Pectinaria (pectinaria) papillosa*	**Oligochaeta**
Eumida sanguinea	*Phyllodoce castanae*	Oligochaeta spp.
Eunereis sp.	*Phyllodoce* cf. *dissotyla*	
Eunice indica	*Pilargis* sp.	**SIPUNCULA**
Eunice sp. juv. Prob. *indica*	*Pista unibranchiata*	*Aspidosiphon* cf. *elegans*
Eusyllis sp.	*Poecilochaetus serpens*	*Golfingia hespera*
Exogone clavator	*Polycirrus* sp.	*Phascolion robertsoni ?*
Exogone sp.	*Polydora (Pseudopolydora) antennata*	*Sipuncula* sp. 2
Exogone verugera ?	*Polydora ciliata*	
Flabelligeridae sp indet.	*Polydora* sp. indet. (juv.)	

Table 2.2 Cont.

CRUSTACEA	*Microdeutopus anomalus*	*Modiolus philippinarum*
Ostracoda	*Perioculoides longicornis*	*Modiolus* sp. juv.
Ostracoda spp.	*Phitisca marina*	*Musculista perfragilis*
	Photis longicaudata	*Musculus cumingiana*
Cirripedia	*Sophrosyne* sp.	*Nucula inconspicua*
Chthamalus sp.	*Urothoe pulchella*	*Nuculana* sp.
		Pectinidae sp.
Leptostraca	**Stomaptopoda (Mantis shrimps)**	*Pinna bicolor* ?
Nebalia cf. *capensis*	*Harpiosquilla* cf. *harpax*	*Pteria* sp.
		Scintilla sp.
Cumacea	**Caridea**	*Tapes sulcarius*
Bodotria siamensis	*Procera* cf. *edulis*	*Tellina (Arcopella) isseli*
Campylaspis sp.	*Procera* sp.	*Tellina (Exotica) triradiata*
Cumella hispida	*Alpheus?* sp.	*Tellina (Moerella)* sp.
Cumella sp.	Hippolytidae sp.	*Tellina (Pinguitellina) pinguis ?*
Cyclaspis cf. *cingulata*	Pasiphaeidae sp.	*Tellina* sp. 1
Eocuma affine		*Tellina vernalis*
Eocuma lata	**Anomura**	*Tellinidae (Exotica)* sp.
Eocuma producta	*Callianassa* sp.	*Timoclea macfadyeni*
Eocuma sp.	Paguridae	
Heterocuma andamani ?	*Petrolisthes carinipes*	**Gastropoda**
Iphinoe stebbing		*Ancilla castanea*
Leptostylis sp.	**Brachyura (True crabs)**	*Architectonica* sp.
Makrokylindrus sp.	*Atelecyclidae kraussia* ?	*Atys cylindricus*
Sympodomma incertum	Calappidae crab	Buccinidae sp.
	Ebalia sp.	*Calyptraea pellucia*
Isopoda	*Inachus* sp.	*Calyptraea* sp. juv.
Amakusantura sp.	Majidae sp.	*Eulima* cf. *bilineata*
Arcturella brevipes	*Micropanope rufopunctata ?*	*Eulimella* sp.
Cymodoce richardsoniae	Ocypodidae sp. 1	Eulimidae sp.
Gnathia rhinobates	Ocypodidae sp. 2	*Gibberula* sp.
Gnathia sp.	*Typhocarcinodes* sp.	*Heliacus variegatus*
Eurydice arabica ?		*Natica lineata*
	MOLLUSCA	*Natica pomatiella* ?
Tanaidacea	**Scaphopoda (Tusk-shells)**	*Natica* sp.
Anatanis gracilis	*Dentalium octangulatum*	*Odostoia* sp.
Apseuda sp. 1	*Dentalium politum*	*Retusa tarutana*
Apseuda sp. 2		*Retusa truncatula*
Apseuda sp. 3	**Polyplacophora (Chitons)**	*Rissoina clathrata* ?
Typhotanais sp.	*Chition lamyi*	*Rissoina* sp.
	Chitonidae sp.	*Strombus decorus persicus*
Amphipoda		*Turbonilla* sp.
Ampelisca sp. 1	**Bivalvia**	*Vitreolina* sp.
Ampelisca sp. 2	*Amphilepida faba ?*	
Ampelisca sp. 3	*Atactodea* sp.	**ECHINODERMATA**
Ampelisca sp. 4	*Barbatia decussata*	Amphiuridae sp.
Ampelisca sp. 5 *(sarsi ?)*	*Bellucina sempriana*	*Asterina* sp.
Aoridae sp.	*Cardita* sp.	Echinoidae sp. juv.
Birubius sp.	*Donax paxillus*	*Labidoplax* sp.
Corophium sp.	*Frigidocardium exasperatum*	*Ophiura* sp.
Ericthonius sp.	*Fulvia papyracea*	Synaptidae sp.
Eriopisella cf. *schellensis*	Galeommatoidea sp. 1	
Gammaropsis sp.	Galeommatoidea sp. 2	**BRACHIOPODA**
Idunella sp.	*Gari* sp.	*Lingula* sp.
Lembos sp.	*Gastrochaena* sp.	
Lepidepecreum sp.	*Kellia cycladiformis*	**UROCHORDATA**
Leptocheirus sp.	*Limaria fragilis*	Tunicata spp.
Maera hirondellei	*Limposis multistriata*	
Melita sp.	*Loripes clausus ?*	

CHAPTER 3

MARINE RESOURCES OF THE ROPME SEA AREA

3.1 Major Marine Habitats

The marine habitat provides the largest inhabitable space for living organisms of any of the habitats of the biosphere. The major environmental variables characterizing the physico-chemical and biological elements that affect the marine habitats of the RSA have been described in the first and second Chapters. Marine habitats range from exposed beaches to open sea areas. Artificial structures (platforms, jetties, etc.) and offshore islands play a considerable role in the variability of resources existing in the RSA.

The RSA coastal and marine habitats have been categorized into benthic deep and shallow subtidal habitats, intertidal habitats, rocky shores, sandy shores and muddy shores (Jones, 1985). The interaction of the physical factors in the RSA has a severe impact on the marine biota of the Region, especially intertidally, so that diversity is lower within the inner part of the RSA than in the Gulf of Oman and the Indian Ocean in general. Four critical marine habitats, namely coral reefs, intertidal marshes, mangroves and seagrass beds, and kelp forest, have been identified in the Region (Basson *et al.*, 1977; Barratt, 1984; Price, 1985). In addition, the importance of others such as intertidal sand and mudflats, algal dominated shores, and subtidal algal coral zones has been stressed (Price, 1985).

Sub-littoral mud habitats are predominant in the northern and eastern part of the inner RSA, while sand predominates in southern and western areas.

The middle RSA on the Omani side from the Strait of Hormuz and the Musandam peninsula is characterized by high mountains, coastal cliffs, rocky shores and semi-enclosed fjord-like bays. From Shinas to Muscat the area is characterized by a wide coastal plain with dense human settlement, long sandy beaches, shallow seas with scattered small rocky shores, lagoons and mangroves. From Muscat to Ra's Al-Hadd there are inshore islands with coral growth, mangroves, raised gravel terraces, coastal cliffs, plains and delta sabkhas. The sandy coast of Ra's Al-Hadd supports nesting green turtles.

The outer RSA, from Ra's Al-Hadd to Masirah is exposed to moderate to high-energy wave action, it has sandy beaches backed by rocky jabal, mangroves and seaweeds mixed with scattered coral colonies. The latter are the feeding ground of the green turtle. Masirah to Ras Al-Madrakah has a high to moderate energy coast, extensive coral reefs, mixed coral-algal areas, dense seagrass beds and a mangrove forest. The muddy bottom around Mahout Island provides a suitable substrate for shrimps and the sandy beaches of Masirah Island provide nesting areas for loggerhead turtles. Ras Al-Madrakah to Ras Sharbithat has a high to moderate energy coast, low dunes, sand-gravel plains, shallow khawr, huge tidal flats and scattered colonies of corals mixed with seaweeds. Ras Sharbithat to Ras Janjah is seasonally exposed to moderate to heavy wave action; has rocky and sandy shores; the Al-Halaniyat islands have a scarped coast with abundant corals and a fringed rock pavement that is covered by algal turfs and is the feeding ground for green and loggerhead turtles. Ras Janjah to the border of Yemen has scarped, rocky and sandy shores. The rocky shores and reefs support a dense growth of brown seaweeds while the rocky pavement, covered by algal turf, is home to abalone. There are nine khawrs with stands of mangroves in this area (Thangaraja, 1995).

3.1.1 Seagrass beds

Seagrasses provide the best habitats for many commercially important marine species. Four species of seagrass are common in the seagrass beds of the RSA, of which *Halodule uninervis* and *Halophila ovalis* are the most common (Sheppard *et al.*, 1992). The productivity of seagrass beds is often enhanced by Cyanophyta-dominated algal mats (Price, 1993). The seagrass beds are patchy and less prevalent further offshore along the coast of Saudi Arabia. They occur along the coasts from Iraq, through I.R. Iran and Kuwait to beyond Bahrain and UAE. In I.R. Iran, extensive seagrass beds are found near the mouth of rivers and in the area of Chabahar (Harrington, 1976). Their distribution in Kuwait is limited. In Saudi Arabia, the greatest concentrations are found between Safaniya and Manifa, in Musallamiyah and the south of Abu Ali, and in the Gulf of Bahrain (WCMC, 1991). In Bahrain, however, they are more extensive, though they do not generally extend deeper than 8m (Price *et al.*, 1993). There appear to be more species at the Shatt Al-Arab entrance. Shallow sediments along the coasts of Oman support sporadic beds of seagrasses.

More than 600 species of animals have been recorded in seagrass beds in the inner RSA (Basson *et al.,* 1977; McCain, 1984; Coles and McCain, 1990). The species richness and abundance of fauna are greater in the RSA than in the Red Sea, at least in the northern parts (Biomass estimated at 0.05–0.24g dry wt/m^2). Benthic fauna (within seagrass and sand/silt beds) in the RSA are principally suspension feeders, which utilize more abundant organic particulates than occur in the clearer waters of the northern Red Sea.

Dugongs consume seagrass directly; however, green turtles, sea urchins and most fish species utilize seagrass indirectly as detritus, after it has been broken down by mechanical and microbial action. To obtain an approximate quantification of productivity, Price and Coles (1992) have estimated that the seagrass bed area such as that in Tarut Bay (Saudi Arabia) could support the production of 2 million kg of fish annually. The potential for the sustainable development of commercial species of fish and shrimp is obvious.

In Oman, in the middle and outer part of the RSA, four species of seagrass have been found. The most common are the smaller species *Halodule uninervis* and *Halophila ovalis*. Occasional beds of the larger species *Syringodium isoetifolium* and *Thalassodendron ciliatum* are found in the Masirah Channel where the highest biomass of *Halodule* has been found in intertidal zones, with increased an biomass of *Halophila* in deeper areas. Biomass data from the west coast of Masirah Island are lower than for other sites in Oman (Ras Suwadi), the RSA and the Red Sea because of lower sea temperatures and increased turbidity during the south-west monsoon. Seagrasses of the area are an important part of the diet of the *Chelonia mydas*. They also provide important habitats for fishes and crustaceans such as the commercially significant *Penaeus semisulcatus* in the Ghubbat Hashish Bay (Jupp and Goddard, 2001).

The distribution by depth of the seagrasses, *Halodule uninervis* and *Halophila ovalis*, the two most abundant seagrasses on the western side of Masirah Island on the Arabian Sea coast of Oman, were found to overlap but be inversely related. *Halodule* dominated the intertidal zone and *Halophila* was more predominant in the deep subtidal zone, although the total biomasses of the two seagrasses were similar at this depth. At all depths, the biomass of *Halophila* was about equally distributed between leaves and roots and rhizomes. Leaf biomass of *Halodule* was only 7–20% of the total biomass and the highest below-ground biomass occurred in the intertidal zone. Their results showed that the reduced growth of seagrasses at Masirah Island seems to be due to stresses casued by the summer monsoon and grazing pressure. The survival of these populations depends on their seasonal growth and flowering (Jupp *et al.*, 1996).

3.1.2 Algal communities

Red, brown and green algae growing in coastal waters of tropical countries, including the RSA are economically important. They are primarily collected for the alginates, agar or carrageenan they contain. They are often used directly as food and also used as organic manure. The extracts of marine algae are observed to be rich in protein, vitamins A, B, C and E, minerals, folic acids, phenolic compounds, sterols, terpenoids and hologenated substances which are used as drugs with anti-pyretic properties and anti-cholestemic compounds.

Algae harvested from the wild and cultured on racks are increasingly valuable coastal resources. FAO has estimated that some 7.8 million tons (Mt) of seaweeds were harvested worldwide in 1995. These included 5.3 Mt of brown seaweeds (Phaeophyta), 1.8 Mt of red seaweeds (Rhodophyta) and 0.3 Mt of green seaweeds (Chlorophyta).

Several areas of hard substrate in the RSA are dominated by algae instead of corals. This is especially true on the Omani coast. This may occur in shallow coral reef areas, where 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 and the Arabian Sea is coldest during the summer upwelling. The brown algae found at most depths are of small species, while large forms occur on reef crests and on the rocky platforms of streams where upwelling is important. Green and red algae are ubiquitous.

In I.R. Iran coastal waters, seaweed beds are found along the Chabahar coastline (200km from Tang to Guatr Bay) and the shores of Lengeh, Bostaneh and Bushehr (MNR-I.R. Iran, 2003). The Iranian southern shoreline supports different agrophytes, *Gelidium*, *Hpnea*, *Laurencia* and *Gracilaria*. Four species of *Gracilaria*, *G. corticata*, *G. millardittii*, *G. pygmaea* and *Gracilaria* sp. are found along the Chabahar coast located in eastern-southern part of I.R. Iran (Ghoroghi *et al.*, 2001).

In Oman, coastal *Sargassum* is the only genus of commercial value that floats on the sea surface either attached or as drifting rafts. The majority of Oman’s seaweed resources are to be found in the southern most part of Oman (Dhofar), and their occurrence is markedly seasonal. The seasonal south-west monsoon (Khareef) directly affects the Arabian Sea of Oman (outer RSA) and indirectly affects the Gulf of Oman (middle RSA). Seaweed growth begins during summer months (July, August) with the onset of the south-west monsoon. This is caused by the seasonal upwelling brought about by the south-east monsoon, which brings with it nutrient rich water. When the monsoon winds cease blowing, in September, and the upwelling diminishes, the seaweeds begin to die back and become detached, eventually being cast up on beaches (MAF–Oman, 1999). Significant quantities of beached algae were found on most of the beaches in the Dhofar coast during the post-monsoon period between September and January (Figure 3.1). The drift material is dominated by brown algae such as *Nizamuddin* and *Sargassum*, and green algae *Ulva* sp. (Figure 3.2).

A recent study revealed the occurrence of 232 taxa in Omani waters (Jupp and Goddard, 2001). Significant growth of seaweeds in the intertidal zone is mainly the result of seasonal development along the Arabian Sea coasts during and for some time after the summer south-west monsoon when the wind-driven waves and spray give rise to a dense intertidal flora. High air temperatures and desiccation reduce growth outside these periods. Dense subtidal beds of seaweeds develop along the Arabian Sea coast during the south-west monsoon and persist in the post-monsoon period until January. These dense seaweed beds, especially in Dhofar, form the basis of food chains in shallow coastal waters. Several herbivores will directly depend on the algal beds in Omani waters such as the commercially important abalone, *Haliotis mariae*, rabbitfish, *Siganus* spp., parrotfish, *Scarus* spp., and the Green turtle, *Chelonia mydas*.

Figure 3.1 Beached seaweeds

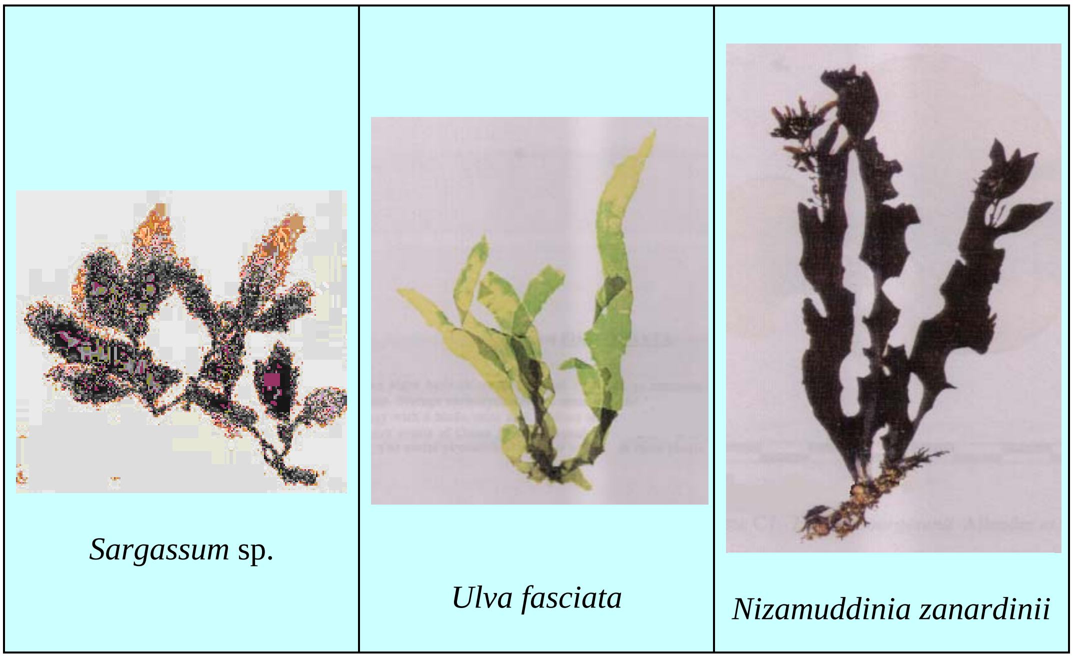


Figure 3.2 Drifting seaweed species

The species of marine algae found in the Anak and Al-Awamiyh mangrove swamps on the coast of Saudi Arabia was studied by Khoja (1998). He recorded eight species of Cyanophyta: *Chroococcus turgidus* var. *maximus*, *Merismopedia glauca, Pleurocapsa fuliginosa, Spirulina subtilissima, Hydrocoleum cantharidosmum, Nodularia spumigena* var. *major; Nostoc punctiforme* and

Homoeothrix varians, and one species of Chlorophyte*: Gomontia polyrhiza* for the first time in the RSA. However, species such as *Gomphosphaeria aponina*, *Lyngbya majuscule*, *Enteromorpha intestinalis*, *Ulva lactuca*, and *U. reticulate* have not so far been found in the coastal waters of Saudi Arabia.

3.1.3 Mangroves

Mangrove ecosystems contain more than 60 species of trees and provide living space for more than 2,000 species of fish, invertebrates and epiphytic plants worldwide (Clough, 1993). In RSA, scattered populations of *Avicennia marina* (Figure 3.3) can be found where there are mudflats.

Figure 3.3 Mangroves (*Avicennia marina)*

The distribution of mangroves in the inner part of the RSA is much less extensive than before intense development took place in the Region. Only about 125-130km^2 of mangrove vegetation remain, 80% of which are on the Iranian side, estimated in the 1970s to be about 8,900 hectares (Harrington, 1976). Severe climatic conditions in conjunction with limited habitats and niches (Sheppard *et al.*, 1992) mean that only one eurythermal and euryhaline species, *Avicennia marina* occurs naturally in the RSA.

In I.R. Iran, the mangroves have expanded mainly in the Nayband Bay and Dayer port areas (Bardestan and Bardkhoon estuaries) in Bushehr province. Most of the mangroves are found in estuaries to which no fresh water flows. There are an estimated 10,000 hectares of *Avicennia marina* along the Iranian coast. The western most mangrove stand at Asaluyeh has been badly cut and is rapidly disappearing. The largest grove of 6,800 hectares is located in the Khouran Straits (UNEP, 1999). The mangrove forest coverage in each area is as follows: Jask (366ha), Guatr (107ha), Siric (459ha), Tiab (514ha), Qeshm (6,647ha), Khamir (321ha), Ni-band (73ha), Bardestan (2ha) and Molegonzeh (9ha) (MNR–I.R. Iran, 2003). Mangroves have formed assemblages with other halophytic flora. Sixteen species of these plants were identified within eight botanical communities. In Bushehr province coastal area the mangroves have created nursery grounds that are used by many aquatic animals for feeding, reproduction, growth and larval life (IFRO, 2000).

In Oman, only the *Avicennia marina* species is found naturally. However, on the southern shores of Oman *Rhisophora stylosa* and *Lumnitzera racemosa* were artificially transplanted by the Japanese in the early 1980s; although *R. stylosa* pollen found later in sediment samples dating from the late Holocene era, indicated that this species colonized the area at that time (Lezine *et al.*, in press). Some mangrove areas in the Dhofar region also contain the associated mangrove plant species *Conocarpus erectus* from the Vervenaceae family. Since the air temperatures drop to freezing in winter over the extreme NW part of the inner RSA, mangrove trees are not found in Kuwait and most of NE coasts of Saudi Arabia.

Cultivation of mangrove plants is being carried out sporadically in the RSA which recently increased the area under mangrove cultivation by up to $10km^2$. In Oman, with the help of JICA (Japan International Cooperation Agency), a project for mangrove afforestation in khawrs was implemented in 2000. This is mainly to establish new forests in khawrs where potential mangrove stands can be developed. The programme consists of three phases: construction and nursery, cultivation of seedlings of *Avicennia marina,* and transplantation of the seedlings to khawrs (Shoji and Tomoo, 2001).

In August 2000, the first nursery of the black mangrove *Avicennia marina* was established in the Qurum Nature Reserve (QNR). All seeds were collected from the existing reduced forest in QNR, and pump irrigation was used. After a 6-month nursing period, in March 2002, 11,500 seedlings were transplanted in Ras Sawadi (Gulf of Oman). One year after transplantation, approximately 85% of the total seedlings had survived and the average height of the trees was 650mm ± 450mm (Figure 3.4).

Figure 3.4 One-year old mangrove plantation at Ras Sawadi, Batinah coast of Oman

The Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR) also established three more nurseries, a new one in QNR (by tidal irrigation) in November 2001, another in Sur (by tidal irrigation) in May 2002, and another (by pump irrigation) in Salalah, southern Oman, in July 2002. All these nurseries are in operation and are expected to produce 60,000 seedlings per year (MRMEWR–Oman, 2003).

All along the coast and islands of Oman, mangroves are found scattered over more than 20 sites, Northern Batinah, the capital area extending to Sur, in the Gulf of Masirah and Bar Al-Hikman, and the Dhofar region (Fouda, 1995). The mangrove vegetation, *Avicennia marina,* varies from 2–6m in height in the Gulf of Oman and up to 10m in the Arabian Sea (Fouda and Al-Muharrami, 1996), whereas in the inner part of RSA proper trees are poorly developed and often stunted (1–2m), at least along the 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, and many waders, gulls and terns. Mahout and Bar Al-Hikman (Oman) are home to internationally important concentrations of shorebirds, notably crabplovers, sandplovers, demlins and redshank. The Olive Ridley turtle, *Lepidochelys olivacea* is found in mangrove areas (Salm, 1991). Gross primary productivity in *Avicennia* stands has been estimated to be <1kg C/m^2/yr, however the biological value of mangrove is much more important (IUCN, 1987).

In Qatar, mangroves occupy the area to the north-east of the coast, where they intermingle with the Sabkha frontier vegetation. *Avicennia marina* (alqurm) is the only species found in Qatar (Sadooni and El-Kassas, 1998). The reproductive period of mangrove extends from April to October, while vegetative activity occurs throughout the year with minimum growth during late autumn and early winter (Hegazy, 1998).

In UAE, estimates have indicated that standing biomass varies between 70 and 110t/ha for the tallest stands and between 14 and 65t/ha for shortest stands (Dodd *et al.*, 1999).

3.1.4 Coral reefs

Although thought not to be present in extreme conditions beyond 23.5^{o}C north and south of the equator, the coral reefs found in the RSA are a unique example of adaptation by marine organisms. In the inner part of the RSA coral reefs occur in an environment characterized by great extremes of temperature and salinity, as well as high turbidity. The extreme environmental conditions in the inner RSA, and the area's relatively short age in geological terms (<10,000 years), and lack of opportunity resulting from the absence of an intermediate platform in the Gulf of Oman, nonetheless mean that coral diversity is low in Indo-Pacific terms.

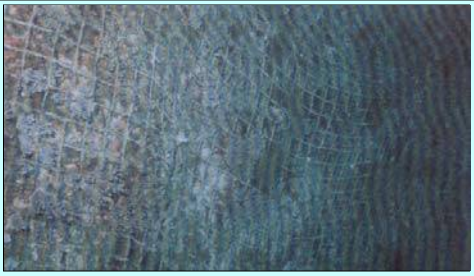
There are numerous patch reefs in the RSA, with coral islands representing the peak of their development. Because of scouring by loose sand in the water column, patch reefs support fewer and less dense communities than island coral reefs, which have extensive reef flats and extend to depths of 10–20m. About 55–60 zooxanthellate species have been identified in the RSA (Sheppard and Sheppard, 1991). This compares to about 200 species in the Red Sea and over 500 species (80 genera) in the western Pacific Ocean. Thus, given the protection and maintenance of the integrity of the ecosystem in the RSA, the potential exists for more species to drift from the Indian Ocean and settle in the RSA. Only 57 hermatypic coral species occur on offshore island reefs, 24 of them are found on inshore reefs, and no corals are found where salinity exceeds 46 $^{0}/_{00}$ (Fouda, 1997).

Bahrain has numerous reefs along its northern and north-eastern sides. The largest group of patch reefs forms a chain leading to the deeper water north of Bahrain, and estimated to provide a larger area of substrate than all the coral islands of the inner RSA combined (Price, 1993). Thirty-one coral species from 19 genera have been reported in Bahrain (Sheppard, 1985). *Acropora valenciennesi* dominates with a cover >80% of large areas at depths of around 2–5m around Fasht Adhm and other smaller northern reefs. *Porites compressa* co-dominates at between 5 and 10m of depth where diversity is at its greatest. *Porites nodifera* constructs substantial frameworks in higher salinity areas, and in these areas diversity is poor.

In I.R. Iran, the islands located in the eastern part are surrounded by extensive coral reefs but no barrier reefs. Coral reefs at depths of 6m have also been sighted in the area of Chabahar. However, with the exception of 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 on the Omani side of the Strait. The sites of coral reefs and the area coverage are as follows: Khark (181ha), Kharko (266ha), Ni-band (181ha), Lavan (18ha), Shidvar (13ha), Kish (62ha), Hendoorabi (20ha), Hormoz (59ha), Larak (116ha), Hengam (36ha), Faroor (19ha), Faroorgan (2.5ha), Siri (16ha), Tonb-e-Bozorg and Tonb-e-Koochak (21ha), and Aboomoosa (11ha) (MNR-I.R. Iran, 2003).

In Kuwait, coral reefs lie around the coral islands where around 26 coral species are found, and like all known reefs in the RSA, they support insignificant coral growth below 15m 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 estuary precludes corals.

In Oman, there are four regions which support coral growth, namely, the Musandam Peninsula (entrance of the inner RSA); the rocky shores, bay and islands adjacent to the capital area (Muscat); the strait west and south of Masirah Island; a number of sheltered bays along mainland Dhofar in the south and the Halaniyat islands offshore (outer RSA). The other parts of the Oman coast either lack corals or support limited growth of small, scattered colonies. This is because of an absence of suitable stable substrate such as that found on the Al-Batinah coast, or the seasonal upwelling of cold water, and 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 towards the equator with Musandam (41 genera), Muscat (42 genera) and Dhofar (48 genera). On Masirah Island there are 27 genera which reflects the isolation of this island (Salm, 1993). The Fahal Island has the highest coral diversity in Oman. 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 reef building coral (Salm, 1993). The other scattered and massive coral communities in Oman waters are *Astrepoid*, *Goniopora* and *Turbinaria*. Coral reefs have been severely degraded in certain areas by abandoned fishing nets especially gillnets, anchors from boats fishing in the coral reef areas (Figure 3.5), and recreational diving by local and foreign divers.



(A) Abandoned fishing net on coral reef

(B) An anchor damaging coral reef

Figure 3.5 Impacts of an abandoned fishing net and anchor on coral reefs

In Qatar, extensive coral growth has been seen along the northern and eastern coasts where salinity is at optimum levels. The west of the country borders the Gulf of Salwa where salinity is double that of oceanic water and thus, coral reefs are absent. Coral reefs are low in diversity but are well developed along the east coast. They form 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 UAE. Shinn (1976) examined several transects leading out from the north and east coasts which crossed extensive reef areas consisting of many kilometres of *Acropora* thickets with some *Porites* and brain corals. A total of eight species of coral have been identified.

The Saudi Arabian islands have well-developed reefs, with approximately 50 coral species (Fouda, 1997). Patch reefs close to the mainland are much less diverse (McCain *et al.*, 1984; Coles, 1988). The fringing reefs surrounding the offshore islands of the Saudi coast support the most diverse fish life and constitute the largest areas of reef in the inner RSA.

In UAE, the number of coral reef communities was evaluated in Dubai before and after a coral mass mortality in 1996. The coral fauna consisted of 34 scleractinian species before and 27 after the event, which removed virtually all *Acropora*. No alcyonacea were recorded. Five community types were identified and characterized by dominant species: (A) a sparse *Porites lutea* community in sandy areas, (B) a dense *Acropora clathrata* community in areas with little sand, (C) a faviid community in muddy areas, (D) a *Siderastrea savignyana* community in sandy areas, and (E) a *Porites compressa* community, which built a framework in sandy areas. These communities are comparable to those described in other areas of the RSA, where a stable pattern of community differentiation appears to exist. The spatial distribution and dynamics of the coral communities appear to be strongly influenced by mass mortality events recurring every 15 to 20 years. A combination of extreme water temperatures and high sedimentation/turbidity appear to be the major cause of mortality (Riegl, 1999).

3.1.4.1 *Conditions and changes to coral reefs*

The coral reefs in the RSA are subject to a wide range of natural environmental stresses and human influences. Coral bleaching has been reported on some reefs in Bahrain, Oman, Saudi Arabia and UAE over the past few years, particularly in 1996 and 1998.

In Bahrain, during 1996 a major bleaching took place at Fasht Al-Dibal where temperatures reached 37.3^{o}C. Most of the corals on Fasht Al-Adham bleached and then died. About 20 miles north of Bahrain 100% coral reef bleaching was observed during August 1998 when the temperature increased from 34^{o}C to 37^{o}C in the deep water and 39^{o}C in the shallow water over the period of a week and stayed at this level for a few weeks. Another 50% bleaching was observed 50 miles north of Bahrain (Wilkinson, 1998).

In Oman, extensive bleaching was reported at the end of May 1998 around Mirbat where temperatures ranged from 29.5–31.5^{o}C. About 75–95% of Stylophora and 50% of large *Porites* colonies were bleached (Wilkinson, 1998).

In Saudi Arabia, severe bleaching was reported during 1996, which killed >90% of *Acropora* (Figure 3.6). The dominant reefs in the northern part of Saudi Arabia, *Porites,* were also damaged. Another bleaching took place during August 1998 when the sea temperature ranged from 35^{o}C to 36^{o}C. During that time, high mortality of *Acropora*, about (95%), and *Platygyma daedalea* were reported (Wilkinson, 1998).

Figure 3.6 *Acropora* colony

3.1.4.2 *Assessment and management of coral reefs*

Harrison and Al-Hazeem carried out an assessment of the health of coral reefs in Oman and UAE during November 1999. The study was initiated by ROPME and UNEP/ROWA to determine the extent of damage to coral reefs caused by the Crown of Thorns Starfish (COTS), *Acanthaster planci* and mass coral bleaching (Figure 3.7). The long-term objective was to develop a plan of action for monitoring the status of coral reefs throughout the Region. The findings from the survey are summarized below:

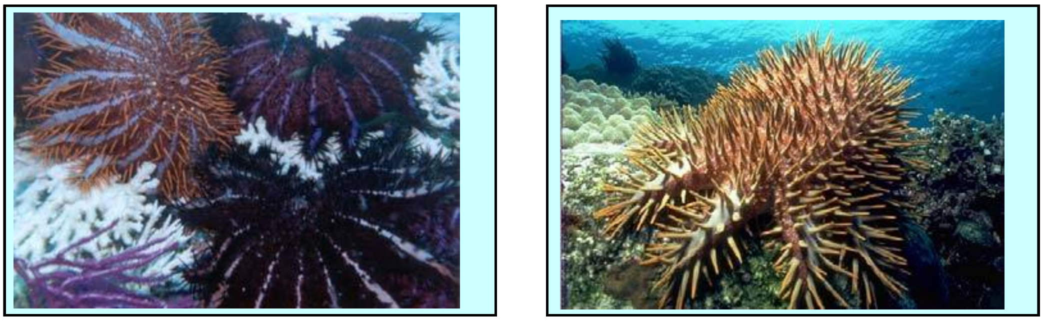


Figure 3.7 Infestation of Crown of Thorns, *Acanthaster planci*, on coral reefs

Significant numbers of COTS were recorded at most of the reefs examined. Crown of Thorns Starfish (COTS) have been reported from the Gulf of Oman over the last few decades, but reports from recent surveys indicate that the populations of these starfish have increased on some reefs (Harrison and Al-Hazeem, 1999). The two reefs at the Dimaniyat Islands were examined and ~25 COTS were observed or recorded at each reef. In some areas, COTS densities were as high as $0.3/m^2$, and significant recent mortality of corals was evident. Ten COTS were also recorded at the popular dive site of Bandar Khayran in Oman.

More than 1,000 COTS have been removed from the coral reefs in Oman and Khor Fakkan recently, and it is recommended that manual removal of COTS should be continued at reefs where ecologically significant and potentially destructive populations of COTS exist. After COTS are removed from the reefs, they should be destroyed by crushing the centre of the disc area.

At Khor Fakkan, UAE, 100 COTS were recorded on the island of Sirat Al-Khawr. Much of the southern area of the reef was severely impacted by COTS feeding, and no living branching corals were observed. Along the north-west area of this reef, a substantial aggregation of COTS was found, with a density of 0.3 COTS/m^2 counted in a transect area 30m long and 4m wide. This aggregation of COTS is ecologically significant and poses a threat to the viability of this small coral. Fifteen COTS were recorded on a mainland fringing reef adjacent to this island, and 13 COTS were recorded on Ras Lulayyah. Two COTS were seen on the fringing reef at Jabal Ras, while no COTS or recent feeding scars were evident on reefs near Zubarah or Jazirat Al-Ghubbah.

In Abu Dhabi, UAE, a number of COTS were recorded on most of the reefs surveyed, however, they were relatively low compared with major COTS outbreaks recorded on other Indo-Pacific reefs in recent years. The COTS populations are regarded as ecologically significant because of the high densities of COTS present compared with the relatively small reef areas, and the substantial recent mortality of corals in these areas. Because of the comparatively small areas of coral reef present in these regions, the dense COTS aggregations, the high rates of feeding and recent coral death observed in some reef areas, it has been concluded that these COTS aggregations pose a significant threat to the viability of some of these coral reefs. This is particularly true at Sirat al Khawr, where densities up to 0.3 COTS/m^2 were recorded on the small fringing reef, and high rates of coral mortality were evident. In other regions, similar densities of COTS have been described as an outbreak, and COTS have been removed to maintain these reefs.

Coral reef management issues encountered during this mission include problems with plastic and other litter, fishing nets abrading and smothering reef corals and other benthos, over-fishing, anchor damage to reef corals, coastal development burying near-shore fringing reefs, dredging causing increased sedimentation and decreased light, and chemical pollution. Some of these problems can be ameliorated effectively; for example, providing mooring buoys at popular anchor sites can prevent anchor damage.

3.1.5 Tidal mudflats

The most extensive mudflat systems are located in the NW of RSA in the proximity of the Shatt Al-Arab delta (Jones, 1986). This habitat constitutes a major part of the coastal areas in Kuwait. Studies of mudflats have been carried out in Saudi Arabia (Feltkemp and Krupp, 1994) and in Kuwait (Halwagy and

Halwagy, 1977; Jones, 1988; Al-Bakri *et al.*, 1989), which show that the cyanophyta-dominated algal mats covering mudflats, account for most of the productivity in the 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 make the greatest contributions to primary production in the RSA (Price *et al.*, 1993).

Mudflats are found in Bahrain on the north-eastern side in bays, which are relatively sheltered from the prevailing wind and wave action and thus their sediments are stable. At low tide shorebirds feed on the mudflats while at high tide their richness is exploited by many species of fish. Much of the natural production of mudflats is carried by these feeders into other areas of the coastal ecosystem. Several of these prime habitats have been and continue to be lost or degraded by coastal developmental activities (Nightingale and Hill, 1993). In I.R. Iran, intertidal mudflats are located in Kolahi, Jask, Sirk and to the north of Qeshm Island (MNR–I.R. Iran, 2003).

Tidal mudflats also provide a good ecosystem for a variety of benthic communities such as crabs, snails, bivalves, polychaetes, sea stars and sea urchins (MNR–Kuwait, 1999). Tidal mudflats also include sabkhas that 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.

3.1.6 Protected areas

There are eight parks and reserves already established along the coasts of the Region, and over 85 sites have been recommended for protection (NFP–Bahrain, 2000; Krupp, 2002; MRMEWR–Oman, 2003; MNR–UAE, 2003). The sites of proposed and established coastal and marine protected areas are given in Figure 3.8. Of the protected areas, some areas are also covered by international conventions and programmes. One site is listed under the international MAB–Unesco Biosphere Reserve Programme: Harra Protected Area in I.R. Iran (Mangroves area); while four sites are recognized as wetlands of international importance under the Ramsar Convention: the Shadegan marshes and mudflats of Khore Al-Amaya, the Khuran Straits, the deltas of Rud-e-Shur and the deltas of Rud-e-Gaz. In Iraq, most of the important nature conservation areas in the country are unprotected although many have been recommended for future protection as national parks or reserves. The coastline of Iraq is restricted to an area next to Faw by the mouth of the Shatt Al-Arab. Little-developed areas recommended for protection include the mudflats near Al-Faw, and Khor Zubair/Khor Abdullah (WCMC, 1991).

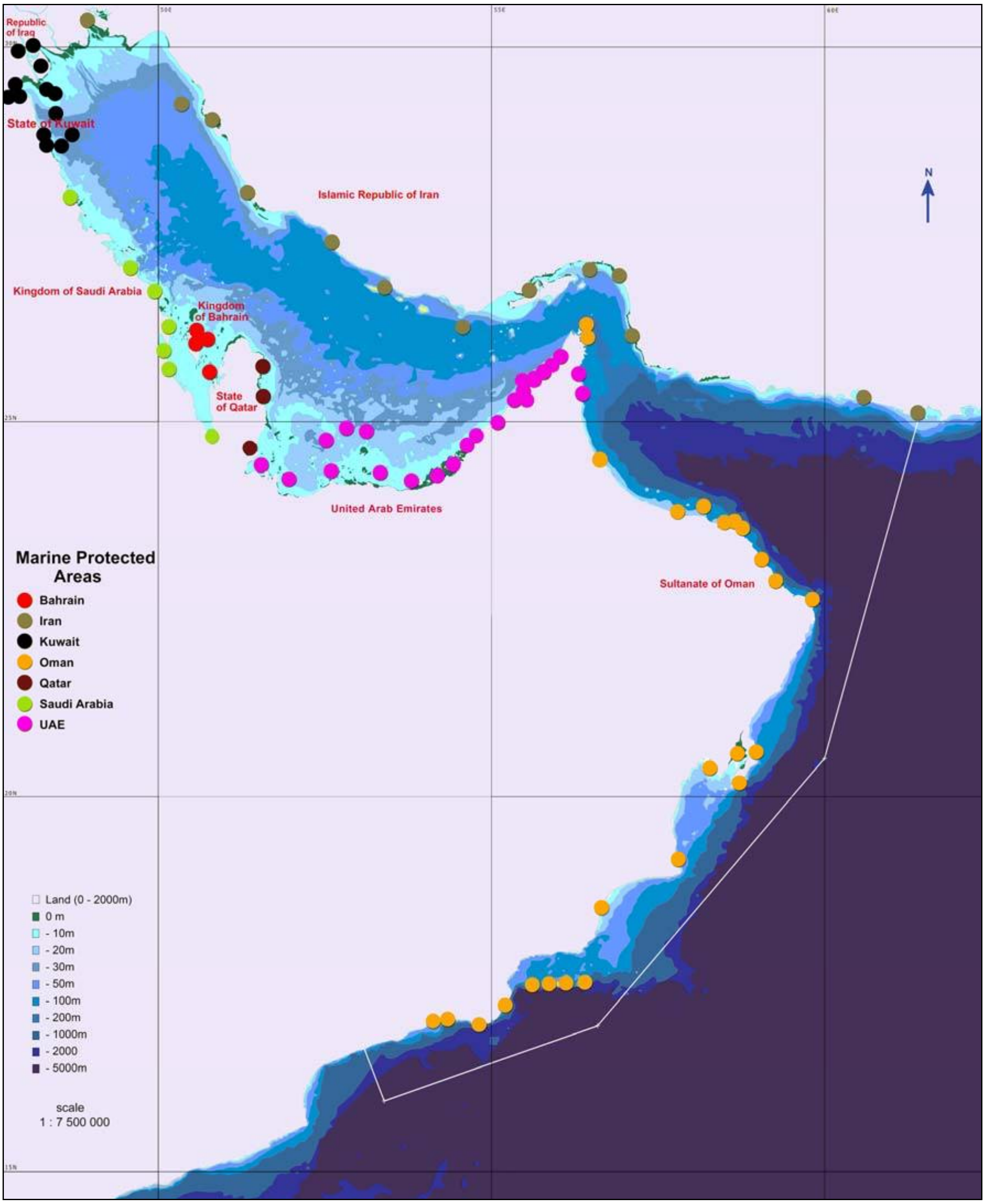


Figure 3.8 Sites of proposed and established coastal and marine protected areas

3.2 Living Marine Resources

3.2.1 Crustacea

3.2.1.1 *Shrimps*

Among crustaceans, prawns are one of the most important seafood commodities as they command a high price and are greatly demand in the export market. Most of the species are distributed over a wide geographical area and support commercial fisheries in the Region. They are mainly confined to the inner half of the continental shelf. Shrimp fishing 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). The richest resources are found off the coasts of I.R. Iran and Kuwait, with smaller catches taken from the Bahraini, Omani, Qatari and Saudi Arabian waters.

In Bahrain, Tubli Bay and shallow areas south of ‘Fasht Al-Adham’ are known for their importance to penaeid shrimps. Seven penaeid species are found in this area; however, commercial shrimp landings are mainly from a single species, *P. semisulcatus*. The six other remaining species make up about 5% of annual shrimp landings. Two species *P. latisulcatus* and *Metapenaeus kutchensis* grow to a good size. The remaining four species *M. stebbingi*, *Trachypenaeus curvirostris*, *Metapenaeopsis stridulans* and *M. mogiensis* are smaller and are usually partially or entirely discarded. Catches of small sized shrimp frequently exceed the amount of big shrimp catches at the end of the season (February and March). Shrimp trawlers are responsible for over-fishing of the main shrimp species, *P. semisulcatus*. Evidence of this is to be found in low catch rates and smaller shrimp sizes observed by the GCC survey. Trawlers are likely to have less impact on the spawning stock of this species (Abdulqader, 1999).

The shrimp, *M. affinis*, contributes substantially to the total shrimp catch in Kuwait. The quantity of catch varies from season to season and the contribution has been recorded as 40% to 50%. The intertidal mudflats of Kuwait and the marsh system of the Tigris and Euphrates Rivers in Iraq had served as nursery habitats for *M. affinis*. Although there is no direct evidence of shrimp migrating from Iraq's inland waters to the northern RSA, it is thought that Kuwait's population of *M. affinis* has been enhanced by recruits from the Iraqi marshes. After the destruction of tens of thousands of hectares of marshlands in Iraq (above Basrah), the volume of *M. affinis* will likely decrease. However, *P. semisulcatus* species was found in southern Kuwaiti waters. Throughout their range, the nursery habitat of juvenile *P. semisulcatus* is characterized by benthic vegetation (Al-Foudari, 2000). *Parapenaeopsis stylifera* has also been found in low percentages among shrimp catches in Kuwait.

In Omani waters, a total of twelve species of the penaeid group of shrimps are known to occur (Cheney, 1985), of which four species contribute to commercial fisheries. These are *Penaeus indicus*, *P. semisulcatus*, *Metapenaeus monoceros* and *M. stebbingi* (Johnson, 1989). The most important commercial species are the *P. indicus* and *P. semisulcatus*. Commercial fishing of shrimp is carried out by traditional fishermen using cast nets, and is confined to the South Sharquiyah region around Mahout Island in the Gulf of Masirah in Arabian Sea. Occasionally, small quantities of shrimps are caught in other regions of Oman, both in the Arabian Sea and Gulf of Oman. The spawning of shrimp species is recorded by collecting them in very early planktonic larval stages from the waters of Mahout. The major nursery ground for shrimp is located in the Mahout waters, a place where a variety of seagrass and rich seaweed communities and a dense growth of mangrove are found. Shrimp seeds have also been recorded in many other mangrove ecosystems, both in the Gulf of Oman and in the Arabian Sea coast of Oman.

Commercial fisheries production of shrimp over a period of fifteen years (1986–2000) ranged from 65 to 586 tons in Oman (Figure 3.9), with the minimum recorded in 1998 and the maximum in 1989 respectively, and an export market value of approximately US$ 0.3 to 2.3 million (Anon, 1991, 1992, 1993, 1998 and MRMEWR–Oman, 2003). Shrimp fishing is a seasonal activity beginning in late August or early September and closing at the end of April with the appearance of young ones in the beginning of the season and disappearance of adults from the fishing ground at the onset of south-west monsoon.

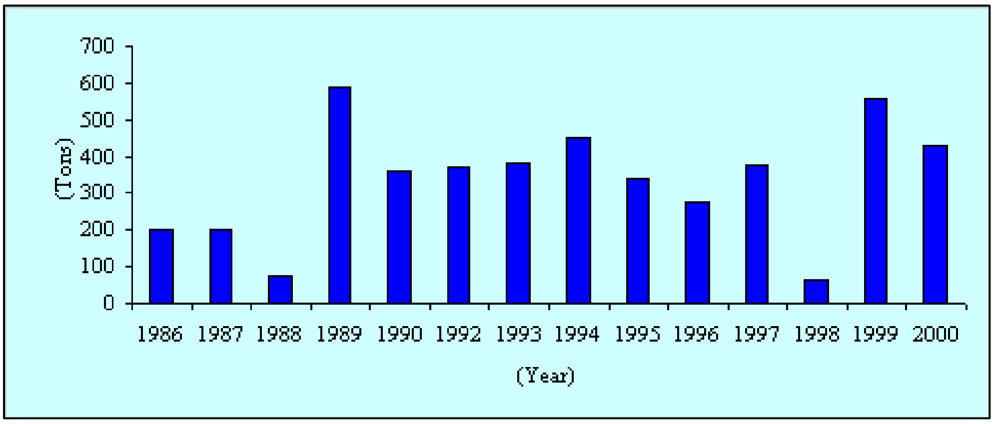


Figure 3.9 Total catch of shrimps in Oman during 1986 – 2000

3.2.1.2 <u>Lobsters</u>

There are four families of lobsters belonging to the crustacea super class, of which the spiny or rock lobsters (family Palinuridae) and the slipper lobsters (family Scyllaridae) are found in the RSA. Among the spiny lobsters, two species such as the scalloped spiny lobster *Panulirus homarus* and the painted spiny lobster *P. versicolor* are commercially exploited in Oman.

The species *P. homarus* is found along the south Arabian Sea coast from Dhalkut to Ra’s Al-Hadd and along Masirah Island. However, *P. versicolor* is found in the Gulf of Oman (North of Ra’s Al-Hadd) but is not found further south in the Arabian Sea off the Oman coast. The lobster catch in Oman is almost entirely (>90%) made up of the P. *homarus* species. The highest catches were registered in 1987 and 1988 and averaged about 3,000 tons. Current catch is about 1,000 tons per year. Current regulations limit harvesting of the species to two months, December and January, during the peak spawning period (Al-Abdessalaam, 1995). However, lobster catch has declined considerably in recent years to 402 tons in 2000 (MAF–Oman, 2002). The spiny lobster tends to shelter in and around coral and rocky reefs and crevices (Figure 3.10).

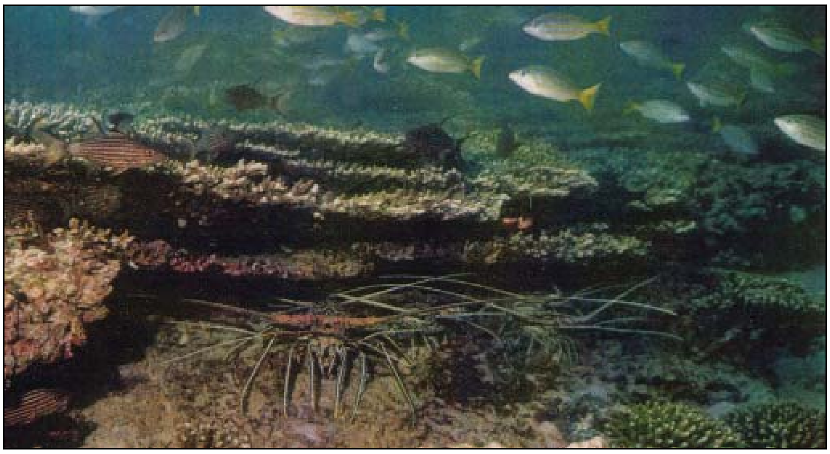


Figure 3.10 Spiny lobster, *Panulirus homarus*, inhabit the crevices of coral reefs

The family Scyllaridae, shovel nose lobster, *Thenus orientalis*, is common in shrimp by-catch in Bahrain (Abdulqader, 1999). This species is found in fish trawls in large quantities during October to January. Nearly 200 tons of shovel nose were landed in a year (FSS, 1998). Although there is no established fish industry in Oman, this species is often found in the traditional beach seines catch along the middle RSA coast of Oman. The other species, *Scyllarides squammosus* commonly occurs in traps and is occasionally caught by divers and in trawl fishing in Oman. These species are not targeted in Oman and there are no estimates of their abundance.

3.2.1.3 <u>*Crabs*</u>

Crabs are found in a variety of habitats from dry land to considerable depths at sea. Most crabs cannot swim but some (members of family Portunidae) are the most powerful and agile swimmers of all crustaceans. The last pair of legs in members of this family is modified into broad, flattened paddles. Some species of marine crabs such as mud crab, sand crab, etc. are commercially important.

Crabs belonging to the Grapsidae and Ocypodidae families are a dominant faunal element of intertidal flats and mangroves in the RSA. A survey of the coasts of Saudi Arabia and the UAE and the species collected from other parts of the RSA revealed a total of six species of grapsid and 21 taxa (species and subspecies) of ocypodid crabs occurring in these habitats within the RSA. Great differences in species diversity and composition exist between different parts of the RSA. The highest diversity was observed in the easternmost part of the UAE (Ras Al-Khaimah, Umm Al-Quwain) and Kuwait. Highly reduced species numbers were observed along the shorelines of Abu Dhabi and Saudi Arabia. The most likely explanation for this pattern is salinity. Zoo-geographically it appears that most of the RSA species are of an 'eastern' (Indian) origin. 'Western' (East African, and Red Sea) species are restricted to the south-eastern part of the RSA (coast of the UAE) and to the Gulf of Oman (Apel and Turkay, 1999).

In Oman, several species of crab occur in different habitats from sandy coasts to coral reefs, however seven species of crab are well documented. They are the matuta crab, *Matuta victor*; sand crab, *Portunus pelagicus*; mud crab, *Scylla serrata*; coral crab, *Carpilius convexus*; calico crab, *Eriphia smithi*; light foot crab, *Grapsus tenuicrustatus*; and the ghost crab, *Ocypode* sp. (Al-Abdessalaam, 1995). Among these, *P. pelagicus* and *S. serrata* are commercially exploited and locally sold (Figure 3.11). *P. pelagicus* is also caught in Kuwaiti waters and locally marketed.

Sand crab, *Portunus pelagicus*

Mud crab, *Scylla serrata*

Figure 3.11 Commercially important species of crab in the RSA

3.2.2 <u>Molluscs</u>

3.2.2.1 *<u>Gastropods and bivalves</u>*

Abalone is herbivorous gastropod, and belongs to phylum molluscs and genus *Haliotis*. There are about 75 known species of abalone inhabiting certain temperate and sub-tropical coasts of the world (Uki, 1987). The abalone fishing industry in the RSA is restricted to Omani waters and only has one species, *Haliotis mariae* (Figure 3.12). It is confined to the Dhofar region on the Arabian Sea coast of Oman. In Oman, the abalone is of major commercial importance for the fishing industry and fetches high prices in both local and international markets.

Figure 3.12 Abalone, *Haliotis mariae*

The fishing industry in Oman took off in earnest in the 1950s and intensive fishing started in the 1980s. The principal areas of fishing in the Dhofar region are Mirbat, Sadah, Hudbin and Sharbithat where there is a higher biomass of seaweeds. Among the fishing products from the RSA, abalone fetches the highest price both on the local and export markets. Until 1990, the price of a kilogram of fresh abalone ranged from US$60 to US$75. From 1990 onwards the price ranged from US$105 to 120US$/kg. In 1997 the price reached a high of US$195/kg. The price for dried abalone now ranges from US$650 to US$780/kg. Fish stocks are now being depleted because of over-fishing. In 1986 and 1987, the highest catch recorded was 60 tons, while the lowest (31.7 tons) was recorded in 1998 (Figure 3.13). Nevertheless, the annual catch in 2000 increased to 45 tons (MAF–Oman, 2002).

In the RSA, pearl producing bivalve oyster beds surrounding Bahrain are among the best in the world but commercial pearl fishing has more or less died out as a consequence of the fall in pearl prices owing to the mass production of cultured pearls by the Japanese, as well as the tendency of younger generation to work in the oil industry rather than to get involved in the dangers and insecurity of pearl diving. Pearl oysters belonging to the genus *Pinctada* are found in the RSA. Of the eight species of *Pinctada*, five are newly recorded in the RSA incuding, *Pinctada maculata, P. anomioides, P. rutila, P. sugillata* and *P. nigra* (Khamdan, 1993). *P. radiata* is both a common and abundant species in Bahraini waters. However, *P. margaritifera* is abundant around the islands of Hinderabi, Shaik Shuaib, Kais Island and Chira on the Iranian coast. It is also found at the Das, Daurnein and Zernkah islands and off the Oman coast between Ras Al-Khaima and Ghobat Ghazira. *P. radiata* and *P. margaritifera* are found along the Oman coast of the Gulf of Oman. *P. radiata* is the most common pearl oyster in Kuwait and Saudi Arabian waters.

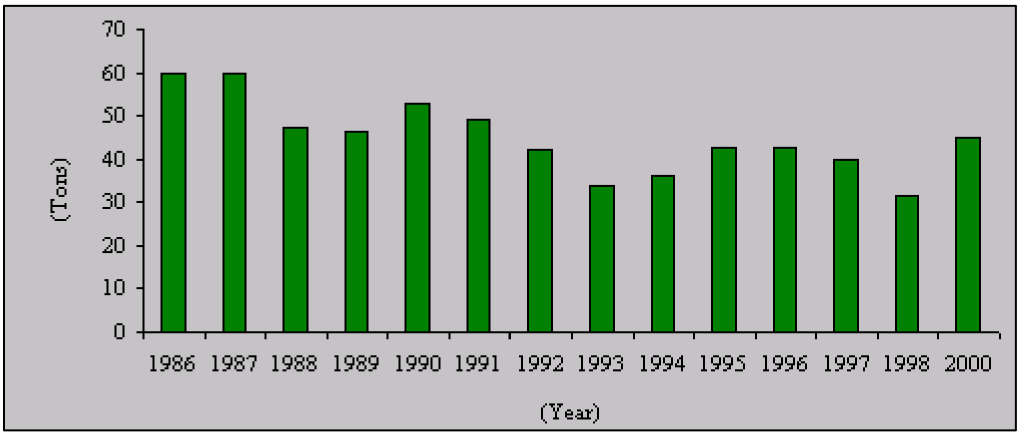


Figure 3.13 Total catch of abalone in Oman during 1986 – 2000

3.2.2.2 <u>*Cephalopods*</u>

Among the cephalopods, squids, cuttlefish and octopods are the most commercially important groups occurring in the waters of the RSA. Members of this class cephalopoda are the most specialized and highly organized of all molluscs and their bodies are adapted for swimming. They occur in a variety of habitats. Some are benthic and occur in coral reefs, grass flats, sand, mud and rocks, while others are epibenthic, pelagic and epipelagic and are found in bays, coastal waters and open oceans over a wide range of depths which extend from the surface down to depths of 500m. Many *Octopus* species have cryptic habits and live in dens located in crevices and holes. They are found in the RSA fish markets, especially in the regions of Dhofar and Musandam where they are quite common, however there is no particular fishing industry for them in Oman. The *Octopus aegina* is often caught with traps and hooks and lines in Oman. The pharaoh cuttlefish, *Sepia pharaonis* is an important commercial species in the RSA (Figure 3.14). In Oman, although found along the entire coastline, the species is particularly common from Ra's Al-Hadd southward. Spawning occurs round the year with peaks from September to December and April to June in Oman. Cuttlefish catches in Oman average 200 tons a year, and are caught traditionally by traps, setnets and handlines. However, the majority of the catch comes from the industrial Korean trawlers. The cuttlefish catch has increased to 2,891 tons in 2000 (MAF–Oman, 2002).

Figure 3.14 Pharaoh cuttlefish, *Sepia pharaonis*

3.2.3 Fishes

There is a generally low diversity of fish species found in the RSA as this Region is predominantly arid and subtropical. However, individual species occur in high numbers (Fouda, 1997). The inner part of the RSA supports more than 500 fish species, most of which live in pelagic or soft substrate demersal habitats (Price *et al.*, 1993); at least 125 species are found on the reefs (Sheppard *et al.*, 1992); about 130 fish species are known to occur in Kuwait; 71 species in Bahrain (Smith *et al.*, 1987); and 106 species from reefs in Saudi Arabia (McCain *et al.*, 1984; Coles and Tarr, 1990; Krupp and Muller, 1994).

A fish survey was carried out in the inner RSA between Kuwait and Qatar during the R/V Mt. Mitchell expedition in late April–early May 1992. During the survey, a total of 790 fishes, including 45 species, were collected. The highest number of fishes, more than 40%, were found in Kuwait Bay, followed by 18% at Manifa-Saudi Arabia, 15% at north Abu Ali, and 11% between Bahrain/Qatar. The most dominant fish species were the slipmouth (*Leiognathus fasciatus*), the pigface bream (*Lethrinus kallopterus*) and the therapon (*Therapon puta*), comprising 27.4%, 11.5% and 11.4% respectively of the total catch (Hashim, 1993).

A survey conducted in the middle and outer RSA by R/V Rastrelliger of FAO in 1989–1990 revealed that the estimated fish biomass was 70,290 tons (17%) and 343,903 tons (83%) in the middle and the outer RSA respectively (Thangaraja, 1995). In Oman, a total of 1,142 species were identified, belonging to 520 genera and 164 families. Most of these are marine species with a broad geographical distribution; only four were freshwater species (*Cyprinion micropthalmum, Garra barreimie, G.longispinnis* and *Oreochromis aureus*).

The Arabian Sea and the Gulf of Oman have a greater diversity of fish species (about 1,000 fish species) than the inner RSA (>500 fish species). More than 400 species are demersal, 511 species inhabit coral reefs and coastal lagoons, two are mesopelagic species, and the remainder are pelagic (157), bathypelagic (30), and bathy demersal (7 species) (Fouda *et al.*, 1998). Current fishing levels of some target species are either close to the maximum sustainable yield or exceed it. A shift in species composition has resulted in declining landings of some high value fishes.

In the inner part of the RSA, environmental extremes 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 observed on the well-developed offshore reefs of Saudi Arabia, while seasonal variations in these parameters are particularly high on the nearshore reefs (Coles and Tarr, 1990; Krupp and Muller, 1994). Moving northwards and southwards from Saudi Arabia, fish diversity falls off as environmental conditions become more extreme. The richest reef fish fauna is to 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 flowing in through the Strait. On the other side, the high diversity of Oman's fish fauna is explained by the diverse coastal habitats, wide climatic spectrum and its unique geographic location at a site of upwelling in the north-western region of the Indian Ocean (Fouda, 1997).

3.2.4 Marine reptiles

3.2.4.1 *Turtles*

In the RSA, the marine turtle population consists of a small resident population of individuals which are sometimes found in seagrass areas, and a much larger migratory population, which breeds on offshore coral islands, including the Karan and Jana islands of Saudi Arabia. The turtle species found in the Region include the Green turtle *(Chelonia mydas)*, Hawksbill *(Eretmochelys imbricata)*, Leatherback (*Dermochelys coriacea)*, Loggerhead *(Caretta caretta*) and Olive Ridley *(Lepidochelys olivacea)*. The female turtles come to the beach for nesting, while the males stay in the offshore waters (Figure 3.15).

The Green turtle, Hawksbill, Leatherback and Loggerhead (*Chelonia mydas, Eretmochelys imbricata, Dermochelys coriacea* and *Caretta caretta*) have all been reported in Bahrain.

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 Qeshm Island and from Tang (Bandar Tang) to the Pakistani border (Ross and Barwani, 1981; Groombridge, 1982).

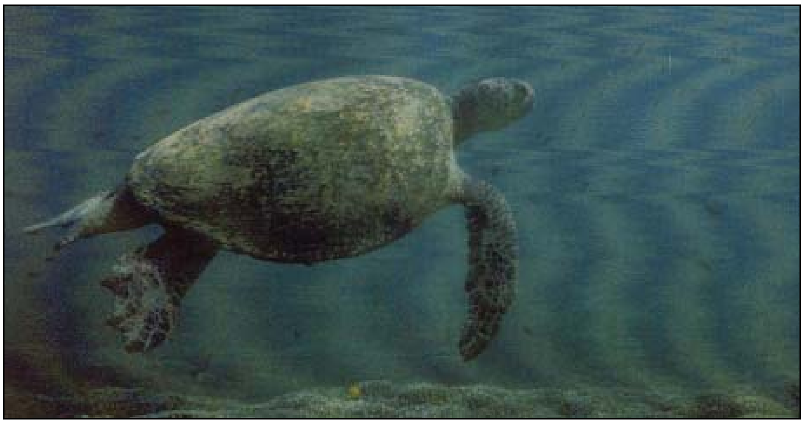


Figure 3.15 A swimming male green turtle, *Chelonia mydas* in the inshore waters of the RSA

In Kuwaiti waters, three species of turtle are commonly found, namely, the Green turtle, Hawksbill turtle and Loggerhead turtle. However, Al-Mohanna and Meakins (2000) reported the presence of Leatherback turtles in Kuwaiti waters. All three species regularly breed and nest in Kuwaiti waters, particularly the islands. Turtle nesting periods vary with the Hawksbill nesting in April–May and Green turtles in June–July. The migratory bird *Sterna* spp. (terns) and the ghost crab *Ocypode rotundata* are the major predators of the turtle hatchlings in Kuwait.

Four species of sea turtle nest in Oman and a fifth species, the Leatherback (*Dermochelys coriacea*) is occasionally found in coastal waters. Three turtle nesting locations in Oman are of international significance. Masirah Island has the largest nesting population of Loggerhead turtles and also supports nesting of Green turtles, Hawksbill turtles and Olive Ridley turtles. A significant feeding area for Green turtles is also found adjacent to Masirah in the Masirah Channel. The beaches at Ra's Al-Hadd support one of the three very large nesting aggregations of Green turtle known in the northern Indian Ocean, while the Damaniyat Islands support extensive Hawksbill turtle nesting. Sea turtles (mostly Green turtles and Hawksbill turtles) nest in smaller numbers and are found on scattered feeding areas throughout the coastal waters of Oman.

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. Oman probably plays host to the greatest number of nesting Green turtles of any single Indian Ocean nation. It has also been confirmed that Masirah Island hosts the world's largest nesting population of Loggerhead, estimated at 30,000. Other significant sites are found along the Dhofar coast and around the Al-Halaniyat Islands in the outer RSA. Hawksbill turtles exist in considerable numbers notably at Daymaniyat Island. Olive Ridleys only nest on Masirah Island and Masirah Channel, and are much less abundant than Greens, Loggerheads and

Hawksbills, while Leatherbacks only feed in the offshore waters of the outer RSA.

In Qatar, the island of Sharaawh hosts nesting populations of Hawksbill turtles (*Eretmochelys imbricata*); hatchlings are seen in early July but nesting numbers are reportedly very low (Ross and Barwani, 1981). The *Chelonia mydas* species has also been reported in Qatari waters (WCMC, 1997).

In Saudi Arabia, areas such as Karan (primary site), Kurayn, Jana, Harqus and Jurayd are nesting grounds for large numbers of Green turtles. Estimates made during the early 1980s suggested that about 2,000 females nested on these islands each season, which extends from May to September; subsequent data suggest a downward revision of this estimate, to between 500 and 1,000 females per season. Females nest every second or third year, so the total number of females using the area will be two to three times these figures (which do not include males or immature turtles), (WCMC, 1991).

3.2.4.2 Sea snakes

Sea snakes (family: Hydrophiidae) are the most venomous snakes in the world. They have vertically compressed tails and very small ventral scutes for use in swimming in marine habitats. At least nine species of sea snake occur in the RSA including *Enhydrina schistosa*, *Hydrophis cyanocinctus*, *H. lapemoides* (Figure 3.16), *H. ornatus*, *H. spiralis*, *Lapemis curtus*, *L. viperina (= Praescutata viperina)*, *Microcephalophis gracilis (= Hydrophis gracilis)*, *Pelamis platurus* (WCMC, 1991). The hook-nosed or beak-nosed sea snake, *E. schistose*, is the most dangerous species and the annulated sea snake, *H. cyanocinctus*, is considered to be the second most dangerous species in the Region (Gallagher, 1990).

Figure 3.16 Sea snake, *Hydrophis lapemoides*

Very little is known about the global population of sea snakes in general, and even less is known about their status in the RSA. The *Hydrophis* is the most popular species. The group is generally found in muddy, warm waters, and its 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).

Recent studies in the Iranian part of the inner and middle RSA, revealed the presence of seven species of sea snake in Iranian waters among the nine species recorded, which includes one additional species, *Hydrophis gracilis* (Safaei, 2001).

3.2.5 Birds

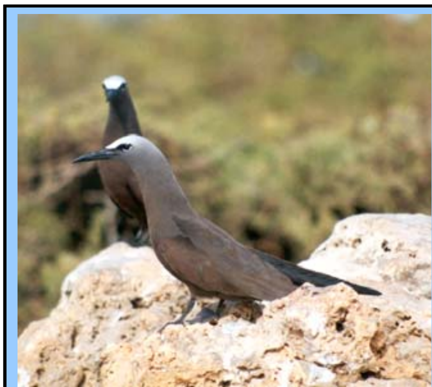
Gallagher *et al.* (1984) recorded huge numbers of seabirds especially Socotra Cormorant and terns Sterninae (Bridled Tern, White-cheeked Tern, Lesser Crested Tern) breeding on the offshore islands in the RSA. The intertidal zone is estimated to support up to four million waders in winter, making the RSA one of the five most important regions of the world for wintering waders (Zwart *et al.*, 1991). In winter and other migratory seasons, about 20 other water bird species including grebes, cormorants, herons, flamingos, gulls and terns are also found in the intertidal and shallow subtidal zones of the RSA. Mudflats support higher wader feeding densities than either rock flats or sand flats. Extensive mudflats occur along the shores of most of the inner part of the RSA. Important species found in the area include oystercatchers, ringed plovers, lesser sandplovers, little stint, dunlin and others.

The islands of Bahrain are of international importance because they are home to a small colony of breeding Sooty Falcon (*Falco concloor*) and a large proportion of the world's population of Socotra cormorants (*Phalacrocorax nigrogularis*). The flamingo (*Phoenicopterus ruber*) is present throughout the year, and the Osprey (*Pandion haliaetus*) breeds there as well.

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

There are at least 300 species of birds representing 55 families listed in Kuwait (Alsdirawi, 2002). One hundred and thirty seven species, over 45% of Kuwait's total, have been recorded in the coastal intertidal ecosystem alone. The coastal population of birds includes 45 species of waders (33%) and 65 species of waterfowl (47%), which are regular users of the coastal areas. It is estimated that more than 53% of the breeding birds in Kuwait are coastal. It is worth mentioning that some of these coastal breeding birds such as spoonbill (*Platalea* *leucorodia*) and crabplover (*Dromas ardeola*) have not recently been recorded as breeding in Kuwait. The oldest egg collection gathered from Warba Island was carried out in May 1878 for the Western reef heron (*Egretta gularis*) (Alsdirawi, 1989). It is well established that coastal birds, especially waders and waterfowl, are good indicators of habitat quality (Evans, 1992; Harbard and Wolstencroft, 1992). Unfortunately such rich and diverse natural resources are currently under the threat. In 2001, UNEP–WCMC listed 15 species of birds as threatened in Kuwait, 60% of which are coastal birds.

The most suitable habitats for birds found in Oman include offshore waters, islands and islets, coastal cliffs, the rocky shores in Musandam, the sandy beaches of the Batinah Coast, the tidal flats in Bar Al-Hikman, the Khawr environment and mangroves. The most common birds found in these habitats include cormorants, herons, egrets, spoonbills, flamingos, many waders, gulls, noddys and terns (Figure 3.17). Bar Al-Hikman and the surrounding areas, including Mahout Island, host internationally important concentrations of shore birds, notably crabplovers, sandplovers, dunlies and redshank.



Common noddy, *Anous stolidus*

Bridled tern, *Sterna anaethetus*

Figure 3.17 Birds photographed in Oman

Seabirds breed in high numbers in the islands of Oman, including Socotra cormorants and masked boobies on the Al-Halaniyat Islands (Mendonca *et al*., in press a). Terns and colonies of sooty gulls nest on the Dimaniyat Islands (Mendonca *et al*., 2001) and Hino Island in the Dhofar region (Mendonca *et al*., in press b). Birds of prey such as osprey and sooty falcons also nest on the Dimaniyat Islands and Al-Halaniyat Islands (Mendonca *et al*., 2001, in press a).

Oman’s coastal zone supports huge numbers of wintering and migrating birds, and of breeding and non-breeding bird species (Eriksen, 1998, 2000). Midwinter counts by a modest number of observers covering only a fraction of the coastline estimate the total mid-winter population to be 300,000–500,000 water birds, belonging to 90–110 species, most of which are shorebirds identified at a single site in Barr al Hikman, opposite Masirah Island. Recent records suggest that the globally endangered slender-billed curlew *Numenius tenuirostris* winters in this area regularly in significant numbers (MRMEWR–Oman, 2003).

The status of breeding colonies of seabirds from several localities around the coast of Qatar and on its islands was studied by Gallagher *et al.* (1984). The study included four species of terns (*Sterna* spp.) and occasionally the Socotra cormorant (*Phalacrocorax nigrogularis*).

In Saudi Arabia, the highest numbers of wintering waders were found on the intertidal mudflats of Tarut Bay, Dawhat and Dafi and the north-western 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 the RSA the number may be as high as 1–2 million. The offshore islands of Saudi Arabia provide major nesting sites for at least three different terns. The most common 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 is the breeding area for a large part of the world's population. Other seabirds such as the Socotra cormorant, a species confined to the Arabian Peninsula, also breed along parts of the western RSA coast.

In the mangroves of UAE, the endemic Kalbaensis subspecies of white-collared Kingfisher *Halcyon chloris* breeds in a single locality – Khor Kalba, Sharjah with a total (world) population of only 44 pairs (Aspinall, 1996). Other important species includes, the Booted Warbler *Hippolais caligata*, which breeds at Khor Kalba and nowhere else in Saudi Arabia, two colonies of crabplover *Dromas ardeola* in Abu Dhabi Emirate, sustained by mangrove-dwelling crabs – these are 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*. The mudflats of UAE support huge numbers (1–3 million) of visiting waterfowl annually.

3.2.6 Marine mammals

The occurrence of dugongs in the RSA is limited to the inner RSA, between Ras Tanura, in Saudi Arabia, and Abu Dhabi, in the United Arab Emirates. The most important dugong habitats in the inner RSA occur on either side of Bahrain, in the pocket of Saudi Arabian territory between Qatar and the UAE, and to the west of Abu Dhabi. Dugongs are not seen in I.R. Iran, Iraq, Kuwait and Oman waters. Herds of dugongs were observed on the seagrass beds, where the largest ever recorded herd of over 600 individuals was spotted in the Gulf of Salwah between the Bahrain and Qatar peninsula. The estimated population of dugongs in the RSA is 7,310. This makes the inner RSA the most important area for the dugongs in the western half of its distribution range, and one of the most important known areas outside of Australia (Preen, 1989). Other marine mammals of interest include whales and dolphins, i.e., Brydes whale and the Humpback whale, the Bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific humpbacked dolphin. Other dolphins and whales known to inhabit adjacent parts of the Indian Ocean are also likely to occur in the inner part of the RSA.

The dolphin species of the RSA were reported by Basson *et al.* (1977). The finless porpoise, *Neophocaena phocaenoides*, is also found in the RSA. Three to four great whales have also been recorded, although it is probable that these animals are not resident but get stranded after becoming trapped (Chiffings, 1998).

In Omani waters, about 20 dolphin and whale species representing 25% of all known species in the world were found to exist (Baldwin and Salm, 1994). They vary greatly in size from the slender agile spinner dolphins (<2m in length) to the huge sperm whales >20m in length). The inshore and offshore waters of Oman support 15 species of toothed whales and dolphins (Odontoceti) and four species of baleen whales (Mysticeti). The Indo-Pacific humpback dolphin, common dolphin (*Delphinus delphis*), spinner dolphin (*Stenella longirostris*), pan-tropical spotted dolphin and Bottlenose dolphin (*Tursiops truncatus*) 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. A pod of over 1,500 spinner dolphins was observed about 4km offshore in the waters of Sur in the Gulf of Oman (Wilson and Baldwin, 1997).

Of the toothed whales, sperms and false killer whales are the most common while Bryde's minke and humpback whales seems to be the most common of the baleen whales. Species recorded at different times in Omani waters in the middle and outer RSA include the Humpback whale (*Megaptera novaeangliae*), False killer whale (*Pseudorca crassidens*), Pygmy killer whale (*Feresa attentuata*), Sperm whale (*Physeter macrocephalus*) and Pilot whale (*Globicephala* sp.). Among these, the Humpback whale is found round the year in Omani waters. There were also a few reported incidents of entanglement of whales in gillnets in Omani waters.

3.2.7 Dangerous marine organisms of the RSA

Among the marine living resources of the RSA, certain species are dangerous to human beings, causing injury or intoxication during direct encounters. Many serious incidents can be avoided through an increase in public education and awareness. It is therefore important to list the dangerous organisms which pose threats to human beings in the Region. Marine organisms which pose threats to human beings belong to both invertebrate and vertebrate groups (Figures 3.18–3.21).

3.2.7.1 *Venomous invertebrates*

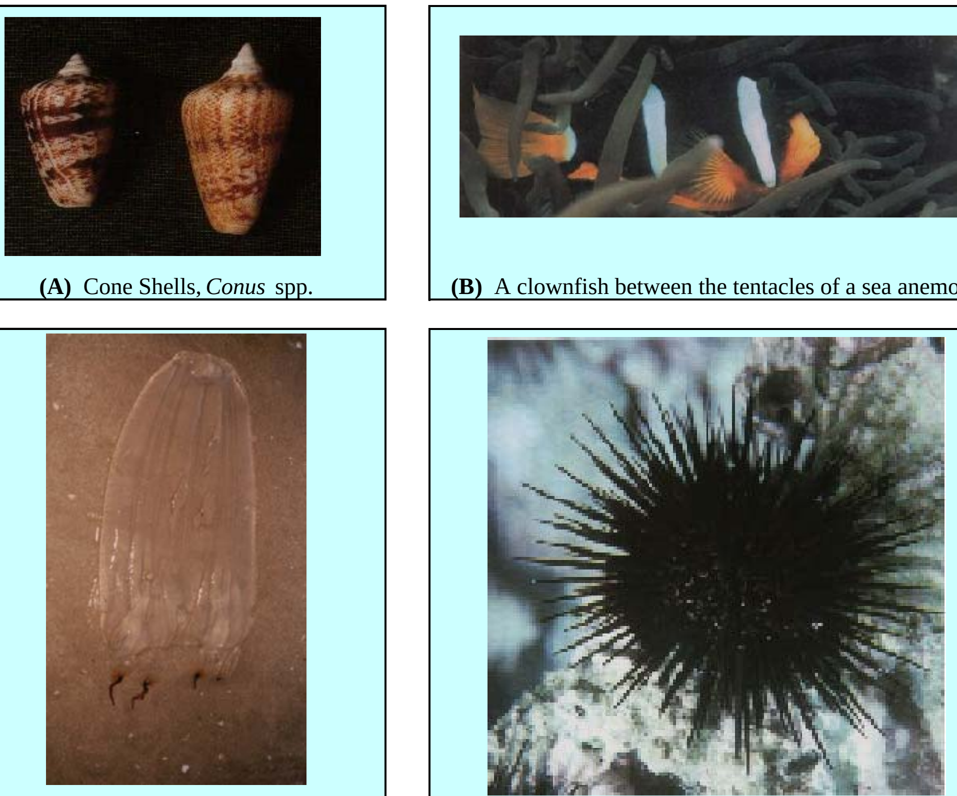
The effects of invertebrate venom on humans range from mild irritation to sudden death. Invertebrates that possess some kind of venomous apparatus belong to one of five large phyla such as Porifera (sponges), Cnidarians (sea anemones, hydroids, corals and jellyfish), Annelida (bristleworms), Mollusca (marine snails and Octopuses), Echinodermata (sea urchins and sea stars).

Sponges are simple multi-cellular animals that live principally in the shallow coastal waters of the RSA. They live on substratum such as seaweeds or hard substances like rock or shells. Many are harmless to humans; however, toxic species are also found. Their most common undesirable effect is painful skin irritations.

Cnidarians fall into four groups, the Hydrozoa (Hydroids 'fire corals', Medusae and Siphonophora), Scyphozoa (free swimming jellyfish), Cubozoa (tall, box-shaped medusae) and Anthozoa (hard corals, soft corals and anemones). Hydroids and jellyfish possess nematocysts (stinging capsules) which, when the cnidae thread is discharged, penetrate the prey and inject a toxin. Sea anemones (Figure 3.18B) and true corals on the other hand have spirocysts or ptychocysts with adhesive cnidae threads. Most of the 2,700 species of hydrozoa known worldwide are harmless, but some, such as fire corals and Portuguese man-of-war can inflict painful stinging injuries on humans.

Scyphozoa are the true jellyfish. They are capable of stinging but not all are a hazard to human health. Species of some genera such as *Cyanea* and *Pelagia* occur in large groups or 'swarms' in the middle and outer RSA, and cause discomfort to fishermen and swimmers (Thangaraja *et al.*, 1999). Species such as *Chironex* sp., *Chiropsalmus* spp. (Goonewardene, 1986; Cooper, 1991), *Chiropsalmus quadrigatus* and *C. quadrumanus* (Halstead *et al.*, 1990), *Cyanea capillata* and *Physalia* sp. (Goonewardene, 1986), *Carybdea* sp. (Figure 3.18C), *Cyanae* sp. and *Pelagia noctiluca* (Thangaraja *et al.*, 1999) are found in Omani waters. Seventy-five cases of jellyfish sting were recorded in Oman from September 1991 to August 1992. The victims were stung in the area round Muscat, the capital city, and were admitted to the Muscat Khoula hospital. Of the affected people, 52 were males, 22 females and 11 children. The time of the sting indicated that 73% were stung in the evening, 18% at noon and 9% in the morning. All patients who received hospital treatment made a full recovery and there were no fatalities (Chand and Victor, 1992).

Hard corals (Anthozoa) often cause abrasion injuries when a bather simply brushes against their hard branches. Certain coral colonies possess stinging nematocysts (Goniopora, Plerogyra, Physogyra), which can leave a rash if touched. The majority of Sea anemones in the RSA are harmless except when their tentacles come into contact with delicate parts of the body such as the face, lips, and under arms, resulting in a painful sting.



(A) Cone Shells, *Conus* spp.

(B) A clownfish between the tentacles of a sea anemone

(C) Stinging jellyfish, *Carybdea* sp.

(D) Black sea urchin, *Echinometra mathaei*

Figure 3.18 Venomous invertebrates of the RSA

Marine polychaete bristleworms exist along the coast of the RSA. This animal is referred to as 'Ghool', which in Arabic means 'Snake'. They live in burrows at the edge of the water, and deliver a painful bite to anything which blocks the opening, in most reports cases, the human foot. It is reddish pink and long, hence its name: 'Ghool'.

Of the representatives of molluscs, only some cephalopods (*Octopus*) and the gastropod cone shells, *Conus* spp. (Figure 3.18A) produce venom harmful to man. All octopuses possess two powerful jaws which they can use to bite humans. The majority of octopus are non-venomous and their bites cause small puncture wounds which cause moderate pain.

About 500 species of cone shells are found worldwide. All of them possess a highly developed venom apparatus. Cone shells are found on sandy bottoms and shallow waters throughout the RSA. They use their harpoon-like darts carrying the venom supply to catch prey and to discourage predators. They often cause localized pain at the site of injury accompanied by nausea, vomiting, dizziness, and weakness. In severe cases victims experience respiratory distress with chest pain, difficulties in swallowing, dizziness, blurring of vision and an inability to focus. Fatalities are the result of respiratory paralysis. Most reported cases are from organisms being handled. Of the known species, 26 are found in Oman. Species such as *Conus textile, C. striatus* and *C. pennaceus* are the most dangerous species found in Omani waters (Bosch and Bosch, 1982).

A few echinoderms are hazardous to humans. The most common injuries are abrasions or punctures acquired as a result of contact with the spines or skin of echinoderms. The Crown of Thorns Starfish (*Acanthaster planci*) is the only venomous starfish and lives on coral reefs in the RSA. Its upper surface is covered with many long, sharp and venomous spikes, which can inflict painful wounds when handled.

Sea urchins (Figure 3.18D) are found on the rocky foreshores and reefs of the RSA. Most sea urchins can be handled safely, however a few species possess venomous spines or jaw-like pedicellariae capable of delivering very painful injuries. In Oman, there are five potentially dangerous species of sea urchins belonging to three genera, *Diadema, Echinothrix* and *Toxopheustes*.

3.2.7.2 <u>*Dangerous vertebrates*</u>

This group is classified into non-venomous, venomous and poisonous vertebrates. The non-venomous vertebrates that pose a threat to human beings belong to certain species of fishes.

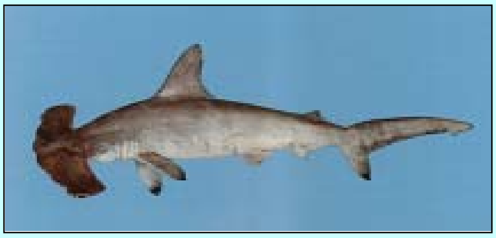
3.2.7.2.1 Non-venomous vertebrates

Electric fishes have specialized organs for producing and discharging electricity and are capable of delivering powerful electric shocks. The most powerful marine electric fishes are the torpedo rays, *Narcine* sp., and *Torpedo* sp. (Figure 3.19A). They live on the bottom of all shallow, temperate and warm seas including the RSA. Electric rays vary greatly in their electric potential, some generate electric discharges of up to 220 volts. Shocks are a defensive response and although strong enough to be dangerous, no fatalities have been reported.

Sharks are abundant in the RSA and are found at all depths. They attack on humans occur during their habitual feeding times in late afternoons and at night. Dangerous shark species that occur in the RSA include the White shark, *Carcharodon carcharias*; Tiger shark, *Galeocerdo cuvier*; Hammerhead shark, *Sphyrna zygaena*; Scalloped hammerhead shark, *Sphyrna lewini* (Figure 3.19B) and Mako shark, *Isurus oxyrinchus*.

The great barracuda, *Sphyraena barracuda* (Figure 3.19C) is widely found throughout the Region. It rarely attacks humans; however frequently intimidates divers and snorkelers by closely shadowing them.

(A) Marbled electric ray, *Torpedo sinuspersici*



(B) Scalloped hammerhead shark, *Sphyrna lewini*

(C) Great barracuda, *Sphyraena barracuda*

(D) Crocodile needlefish, *Tylosurus crocodilus crocodilus*

(E) Malabar grouper, *Epinephelus malabaricus*

(F) Honeycomb moray, *Gymnothorax favagineus*

Figure 3.19 Certain dangerous fishes of the RSA

Various species of needlefish, such as the one that occurs in the RSA, the Crocodile needlefish, *Tylosurus crocodilus crocodilus* (Figure 3.19D), pose a more significant threat to humans. They are slender, possess very long, strong and pointed jaws and reach an average length of 1.8m. They are most often found swimming in surface waters. Fishermen or divers on night expeditions are often severely wounded or even killed by jumping needlefish in many parts of the world.

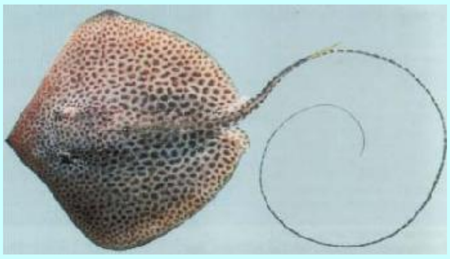
Groupers are very common, commercially important fishes in the RSA and live in the shallow waters on coral reefs, rocky areas and in sandy areas. The giant Malabar grouper, *Epinephelus malabaricus* (Figure 3.19E), is generally non-aggressive, however, potentially dangerous. Groupers are territorial fishes. Divers should look out for groupers before entering underwater caves.

The majority of eels are harmless. When provoked they will attack and can inflict fairly deep puncture wounds. Moray eels such as the Honeycomb moray, *Gymnothorax favagineus* (Figure 3.19F), live on coral reef platforms where they hide in crevices and holes among the dead corals.

3.2.7.2.2 Venomous vertebrates

Venomous vertebrates deliver their venom either via spines, as in the case of many fish species, or through fangs, as in the case of sea snakes. The catfish possesses venomous dorsal spines which can inflict painful wounds even when the fish is dead. The species, *Plotosus lineatus* (Figure 3.20A) and *Arius tenuispinis* are the most common dangerous venomous catfish of the RSA.

(A) A school of Catfish, *Plotosus lineatus*



(B) Darkspotted stingray, *Himantura uarnak*

(C) Spotfin lionfish, *Pterois antennata*

(D) Lined surgeonfish, *Acanthurus sohal*

Figure 3.20 Certain venomous fishes of the RSA

Stingrays tend to lurk partially buried on sandy or silt bottoms in shallow inshore waters. One or two venomous spines in their tails can stab swimmers who happen to step on, or unknowingly disturb them. All stingray wounds, whether minor or major, should receive medical attention to avoid the chance of secondary infection. Some injuries caused by venomous stingrays can be fatal for humans if the spine pierces the victim's trunk; deaths have been reported. The darkspotted stingray, *Himantura uarnak*, which occurs in the RSA (Figure 3.20B) is to be handled carefully.

All species of Scorpionfish, which possess a highly developed venom apparatus, are found throughout the RSA. The reef stonefish, *Synanceia verrucosa*, resembles coral rubble and lies motionless in coral crevices, under rocks, in holes, or buried in sand or mud where divers often mistake them for rocks. The lionfish such as Spotfin lionfish, *Pterois antennata* (Figure 3.20C) and true scorpionfish also possess venom. In the RSA, three genera, *Pterois*, *Synanceia* and *Scorpaenopsis,* are known to occur.

The Surgeonfish, for example the Lined surgeonfish, *Acanthurus sohal* (Figure 3.20D), is a herbivorous reef dweller equipped with a sharp, moveable spine on the side and base of the tail. When excited, the fish can direct the spine forward at a right angle to the body, ready to attack.

The Sea snakes are front-fanged venomous reptiles. Of the 50 species of sea snakes, the majority live inshore or around coral reefs. All sea snakes are venomous and can inflict considerable harm if disturbed. White (1995) estimated a worldwide sea snake fatality rate of at least 150 per year.

3.2.7.2.3 Poisonous vertebrates

The use of certain species of fishes for human consumption causes acute or simple poisoning. Eating flesh or viscera from such marine fish species is poisonous and may lead to death in human beings. The poisonous fish species of the RSA, which are to be avoided for human consumption, include scorpionfish and pufferfish (Figure 3.21).

Devil scorpionfish, *Scorpaenopsis diabolus*

Blackedged puffer, *Arothron immaculatus*

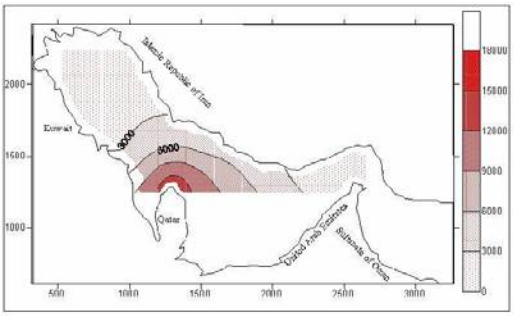
Figure 3.21 Certain poisonous fishes of the RSA

Pufferfish are the most poisonous of all marine fishes. They have the most dangerous nerve poison known as ‘Tetraodontoxin’. The toxin is not present in all body parts but is concentrated in viscera (liver, gonads, intestines, etc.), sometimes in skin and rarely in the muscle tissues. The flesh of pufferfish, despite being toxic, is considered a delicacy in Japan and a few other countries. Scorpionfish are the most beautiful as well as ugly fish among the marine fish species. They can cause a painful venomous sting with their fin spines. The flesh of this fish is also poisonous for human consumption.

The most commonly known marine toxin in the world found in fishes is ‘Ciguatera’, which is associated with the consumption of toxic contaminated reef fish species such as barracuda, grouper, snapper, etc. Worldwide, approximately fifty thousand people per year in tropical and subtropical regions suffer from ciguatera. The toxic ciguatera is primarily caused by the dinoflagellate microalgae, *Gambierdiscus toxicus*, an epiphyte living on calcareous macroalgae and other substrates on coral reefs. The herbivorous reef fishes browsing on reef algae ingest *G. toxicus* and the ciguatoxins accumulate in the viscera and muscle tissues. Other carnivorous fishes may become toxic after consuming the infected herbivorous fish. Other benthic ciguatoxic algae (dinoflagellates species) linked to ciguatera outbreaks are *Prorocentrum lima*, *P. concavum*, *Ostreopsis lenticularis*, *O. siamensis* and *Coolia* sp. (Tosteson *et al.*, 1988; NRC, 1999). Although ciguatera poisoning has not so far been reported in the RSA, the occurrence of two other toxic dinoflagellate species of the same *Prorocentrum* (*P. triestinum* and *P. minimum*) species in the RSA is an indication that it could occur in the Region and merits thorough scientific investigation.

3.3 Non-Living Marine 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. The dawning of the petroleum era (1950s) saw the introduction of desalination plants that convert seawater into steam and brine. The steam is used to run electricity turbines and produce drinking water by mixing it with ~10% brackish water (mined from the aquifers). The brines are used to produce salt, chlorine and caustic soda. Desalination and power plants are run by oil and/or gas, the most readily available source of energy. However, oil and gas remain the dominant non-living resource exploited in the coastal and marine areas of the RSA.



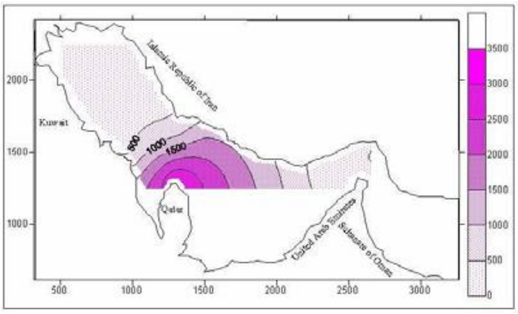
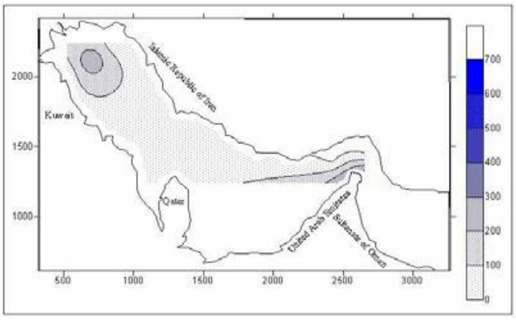


Figure 2.21 Total number of benthic Invertebrates/m^2 in the inner RSA – Summer 2001

Figure 2.22 Total number of Molluscs/m^2 in the inner RSA – Summer 2001



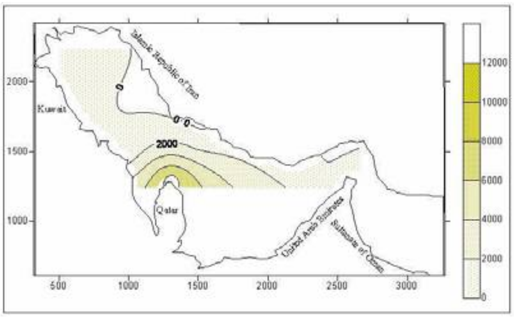


Figure 2.23 Total number of Echinoids/m^2 in the inner RSA – Summer 2001

Figure 2.24 Total number of Crustacea/m^2 in the inner RSA – Summer 2001

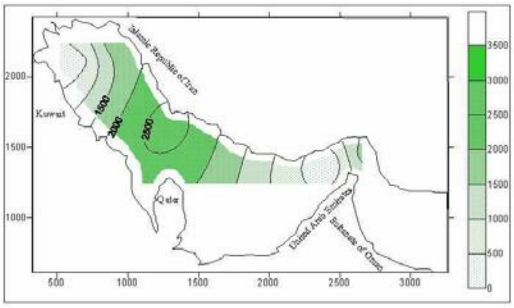


Figure 2.25 Total number of Annelida/m^2 in the inner RSA – Summer 2001

SOCIO-ECONOMIC ACTIVITIES AND STRUCTURES AFFECTING THE ROPME SEA AREA

CHAPTER 4

The quality 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. The Region has witnessed rapid socio-economic transformation since 1970s with an unprecedented growth of urbanization, mass immigration and industrialization along the coast. This growth has tended to outstrip the carrying capacity of the area, leading to tremendous ecological impacts. It is of prime importance, therefore, to focus on those activities that are likely have an adverse impact on the marine and coastal environment, especially those resulting from domestic sewage, industrial effluents, and the introduction of persistent organic pollutants, petroleum hydrocarbons, trace metals and nutrients, as well as sediment mobilization, physical alteration and litter. The aim of this Chapter then is to briefly review both the land-based and the sea-based activities that are potential sources of pollution in the RSA.

4.1 Land-Based Activities

4.1.1 Major industries and industrial production

The industrial sector has witnessed unprecedented growth during the past 30 years. Key industries include petroleum refineries, petrochemical complexes, desalination plants, power plants as well as light industries such as agricultural and livestock production, and food and beverage processing which are the major contributors to the organic carbon load in the marine environment and the main sources of oxygen demand.

Bahrain has a daily production of 1,700 tons of granulated urea and an annual production of 500,000 tons of high-grade aluminium. The wastes from these industries include high amounts of gases, liquids and solid wastes (UNEP, 1999).

Based in I.R. Iran, the refinery in Bandar Abbas is the largest refinery in the world (UNEP, 1999). It started working in early 1998. Many oil refineries in I.R. Iran were damaged during the Iraq-Iran War, some have since been renovated and others under construction. The total production of the Abadan refinery was 2,500 barrels/day in 1912 (LBA–I.R. Iran, 1999), it increased to 610,000 barrels/day in 1977 (pre the Iraq-Iran War) and has since been maintained at 450,000 barrels/day since the system was rebuilt in 1993.

Some of the largest heavy industrial plants of I.R. Iran are located in five major cities of the Karun River basin (LBA–I.R. Iran, 1999). The amount of industrial effluent discharge varies from $0.03m^3$/hr from the Fakhr Khorramshahr chemical company to $14,640m^3$/hr from the Abadan refinery, which discharges the waste into the Arvand River (LBA–I.R. Iran, 1999). The most polluting industries, in terms of the quantity of industrial sewage discharged into the Karun basin, are the cellulose-processing industries, followed by the chemical and petrochemical plants, followed by the food processing and steel industries.

In Kuwait, oil production in 1998 reached 2.4 million barrels a day and is expected to reach 3 million barrels a day by the year 2005. The production of refined oil from three refineries in 1998 amounted to 854,000 barrels a day. Liquid oil gas production in 1998 amounted to 121,000 barrels a day. The production of liquid ammonia stands at 594,000 metric tons per annum, and the annual production of urea is 792,000 metric tons. Annual petrochemical production of products such as ethylene, hard density polyethylene and ethylene glycol reached 650,000, 350,000 and 350,000 metric tons respectively in 1997 (EPA–Kuwait, 2002).

The National Oil Distribution Company (NODCO) of Qatar processes 62,000 barrels/day of crude oil and is presently going through an expansion process to increase the crude-oil refining capacity to 82,000 barrels/day. In addition, 27,000 barrels of stabilized condensate from the North field are also processed daily (LBA–Qatar, 1999). Two identical plants were established in 1973 and 1979 in Qatar, which produce 800,000 tons/yr of ammonia and 900,000 tons/yr of urea. A third plant was established in 1997 to produce 547,500 tons/yr of ammonia and 730,000 tons/yr of urea and a fourth plant is under construction (LBA–Qatar, 1999). Other petrochemical products from Qatar include 525,000 tons/yr of ethylene, 360,000 tons/yr of low-density polyethylene and 70,000 tons/yr of sulphur.

The estimated production of the three refineries along the eastern coast of Saudi Arabia in the RSA, namely, Jubail, Ras Tanura and Ras Al-Khafji is 551,351 barrels/day. Nine petrochemical plants situated in the area produce 7.32 million tons annually of petrochemical products ranging from methanol, ethanol, ethylene chloride, ethylbenzene, styrene, chloride, caustic soda, formaldehyde, MTBE, polyethylene, methane, ethylene, nitrogen, oxygen gases, monoethylene glycol, and etc. (LBA–Saudi Arabia, 1999).

The total production of oil refineries in the UAE has increased from 180,000 barrels/day in 1986 to 240,000 barrels/day in 1997, representing 12% of UAE oil production. About 50% of this is for local consumption (LBA–UAE, 1999).

4.1.1.1 *Impacts of desalination and power plants*

In the ROPME Region, conventional water resources such as fresh surface water and renewable groundwater are extremely limited. In order to provide a sufficient supply of drinking water to the growing population of the Region, desalination technology was introduced during the 1960s. More than 11,000 desalination plants are in operation throughout the world, producing approximately 20 million m^3/day of processed water. About 65% of the world's capacity is found in West Asia and the Middle East (WHO, 2000). Some 68 power and desalination plants are operational in the RSA. The production capacity of desalination plants varies from 113,650m^3/day in Bahrain to 1,698,874m^3/day in Saudi Arabia. Various desalination technologies are used, including Reverse Osmosis (RO), Electro-dialysis (ED), Thermal Compression (TC) and Vapour Compression (VC).

The large-scale desalination plants in the RSA are located along the coastline and discharge brine water into the adjacent coastal area. The discharged water contributes brine, chlorine and thermal pollution, which continue to pose a serious threat to the marine environment of the RSA. The water also contains micro-organisms that could be pathogenic bacteria, protozoa and possibly viruses (WHO, 2000). Nearly 43% of the world's desalinated water is produced in GCC countries and the trend is increasing (GEO3, 2002). Although heated, brine is likely to interfere with the balance of the marine ecosystem. The extent of its impact on the marine environment is not yet well established (LBA–Saudi Arabia, 1999).

The environmental impact of brine depends on the physical, chemical and biological characteristics of the coastal environment into which it is discharged. Most of the time, the discharged brine water re-enters the feed water intake system of the desalination plant, leading to lower operational efficiency and the reintroduction of pollutants. According to SWCC (1997), the largest desalination plant in the world is located in Jubail. It has well-segregated intake fore-bays and outfall bays to minimize the potential contamination of feed waters with the discharged brine concentrate. The outfall bay is designed to achieve maximum mixing and dispersion of the discharged brine prior to its dissipation into the open sea. The Doha East, Doha West and Al-Zour power desalination plants in Kuwait (Al-Awadi, 1995), and the Al-Taweela Desalination plant in Abu Dhabi (Al-Gobaisi, 1994) have modern and carefully segregated intake and outfall bays, in order to minimize adverse physical, chemical and biological impacts.

The volume of discharged liquid from the Bandar Abbas power plant in I.R. Iran is 1,391,088m^3/yr. Pollution is caused by the indirect dumping of chemicals such as hydrazine, antifoam materials, phosphate, acids and sodium hydroxide (MNR–I.R. Iran, 2003).

Measures of conductivity of the discharged water from desalination plants in Oman showed that it ranged from 70,000–90,000µS/cm at Kamzor plant, 80,000–180,000µS/cm at Lima plant, and 80,000–90,000µS/cm at Shussa plant (MRMEWR–Oman, 2003).

4.1.1.2 *Estimates of industrial liquid wastes*

Industries located along the coast usually discharge their effluents directly into the sea. The desalination and power plants discharge around 48% of the total industrial effluent volume which contribute to the BOD, COD and SS (Suspended Solids) load in the marine environment. The petroleum refineries have been reported to contribute 28% of the total waste volume. They are major contributors to the COD, oil and metals load. Petrochemical and other industries contribute 19% and all other industries 5%, of the total discharge into to the RSA, respectively (SOMER, 2000). Power and desalination plants are also responsible for the high load of oil contaminants in the RSA.

The amount of oily liquid wastes discharged into the environment in Bahrain during the period 1996–1998 varied according to the type of waste. The highest oily waste recorded, tarry pitch, amounted to 1,500,000 tons/yr followed by oil sludge, which varied from 3,000–10,600 tons/yr and waste oil of 12 tons/yr (LBA–Bahrain, 1999). This represents an increase of 14.5% compared with data from the mid-1980's. Most of these liquid wastes are sent for recycling, while the rest are incinerated to reduce their volume and weight, which could reduce the potential risk of hazard since the residues from incineration processes can be buried in land fills (LBA–Bahrain, 1999).

In the I.R. Iran, the total concentration of contaminants in liquid wastes from petrochemical industries in Bandar-e-Emam was estimated as COD 2,408, SS 2,628, TDS 31,660, N(NO_{3-}) 23.860, and P (PO_4^{3-}) 1.075mg/l, while the concentration of contaminants in Abadan area was BOD 122, COD 372, SS 533, TDS 9,366, N(NO_{3-}) 13.724, and P(PO_4^{3-}) 0.009mg/l, however, the total load for each has not been reported (MNR–I.R. Iran, 2003).

The effluent discharged from treatment plants into the marine environment at Mina Al-Fahal from January to December in 2001 and 2002 were 203,819 and 203,822m^3/year, with concentrations of hydrocarbon of 15 and 14mg/l respectively (PDO–Oman, 2002). The monthly volume of cooling water discharged from OLNG into the marine environment was 64,000m^3/hour during 2001 and 2002 (OLNG Monthly Reports, 2001 and 2002). The elevated ambient seawater temperatures and chlorine levels resulting from the discharge of cooling water effluent from the plant was within acceptable limits (Figure 4.1).

The quantity of cooling and brine water discharged from the power and desalination plants of Qatar varied between 25,000 and 124,800m^3/hr (219-1093 million m^3/yr). Residual chlorine of 0.1ppm (equivalent to 21,900–109,300 tons/yr of chlorine) and the thermal pollution load are high. It has been suggested that incineration should be used to dispose of the residual load (5-10 tons/yr) of oil and chemicals produced by the power and desalination plants. The main effluents discharged from oil refineries are made up of liquid hydrocarbons, which may also contain phenol, sulphides and dissolved solids. The volume of processed wastewater has been estimated at 800m^3/day, with an oil content of 103.2m^3/day. Petrochemical and fertilizer plants also generate considerable quantities of liquid waste, in addition to producing gas and fuel (LBA–Qatar, 1999).

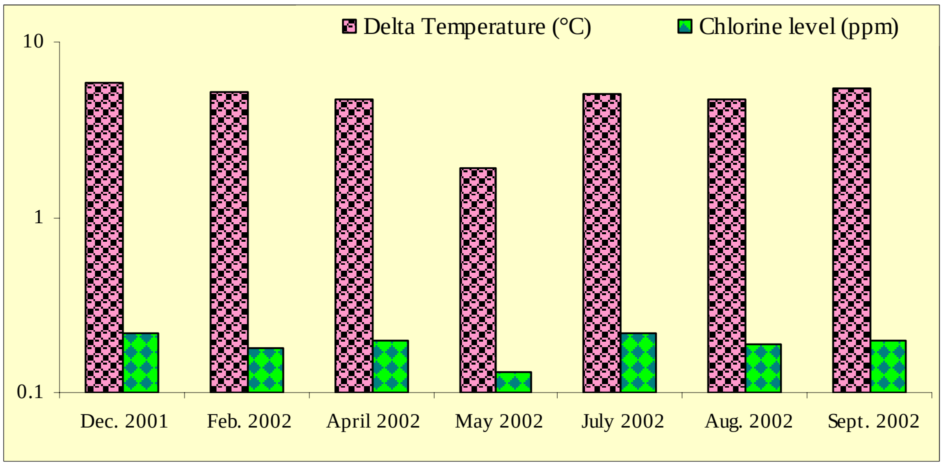


Figure 4.1 Characteristics of seawater cooling water (SCW) discharged into the marine environment by Oman LNG in some months of 2001 and 2002

The liquid industrial discharge from Saudi Arabia is mainly from sewage treatment plants, and includes domestic and industrial wastes. In 1999, the total load of liquid waste generated was 772,500m^3/day and the quantity of waste discharged on the Saudi Arabian coast of the RSA was 600,000m^3/day (LBA–Saudi Arabia, 1999). The contaminant load of the discharged waste indicated that the highest load was COD, 22,079 tons/yr, followed by TSS, 10,380 and BOD, 6,622 tons/yr. The percentage composition of the contaminants discharged from various sources is shown in Figure 4.2. The total contaminant load of NH_3-N was 1,802 tons/yr and PO_4-P was 4,396 tons/yr. The lowest load of total chlorine (T-Cl_2) recorded was 1,337 tons/yr. Saudi Aramco has four industrial facilities discharging treated wastewater into the sea after partial use for irrigation. However, data on the volumes of waste discharged into the sea from these facilities and the volume used for irrigation are not available (LBA–Saudi Arabia, 1999).

The volume of liquid industrial waste discharged from Saudi Arabia was 399,831,950m^3/yr during 2001 (MNR–Saudi Arabia, 2003). The liquid wastes contained high concentrations of contaminants including: SS ranging from 6mg/l (October) to 21mg/l (March) and TOC 2.3mg/l (December) to 10.5mg/l (July), Oil and grease 0.1 to 0.2mg/l (April), Nitrogen 0.1mg/l (September) to 0.41mg/l (November), Chlorine 0.01mg/l (October) to 0.18mg/l (December) (Figure 4.3), and Phosphorus <0.01mg/l (May, June, October) to 0.05mg/l (August).

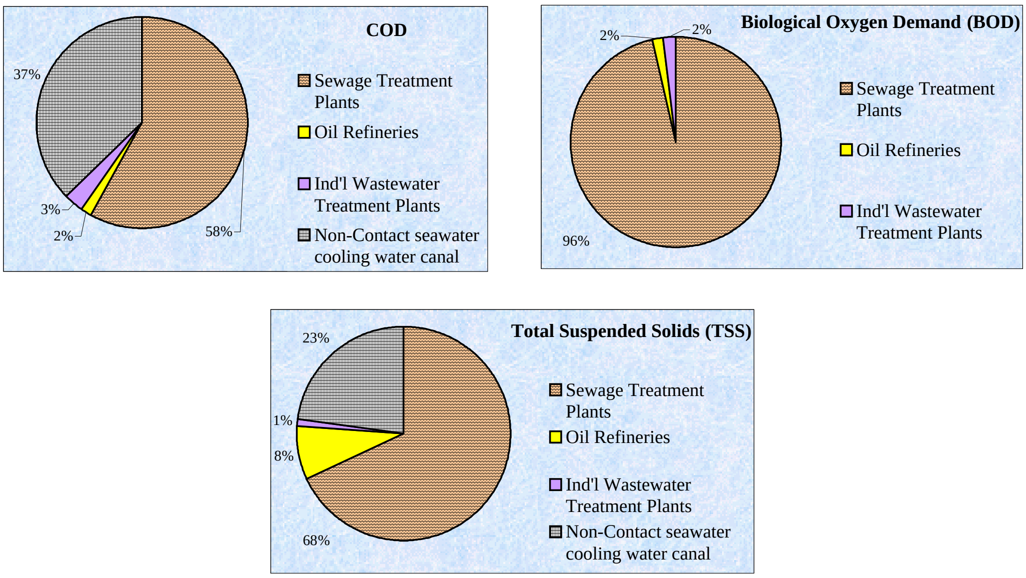


Figure 4.2 Percentage of various liquid contaminants discharged in the Saudi Arabian part of the RSA in 1999

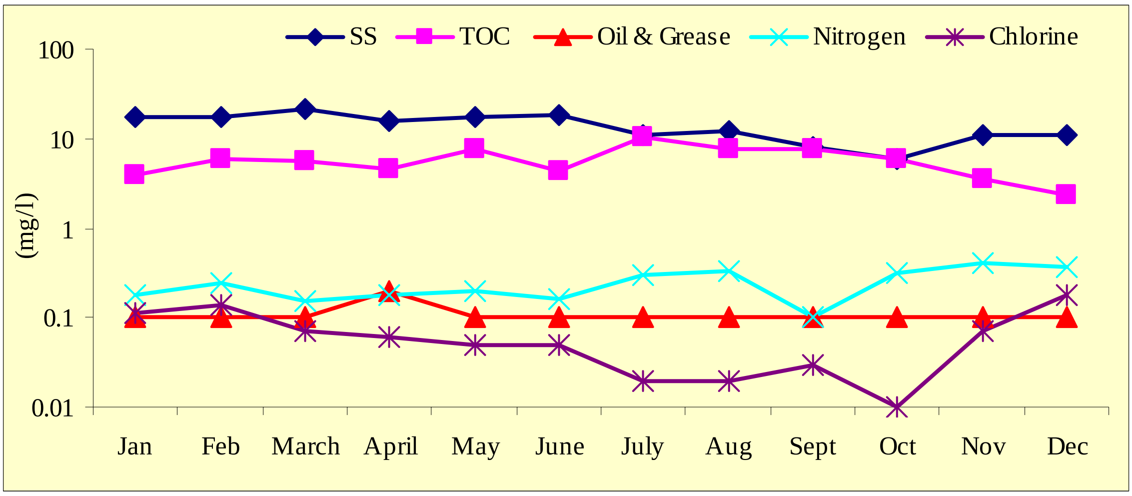


Figure 4.3 Levels of SS, TOC, Oil & Grease, Nitrogen and Chlorine (mg/l) in industrial liquid wastes discharged from Saudi Arabia in 2001

Levels of industrial liquid waste produced in UAE were estimated at 37 million m^3 in 1998. The BOD, TSS and oil pollution loads were 11,082, 29,727 and 20,140 tons/yr respectively. In Abu Dhabi, the BOD, TSS and oil loads are estimated at 3,018, 10,330 and 6,748 tons/yr, respectively. The main sources of BOD in Abu Dhabi are: dairy farms and the dairy industry, poultry farms, petroleum refineries and slaughter houses that account for 44%, 27%, 20% and 9% of the total load, respectively, whereas the major sources of TSS loads are dairy farms and the dairy industry, poultry farms and power plants (LBA–UAE, 1999). Liquid wastes were disposed of in the sea from three sites in Dubai Emirate at a rate of 176,150,469m^3/month from a power plant, a desalination plant and a waste treatment plant at the DEWA site, at a rate of 30,000–50,000m^3/hour from the Dubal site in Jabel Ali, and at a rate of 22,000m^3/month from the Gulf Extrusions site in Jabel Ali. The BOD levels at the sites mentioned above were 8.8mg/l, 2.6mg/l and 13mg/l respectively (MNR–UAE, 2003).

4.1.1.3 *Estimates of industrial solid wastes*

According to ROPME's rapid assessment data and country reports, in 1999 oil sludge was the main industrial solid waste produced in the RSA. The solid wastes produced by various industries in the Region may affect the RSA if they are not properly managed and handled.

Major industrial solid wastes from Bahrain include sand blasting grit and silt. Over the period 1996–1998, these amounted to 35,000 tons/yr for each and both accounted for 57% of the total industrial solid wastes produced in Bahrain. The data show a reduction of 20% over that reported in 1990. All solid wastes are disposed off at the municipal dumping site in Askar (LBA–Bahrain, 1999).

The quantity of solid and semi-solid industrial waste produced in Kuwait was estimated to be 1,742,688 tons/yr, of which, semi-solid waste accounted for about 697,724 tons/yr. Apart from industrial sludge waste generated from the Shuaiba, Al-Wafra and Al-Ahmadi regions, the toxic waste from other industries amounted to about 7,400 tons/yr. Sludge wastes generated in the Shuaiba industrial area amounted to about 64,000 tons/yr (69.6%). The waste generated from aluminium and lead melting industries contains high levels of trace metals such as chromium, nickel and lead. The hazardous wastes from damaged drugs and chemicals are estimated to be about 5 tons annually (EPA–Kuwait, 2002).

Solid industrial waste from Oman was estimated to be about 49,172 tons/yr, which amounted to 4% of all solid wastes produced by ROPME Member States (1,276,231 tons/yr, according to 1984–87 data). However, levels of solid waste are not a problem in Oman thanks to the proper enforcement of regulations (Ministerial Decision No. 17/93). The wastes are adequately managed so as not to pose a danger to the environment or to human beings (LBA–Oman, 1999).

The amount of solid waste in Qatar varies according to the industry. Most of the solid wastes produced in Qatar contain oily sludge, iron dust and other solids generated from the steel industry. The solid waste from power and desalination plants consists of residues from tank farms, oil water separation and residues from lubricating oils, which add up to about 10 tons/yr. These are stored on site and are disposed of by incineration. Oil refining generates 16.2 tons/yr of solid wastes consisting of catalysts, molecular sieves and sludge which are disposed off in the landfill site at Messaieed. Urea and ammonia plants generate 100 tons/yr of catalyst waste, which is recycled. About 150 tons/yr of hydrocarbon waste is generated from the liquefied natural gas in addition to the small quantities of filters and catalysts produced. Eventually these will be disposed of in a dumpsite currently being developed within the Ras Laffan industrial city. The fuel additives industry also generates solid wastes; these are classified as non-hazardous wastes. The quantities vary from $3m^3$/yr for used filter cartridges to $352m^3$/yr for used catalysts (LBA–Qatar, 1999).

Municipal and commercial activities in Saudi Arabia are estimated to generate 12 million tons/yr of solid waste. The eastern province has generated about 2 million tons of waste annually. MEPA (1994) estimated the quantity of industrial (hazardous and non-hazardous) waste generated industry, including petrochemical, cement, fertilizer, iron and steel, small and medium scale industries, port facilities, oil refineries etc., in the eastern province at 106,700 tons/yr. However, more a recent estimation (LBA–Saudi Arabia, 1999) indicated an increase in solid wastes of up to 199,366 tons/yr. This estimate includes the solid wastes generated by petrochemical industries, cement plants and oil refineries. It also worth noting that it is prohibited to dump hazardous solid wastes at sea. There are various licensed companies within the Kingdom responsible for managing and operating landfills, land-farms, chemical treatment, encapsulation, stabilization and incineration facilities for the environmental management of industrial wastes (LBA–Saudi Arabia, 1999).

In the UAE, the estimated volume of industrial solid waste generated in 1998 was 327,086 tons/yr, of which 48% was oily wastes, 14% organic waste and 37% inorganic waste. Processing of used oil is one of the major industrial sources of oily sludge, and accounts for 80% of the total production of oily sludge. In Dubai the reported quantity of hazardous waste produced was 110,650 tons/yr in 1997 of which 17% was oily sludge, 1% organic sludge and 82% inorganic sludge. In Abu Dhabi, the petroleum refinery is the main industrial source of oily sludge (28,413 tons/yr) and represents 20% of the total production of oily sludge in the UAE. The aluminium industry is the major source of organic sludge in the UAE and is estimated at ~1,000,000 tons/yr. The actual data provided by the factory indicated that inorganic sludge generated by the factory represents 90% (109,896 tons/yr) of the total inorganic waste generated in UAE. Oily sludge produced at oil export terminals was estimated at 130,000 tons/yr (LBA–UAE, 1999). In 2001, the solid waste generated from domestic activities in Dubai, contained paper, plastic, glass, metal, rubber, and organic wastes was 660,572 tons/yr (MNR–UAE, 2003).

4.1.1.4 *Estimates of industrial atmospheric emissions*

The major source of atmospheric emissions that pollute the environment of the RSA are the industrial areas, and include oil refineries, oil gathering centres, oil platforms, petrochemical and fertilizer plants, power plants and motor vehicles. The existence of polycyclic aromatic hydrocarbons (PAHs) from the combustion of fuel from vehicles poses a great risk to both the environment and health.

Atmospheric deposition also contributes to regional marine environmental pollution to a certain extent.

In Bahrain, the number of motor vehicles increased from 120,000 in 1990 to 185,000 in 1998; they have become a major source of air pollution. The waste oil from motor vehicles during the period 1996–1998 was put at 3,000 tons/yr (LBA–Bahrain, 1999).

An assessment of the atmospheric emission load of pollutants from three provinces of I.R. Iran indicated that carbon monoxide (CO), which amounts to 391,737 tons/yr, is a major airborne pollutant. The next pollution contributors are nitrogen oxides (NO_x) that amount to 113,757 tons/yr, followed by 92,089 tons/yr of sulphur oxides (SO_x) and 31,227 tons/yr of Suspended Particulate Matter (SPM). About 62% (390,891 tons/yr) of the total pollutant load (634,810 tons/yr) in the Iranian region was emitted to the atmosphere from industrial activities in Khuzestan, followed by 26% (166,400 tons/yr) from Hormozgan and 12% (71,519 tons/yr) from Bushehr province (LBA–I.R. Iran, 1999). However, atmospheric emissions from petrochemical industries namely in Bandar-e-Emam, Razi, Farabi, Abadan, as well as from the Abadan refinery produced a total contaminant load of NO_x 43,380.56 tons/yr, SO_x 585.56 tons/yr, CO 4,507.27 tons/yr, HC 32,0543.94 tons/yr and particulates 34,842.85 tons/yr (MNR–I.R. Iran, 2003).

The number of motor vehicles in Kuwait increased from 746,994 in 1993 to 914,274 in 1997 (ASA, 1998). This also led to an increase in the consumption of gasoline from 10,923 barrels/yr in 1993 to 14,445 barrels/yr in 1997 (ASA, 1998). Atmospheric emissions from industries showed that 49% of the contaminant load (610,601 tons/yr) is from sulphur oxides, CO_2 contributes 28% (350,000 tons/yr), nitrogen oxides 9.8% and hydrocarbons 5% (ROPME, 1997a). However, the atmospheric pollution from motor vehicles and industrial sources showed a contribution of 34% from fuel combustion, 30% from oilfields and export terminals, and 20% from power and desalination plants. The major contaminant from fuel combustion is CO_2 (337,622 tons/yr). Sulphur oxides are produced by fields and export terminals (372,800 tons/yr) and power and desalination plants (207,940 tons/yr). Power and desalination plants also produce atmospheric emissions of nitrogen oxides of up to 62,060 tons/yr (UNEP, 1999).

In Oman, the release of industrial and domestic wastes into the marine environment takes place either directly through liquid or solid discharges or indirectly through atmospheric emissions. The overall atmospheric emissions concentration from power plants, boilers, refineries and traffic in 2001 are given in Table 4.1. The levels of all these pollutants are within the permissible limits set by USEPA/WHO Standards (MRMEWR–Oman, 2002).

Table 4.1 Concentration of atmospheric emissions from power stations, boiler plants, refineries, and vehicle traffic in the Sultanate of Oman in 2001

Site	NO_x (ppb)	SO_x (ppb)	O_3 (ppb)	Pb (µg/m^3)	THC (µg/m^3)	Particulates PM_{10} (µg/m^3)
Rusayl Industrial Estate, Muscat	14	14.02	-	0.498	3.27	103.6
Mina Al Fahal, Muscat	-	16.58	18.25	-	-	-
Ghubrah, Muscat	14.82	2.59	6.4	-	-	-
Ruwi, Muscat	-	-	-	0.169	3.24	88.26
Sohar	-	14.65	-	-	-	-
Sur	-	-	-	0.084	2.43	143.77
Salalah	-	-	-	0.019	2.11	73.29
USEPA/WHO Standards	150	140	80	1.5	160	150

In Qatar, the total emission load of pollutants from different industrial activities is 186,812 tons/yr, of which, more than 55% (102,873 tons/yr) is in the form of sulphur oxides from the petrochemical industries. The NO_x represents 28.9% (53,977 tons/yr) of the total pollutant load. The remaining proportion is distributed between particulate matter (9.2%), CO (2.8%), ammonia (2.4%), urea (1.7%) and volatile organic carbon (VOC) <1.0% (LBA–Qatar, 1999).

In the eastern province of Saudi Arabia, the emission load of contaminants varied from 2 tons/yr (Vanadium emitted from the power plants) to 166,750 tons/yr (NO_x emitted from different industrial facilities), followed by sulphur dioxides (32,152.5 tons/yr), particulate (5,248 tons/yr), VOC (84,395 tons/yr), ammonia (1,870 tons/yr) and urea (380 tons/yr). About 66% of the NOs are emitted from the power and desalination plants and 98% of VOC is attributed to the oil refineries (LBA–Saudi Arabia, 1999). The percentage of air emissions from various industrial facilities in the Saudi Arabian part of RSA is shown in Figure 4.4.

In UAE, the estimated atmospheric pollution loads of SO_x, NO_x, particulate matter, CO and VOC for 1998 were 57,933, 159,093, 60,000, 303,854 and 71,452 tons/yr. The biggest contributor was CO, which represented 46.6% of the total pollutant load. Gasoline and motor vehicles are the main sources of CO emissions in the atmosphere in the UAE. Power plants accounted for 51% of the NO_x emitted, industrial processes for 37% and 12% from traffic. Industrial process accounted for 62% of sulphur oxides (SO_x), power plants for 26% and traffic for 12.5%. The particulate matter load was the result of emissions from industrial processes (90%), with the remaining 10% distributed between traffic and power plants (6% and 4% respectively). The highest level of pollution reported in Abu Dhabi was 311,416 tons/yr (47.7%). However, the other Emirates produced the following quantities: Sharjah 94,084 tons/yr (14.4%), Ras Al-Khaimah 60,952 tons/yr (9.3%), Ajman 23,225 tons/yr (3.8%), Fujairah 20,200 tons/yr (3.1%) and Umm Al-Quwain 9,064 tons/yr (1.4%) (LBA–UAE, 1999).

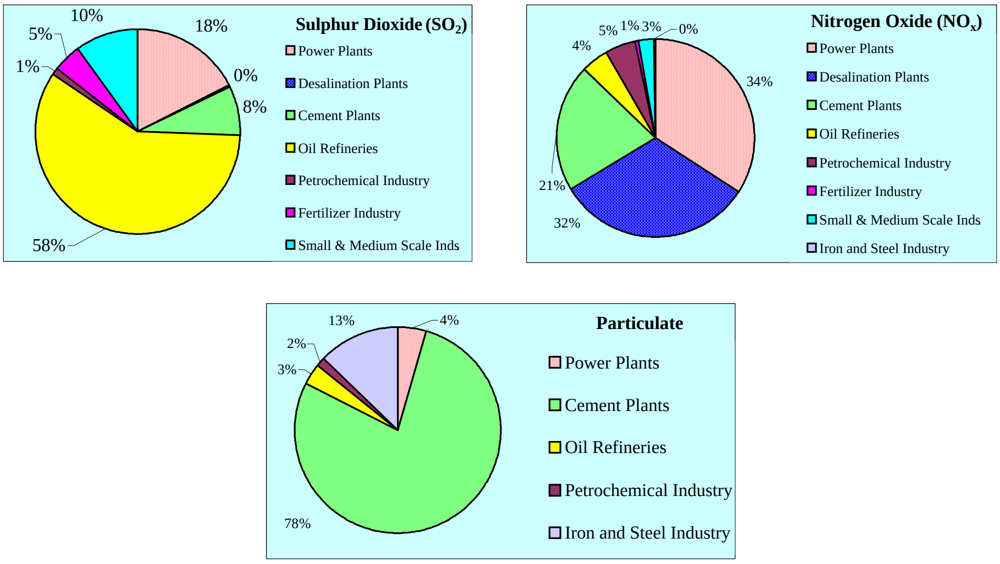


Figure 4.4 Percentage of various atmospheric contaminants in the Saudi Arabian part of the RSA in 1999

The industrial emission inventory of Dubai for 1999 showed that the contaminant load from power plants, natural gas refineries, cement production, aluminium production, glass manufacturing, steel manufacturing, sulphuric acid production and industrial/commercial boilers and furnaces amounted to 22,785.10 tons/yr of NO_x, 9,668.05 tons/yr of SO_2, 484.67 tons/yr of PM, 2,625.91 tons/yr of CO, 517.46 tons/yr of HC, and 60.65 tons/yr of Hydrogen fluoride (MNR–UAE, 2003). The emissions and contaminant loads from the individual plants from Dubai are illustrated in Figure 4.5.

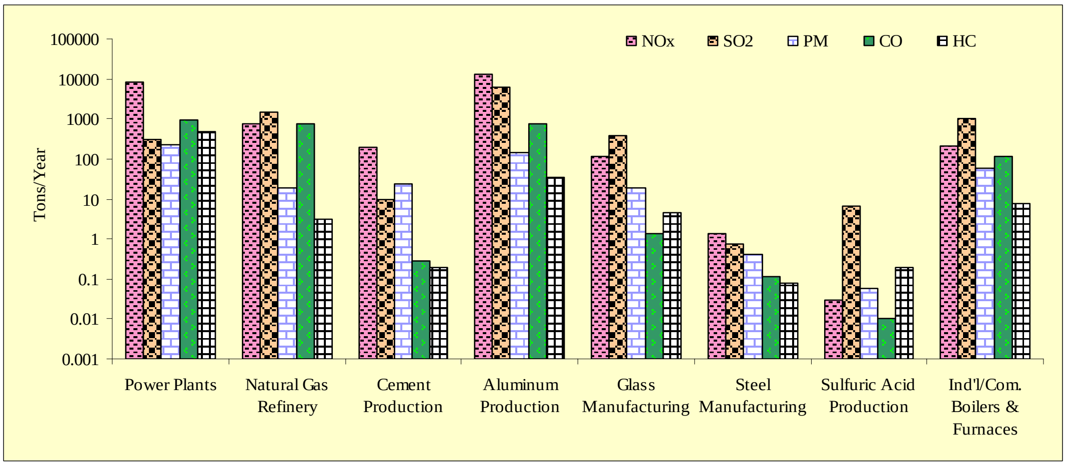


Figure 4.5 Emissions and contaminant loads from industries of Dubai, UAE in 1999

4.1.2 Domestic wastewater discharges

Domestic sewage discharges from urban and rural areas of Member States have major impacts on the coastal and marine environment of the RSA. The sewage is either partially treated or untreated, depending on the source and the types of treatment available. The volume of domestic sewage is on the increase and the estimated capacity of the sewage treatment plants in the RSA is more than 2 millions m^3/day (Abu-Ghararah and Abdulraheem, 1999). Among ROPME Member States, Bahrain, Kuwait and UAE are the only states that treat domestic wastewater properly prior to discharge, however a certain quantity is recycled (GEO3, 2002).

The major source of coastal pollution in Bahrain is sewage discharge. Of Bahrain's population, 70% are connected to the main sewerage network (UNEP, 1999). The main wastewater treatment facility receives 150,000 m^3/day of municipal wastewater from all parts of the country, in addition to ~15,000 m^3/day received from small plants scattered throughout the country. The volume of untreated wastewater dumped into the sea has been estimated at 130,000m^3/day. The concentration of dissolved solids in domestic wastewater varies from 12,500–35,000ppm. In 1998, the volume of domestic waste was estimated at 2.880 million tons/yr (LBA–Bahrain, 1999).

In I.R. Iran, sewage treatment facilities along the long Iranian coast are limited to coastal cities such as Bandar Imam, Bandar Abbas, and Bushehr. The volume of urban sewage discharged into the Karun and Dez Rivers was estimated at 151.7 million m^3/day. The contaminant load varied from 277.3 tons/yr for nitrates to 448,492 tons/yr for total dissolved solids. The remaining contaminants were estimated as BOD (53,954 tons/yr), COD (97,300 tons/yr), sulphates (76,380 tons/yr), chlorine (149,099 tons/yr) and calcium carbonates (142,344 tons/yr) (LBA–I.R.Iran, 1999). In 2002, the rate of discharge of untreated domestic liquid wastes from the Abadan, Khorramshahr, Bandar-e-Emam, Bandar-e-Mahshahr and Hendijan areas was 190,869m^3/day. The volume of liquid wastes discharged from each area is given in Figure 4.6 (MNR–I.R. Iran, 2003).

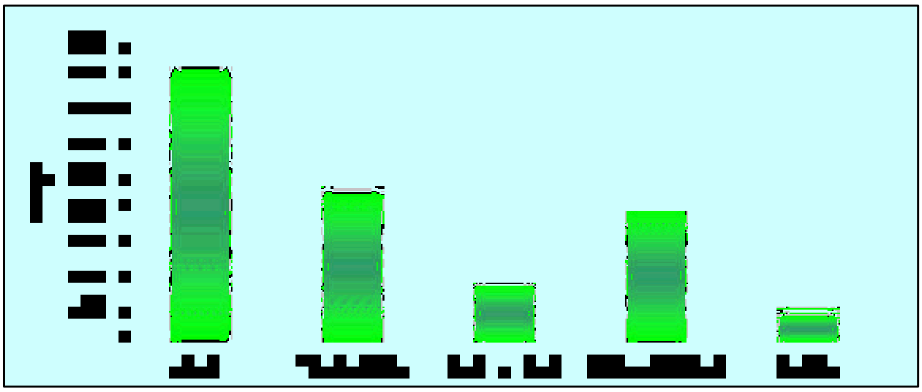


Figure 4.6 Volume of untreated municipal liquid wastes (m^3/day) discharged in I.R. Iran in 2002

In Kuwait, about 90% of the city's population are served by an elaborate sewage system. There are three major sewage treatment plants operating at Ardhiya, Jahra and Riggae generating about 150,000m^3/yr of sewage sludge. The sewage (60%) is treated up to the tertiary level and the rest (40%) receives only primary and secondary treatment (Al-Ghadban and Al-Majed, 1997). Three-quarters of the volume of the tertiary treated sewage is used for irrigation and the rest is discharged into the marine environment. The total daily volume of sewage has been estimated at 275,000m^3. About 70% of the sewage comes from Kuwait's coastal population and 14.6% of wastewater from industrial sources (UNEP, 1999). Emergency discharges of untreated sewage, by pumping stations located along the coast, especially in Kuwait Bay, are a major source of coastal pollution (Khan *et al*., 1999).

In Oman, several stabilization ponds for the seed-bed tertiary treatment of sewage wastewater have been installed in rural areas. There are about 250 wastewater treatment plants and a few central facilities operating in Oman (Al-Sabahi, 1997). The volume of discharged treated water is estimated to be about 28.9m^3/yr of which 21.5m^3/yr is used for irrigation (UNEP, 1999). The volume of treated effluents discharged to the sea from six coastal sewage treatment plants in Muscat and two plants from Musandam have been estimated at 250,000m^3/yr (LBA–Oman, 1999).

The volumes of industrial and domestic waste, in the form of liquid effluent discharges from sewage treatment plants in Oman in the year 2001 are shown in Figure 4.7. The Darsait sewage treatment plant in the capital area had the highest overflow discharge into the sea with an average volume of 1,110m^3/day, which varied depending on the volume of rainfall and its normal overflow. The sewage treatment plant in Muscat is presently being upgraded as part of the new Muscat Wastewater Master Plan which will eventually stop discharges into the sea (MRMEWR–Oman, 2002).

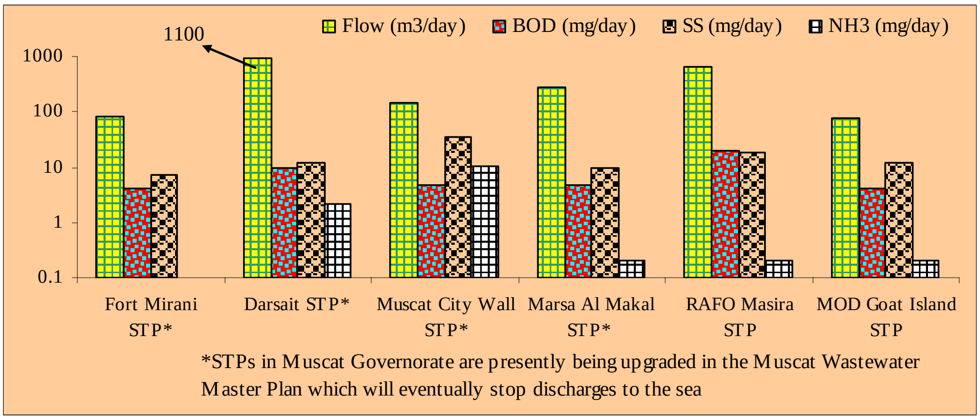


Figure 4.7 Industrial and domestic waste discharges from Sewage Treatment Plants (STPs) in the Sultanate of Oman in 2001

Qatar has thirteen sewage treatment plants with a total capacity to process 33.0 million m^3/yr (LBA–Qatar, 1999). Domestic sewage is no longer discharged to the marine environment. A large portion of tertiary treated water is used for irrigating fodder crops, gardens and the urban landscape (Al-Zubari, 1997).

In Saudi Arabia, there are thirty major sewage treatment plants with a capacity of 1,424,000m^3/day. Of these, seven sewage treatment plants operate in the eastern province. Most of them are secondary level aerobic biological treatment plants while the others (Jubail and Saudi Aramco) are advanced tertiary plants. The treated water is partially used for irrigating landscape areas and parks, recreation facilities and highways, and the remaining water is discharged to the sea (LBA–Saudi Arabia, 1999).

Four large sewage treatment plants are in operation in UAE. They have a total treatment capacity of 461,000m^3/day. About 60% of the tertiary treated effluent is used for irrigation, parks, golf courses, highways and urban water features, and the remaining 40% is discharged into the RSA (LBA–UAE, 1999). Despite the existence of tertiary treatment facilities there has been evidence of sewage pollution in some coastal areas of UAE (Banat *et al.*, 1998).

4.1.3 Marshlands and river inflow

The greatest volume of river inflow in the RSA occurs at the north-western end of the Sea Area, primarily from the Shatt Al-Arab system and the rivers on the Iranian side. The Shatt Al-Arab forms the nexus of three major rivers, Tigris, Euphrates and Karun. These rivers and their associated wetlands in southern Iraq are an integral part of the inner RSA ecosystem and their overall sustenance is critical. In recent decades, human activities in these river basins as well as engineering works, manmade structures and alterations, and dams built on rivers have had significant effects on the marshlands, marine, and coastal ecosystems. The effects are being felt both on the hydrological and biological cycles, because of the changing pattern of river flows and the quality of water discharged into the marine environment, which usually carries large amounts of dissolved and particulate matter to the sea.

The Mesopotamian marshlands, which extended over an original area of 15,000–20,000km^2 have been considerably damaged by the impact of massive drainage works that began in southern Iraq between the late 1980s and early 1990s and the construction of dams on the river in the upstream part of basin area. The Central and Al-Hammar marshlands have been destroyed with 97% and 94% respectively of their land cover transformed into bare lands and salt crusts, while less than a third of the transboundary Hawr Al-Hawizeh/Al Azim remains. The Al-Hawizeh marshes are the largest remaining tract of wetlands in the Mesopotamian marshlands of I.R. Iran and Iraq. This remaining area is also under great threat as a result of activities upstream, including the recently inaugurated Karkheh dam in

I.R. Iran and associated plans for water transfer to Kuwait and the planned Ilisu dam in Turkey (UNEP, 2001).

Damming and siphoning off of the waters from the Tigris and Euphrates rivers have decimated the ecosystem, resulting in serious damage or destruction to the wildlife and endemic species of mammals, birds and fish. The draining of the marshlands has resulted in the elimination of about 40 species of winter migratory birds from this area. Fish species from the northern part of inner RSA that depend on the marshland habitats for spawning migrations and nursery grounds have also been significantly affected. The decrease of the freshwater flow through the Shatt Al-Arab estuary has brought about the intrusion of seawater and disrupted its complex ecosystem (UNEP, 2001).

Another major coastal activity observed in the north-western part of the RSA in the aftermath of the 1991 War and which has had negative consequences on the fisheries and the ecology of the area is the drainage of Iraqi marshes. Iraq has reduced the area of marshland by an estimated 0.5 million hectares (Maltby, 1994). Today, water channels deliver river water directly into the RSA, with all its sediment loads, agrochemical substances, 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 and migratory fish at the Shatt Al-Arab delta and in Kuwait Bay.

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 (wetland) of Iraq in recent years. The elimination of the filtering role of the Iraqi wetlands and the newly constructed drainage channel discharging river water into Khor Al-Zubair (at the Iraq-Kuwait border, around Warba Island), has resulted in a reduction of the salinity, increased nutrient input and is likely to result in a higher level of agricultural drainage into the wetland area (Al-Yamani *et al.*, 1997a). The concentration of contaminants in the three major rivers of I.R. Iran that flow into the RSA, the Karun, Mond and Hilleh, has been estimated (MNR–I.R. Iran, 2003) and is shown in Table 4.2.

It should be noted that the dams on the Shatt Al-Arab are not only a source of water concerns for the countries through which the major rivers run, but in addition, the levels of fresh water and nutrients carried by the Tigris and Euphrates rivers will also significantly affect fishery resources in the NW part of the RSA. The reduction of the volume of river water discharged into the RSA is therefore of a wider regional significance than hitherto thought.

A satellite image of the ROPME Region acquired from MODIS/Terra1 on 2 April 2003 reveals that the wetlands that once covered as much as 20,000km^2 of parts of I.R. Iran and Iraq have been reduced to about 15% of their original size. Most

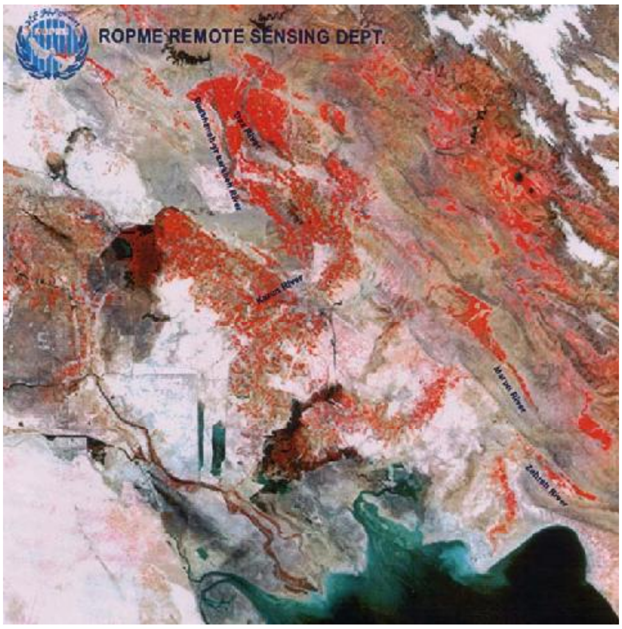
Table 4.2 Concentration of contaminants in three major rivers from I.R. Iran that discharge into the RSA

Parameters	Karun River Mean ± S.D.	Mond River[¤] Mean	Hilleh River[¤] Mean
Water Discharge (km^3/yr)	22* 10^9 mm^3/yr[@]	34	5.202
Suspended Solids (mg/l)	-	-	444
BOD_5 (mg/l)	4.0 ± 1.3[@]	54	396.2
Nutrients (µg/l)	4450 ± 600[@]	-	-
Heavy metals :			
Mercury (µg/l)	2.95 ± 0.95[#]	0.08	0.62
Cadmium (µg/l)	6.28 ± 6.14[#]	-	-
Lead (µg/l)	6.15 ± 5.30[#]	0.35	6.5
Nickel (µg/l)	41.7 ± 7.64[#]	-	-
Cobalt (µg/l)	63.6 ± 15.0[#]	-	-
Iron (µg/l)	1216 ± 464.6[#]	-	-
Chromium (µg/l)	9.78 ± 9.18[#]	-	-
Copper (µg/l)	16.5 ± 10.8[#]	0.11	15.8
Zinc (µg/l)	51.3 ± 7.50[#]	-	-

[@]1998-99 [#]1995-96 [¤]2002 - 2003

of the central marshes appear as olive to greyish-brown patches indicating low vegetation cover (red) on moist to dry ground. The very light to grey patches are areas of exposed ground with no vegetation, which may actually be salt flats. The Al-Hawizeh marsh (straddling the I.R. Iran-Iraq border just east of the Tigris river) appears to be all that remains of the region's natural wetlands, and it has been reduced significantly in size. The water is depicted as a dark colour and vegetation is in red. The river that flows into the Mesopotamian marshlands has been reduced by 20—50% and the spring floods that sustained the marshlands have disappeared. What was once a vast, interconnected mosaic of densely vegetated marshlands and lakes, teeming with life, are now mostly lifeless desert and salt-encrusted lakebeds and riverbeds (Figure 4.8).

However, positive signs of environmental recovery are visible in satellite images of the Mesopotamian marshlands taken in May 2003. Formerly dry areas have been inundated as floodgates are opened, embankments and dykes breached, and dams emptied upstream. Heavy rains have also contributed to the rising water levels. In the past decade, dams and drainage channels prevented water from flowing into the marshlands. When control structures were opened and levees broken by mechanical diggers in April and May 2003, however, water swept through the desiccated landscape flooding some areas (UNEP/DEWA/GRID–Geneva, 2003).



Intensive agriculture vegetation is seen as red and brighter. On the west, dry lands of Mesopotamia marshes are seen in brownish grey. On the south, coastal salt marshes of Shatt Al Arab is light greyish. Shatt Al Arab sediment patterns in waters are light bluish. On the north east, snow covers the Zagros Mountains.

Figure 4.8 The satellite image shows a view of the river valleys of the Tigris, Euphrates, Karun, Kharkeh, Dez, Marun and Zohreh, and the Mesopotamia marshes. 2 April 2003, MODIS / Terra1 (L2, 250m resolution, colour combination channels 122)

4.1.4 Coastal development and physical alterations

The coastline of RSA is under increasing pressure from the high pace of development and extensive economic activities. By the early 1990s, some Member States had already developed more than 40% of the coastline (Price and Robinson, 1993), and recent reports indicate that coastal investment in the Region is between 20–40 million US$/km of the coast (Fouda, 1998).

Coastal development requires extensive dredging and land reclamation of the coastal zone. Several coastal developmental projects have been or are being implemented in Member States. In Bahrain such activities considerably increased in the 1970s, due to industrial and residential pressures. Reclamation of large areas was required for the construction of industrial complexes and to build the King Fahd Causeway connecting Bahrain to Saudi Arabia. The reclaimed land in Bahrain increased the surface area of Bahrain from 661.87km^2 in 1975 to 700km^2 in 1994, increasing the area of the coastal zone about 39km^2 in less than 20 years. Recently, urbanization has encroached on significant parts of the coastal areas of Bahrain (Figure 4.9).

Urban areas are in light grey, vegetation is red, shallow waters and reef areas are light greenish – blue, and bared arid lands are light.

Figure 4.9 Satellite image shows a view of urbanization covering significant parts of Bahrain in March 2003. MODIS (L2, 250m resolution, colour combination channels 122)

Considerable stretches of the intertidal areas along the Kuwait City coast and some sections along the southern coast of Kuwait have been reclaimed. Land reclamation has disturbed the natural hydrodynamic conditions of the coastal water and local beach processes mean that the fill material is not stable. As a result, 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.

The main reason for coastal development in Oman is residential construction. In many coastal regions of Oman houses are built along the beaches. Historically houses were built near the shore using palm fronds and mud bricks, however, these have now been replaced with concrete blocks and permanent concrete structures. Coastal erosion occurs as a result of the construction of houses, commercial buildings, roads and harbours along the shores (UNEP, 1999). Ten kilometres of Omani coastline, covering an area of about 3.6km^2 has been reclaimed with 1,625 tons of quarry and/or beach sand material.

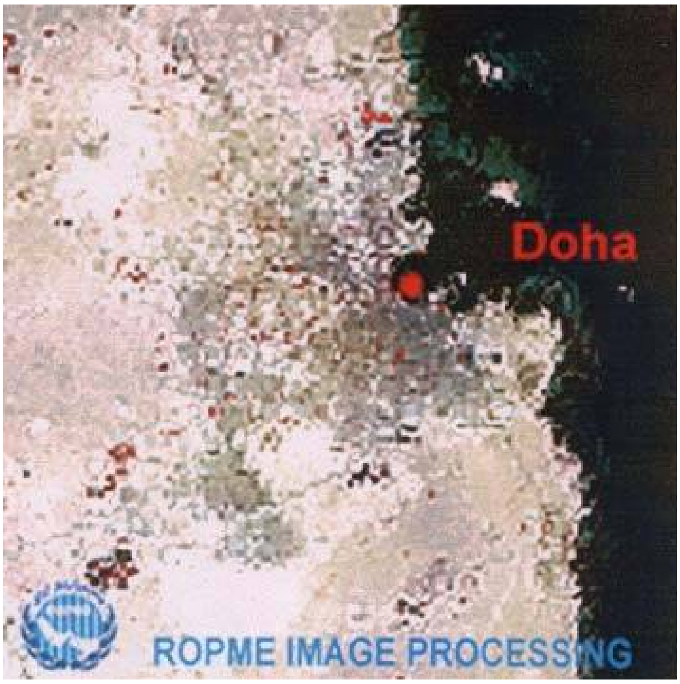
With the current drive towards coastal industrialization in the ports of Sohar and Salalah, and the development of coastal structures such as large power and desalination plants at Barka, Sohar and the OLNG near Sur, there is a need for long-term monitoring of their potential impacts. These include monitoring the impact of construction such as the effects of sedimentation on coral communities, the impact of erosion during operational phases, the impact of effluent discharges (the planned Sohar Industrial Estate will include an aluminium smelter, a petrochemical complex, a desalination plant, etc.) as well as monitoring the potential hazards arising from shipping, loading and unloading and the transport of products arising from this development.

Reclamation and particularly dredging for port, harbour and seafront development contributed to changes in coastal environments in the Sultanate of Oman in 2002. The main activities were carried out in the ports of Shinas (Al-Batinah), Khasab (Musandam), and Sohar (Al-Batinah). The reclaimed areas are listed in Table 4.3. Other projects involving seafront development are currently under evaluation for future construction (MRMEWR–Oman, 2003).

Table 4.3 Port development and land reclamation in Oman in 2002

Coastal Practices	Sohar Port (Zone B - ongoing work for 56 months)	Shinas Port (136 days in 2002)	Khasab Port (2002) All year round
Land reclamation (filling characteristics) Area Length of coastline affected	660,000 m^2 2.8 km	0.048 km^2 0.8 km	60 ha -
Port, harbour and seafront development Area Length of coastline affected	55,000 m^2 3.5 km	0.05 km^2 0.15 km	120 ha -
Dredging Area dredged	2,200,000 m^2	71,300 m^2	60 ha

A satellite remote sensing image taken in 2003 shows intense urbanization around Doha, Qatar (Figure 4.10). Commercial and residential development has taken place along the coastal areas of Saudi Arabia, particularly around Jubail, and further south around Tarut Bay, Dammam and Khobar. Major land filling activities have been noticed in the coastal areas around Tarut Bay. In this area, land filling not only causes permanent destruction of coastal habitats but could also lead to have indirect environmental impacts such as sedimentation. Land-filling activities are routine in coastal development projects in Saudi Arabia. They cause changes in water circulation in the vicinity that can alter the structure of the fauna and flora community of the area. Construction activities including causeways, ports, residential and commercial areas, industrial facilities and roads on land filled areas have been carried out all along the coast (LBA–Saudi Arabia, 1999).



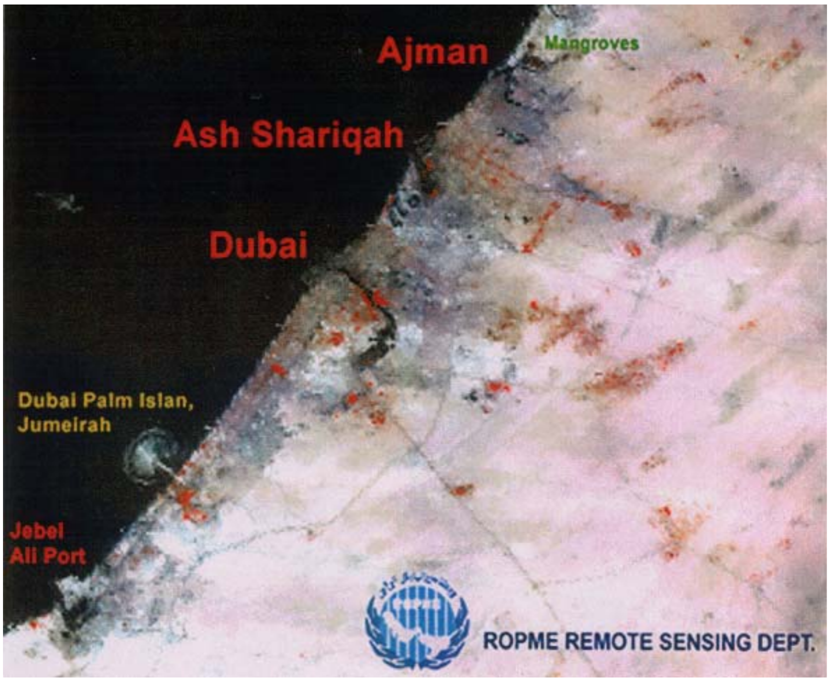
Dark grey is Doha urban areas. Vegetation is red. Seawaters are dark. Shallow waters and reef areas are in more light greenish – blue. Bared arid land is light and red spots are agriculture farms.

Figure 4.10 Satellite image showing increased urbanization in a part of Qatar, in 2003. MODIS (L2, 250m resolution, colour combination channels 122)

Coastal development projects are being implemented at a high pace in other ROPME Member States. These include the development and establishment of aquaculture facilities in I.R. Iran, high-density single-family dwellings in Oman and modern urban centres, industrial complexes and desalination plants in UAE (Fouda, 1998). Significant urban development is taking place along the coasts and their surrounding areas in Abu Dhabi and Dubai (Figure 4.11). Additionally, in some cases, construction of causeways or other structures that block the flow of water and slow down the natural flushing action can make the area around the construction more susceptible to water pollution.

The alarming magnitude of the physical alteration of the coastline of RSA has had several adverse environmental effects on the coastal environment, including damage to the spawning ground of various marine species and to seagrass beds, and the removal or alteration of the benthos that form the main source of food for many commercial fish species. This has been accompanied by an increase in siltation caused by the release of fine material during dredging operations and resulting in an increase in water turbidity that may irritate or clog fish gills, interfere with visual feeding and inhibit photosynthesis.

(A) Abu Dhabi appears as a greenish City. Vegetation is red, urban areas are mixed dark grey and reddish. Significant urban development is seen in surrounding areas, including patches of intensive agriculture. Shallow waters are in light bluish. Channels are dark, as seawaters. Coastal sabkhas are light greyish with evidences of salt.



(B) The image shows Dubai Conglomerate (from Ajman to Jebel Ali). Urban areas are seen in mixed dark grey. Highways are as grey lines. Vegetation is red and reddish. Significant urban development is seen in all coastal areas, including patches of intensive agriculture. Land filling processes are visible along Jumeirah beach – Dubai Palm Island. Shallow waters are in light bluish. Channels are dark, as seawaters. Coastal sabkhas are greyish.

Figure 4.11 Satellite images showing urban development in Abu Dhabi and Dubai Emirates of UAE, in 2003. MODIS (L2, 250m resolution, colour combination channels 122)

4.1.5 Recreation and tourism facilities

ROPME Member States are developing recreation and tourism facilities along the coast at a rapid rate. These include marinas, facilities for water sports, fishing, marine parks, archaeological sites and other recreational facilities. In recent times, these development activities have considerably increased in Bahrain, Oman and UAE. Similar activities are also taking place in Saudi Arabia on the Jurayd and Jana Islands, Jubail, Muntazah, Dawhat As'sayh and Zalum and Al-Khobar; in I.R. Iran at Kish and Qeshm Islands; and in Kuwait at the waterfront and Al-Khiran recreational areas.

The construction of water sports facilities, marinas and campsites is a recent development along the Omani coasts, where beaches are used for a variety of recreational purposes which include water sports, football, fishing, picnicking and camping.

Given that the development of recreational and tourism facilities in the coastal area is an important industry for the diversification of national economies, a number of luxury modern hotels and furnished holiday apartments and an extensive range of restaurants have also been built along with the necessary coastal roads and other infrastructures to cater for the diverse needs of individual travellers and tourist groups. All these installations, when built haphazardly or not managed in an environmentally sound manner could have adverse effects on the marine and coastal environment. They should be carefully monitored and regulated with a view to protecting the coastal area against degradation, damage and misuse.

4.2 Exploration and Exploitation of the Living Marine Resources

The fisheries sector plays only a minor role in the national economies in the Region, although the Region is quite rich in commercial fin and shellfish species. The contribution of the fisheries sector to the gross domestic product (GDP) of the Member States is very limited, and amounts to 0.3% in Bahrain, 0.1% in Kuwait and 1% in Qatar (fisheries and agriculture) of the GDP. In Oman, however, the revenue generated by fisheries was 36.5% of the total oil exports revenue generated in 1984.

The commercial fisheries of the Region are supported by over 1,000 species of finfish and shellfish, including six species of shrimp (*Penaeus semisulcatus, P. indicus, Metapenaeus affinis, M. stebbingi, M. monoceros, Parapenaeopsis stylifera*), two species of spiny lobster (*Panulirus 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*) (Mohammed *et al.*, 1981; Johnson *et al.*, 1992; Fouda and

Hermosa, 1993; Krupp and Muller, 1994; Abdulqadar, 1994; Siddeek *et al.*, 1997; Fouda, 1997). Pearl oysters (*Pinctada margaritifera* and *P. radiata*) were also a major source of income in the RSA until the middle of the 20th century.

The I.R. Iran has stepped up 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 (I.R. Iran 80, Kuwait 70, Saudi Arabia 20, Bahrain 10), (FAO, 1997).

Among the Member States, the highest fish landings have been reported by I.R. Iran followed by Oman and UAE. Qatar had the lowest quantities during the period 1995–1999. Bahrain and Kuwait had similar volumes of landings (SOMER, 2000).

Siddeek *et al.* (1999) found that the demersal fisheries on the continental shelves of the RSA are supported by over 350 commercial fish species, eight shrimp species, two spiny lobster species, one shovel nose lobster species, one cuttlefish species, one crab species, and one species of abalone. Artisanal and industrial vessels with over 120,000 fishermen are involved in demersal fishing activities. Fishing boats include fish and shrimp trawlers (wooden and steel hulled), large wooden boats (dhow) with inboard engines, small dhows with outboard engines, and fibreglass boats. Fishing gear consists of trawls, bottom gill nets, traps (wire mesh and plastic types), barrier traps, hand lines, bare hands and knives (to dislodge abalone). Demersal fish (primarily Lethrinidae, Sparidae, Serranidae, Siganidae, Sciaenidae, Stromateidae, Lutjanidae, Trichiuridae, and Nemipteridae) and shrimp (primarily *Penaeus semisulcatus, Metapenaeus affinis, Parapenaeopsis stylifera, and Penaeus merguiensis*) are the two main commercial demersal resources. Approximately 198,000–214,000 tons of demersals were landed annually between 1988–1993, accounting for nearly 40% of the total marine landings (475,000–552,000 tons). This percentage however varied among countries and amounted to 56% in Bahrain, 41 % in I.R. Iran, close to 100% in Iraq, 55% in Kuwait, 25% in Oman, 71% in Qatar, 52% in Saudi Arabia, and 32% in UAE (Siddeek *et al.*, 1999).

The fish production estimate for the five-year period from 1996 to 2000, revealed that the average production of fishes and shellfish landed in Oman was 115,202 tons. The year 2000 was considered a good year for the fishing industry with a total landing of 120,421 tons (Figure 4.12). Large pelagic fish form the mainstay of Oman's fisheries, with *Scomberomorus commerson*, *Thunnus tonggol* and *T. albacares* accounting for nearly half of the total catch. The small pelagic fish, sardines, anchovies and Indian mackerel, and demersals such as emperors and groupers also account for an important share (MAF–Oman, 2002).

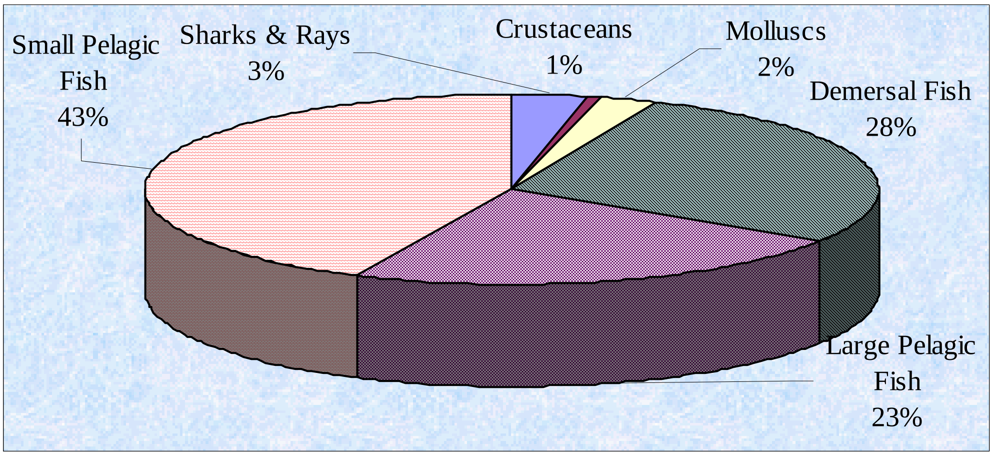


Figure 4.12 Fisheries in the Sultanate of Oman in 2000

The total catch from Abu Dhabi Emirates, UAE in 2001 was 5,813 tons. Nets, traps and lines are used for catching fishes in UAE (MNR–UAE, 2003).

The fisheries of the Region are affected by environmental degradation caused by coastal zone activities which have led to the elimination of nursery areas for commercially important species of fin and shellfish. The reduction of outflow from Shatt Al-Arab has had significant negative effects on the reproduction of certain marine species. Bottom trawling has severely destroyed the benthic communities of the Region. Several countries have taken remedial measures to protect shrimp stocks. These include imposing a closed season for shrimp fisheries, decreasing fishing efforts and banning bottom trawling, issuing no new licenses, and imposing a limit on the size of fishing boats.

The fishing efforts of certain stocks of commercially important fish species may have been reported as below the optimum level (e.g., certain Omani demersal fish), near the optimum level (e.g., Omani shrimp), or above the optimum level (e.g., RSA shrimp and demersal fish). Overexploitation has led to the implementation of restrictions on fishing activities through limiting fishing licenses, regulating fishing gear (mesh size) and capture size, closing fishing areas, restricting fishing seasons, and banning certain fisheries. Nevertheless, fisheries management in the Region is hampered by a lack of appropriate management regulations, a lack of enforcement and sparse data on most stocks. Pollution and degradation of nursery areas also affect the productivity of fisheries resources. To achieve sustainable demersal fisheries, it is necessary to maintain a healthy marine environment, reduce fishing efforts, and strictly enforce closed seasons and closed areas. These measures are being implemented with varying degrees of success by all the countries (Siddeek *et al.*, 1999).

4.3 Exploitation of Non-Living Marine Resources – Sea-Based Activities, and Their Impacts

There are about 34 offshore gas and oil fields in the Region with over 800 productive oil wells. The largest number of offshore oilfields is located in Saudi Arabia, I.R. Iran and the United Arab Emirates.

In I.R. Iran, exploration, exploitation and export of crude oil from offshore fields are carried out at different locations. The volume of oil produced varies from 200 barrels/day in Nowruz field to 115,000 barrels/day in the Salman field; and the oil content varies from 25mg/l in Sirri district to 270mg/l in Reshadat field (SBA–I.R. Iran, 2000).

The average estimated volume of chemical discharges from offshore activities in Qatar during 1999 was 31.5 tons/month (SOMER, 2000). The chemicals used by offshore operations were mainly corrosion inhibitors, scale inhibitors, anti-foams, demulsifiers/oil dispersant, biocides and water clarifier. It is also worth noting that all the drilling muds used are water-based and pH neutral and that none of the drilling mud chemicals used contain any of the toxic or hazardous constituents listed by ROPME (SBA–Qatar, 2000).

The use 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 drinking 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^{o}C higher than the ambient seawater temperature with an increase in salinity of about 3‰. The effluents also contain residual chlorine (mainly as brominated, iodated and chlorinated organic), corrosion products and polyphosphates. The effect 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, 1986).

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

The major hazard of offshore drilling is well blowout. For example, during the six-year period between 1993 and 1998, two major spills have been caused by well blowouts (SOMER, 2000). Environmental can be felt during all stages of offshore oil exploration and production activities. In particular, the impact of the water produced on the marine environment, especially in shallow waters or near to ecologically sensitive areas, is more noticeable. The magnitude of the environmental impacts also depends on the volume of water and the composition of effluent discharge (i.e., oil, chemicals, dissolved and suspended solids, inorganic material and metal salts). Such operational discharges are for the most part regulated by international agreements and the ROPME Protocol. In addition to these environmental effects, offshore 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.

ROPME Member States adopted the Protocol Concerning Marine Pollution Resulting from Exploration and Exploitation of the Continental Shelf in 1989. The Protocol and its Guidelines aim to control the pollution resulting from all types of offshore operations including exploration and exploitation of resources, conduct of seismic operations, use of E & P chemicals and the disposal of drill cuttings on the seabed. With the implementation of this Protocol it is hoped that proper regional coordination for sound environmental practices in offshore oil and gas exploration and production activities will be achieved.

4.3.1 Dredging

Large-scale dredging activities have been carried out in most of the coastal areas of the RSA. Regular dredging operations are carried out to keep harbours, rivers and other waterways from silting up, as well as for new construction and engineering projects offshore. The dredged material consists of sandy and muddy substances which are used for infilling.

In Bahrain, extensive dredging has been carried out and 15–20km^2 of shallow coastal waters and habitats have been removed. During the construction of the Saudi-Bahrain Causeway about 60 million m^3 of mud and sand were dredged. (Linden *et al.,* 1990). The quantity of dredged material from Bahrain was estimated as more than 60,000m^3 and the material contained sand, rock, cap-rock, clay and soft limestone (Madany *et al.*, 1987).

In Oman large areas, estimated at 2,200,000m^3, 71,300m^3 and 60ha respectively, were dredged for the construction of three new major ports at Sohar, Shinas and Khasab (MTC–Oman, 2002).

In Saudi Arabia, about 46.5km^2 of the coastal area have been dredged for the Jubail and Dammam projects. In Jubail City more than 200 million m^3 of sediments were removed for the development of residential and industrial projects (IUCN, 1987).

When the dredged material is uncontaminated and properly handled it causes only a few long-term problems, 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 dumpsites is important. However, around 10% of dredged materials are found to be contaminated by a variety of sources, including shipping, industrial and municipal discharges, and land run-off. Typical contaminants include oil, trace metals, nutrients and organochlorine compounds. Dumped dredged material has liquid and suspended particulate phases, but the greatest impact generally comes from the settleable or solid-phase material which may affect benthic organisms by smothering and physical disruption of habitats; and from bioaccumulation and toxicity from both soluble and suspended phases.

The contaminated dredged material may slowly release its adsorbed burden and casue 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 those in the background water but mixing processes tend to mitigate the effects. The major result at disposal sites characterized by small current velocity and low wave-energy is the physical mounding of the material. Benthic re-colonization of these mounds is relatively rapid on fine-grained sediments and slower on coarse-grained material.

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

4.3.2 Maritime transport

About 25,000 tankers carrying about 60% of total oil exports to the world navigate through the Strait of Hormuz annually. The oil is exported from 34 major oil terminals in the Region (UNEP, 1999). About 2 million barrels of oil are spilled in the Region every year (Hinrichsen, 1996) from the routine discharge of dirty ballast water (UNEP, 1999). Besides the dirty ballast water, ships also generate other types of waste. All ships produce bilge water, oily slops from the centrifugation of bunker oil, as well as leakage 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 household refuse. The volume of garbage has been estimated at 8.3 metric tons/yr (Abdulraheem, 1997). However, in order for ships to deliver their waste, adequate reception facilities must be provided.

Significant reductions in oil spillage have been achieved through the introduction of efficient ‘load-on-top’ systems by which tank washings are retained on board ship. However, the reduction of oil spills has not been uniform in the ROPME Region. This is reflected by the amount of hydrocarbons found in marine sediments and the wide distribution of tar balls on the beaches, especially in Oman.

4.3.3 Pipeline networks

Thousands of kilometres of pipelines lie on the bottom of the RSA. These pipelines carry out oil, gas and production water from the offshore oil wells to the land based facilities and terminals. The practice of burying pipelines in coastal areas is rarely used because of its high cost. Sediment entrapment techniques around pipelines have also been used to provide protection from anchoring ships and dredging vessels (SOMER, 2000), but the leakage of oil and oil products caused by the rupture of submerged pipelines is often not reported.

4.4 Tar Balls

In the RSA, oil pollution is a chronic environmental hazard. Beach deposits of tar balls, and floating semi-solid oil are frequently seen all along the coast. Because of the high ambient temperature, the volatile fraction of the crude oil evaporates and the remaining substances become tar balls which drift to the shore and pollute the beaches. Many investigations have been carried out by Member States to quantify the rate and distribution of tar balls on the beaches. The densities of tar balls on beaches along the coast of the Sultanate of Oman have been measured, as an indicator of oil pollution in the marine environment (Figures 4.13). The study reveals that tar balls along the beach at Shati Al-Qurum in the Muscat area of Oman are not only a threat to the health of the natural ecosystem, but also to recreational activities (MNR–Oman, 1999).

Figure 4.13 Tar balls deposited along the coast of Oman in 1996

Results of surveys have shown that currently there are lower levels of tar balls on beaches of the Sultanate of Oman than in previous years (Figure 4.14). This has been especially observed on the beaches in the Arabian Sea, although high levels were still found in 2002 at Sawadi and Diba (Gulf of Oman) with the latter site experiencing heavy tar pollution of up to 2252g/m of beachfront. The main source of pollution of the marine environment in Oman is from tar balls formed as a result of the illegal discharge of oily ballast water by passing tankers (MRMEWR–Oman, 2003).

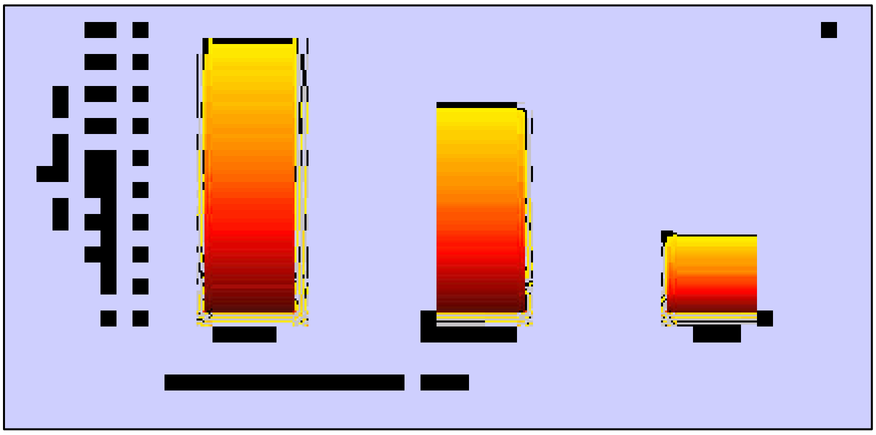


Figure 4.14 Density of tar balls (g/m of beachfront) in the Sultanate of Oman

The concentration of tar balls along the coast of Qatar was measured at 11 locations, the concentrations varied over space and time with values ranging between 2 and 1132g/m (average 290 g/m) of beachfront (Al-Madfa *et al.*, 1999). Tar deposits were highest following the 1991 War oil spill, especially along the north-western (average 723 g/m) and northern coasts (average 620 g/m). With the exception of higher levels off Saudi Arabia and Oman, the levels of beach tar around Qatar appear to be within the range of previously recorded RSA values. There appears to be lower concentrations of fresh tar on the eastern coast (average 150 g/m) than on the western coast (average 304 g/m), where older tar from earlier spills still persists in large volumes. The application of strict regulations on ballast water disposal in the RSA has led to a clear decline in tar deposits since 1993, reaching as low as baseline limits in some locations.

4.5 Litter

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

The shallow coastal areas of RSA 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, tires and even entire scrapped automobiles in some places. In terms of quantity, oil sludge constitutes the most important type of solid waste (Linden *et al.*, 1990).

Littering of the shoreline is a very obvious sign of environmental deterioration in many parts of the Region. Much of the lighter debris has spread out along widespread tracts of shoreline as a result of wind and water movements. This situation has rendered many beaches unsuitable for recreation particularly near more densely populated areas. In most cases, visitors have probably left the litter on the beaches. Even in very remote areas, the beaches are severely contaminated by litter, probably washed up from the sea to the shore (UNEP, 1999).

CHAPTER 5

CONTAMINATION OF THE ROPME SEA AREA

This Chapter deals with specific groups of contaminants whose observed levels in the water, sediments and biota are being used as indicators of the health of the marine environment. The principal sources of marine contaminants in the RSA are land-based sources, offshore oil operations and shipping activities, which contribute significantly to the overall impact of human activities on the marine environment.

The assessment of contaminants in the RSA is based on various investigations which include: the ROPME–IAEA contaminant screening project for trace metals and organic contaminants in water, sediments and biota, which have been conducted at selected sites in Member States over the past two decades; contaminants measurements in sediments during the ROPME Oceanographic Cruise – Summer 2001; and some of the recent contaminant studies carried out by Member States. The results of the ROPME–IAEA contaminants studies as well as the national investigations of Member States provide a report on the status of nearshore or coastal water contamination and the areas of 'hotspots', while the ROPME Oceanographic Cruise – Summer 2001 mainly provides data for the basin-wide assessment as well as the pattern of contaminants over the open RSA.

5.1 Contamination of Coastal Waters

The ROPME–IAEA Contaminant Screening results are the main source of reliable data for the assessment of the level of contaminants in the coastal waters of member states. The ROPME–IAEA Contaminant Screening Project includes, surveys of trace metals and organic contaminants which were conducted in Kuwait, Bahrain and UAE (June 1994), in I.R. Iran, Oman and Qatar (May, June 1997), in Saudi Arabia and Kuwait (October 1998) and in Qatar, UAE, Bahrain and Oman (2000, 2001). The results of these individual surveys have been reported to the ROPME by the IAEA (1996, 1998, 1999 and 2001). This chapter provides an overview of these surveys, and in particular, compares the results obtained during 2000 and 2001 with earlier surveys in the same area. All stations sampled during the different surveys are indicated on the map in Figure 5.1. The Codes used for the stations are provided in Table 5.1. Some of the available data from Member States' investigations have also been used for an assessment of contaminants in coastal waters.

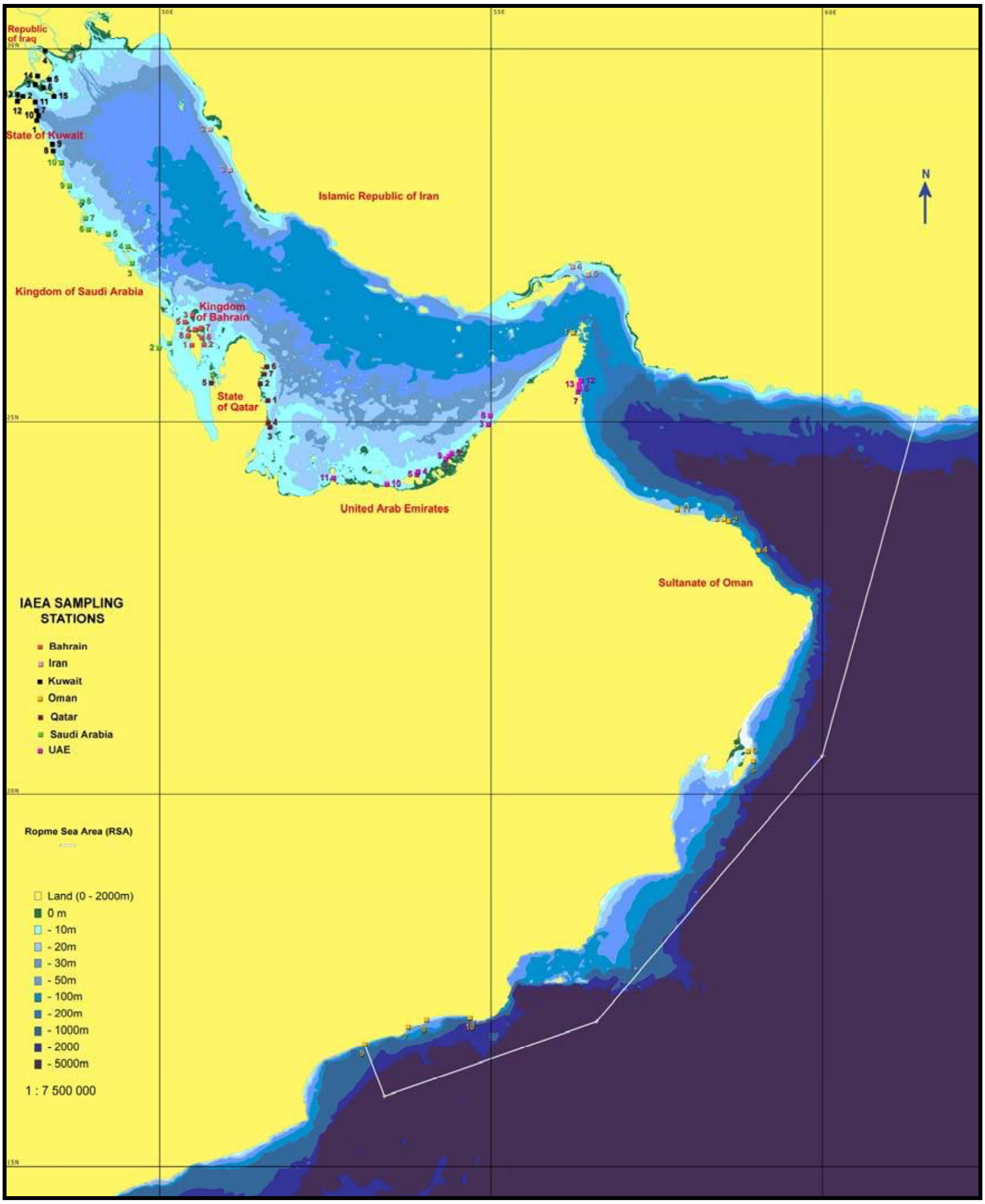


Figure 5.1 Map of the ROPME–IAEA Contaminant Screening sampling stations in coastal waters of the RSA

Table 5.1 Codes of the Contaminant Screening sampling stations in the RSA

Member States	Code	Station	Member States	Code	Station
Bahrain	B1	Jasra	Oman	O7	Mughsayl (Beach)
	B2	Askar		O8	Raysut Port Area (East Branch)
	B3	West Fasht Al Jarim		O9	Sagar
	B4	South Fasht Al Jarim		O10	Mirbat
	B5	Budaiya K. Fahed		O11	Al-Sawadi
	B6	Off BAPCO Refinery	Qatar	Q1	Doha
	B7	North of Meridien Hotel		Q2	Al-Khawr
	B8	Badaiya		Q3	Messaieed
	B9	Fasht Al Adham		Q4	Messaieed
I.R. Iran	I1	Abadan		Q5	Dukhan
	I2	Bushehr		Q6	Ras Laffan
	I3	Mond		Q7	Ras Al Nouf
	I4	Hormuz / Bandar Abbas	Saudi Arabia	S1	Ras Al Qurrayyah
	I5	Hormuz Island		S2	Qatif / Tarut Bay
Kuwait	K1	Shuaiba		S3	Jubail
	K2	Shuwaikh Bay		S4	Abu Ali
	K3	North Kuwait Bay		S5	Ras Al Ghar
	K4	North-west Khor Bubiyan		S6	Manifa Bay
	K5	South Bubiyan Island		S7	Ras Al Tanajib
	K6	Between Miskani and Bubiyan Island		S8	Safaniyah
	K7	Mangaf Area		S9	Ras Al Mishab
	K8	Khiran		S10	Ras Al Khafji
	K9	Ras Al Zoor	UAE	U1	Abu Dhabi West ADNOC
	K10	Fahaheel		U2	Abu Dhabi Port
	K11	Al Bida'a		U3	Jebel Ali
	K12	Sulaibikhat		U4	Off Al Abyad Island
	K13	Doha Bay		U5	Off Al Abyad Island
	K14	Khor Sabiyah		U6	Bidya
	K15	South Falaika Island		U7	Dhadnah
Oman	O1	Musandam		U8	Jebel Ali
	O2	Mina Al Fahal (PDO Beach)		U9	Abu Dhabi
	O3	Ras Al Hamra		U10	Al-Marfa
	O4	Quriyat		U11	Al-Ruweis
	O5	Ras Al Yei (Masirah East Coast)		U12	Akkah Head
	O6	Hilf (Masirah West Coast)		U13	Akkah Beach

5.1.1 Petroleum hydrocarbons

5.1.1.1 *Petroleum hydrocarbons in coastal waters*

Measurements of petroleum hydrocarbon compounds in the surface micro layer (SML) and subsurface water (SSW) at various locations within UAE, Qatar and Oman indicated that increased levels of aliphatics were only present at Akkah Beach near Akkah Head with lesser amounts noted at Doha. A SML enrichment factor of approximately 10 was noted for $\sum nC_{14}$-C_{34} alkanes at Doha. No significant enrichments of total n-alcanes were found in Oman. PAHs generally followed the same trends as those noted for aliphatics. Total petroleum hydrocarbon concentrations in the SML at Akkah Beach were 15µg l^{-1} as a ROPME oil equivalent, however, SSW concentrations at the same location (19µg l^{-1}) were very similar. Nevertheless, in general, the petroleum hydrocarbon levels measured at all locations in the SML and SSW (1.1–19µg l^{-1} in UAE; 0.62–3.5µg l^{-1} in Qatar, 0.51–6.7µg l^{-1} in Oman) were much lower than average levels measured in Saudi Arabia and Kuwait in 1992 following the 1991 War oil spill

($X = 149 \pm 77$µg l^{-1} (n = 10) in the SML; 64 ± 100µg l^{-1} (n = 10) in SSW (Hardy *et al.*, 1993), and were typical of concentrations reported previously in the majority of SSW of UAE and Oman during the early 1980s (e.g., 0.1–16.8µg l^{-1}, Fowler, 1988).

5.1.1.2 *Petroleum hydrocarbons in coastal sediments*

Trends in both total petroleum hydrocarbons and aliphatics in sediments have been used to identify 'hotspots' in four Member States, Bahrain, Oman, Qatar and UAE. In the UAE only the area around Akkah Head and Akkah Beach on the east coast in the Gulf of Oman showed indications of oil contamination with 10-12µg g^{-1} total aliphatics and 73-100µg g^{-1} total petroleum hydrocarbons as ROPME oil equivalents. Interestingly, high primary and secondary productivity and many dead sardines were also noted at this site during sampling. In fact, an earlier survey carried out in June 1994 at Bidya, approximately 3 to 4km south of Akkah Head, also demonstrated substantial oil contamination in the area which likely resulted from a severe oil spill that occurred along this coast three months earlier (IAEA, 1996). An earlier study by Shriadah (1998) showed that petroleum hydrocarbons in seawater and sediments in this area decreased dramatically within a few months of the spill; however, it is noteworthy that levels of petroleum hydrocarbons and PAHs were still high in sediments and seawater six years after the spill.

In Qatar total petroleum hydrocarbons were at their highest level in sediments at Messaieed (45µg g^{-1}) and Ras Al-Nouf (64µg g^{-1}), while total aliphatics were highest in sediments at Messaieed (73µg g^{-1}) and Doha (39µg g^{-1}). In Bahrain, only sediments collected off the BAPCO refinery area showed signs of substantial oil contamination with concentrations of 690µg g^{-1} and 1600µg g^{-1} for total aliphatics and total petroleum hydrocarbons, respectively. Where comparisons can be made with earlier surveys at some of these sites, total aliphatic and ∑n-alcane concentrations varied by less than a factor of three at Jebel Ali, Doha, Askar and Jasra between 1994 and 2000 (IAEA, 1996, 1998). As far as total petroleum hydrocarbons at the same locations were concerned, the variations over time were in some cases of a greater order of magnitude, e.g., at Jasra 620µg g^{-1} in 1994 and 25µg g^{-1} in 2000 (ibid). Nevertheless, it should be kept in mind that the sampling site at each location was not always exactly the same and spatial variability over small distances could be a factor in the differences noted in the concentrations.

Levels of total petroleum hydrocarbons, total aliphatics and ∑n-alcanes were in general lower in sediments from Oman than in those from the other three Member States. The maximum concentration of total petroleum hydrocarbons was only 11µg g^{-1} dry at Al-Sawadi whereas the ∑PAH levels (30ng g^{-1}) were highest at Hilf. In general, these concentrations were similar to those measured in some of the same areas of Oman just following the 1991 War (Fowler *et al.*, 1993).

The petroleum concentrations in these sediments were, for the most part, lower than or similar to those which have been measured elsewhere in the RSA (Fowler, 1988; Fowler *et al.*, 1993; IAEA, 1996, 1998, 1999). Only in the case of the sediments collected near the BAPCO oil refinery in Bahrain were levels (1600µg g^{-1} dry) comparable to those found in Saudi Arabian sediments contaminated by the 1991 War spill (Fowler *et al.*, 1993). Likewise, PAH concentrations generally mirrored those found for petroleum hydrocarbons. Most values were not exceptional apart from those found in sediments near the BAPCO refinery which contained 6.6µg g^{-1} dry total PAHs, one of the largest values reported so far in the RSA. Such a concentration was of an order of magnitude of 2 to 4 times higher than those found in most of the other sediments sampled in 2000–2001. With the exception of the sediments near BAPCO and Askar, pyrene concentrations were relatively low (0.08–12ng g^{-1} dry) and were at the lower end of the ranges measured in RSA sediments collected after the War spill in 1991 (1–450ng g^{-1}, Fowler *et al.*, 1993) and in 1994 (1.6–510ng g^{-1}, IAEA, 1996). However, the extremely high benzo(a) pyrene levels, 150 and 880ng g^{-1} dry, recorded at Askar and BAPCO in Bahrain respectively, are certainly some of the highest concentrations reported to date in the Region and warrant continued monitoring. Likewise, a continued watch on the area around Akkah Head on the east coast of the UAE should be maintained in order to follow any changes in the residual oil contamination originating from the spill in 1994. A comparison of concentrations of petroleum hydrocarbons over time for five stations is given in Figure 5.2.

In Bahrain, the national study of the temporal variation of petroleum hydrocarbons in sediments conducted on the east coast during 1993–1998 indicated a lowest mean concentration value of 107.15mg/kg in 1996 and the highest mean value of 182.17mg/kg in 1993 (Figure 5.3).

5.1.1.3 *Petroleum hydrocarbons in biota*

Total PHs based on ROPME oil equivalents in fish muscle were unexceptional and ranged from 0.18 to 11µg g^{-1} dry. Corresponding ranges in fish liver were slightly higher, i.e., 2.2–38µg g^{-1} dry. In a 1994 survey in Bahrain, somewhat higher oil concentrations (65 and 54µg g^{-1} dry) were noted in the livers of orange-spotted groupers from Askar and Budaiya K. Fahed, respectively (IAEA, 1996). Likewise, the PAH concentrations were similar to those reported for the same species (*Epinephelus coioides* and *Lethrinus nebulosus*) in previous surveys carried out in Saudi Arabia, UAE, Bahrain and Oman (Fowler *et al.*, 1993; IAEA, 1996, 1998, 1999).

Concentrations measured in bivalves provided a more accurate reflection of corresponding PH levels in their ambient environment. Clearly, the high concentrations of total PHs found in rock oysters from Akkah Beach in UAE (289µg g^{-1} dry as ROPME oil equivalents) were most likely residues from the

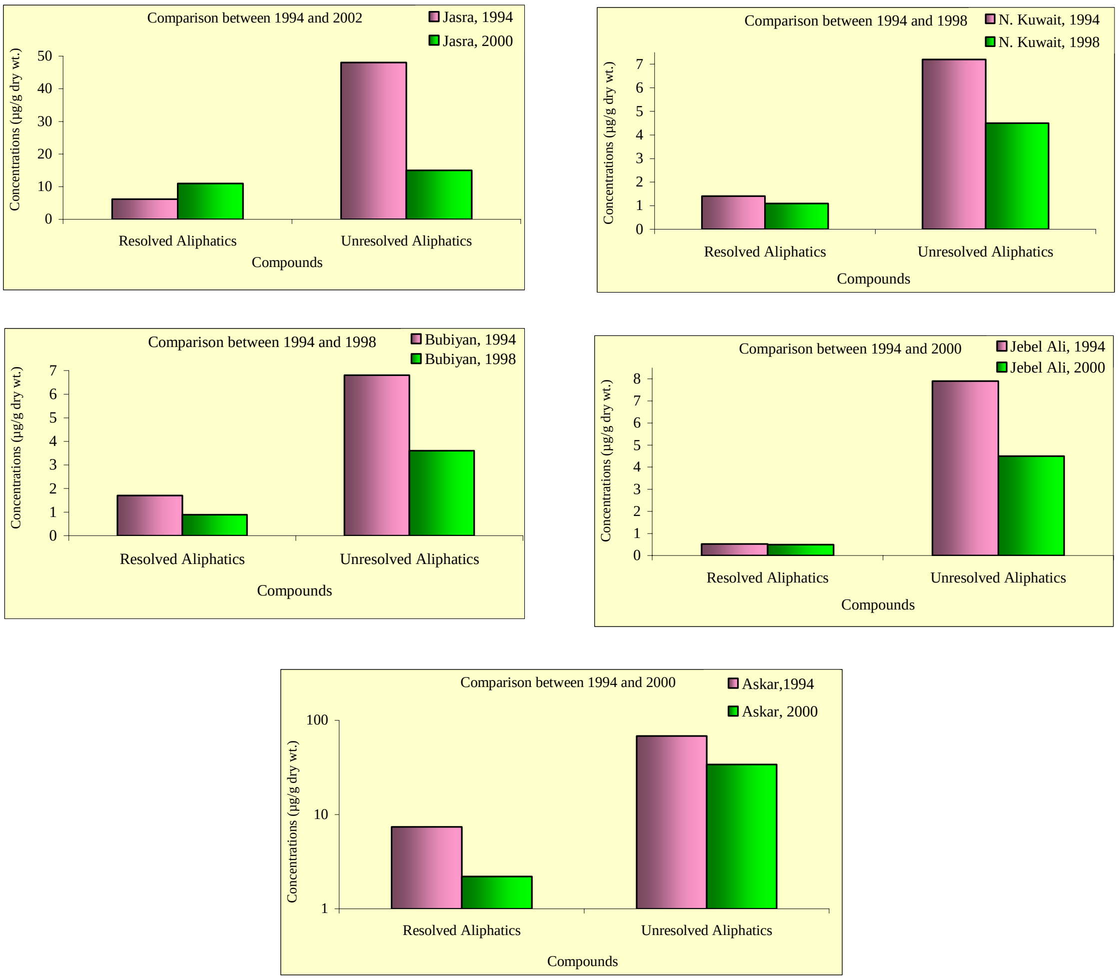


Figure 5.2 Comparison of petroleum hydrocarbon concentrations at different stations over time (1994 – 2000)

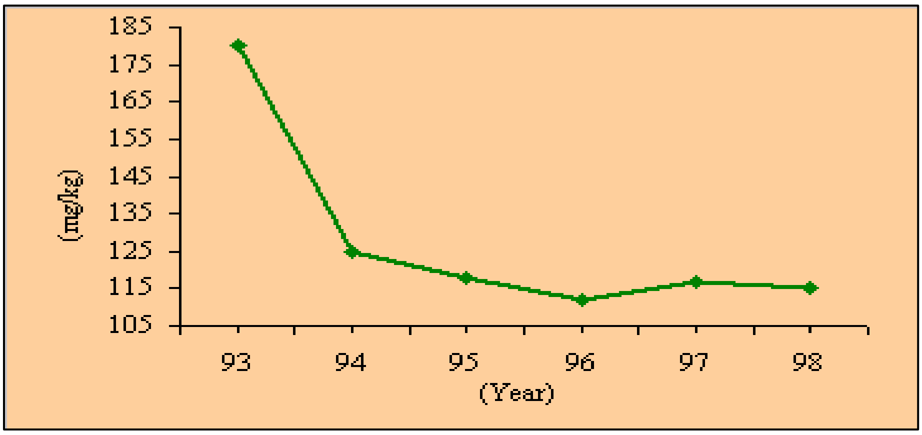


Figure 5.3 Temporal variation in petroleum hydrocarbons in sediment samples taken along the east coast of Bahrain for the period 1993 – 1998

March 1994 oil spill in that area. Nevertheless, this concentration was of a lower order of magnitude than levels (5,200µg g^{-1} dry) recorded in June 1994 in rock oysters from Dhadnah, a headland about 5km south of the Akkah Beach site (IAEA, 1996). This observation suggests that following the oil spill at the site, PH concentrations in the local environment are in fact decreasing but at a slow rate. Slow rates of recovery from severe oil contamination have also been noted in Kuwait and Saudi Arabia following the 1991 War oil spill (Readman *et al.*, 1996).

The only other bivalves showing some indication of oil contamination were the pearl oysters from Abu Dhabi and rock oysters from Mirbat in southern Oman. Total PHs, aliphatics, aromatics and the alkylated dibenzothiophenes were all somewhat higher in both these oysters. Individuals were sampled near the flour storage silos just at the entrance to the port of Abu Dhabi. They came from a site near the more remote area around Mirbat which logically seemed to be far removed from any obvious oil inputs. Nevertheless, the total PHs concentration of 35µg g^{-1} found in the Abu Dhabi pearl oysters was of the same order or magnitude as concentrations (19-30µg g^{-1}) which have been measured in this species from the same general area around Abu Dhabi port since 1983 (Fowler, 1988; IAEA, 1996). On the other hand, the total PHs concentration (99µg g^{-1} dry) in the rock oysters from Mirbat was approximately three times higher than that measured previously in this species from the remote areas of southern Oman (Fowler, 1988; Fowler *et al.*, 1993), but it did approach the relatively high levels (116–141µg g^{-1} dry) reported for rock oysters from Musandam in northern Oman during the early 1980s (Fowler, 1988).

Bivalves from other areas displayed relatively low concentrations compared to those reported in the earlier surveys. For example, the concentration of total PHs in the single sample of clams from Ras Al-Nouf in Qatar (0.86µg g^{-1} dry) was of a lower order of magnitude than concentrations (12–57µg g^{-1}) reported for similar species from Kuwait and Saudi Arabia, that were analysed seven years after the initial 1991 War oil contamination (IAEA, 1999). Furthermore, total phenanthrenes and dibenzothiophenes in the clams were of an order of magnitude one to two times lower than concentrations found in a related species from oil impacted and non-impacted sediments in Saudi Arabia sampled before and after the oil spill (Vazquez *et al.*, 2000).

5.1.2 Organochlorine compounds

5.1.2.1 *Organochlorine compounds in sediments*

Average concentrations of PCBs in sediment samples are at the low end of the values reported for other parts of the world (Table 5.2). Extremely high levels of PCBs (5ng g^{-1} dry, quantified as Aroclor 1254) were only noted off BAPCO in Bahrain (Table 5.3 and Figures 5.4 & 5.5). Concentrations of PCBs in the

Table 5.2 Worldwide concentration of Polychlorinated Biphenyls (PCBs) in sediments

Area	Survey Year	Concentrations (ng g-1 dry weight)	References
South Western Coast, Baltic Sea	1995	<0.1 - 16 (23 cong)	Dannenberg *et al* ., 1997
South Western Coast, Baltic Sea	1995	0.1 - 11 (23 cong)	Dannenberg *et al* ., 1997
Humber Estuary, UK	1991-93	n.d. - 84 (7 cong)	Tyler and Millward, 1996
Irish Sea, UK	1993	0.2 - 42 (21 cong)	Thompson *et al* ., 1996
San Quintin Bay, Mexico	1992	<10	Galindo *et al* ., 1996
Gulf of Bothnia, Baltic Sea	1991-92	2 - 14 (63 cong)	Van Bavel *et al* ., 1995
Lake Baikal, Russia	1992	0.08 - 6.1 (sum of Kaneclors)	Iwata *et al* ., 1995
Xiamen Harbour, China	1993	0.05 - 7.2 (Supelco PCB mixt)	Hong *et al* ., 1995
Victoria Harbour, Hong Kong	1992	3.2 - 81 (SupelcoPCB mixt)	Hong *et al* ., 1995
Western Coast, Australia	1991	<10	Burt and Ebell, 1995
Firth of Clyde, Scotland	1989	0.5 - 500 (7 cong)	Kelly and Campbell, 1995
Gulf of Alaska, Bering Sea, Chukchi Sea	1990	0.1 - 2 (36 cong)	Iwata *et al* ., 1994 (b)
San Francisco Estuary, USA	1992	0.1 - 8.1 (Sum of 4,5 and 6 Cl)	Pereira *et al* ., 1994
Cities, India	1989	4.8 - 1000 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Thailand	1990	11 - 520 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Vietnam	1990	0.2 - 630 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Indonesia	1991	5.9 - 220 (Sum of Kaneclors)	Iwata et al., 1994 (a)
Cities, Papua New Guinea	1990	3.3 - 54 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Solomon Islands	1990	1.1 - 5.0 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Japan	1990	63 - 240 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Taiwan	1990	2.3 - 230 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Cities, Australia	1990	0.5 - 790 (Sum of Kaneclors)	Iwata *et al* ., 1994 (a)
Danube River	1992	0.02 - 85 (Ar54+Ar60)	Equipe Cousteau, 1993
Bosphorus, Black Sea, Turkey	1995	0.4 - 4.4 (13 cong)	Readman *et al* ., 1999
Sochi, Black Sea, Russia	1995	0.3 - 4.7 (13 cong)	Readman *et al* ., 1999
Odessa, Black Sea, Ukraine	1995	5.7 - 6.3 (13 cong)	Readman *et al* ., 1999
Coastline, Black Sea, Ukraine	1995	n.d. - 0.4 (13 cong)	Readman *et al* ., 1999
Danube Coastline, Black Sea, Ukraine	1995	1.4 - 2.7 (13 cong)	Readman *et al* ., 1999
Romania Coastline, Black Sea	1995	0.1 - 24 (9 cong)	Readman *et al* ., 1999
Coast of North Vietnam	1997	0.47 - 28.1 (Ar 1254)	Nhan *et al* ., 1999
Coastal Lagoon, Nicaragua	1995	n.d - 50 (Ar54-Ar60)	Carvalho *et al* ., 1999
Caspian Sea, Azerbaijan	2000	0.296 - 3.5 (Ar54+Ar60)	Villeneuve *et al* ., in prep.
Caspian Sea, Russia	2000	1.75 - 10.6 (Ar54)	Villeneuve *et al* ., in prep.
Caspian Sea, Iran	2001	0.05 - 0.995	Villeneuve *et al* ., in prep.
Caspian Sea, Kazakhstan	2001	0.032 - 0.09	Villeneuve *et al* ., in prep.
Bahrain	1994	0.81 - 3.4 {Ar54+Ar60)	IAEA, 1996
	2000	0.301 - 12.2 (Ar54+Ar60)	IAEA, 2001
I.R. Iran	1997	0.145 - 1.59 (Ar54+Ar60)	IAEA, 1998
Kuwait	1994	1.2 - 17.2 (Ar54+Ar60)	IAEA, 1996
	1998	0.145 - 30.7 (Ar54+Ar60)	IAEA, 1999
Oman	1997	0.46 (Ar54+Ar60)	IAEA, 1998
	2001	n.d. - 4.11 (Ar54+Ar60)	IAEA, 2001
Qatar	1997	0.85 - 1.045 (Ar54+Ar60)	IAEA, 1998
	2000	0.02 - 0.79 (Ar54+Ar60)	IAEA, 2001
Saudi Arabia	1998	n.d. - 0.32 (Ar54+Ar60)	IAEA, 1999
U.A.E.	1994	0.51 - 1.21 (Ar54+Ar60)	IAEA, 1996
	2000	0.013 - 0.171 (Ar54+Ar60)	IAEA, 2001
ROPME - Summer Cruise	2001	0.0495 - 0.913 (Ar54+Ar60)	ROPME, 2002

Table 5.3 Average concentrations and ranges of Total PCBs and Total DDTs in sediment samples collected at several locations in coastal waters (concentrations in pg/g dry wt.)

Stations	Total PCBs		Total DDTs	
	Average	Range	Average	Range
Bahrain (6/1994)	1800	810 - 3400	390	174 - 639
Bahrain (11/2000)	3600	301 - 12200	190	88 - 430
I.R. Iran (5/1997)	790	145 - 1590	1600	247 - 3386
Kuwait (6/1994)	3700	1200 - 17200	1600	163 - 6530
Kuwait (10/1998)	3990	145 - 30700	370	4.8 - 1569
Oman (8/1997)	460	-	49	-
Oman (7/2001)	910	0 - 4110	29	0.7 - 85.2
Qatar (6/1997)	950	850 - 1045	2450	404 - 4484
Qatar (3/2000)	390	20 - 790	23	0.63 - 36.7
Saudi Arabia (10/1998)	68	0 - 320	23	0 - 91.3
UAE (6/1994)	750	510 - 1210	49	32 - 66
UAE (3/2000)	57	13 - 171	13	0 - 51.9

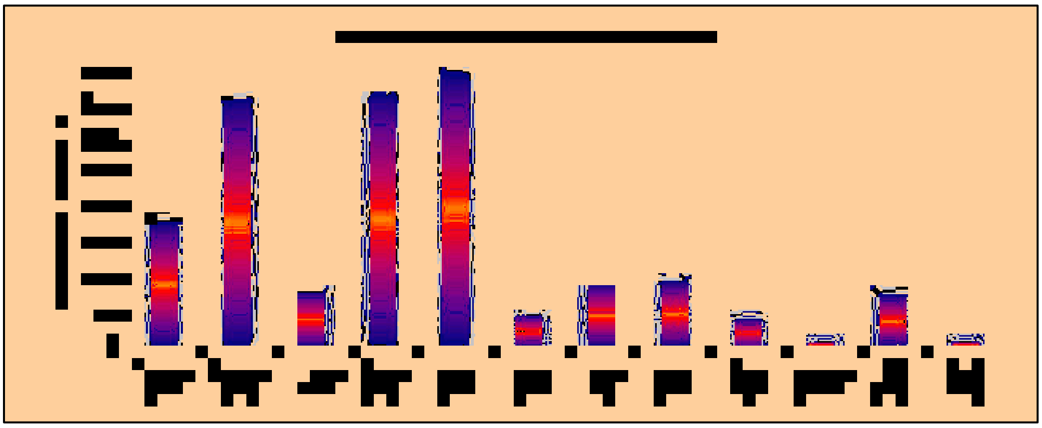


Figure 5.4 Trend in PCBs concentrations in sediment samples within a decade in selected sites of coastal waters in the RSA (1994 – 2000)

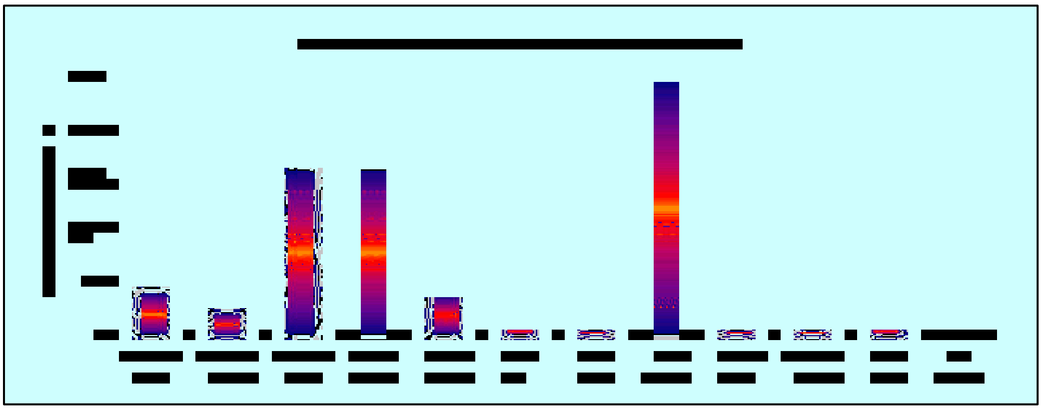


Figure 5.5 Trend in Total DDTs concentrations in sediment samples within a decade in selected sites of coastal waters in the RSA (1994 – 2000)

sediments from all other stations were not exceptional and were similar to levels reported previously for these or nearby sites (IAEA 1996, 1998, 1999; Fowler, 2002a). Maximum PCB (Aroclor 1254) concentrations in the other three Member States were 130, 290 and 510pg g^{-1} dry at Akkah Head ("Three Rocks") in UAE, Doha, Qatar, and PDO beach at Mina Al-Fahal, Oman, respectively. At the latter site in Oman, the very high PCB concentration quantified as Aroclor 1260 (3.6ng g^{-1}) is worth noting and may be specific to land-based inputs from the PDO refinery wastewaters.

DDT residues were also relatively low when compared to other parts of the world (Table 5.4) with the exception of a couple of 'hotspots' identified. The highest levels of ∑DDT were roughly 52pg g^{-1} at Akkah Beach, UAE and 54pg g^{-1} at Al-Sawadi in Oman. At both locations, 30–50% of this amount was pp'DDT, suggesting relatively recent inputs of DDT. Other high ∑DDT levels were 37pg g^{-1} measured at Messaieed, Qatar and 430pg g^{-1} recorded off BAPCO in Bahrain. Also of note are the very low levels of DDT residues measured at Raysut Port and Mughsayl in southern Oman. This observation is consistent with previous organochlorine compound measurements made over the last two decades in Oman and can probably be explained by the more remote nature of this portion of the RSA (Figure 5.5). In summary, DDT concentrations measured in 2000 and 2001 were generally of the same or lower order of magnitude than those measured in previous surveys in the Region (IAEA, 1996, 1998, 1999), and even the maximum concentrations noted at certain 'hotspots' (e.g., off BAPCO) are at the low end of values reported for surface sediments from other seas (Fowler, 1990).

Other interesting results that came to light include the strong lindane signal (100pg g^{-1} dry) recorded at Ras Al-Nouf in Qatar, the clear indication of prior endosulfan use near Askar in Bahrain, Akkah Head ("Three Rocks") in UAE and Ras Al-Nouf, Qatar, and the presence of fresh endosulfan in sediments from BAPCO, Jasra and north of the Meridien Hotel in Bahrain, from Jebel Ali, UAE, Messaieed in Qatar, and Al-Sawadi, Oman. Furthermore, endrin was particularly evident at Akkah Head ("Three Rocks"), Messaieed and near the BAPCO refinery. Dieldrin was quantifiable in most of the sediments but was only relatively high (150pg g^{-1} dry) near BAPCO. Nevertheless, such concentrations were well within the range of concentrations of these pesticides which have been reported in these and other areas of the RSA (IAEA, 1996, 1998, 1999; Fowler, 2002b).

A comparison of concentrations over time for some chlorinated pesticides (HCB, Lindane, total DDT and total PCB) in sediment samples collected at six stations (concentrations in pg/g dry wt.) is illustrated in Figure 5.6.

Table 5.4 Worldwide concentration of DDTs in sediments

Area	Survey Year	Total DDT (ng g-1 dry weight)	References
South Western Coast, Baltic Sea	1993	<0.04 - 88	Dannenberg *et al* .,1997
Vanuatu and Tonga, South Pacific Islands	1991	<0.1 - 1027	Harrison *et al* ., 1996
San Quintin Bay, Mexico	1992	<2 - 15	Galindo *et al* ., 1996
Lake Baikal, Russia	1992	0.01 - 2.7	Iwata *et al* ., 1995
Xiamen Harbour, China	1993	4.5 - 311	Hong *et al* ., 1995
Victoria Harbour, Hong Kong	1992	1.4 - 97	Hong *et al* ., 1995
Western Coast, Australia	1991	1 - 22	Burt and Ebell, 1995
Saratosa Bay, Florida, USA	-	<1 - 69	Sherblom *et al* ., 1995
Gulf of Alaska, Bering Sea, Chukchi Sea	1990	0.01 - 0.2	Iwata *et al* ., 1994 (b)
San Francisco Estuary, USA	1992	<0.1 - 9	Pereira *et al* ., 1994
Cities, India	1989	8 - 450	Iwata *et al* ., 1994 (a)
Cities, Thailand	1990	4.8 - 170	Iwata *et al* ., 1994 (a)
Cities, Vietnam	1990	0.4 - 790	Iwata *et al* ., 1994 (a)
Cities, Indonesia	1991	3.4 - 42	Iwata *et al* ., 1994 (a)
Cities, Papua New Guinea	1990	4.7 - 130	Iwata *et al* ., 1994 (a)
Cities, Solomon Islands	1990	9.3 - 750	Iwata *et al* ., 1994 (a)
Cities, Japan	1990	2.5 - 12	Iwata *et al* ., 1994 (a)
Cities, Taiwan	1990	0.4 - 11	Iwata et al., 1994 (a)
Cities, Australia	1990	0.08 - 1700	Iwata *et al* ., 1994 (a)
Danube River	1992	<0.04 - 41	Equipe Cousteau, 1993
Bosphorus, Black sea, Turkey	1995	0.2 - 7.2	Readman *et al* ., 1999
Sochi, Black Sea, Russia	1995	3.3 - 12	Readman *et al* ., 1999
Odessa, Black Sea, Ukraine	1995	35 - 65	Readman *et al* ., 1999
Coastline, Black Sea, Ukraine	1995	0.06 - 0.6	Readman *et al* ., 1999
Danube Coastline, Black Sea, Ukraine	1995	9.2 - 43	Readman *et al* ., 1999
Romania Coastline, Black Sea	1995	0.6 - 72	Readman *et al* ., 1999
Coast of North Vietnam	1997	6.2 - 10.4	Nhan *et al* ., 1999
Coastal Lagoon, Nicaragua	1995	n.d. - 270	Carvalho *et al* ., 1999
Caspian Sea, Azerbaijan	2000	0.56 - 13.4	Villeneuve *et al* ., in prep.
Caspian Sea, Russia	2000	0.006 - 1.86	Villeneuve *et al* ., in prep
Caspian Sea, Iran	2001	0.057 - 3.897	Villeneuve *et al* ., in prep.
Caspian Sea, Kazakhstan	2001	0.011 - 1.89	Villeneuve *et al* ., in prep.
Bahrain	1994	0.174 - 0.639	IAEA, 1996
	2000	0.088 - 0.43	IAEA, 2001
I.R.Iran	1997	0.247 - 3.386	IAEA, 1998
Kuwait	1994	163 - 6.53	IAEA, 1996
	1998	0.0048 - 1.569	IAEA, 1999
Oman	1997	0.049	IAEA, 1998
	2001	0.0007 - 0.0852	IAEA, 2001
Qatar	1997	0.404 - 4.484	IAEA, 1998
	2000	0.0006 - 0.0367	IAEA, 2001
Saudi Arabia	1998	n.d. - 0.0913	IAEA, 1999
U.A.E.	1994	0.032 - 0.066	IAEA, 1996
	2000	n.d. - 0.0519	IAEA, 2001
ROPME - Summer Cruise	2001	0.012 - 0.204	ROPME, 2002

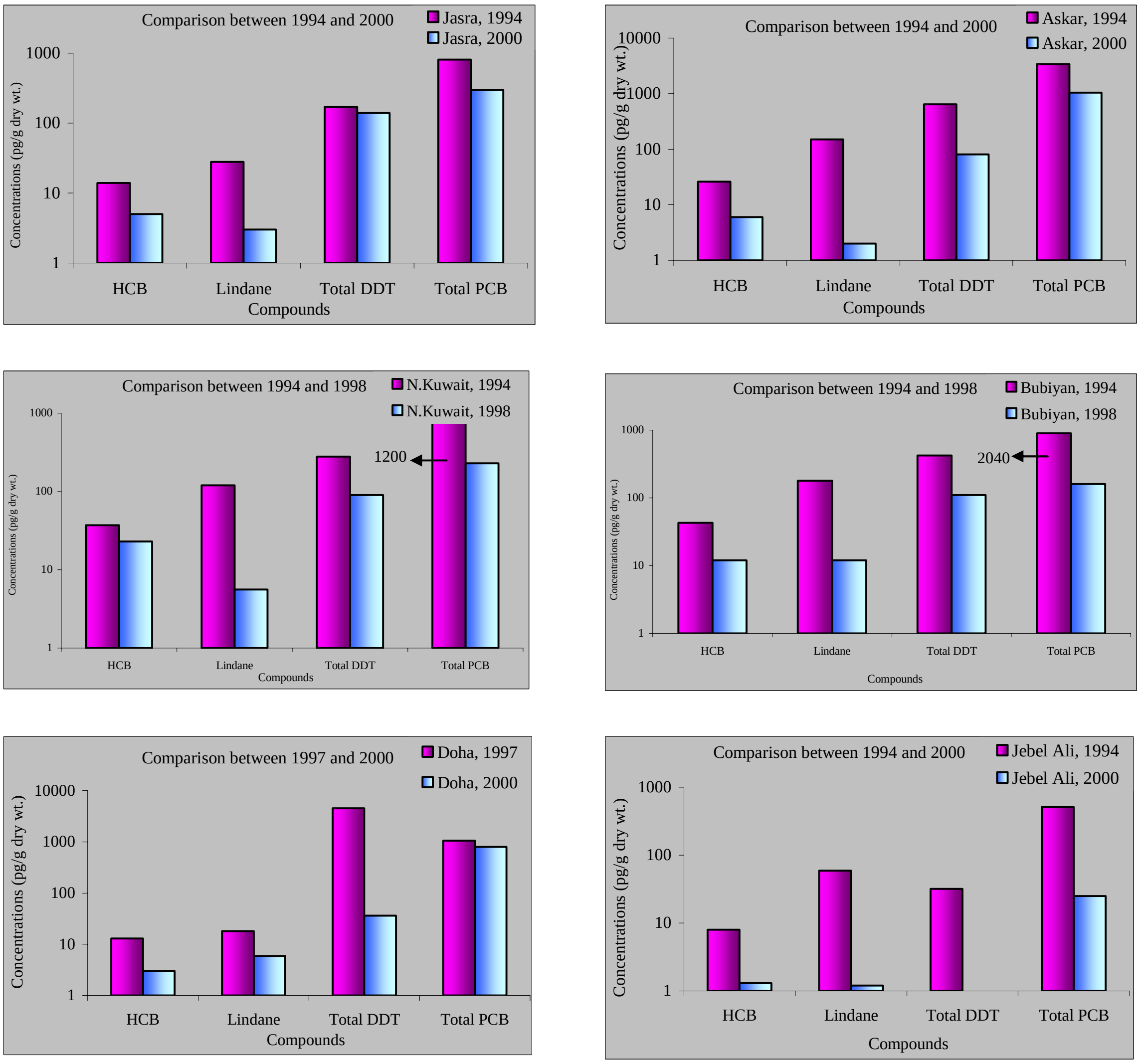


Figure 5.6 Comparison of concentrations of chlorinated pesticides and PCBs in sediment samples over time in selected areas of the RSA (1994 – 2000)

5.1.2.2 *Organochlorine compounds in biota*

Reliable data for organochlorine compounds in edible fish from the RSA are still sparse. Results of tests carried out on fishes revealed that concentrations of PCBs such as Aroclor 1254 were for the most part <1ng g^{-1} in fish muscle with the exception of 1.4ng g^{-1} dry in an orange-spotted grouper from Fasht Al-Adham and 1.8ng g^{-1} in a spangled emperor from Dhannah. PCBs in fish liver were somewhat higher ranging from approximately 3-29ng g^{-1} dry. Similarly ∑DDT levels were low in muscle of all fishes analysed. For studies carried out in Bahrain, concentrations of these DDT residues were consistently found to be in the narrow range of 0.7–1.1ng g^{-1} dry. In the other Member States fishes contained ∑DDTs at levels of less than 0.9ng g^{-1} in muscle and less than 9ng g^{-1}

in liver. Other compounds such as lindane, dieldrin, endrin and HCB were all present in very low concentrations. Endosulfan sulphate was also very low except for 2.1ng g^{-1} dry found in the liver of a spangled emperor from Dhannah near Al-Ruweis, UAE. This concentration was somewhat higher than the 1.6ng g^{-1} dry measured in the muscle of groupers from Musandam in Oman (IAEA, 1998). The presence of the endosulfan sulphate residue in the liver and not in the muscle of the carnivorous spangled emperor from Dhannah suggests that it may have been passed along the food chain to this top predator fairly recently.

Somewhat more data exist for the presence of chlorinated hydrocarbons in bivalves than in fishes. Previous surveys have underscored the difficulty of making regional comparisons because not all bivalve species which have been monitored are ubiquitous throughout the RSA. Only a single clam sample was obtained from the Ras Al-Nouf area in Qatar. The PCB concentration of Aroclor 1254 (0.11ng g^{-1} dry) was very low and can be compared to similar data showing concentrations ranging from 0.7–3.8ng g^{-1} in clams at four stations monitored in 1998 between Tanajib, Saudi Arabia and Doha Bay in Kuwait (IAEA, 1999). Likewise, PCB concentrations in pen shells from Jebel Ali (0.25g g^{-1} dry) were lower by a factor of four than concentrations reported in this bivalve from Khafji, Saudi Arabia (1.1ng g^{-1} dry, IAEA, 1999). The rock scallops from Abu Dhabi displayed PCB levels (1.2ng g^{-1} dry) of a lower order of magnitude than those (11ng g^{-1} dry) found in this bivalve sampled further west off Bidya, UAE in 1994. The only other data available for rock scallops are from 1983 and 1984 surveys made at Askar, in Bahrain, which reported levels of dry PCBs of 19.2 and 7.0ng g^{-1}, respectively, in this bivalve (Fowler, 1988).

Pearl oysters have been used most extensively in such surveys and hence, present one of the best possibilities for making sub-regional comparisons of chlorinated hydrocarbon levels. Total PCB concentrations ranged between 0.1 and 3.7ng g^{-1} dry in pearl oysters from two of the Member States surveyed in 2000. The highest value was recorded in oysters from Abu Dhabi. Since high levels of other chlorinated compounds were also measured in these individuals, this suggests the nearby presence of a local source of mixed contaminants. Nevertheless, when compared to PCB data from previous surveys in the RSA, the concentrations noted at Abu Dhabi are not particularly high; for example, PCB concentrations ranging from <1.0–71 have been reported in pearl oysters from the Region since the late 1970s (Fowler, 2002a).

Pearl oysters have also been used for biomonitoring of organochlorine pesticide compounds. The values of all the pesticide residues were generally low in pearl oysters as well as in the other bivalve species analysed. Only the pearl oysters from Abu Dhabi showed any indication of contamination. For example, the highest levels of ∑DDT residues (5.9ng g^{-1} dry) were found in these oysters, most of which was degraded pp'DDE suggesting an earlier contamination. Many of the other pesticides, such as lindane and HCB, were also found in high levels in oysters from Abu Dhabi, but the levels were not exceptional when compared with concentrations measured previously in these species (Fowler, 2002b).

Rock oysters are another bivalve species which has been continually used in surveys carried out in UAE, Oman and I.R. Iran (Table 5.5). The PCB concentration of Aroclor 1254 (1.1ng g^{-1}) recorded in rock oysters from Akkah Beach in the Gulf of Oman is low in comparison with most of the earlier data for these Member States (Fowler, 2002a). Likewise, PCB levels (1.2–2.7ng g^{-1} dry) in oysters from Oman were also low relative to concentrations measured in the same populations in previous years. It is interesting to examine these recent values in the context of temporal data for this species from Omani stations surveyed since 1980. There has been an irregular but generally decreasing trend in PCB concentrations during the last two decades (Figure 5.7). These compounds are indeed persistent and although three of the most recent data points are defined only by single composite samples, they include some of the lowest PCB concentrations measured to date in rock oysters from the RSA.

Table 5.5 Average concentrations and ranges (ng/g) of Total PCBs and Total DDTs in rock oysters, *Saccostrea cucullata* from several locations of Oman and UAE

Station	Total PCBs		Total DDTs	
	Average[3]	Range	Average	Range
Oman (9/1980)[1]	17.4	7.8 - 39.5	2.7	1.03 - 4.4
Oman (10/1983)	23.7	0.3 - 68.7	4.9	3.0 - 7.7
Oman (1/1984)	5.2	1.9 - 11.4	0.58	0.16 - 0.86
Oman (3/1984)	3.8	1.4 - 7.3	0.37	0.1 - 0.6
Oman (4/1984)	2	0.1 - 4.0	0.43	0.14 - 0.86
Oman (5/1984)	4.5	1.2 - 9.3	0.4	0.32 - 0.47
Oman (7/1984)	3.6	1.5 - 8.1	0.46	0.15 - 0.66
Oman (9/1985)	8.4	6.4 - 11.0	2.9	2.2 - 3.3
Oman (4/1986)	9.1	6.4 - 13.0	3.3	1.1 - 8.4
Oman (9/1986)	3.4	1.0 - 6.0	2.1	1.3 - 2.9
Oman (8/1997)[2]	2.4	-	1.2	-
Oman (7/2001)	1.7	1.2 - 2.7	2.4	0.9 - 4.6
UAE (6/1994)[2]	5.6	-	2.5	-
UAE (4/2000)[2]	1.1	-	1.8	-

[1]Burns *et al.* (1982)

[2]Single composite samples from Dhadnah(1994), Musandam (1997) and Akkah Beach (2000).

[3]PCB as Aroclor 1254

Rock oysters contained chlorinated pesticide concentrations which were relatively low and quite similar to those measured in pearl oysters and the other bivalve species. The ∑DDT residue levels ranged from 0.9–4.6ng g^{-1} dry with the highest concentrations (3.4 and 4.6ng g^{-1}) found in oysters from Al-Sawadi and Hilf. Roughly half of the ∑DDT residue concentrations in these individuals were present as pp'DDT suggesting relatively fresh contamination with DDT at those two locations.

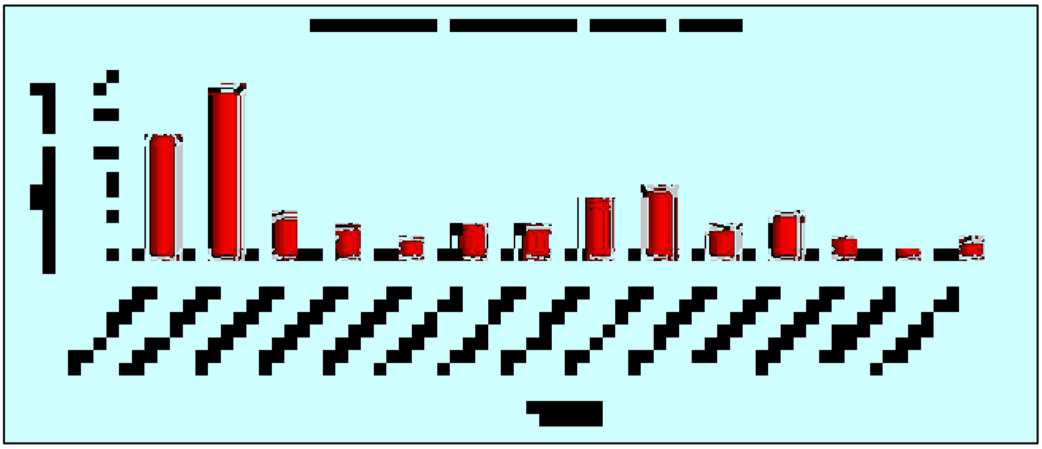


Figure 5.7 Trend of PCBs in rock oysters within two decades in selected areas of the RSA (1980 – 2001)

As in the case of PCBs, it is instructive to examine the temporal data for ∑DDT residues in rock oysters that have been periodically monitored outside the Strait of Hormuz since 1980 (Figure 5.8). It is clear that the levels of ∑DDT in the oysters, while relatively low, have varied little over the last two decades. These low, fairly constant DDT concentrations present in oysters from urbanized and remote areas attest both to their environmental persistence and to their constant release into the environment of the RSA most likely as a result of long range atmospheric transport.

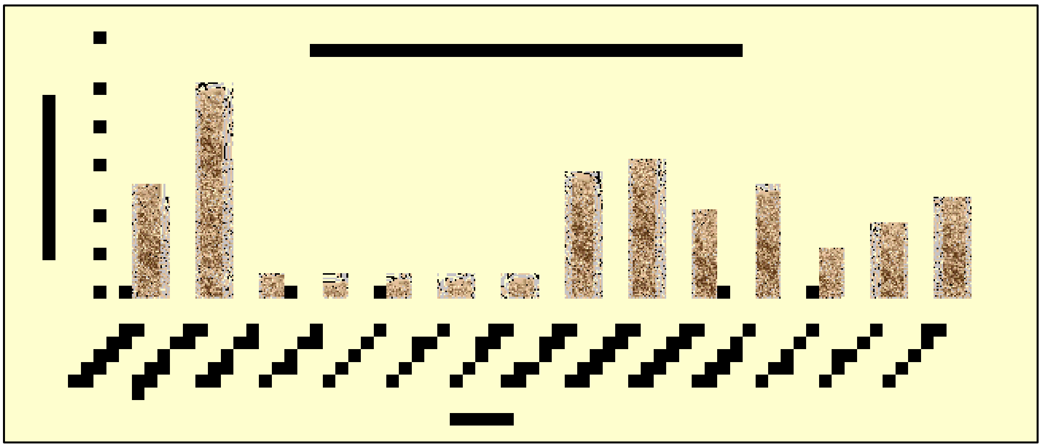


Figure 5.8 Trend of Total DDTs in rock oysters within two decades in selected areas of the RSA (1980 – 2001)

5.1.3 Trace metals

5.1.3.1 *Trace metals in sediments*

The concentration of trace metals in nearshore sediments in Bahrain, Oman, Qatar and UAE indicated that only two locations stand out for having high levels of trace metals in sediments: off BAPCO in Bahrain and at Akkah Beach on the east coast of UAE. Remarkable levels of certain trace metals were noted, e.g., 220ng g^{-1} Hg at BAPCO and 1010µg g^{-1} Ni at Akkah Beach. While the sediments near BAPCO also contained the highest levels of Cu, Pb and Cd noted in the survey, concentrations were highest for Cr, Mn, Co, Fe and As in Akkah Beach sediments. Concentrations of trace metals at the other locations were for the most part substantially lower and fell within the ranges reported previously for these trace metals in the RSA (Fowler *et al.*, 1993; IAEA, 1996, 1998, 1999).

In the 2001 dataset from Oman, the highest concentrations of most of the trace metals were found in sediments near Masirah Island, particularly those from Ras Al-Yei on the east coast of the island. As population density is very low and there are no major industrial activities on the island, the trace metal concentrations in coastal sediments are most likely natural and reflect the local mineralogy. The only notable exception was the concentration of cadmium which was somewhat higher in sediments from Raysut Port and Mughsayl in the south. This trend for high cadmium levels towards the south is consistent with data from earlier surveys which indicated high concentrations of cadmium in sediments around Salalah compared to other areas in Oman (Fowler *et al.*, 1993).

The sediments from Akkah Beach contained high levels of Ni, Cr, Fe, Mn, Co and As as well as many hydrocarbon contaminants, which strongly suggests that they are exposed to an important source of mixed pollutants. However, since there is no major industrial activity or high population centre in this fairly remote area, the source of this type of contamination is not evident. With respect to this particular eastern region of UAE, it is important to note that in June 1994, very high concentrations of Cr (506µg g^{-1}), Ni (187µg g^{-1}) and Co (36µg g^{-1}) were found in sediments from Bidya approximately 4km south of Akkah Beach (IAEA, 1996). In fact the levels of Cr and Co were quite similar to those measured at Akkah Beach six years later. It is not known to what extent these high levels are related to the March 1994 oil spill off Bidya; however, the corresponding concentration of V, a metal sometimes used as a marker for oil, was not particularly high compared to the levels found in other sediments from the region (Fowler, 2002a). Table 5.6 gives a comparison over time of trace metals at three stations. Further sampling in this area is recommended and efforts should be made to determine if specific dumping activities have taken place in the vicinity.

Table 5.6 Concentrations of some trace metals in sediment samples collected at three stations (concentrations in µg/g dry wt.)

Stations	Cr	Ni	Zn	Pb
Jasra, 1994	37.25	19.58	22.44	4.59
Jasra, 2000	14.2	6.63	18.4	2.49
Askar, 1994	No data	32.02	20.52	27.43
Askar, 2000	No data	3.79	8.92	13.2
Jebel Ali, 1994	105.8	46.23	22.9	13.65
Jebel Ali, 2000	31.7	8.3	0	2.1

In the case of the sediments collected off BAPCO in Bahrain, the source of contamination is in all likelihood the industrial and refinery complex around the aluminium plant situated just shoreward of the sampling site. Relatively high concentrations of certain trace metals were also noted nearby at Askar supporting the hypothesis that BAPCO is the source of contamination of Cu, Hg, Pb and Cd, the effects of which diminish with distance from the source. This decrease is most notable for Pb and Hg. It is noteworthy that very high metal concentrations in sediments from near this site have been reported since the early 1980s; for example, in 1983–84 mercury levels in sediments off Askar ranged from 106–286ng g^{-1} dry (Fowler, 1985). Similar samples analysed in 1994 contained 45ng g^{-1} (IAEA, 1996) and those from the present survey show levels of 11ng g^{-1} dry. The approximate decrease in the order of magnitude of these levels over 17 years may reflect an actual reduction in the amount of Hg being released into the environment over this same period.

Organotin compounds in sediments were also analysed to determine the extent and persistence of this toxic organometalic biocide in the RSA. In UAE only monobutyltin was found in significant enough amounts to be measured at the Jebel Ali port complex. In contrast, all three derivatives were measurable at Messaieed and Dukhan in Qatar, and off BAPCO and Askar in Bahrain. In Oman relatively high organotin concentrations were observed only on the west coast of Masirah Island at Hilf (e.g., 60ng Sn g^{-1} dry for TBT). The source of these TBT compounds is not immediately apparent, although many small fishing boats are located in the area around Hilf. The only published data on TBT in the RSA appear to be those of Hasan and Juma (1992) for Bahrain. They reported TBT-Sn concentrations in sediments in the early 1990s ranging from 128–1930ng Sn g^{-1}, i.e., one to two times higher than the 40 and 60ng Sn g^{-1} dry measured at BAPCO, Bahrain and Hilf, Oman, respectively. This apparent sharp decrease in concentration over the last decade may in fact be a result of a ban on the use of TBT that has been in operation for the last few years; however, many more data are needed to confirm this hypothesis. Nevertheless, the concentrations of total butyltins ranging from below detection limits up to 80ng Sn g^{-1} dry are relatively low when compared to European coastal sediments in which levels of 1,000 to over 12,000ng g^{-1} dry are commonly found (Kannan and Falandysz, 1997).

In Bahrain, the national study of trace metals in nearshore sediments during the period 1993–98 indicated concentrations of Zn (21–117.07mg/kg), Cd (0.01–0.10mg/kg), Pb (24.00–76.95mg/kg), and Cu (11.00–76.95mg/kg). Results of recent studies conducted in Bahrain during 2001 and 2002 were compared with the results of other countries; these are shown in Table 5.7. This study included industrial areas like BAPCO, Sitra (SPP) and the Reverse Osmosis Plant (ROP) desalination and power plants, and Addur desalination plant (Figure 5.9). This shows that the levels of trace metals in some sediment samples around Bahrain exceed the Canadian Interim Marine Sediment Quality Guidelines (ISQGs). The reported values are higher than those reported for the other nearshore sites and this is because of the impact of industrial and developmental projects (MNR–Bahrain, 2003).

The Oman national study of trace metals in sediments conducted during 2001 and 2002 indicated relatively high concentrations of Cr, Ni, V and Mn at most of the study sites. The trace metal Cr was especially high in Hqual Masirah (1298mg/kg, dry wt.) and Ni in Khabourah (667mg/kg, dry wt.) during 2001. In 2002, high concentrations of Cu, Cr, V and Ni were observed at Suwadi, Sohar and Khabourah. The range of concentrations for these trace metals recorded during the period is given in Table 5.8.

Table 5.7 Comparison of trace metals concentration ranges (mg/kg dry wt.) in the marine sediments of Bahrain with other countries. For Canadian guidelines, the Interim Marine Sediment Quality Guidelines (ISQGs): dry weight, and numbers in parentheses are probable effect levels, Pels: dry weight.

Reference	Zn	Cd	Pb	Cu
Bahrain - nearshore (1993-1998)	21 - 117.07	0.01 - 0.10	24 - 76.95	11 - 76.95
Bahrain - transect (2001)	12 - 451	71 - 587	0 - 846	9.4 - 257
Bahrain - transect (2002)	3.6 - 29	19 - 147	0 - 12	4 - 60
Bahrain (1983 - 1991)	2.34 - 3.79	0.011 - 0.753	0.64 - 24	1.16 - 17.6
ROPME	0.7 - 410.3	0.01 - 4.5	0.2 - 64.3	1.3 - 142
Arctic	111		21	26
Antarctic	42.3 ± 10.4	0.26 ± 0.16	20.7 ± 2.8	-
Indonesia	1257	< 0.03	2666	448
Togo	60 - 632	2 - 44	22 - 176	22 - 184
Australia	4 - 1150	0.1 - 13	0.5 - 520	0.2 - 180
Indonesia Ref. Value	132.2	-	25.6	40.7
Canadian Guidelines	124 (271)	0.7 (4.2)	30.2 (112)	18.7 (108)

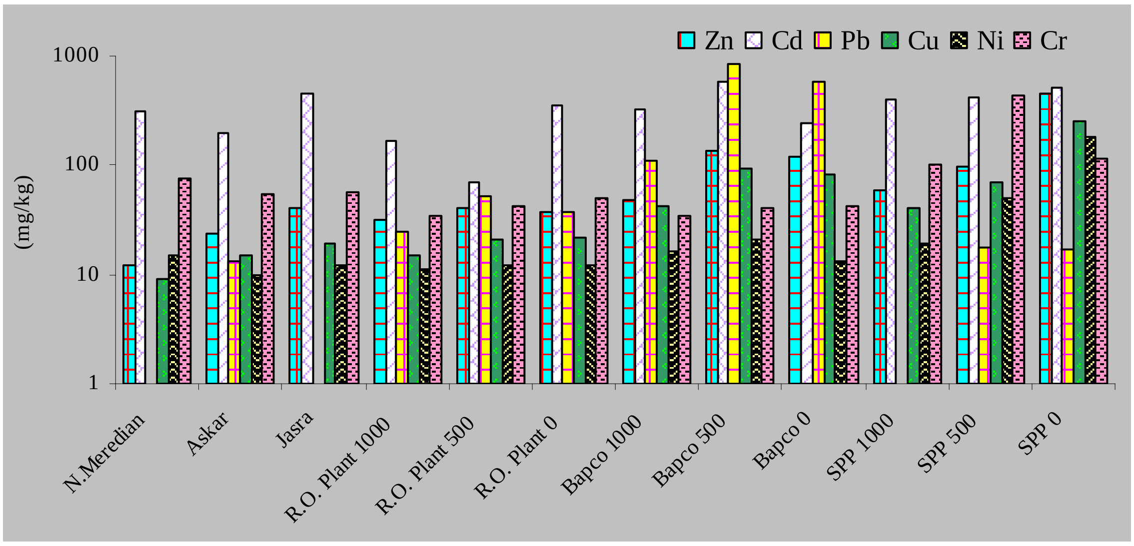


Figure 5.9 Levels of trace metal concentrations in sediment samples taken along the east coast of Bahrain during 2001

Table 5.8 Concentration range of trace metals in the coastal sediments of Oman

Metal	Observed Range (mg/kg dry wt.) 1996-97	Observed Range (mg/kg dry wt.) Feb-Apr 2001	Observed Range (mg/kg dry wt.) Jan-Jun 2002	MAFF Recommended limits+ (mg/kg dry wt.)	EPA Recommended limits+ (mg/kg dry wt.)
Lead (Pb)	Not measured	0.32 – 3.52	0.82-6.87	40	132
Cadmium (Cd)	Not measured	0.15 – 1-60	0.053-0.33	2	31
Copper (Cu)	18.19-29.23	1.09 – 30.1	2.1-22.37	40	136
Chromium (Cr)	**355-496**	**5.96 – 1298.0**	**14.7-951**	**25**	**100**
Nickel (Ni)	**1035-1164**	**4.01 – 667.00**	**10.3-1167**	**20**	**100**
Manganese (Mn)	Not measured	27.90 – 1913.00	36.04-86	No threshold or unknown*	No threshold or unknown*
Vanadium (V)	**27.2-46.8**	**0.77 – 39.90**	**1.01-66.8**	**2**	**31**
Zinc (Zn)	Not measured	<0.05-52.50	40.63-58.04	200	760
Cobalt (Co)	Not measured	Not measured	1.74-5.56	No threshold or unknown*	No threshold or unknown*
Iron (Fe)	Not measured	Not measured	3251-8857	No threshold or unknown*	No threshold or unknown*

Exceeded concentrations are highlighted (MAFF = Ministry of Agriculture, Fisheries and Food of UK; EPA= Environmental Protection Agency of US)
* Information still scarce worldwide
+Values should not exceed these limits

High levels of Cr and Ni (>1,000ppm) have been noted before and appear to be the result of the natural mineralization of ophiolite rocks; thus high levels of Cr and Ni in the sediments from sites such as Bustan can be ascribed to the mineralization of the nearby coastal block of ophiolite rock which is rich in metals with up to 2,000ppm of Cr and Ni. Fans of ophiolite also come out near Sawadi and are found near Haql, Masirah Island. Levels of Cu are mostly below 10ppm, whilst higher values (20 – 30ppm) may be derived from cupriferous ores inland. The values do not exceed the Action Level of 40ppm Cu. It is not clear whether higher levels of V (a 'marker' for crude oil) might also be the result of natural mineralization or whether the presence of this trace metal is an indication of oil pollution (MRMEWR–Oman, 2003).

5.1.3.2 *Trace metals in biota*

For the most part concentrations of trace metals in fish muscle and liver fall within the range of values measured previously in two economically important species (Grouper and Emperor) from the RSA. Values of Cd in the liver of spangled emperor from Dhannah (9.94µg g^{-1} dry) and Al-Marfa (7.19µg g^{-1} dry) were relatively high but corresponding Cd concentrations in the muscle of these fishes were very low. Of particular note were the extremely high Cd concentrations (109 and 19.5µg g^{-1} dry) in the livers of spangled emperor from southern Oman. These levels, which were higher than those observed in the same species from UAE, were verified by analysing a separate aliquot of the freeze-dried sample. To our knowledge, such high Cd concentrations in fish tissue have not been reported previously. While anthropogenic contamination cannot be ruled out, the apparent increase may be due to a transfer within the food chain of high levels of Cd brought into the surface waters through the strong upwelling of nutrient rich waters which took place during the sampling period. Cadmium, which has been shown to maintain a one to one relationship with phosphorus in upwelled waters (Bruland, 1983) could be readily bioaccumulated in the lower portion of the food chain and passed along and eventually bio-concentrated to high levels in the liver of the top predator fish, in much the same way as mercury. This hypothesis could be examined by sampling this species as well as some of its natural prey both during and outside the upwelling period to look for variations in Cd content in liver and muscle. Unfortunately until such data are available, these extremely high Cd levels in the liver of the spangled emperor will remain unexplained.

The highest concentration of Hg (2.35µg g^{-1} dry or 0.49µg g^{-1} wet) was noted in a 4.7kg grouper from Al-Marfa in UAE; nevertheless, the concentration was within the range reported for a wide variety of fishes surveyed previously in the RSA (IAEA, 1990; Al-Majed and Rajab, 1998; Al-Majed and Preston, 2000), and only just approached 0.5ppm wet, a level considered by many Member States to be the acceptable upper limit for consumable fishes.

Concentrations of trace metals in the different bivalves were also estimated. For pearl oysters, rock oysters and the single sample of clams, concentrations of all the trace metals were similar to the levels measured in these species at many of the same locations since the early 1980s (Fowler, 1988; Fowler, 2002a; Fowler *et* *al.*, 1993). Pearl oysters from Abu Dhabi contained relatively high concentrations of V, Ni, Sn and Pb. High concentrations of V and Pb were also noted in pearl oysters from near BAPCO in Bahrain. It is of particular interest that concentrations of trace metals in oysters from Akkah Head and Akkah Beach were not as high as those found in sediments from the same sites (e.g., Ni in UAE). This observation suggests that the trace metals now associated with the local sediments are less bio-available than they were six years earlier when Ni and Cr concentrations in pearl oysters were 15 and 8 times higher, respectively, than they were in June 2000. This may demonstrate that after several years the trace metal contaminants in these sediments are acting as a sink rather than a source to filter-feeding bivalves living near them.

It is also noteworthy that rock oysters from Ras Al-Yei on the seaward side of Masirah Island contained the highest levels of many of the trace metals analysed. In particular, Cd, a nutrient-type element associated with upwelled waters has always been high in oysters from this location especially during the south-west monsoon season (e.g., 16-35µg g^{-1} dry, Fowler *et al.*, 1993). It is possible that during the monsoon months many of these trace metals increase in the water and in the filterable suspended particulates when upwelling and rough sea conditions predominate.

Of all the bivalves examined, clams and pen shells contained the highest levels of As (156 and 153µg g^{-1} dry, respectively). The highest As concentrations reported previously for bivalves from the RSA were approximately 100µg g^{-1} dry in clams collected from Ras Al-Tanajib in Saudi Arabia in 1991 and 1998 (Fowler *et al.*, 1993; IAEA, 1999). If data on the presence of arsenic in all the bivalves sampled during present and previous surveys are examined, it is clear that on average, clams typically contain higher As concentrations than the other bivalve species. For example, the average As concentration for clams collected in these surveys since 1991 is 67.4 ± 42.6µg g^{-1} dry (range 19–156µg g^{-1}, n = 11). It is noteworthy that this average concentration is six times higher than the national average recorded (11.1 ± 3.4µg g^{-1} dry) in bivalves (principally oysters and mussels) collected during 1986–92 for the USA National Status and Trends Mussel Watch project (Valette-Silver *et al.*, 1999). Furthermore, the same study demonstrated that As in oysters (*Crassostrea virginica*) from the SE coast of USA averaged more than double the national average (25.4 ± 10.4µg g^{-1} dry) with the highest values reaching 66µg g^{-1}. Valette-Silver *et al.* (1999) attributed the high concentrations in these oysters to higher levels of As being released into the south-eastern region of the USA from natural phosphate deposits and soil pesticide residues. In all our surveys dating from 1991, As concentrations in pearl oysters and rock oysters from the RSA averaged 32.6 ± 17.4 (n = 15, range 4.5–73µg g^{-1} dry) and 16.7 ± 4.8µg g^{-1} dry (n = 15, range 11.1–29.7µg g^{-1} dry), respectively, levels which are similar to those recorded in oysters from the SE coast of the USA. Aside from these data, virtually no other published information is available on As levels in bivalves from the RSA. However, the few other data which exist for As in fish suggests that the levels found in RSA fish are some of the highest reported in the literature (Attar *et al.*, 1992; Fowler *et al.*, 1993). Given these observations, it would be worthwhile to examine in more detail what factors might contribute to the greater concentrations of As recorded in many biota from the RSA.

Pen shells also revealed relatively high rates of Co and Ni, but only very few comparable data are available for this species (IAEA, 1999). Rock scallops have been analysed in past surveys in UAE and Bahrain. Those specimens collected at Abu Dhabi contained considerably lower concentrations of V, Pb, Ag, Co, Cr and Ni than the scallops analysed in previous years (Fowler *et al.*, 1993). Only Zn levels (1150µg g^{-1} dry) were higher in the sample from Abu Dhabi. Nevertheless, aside from the 'hotspots' which are readily identified by these bivalve indicator organisms, it must be kept in mind that each species shows different abilities to accumulate certain trace metals, hence, cross comparisons using different bivalve species must be made with great care. Therefore, wherever possible, spatial and temporal comparisons of trace metal concentrations using bivalves should use the same species or genera.

A series of biota samples were also analysed for organotin compounds for which very few data are available in the RSA. Concentrations of these compounds were very low in most fish samples and in many cases can only be reported as 'less than' values. Exceptions were 8.8 and 20ng Sn g^{-1} dry for TBT in muscle of two orange-spotted groupers from Badaiya, Bahrain and 16 and 14ng Sn g^{-1} dry respectively in the same species from Messaieed and Doha in Qatar. Likewise, grouper from Quriyat in Oman contained 9.3 and 18ng Sn g^{-1} dry for TBT in their muscle tissue. Diphenyltin (17ng Sn g^{-1}) and triphenyltin (24ng Sn g^{-1}) were also noted in grouper from Al-Khawr, Qatar whereas the corresponding TBT concentration was very low (<6.8ng Sn g^{-1} dry). Overall, the total butyltin concentrations in muscle tissue ranging from approximately 2 to 30ng Sn g^{-1} dry (~0.5-7.0ng g^{-1} wet) are quite low when compared to fishes from other areas. For example, bluefin tuna from the Mediterranean have average butyltin concentrations of 62ng g^{-1} wet (range 16–230ng g^{-1} wet) in muscle (Kannan *et al.*, 1996). Likewise, fishes from coastal areas in the North Sea and Baltic Sea contain much higher concentrations in muscle of 293 ± 21ng g^{-1} wet and from 14–455ng g^{-1} wet, respectively (Shawky and Emons, 1998; Kannan and Falandysz, 1997). Therefore based on the limited data at hand, it appears that organotin concentrations in edible fishes from the four Member States screened pose no immediate problems.

Concentrations of organotin compounds were much higher in bivalves with levels of TBT, DBT and TPhT reading 480, 450 and 110ng Sn g^{-1} dry, respectively, in pearl oysters from Abu Dhabi, i.e., the same bivalves which displayed maximum levels of other trace metals and organic contaminants. Likewise, pearl oysters collected off BAPCO in Bahrain also contained a relatively high level of TBT (150ng Sn g^{-1} dry) but the TPhT concentration was very low (<0.59ng Sn g^{-1}), indicating the likelihood of fresh releases of TBT near this location. Rock scallops from Abu Dhabi also displayed a high concentration of TBT (270 16ng Sn g^{-1} dry), however, the corresponding DBT levels (47ng Sn g^{-1} dry) were lower that those found in the pearl oysters. Both species were collected in areas near the port of Abu Dhabi where small and large boat traffic is common.

TBT concentrations in rock oysters from the Gulf of Oman were all relatively low except in those originating from Akkah Beach, UAE (61ng Sn g^{-1} dry) and Hilf on Masirah Island in southern Oman (176ng Sn g^{-1} dry). Both these locations are fairly remote and far from any significant port activity. However, as far as the high concentrations of TBT in oysters from Hilf are concerned, they mirror the high levels of TBT measured in the surrounding sediments and are a clear indication of fresh releases of TBT into the environment at this location. Such TBT concentrations (ranging from 0.8–176ng Sn g^{-1} dry) are similar to those measured in Sydney rock oysters (approximately 1–90ng Sn g^{-1} dry using a dry/wet ratio of 0.23) in 1991 following the ban on the use of TBT (Bately *et al.*, 1992).

Concentrations of total butyltins in oysters from these four Member States ranged over three orders of magnitude from 6.5 to 1023ng Sn g^{-1} dry. If the two highest concentrations at Abu Dhabi and Hilf are excluded, the range (6.5–188ng g^{-1} dry) is narrowed considerably. These concentrations can be compared with those from the USA Mussel Watch Programme in which total butyltin levels from the East, West and Gulf Coasts ranged from 50–770, 200–2820, and <5-1677ng Sn g^{-1} dry, respectively (Wade *et al.*, 1988, 1991). Furthermore, Wade *et al.* (1991) have shown that mean butyltin concentrations in oysters have decreased over time in the Gulf of Mexico from 328ng Sn g^{-1} dry in 1987 to 140ng Sn g^{-1} dry in 1990. Thus, if we consider the range of butyltin concentrations in oysters from a variety of coastal sites around the USA (Wade *et al.*, 1988, 1991) as well as those from other regions of the world (Alzieu, 1996), it would appear that levels in oysters and other bivalves from the RSA generally fall in the lower end of the range of concentrations typically reported for oysters.

A more in-depth analysis of these first screening results within the RSA is difficult because of the lack of comparable data for organotin compounds in fishes or bivalves from the Region. Some effort should be made to enhance the present database given the widespread occurrence of organotin compounds in the Region, despite a ban on their use.

5.1.4 Faecal sterols in sediments

Coprostanol (5β-cholestan 3β-ol), a metabolic by-product of cholesterol, is one of the principal sterols found in human and animal faeces, and is thus a useful indicator of sewage pollution in coastal waters (Readman *et al.*, 1986a, b). The levels of sterols in selected sediments from UAE, Qatar and Oman were studied. Table 5.9, below, gives a comparison, over time, for two stations where these compounds have been analysed in Qatar and UAE.

Table 5.9 Comparison of concentrations in faecal sterols for sediment samples collected in Qatar and UAE (concentrations in ng/g dry wt.)

Compounds	Doha 1997	Doha 2000	Jebel Ali 1994	Jebel Ali 2000
Coprostanol	60	66	30	20
Coprostan-3-one	22	67	80	54
Cholesterol	540	1000	890	470
Cholestanol	41	390	300	79
Cholestanone	<5.5	60	93	38
Campesterol	65	140	220	79
Stigmasterol	74	570	610	200
ß Sitosterol	640	360	420	220

The levels measured in sediments in the UAE were all quite low and very similar to measurements made six years earlier (IAEA, 1996). Only the sediments from off Akkah Head at "Three Rocks" showed slightly higher levels (68ng g^{-1}) but this area was far from any major population centre and there was no obvious source of sewage in the vicinity. In Qatar, levels at all locations were somewhat higher than in UAE with a maximum value of 170ng g^{-1} recorded at Ras Al-Nouf, again in an area outside a major population centre. Likewise, in Oman only the Al-Sawadi sediments (160ng g^{-1} dry coprostanol) showed evidence of significant sewage input even though this area was also not located near any major city. Given the concentrations which have been measured around Kuwait City (e.g., 300–2,000ng g^{-1} dry, IAEA 1996, 1999), the present levels in Qatar, UAE and Oman do not indicate the occurrence of significant domestic pollution.

5.2 Basin-wide Contamination in the ROPME Sea Area

Basin-wide assessment of contaminants in the inner RSA can be made from the recent investigation conducted by ROPME (Oceanographic Cruise – Summer 2001). A total of thirty-five surface sediment samples were collected for contaminant analyses. The sampling locations are marked in Figure 5.10.

5.2.1 TOC distribution

The total organic carbon (TOC) concentration in the open area of the RSA ranges between 0.7 and 3.7% with an average of 1.7%. These values are higher than those measured in the same area in 1992 (0.4–2.8% with an average of 1.3%), (Al-Ghadban *et al.*, 1994). Since the concentrations of petroleum hydrocarbons have not increased since the previous investigations, this increase in TOC concentrations could be attributed to an increase in biological productivity. New studies on the full annual cycle of biological productivity would help to clarify the TOC distribution of the inner RSA.

The lipid content varies in the range of 0.042–0.371 mg g' and the sediments are characterized by a relatively high percentage of carbonate, namely a mean of 6.2%.

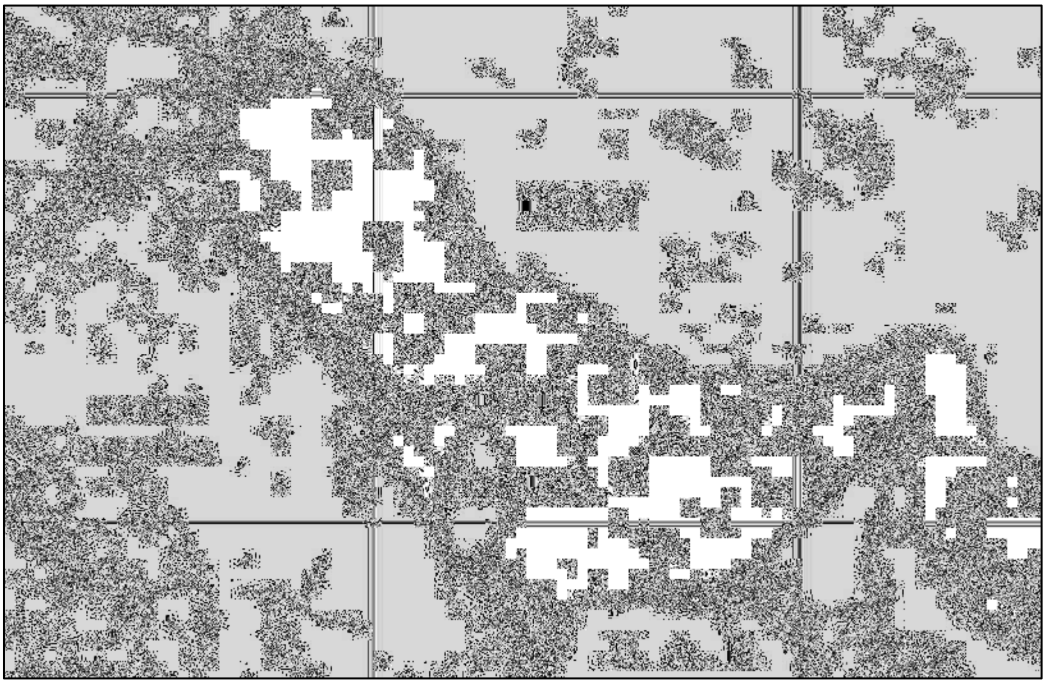


Figure 5.10 Sampling locations for contaminant analyses in the inner RSA

5.2.2 Petroleum hydrocarbons

Total petroleum hydrocarbon concentrations in sediments from the inner RSA are expressed in three ways: Total aliphatic and aromatic hydrocarbon concentrations (Total PHs), Chrysene equivalents, and ROPME oil equivalents. The total petroleum hydrocarbon (TPH) concentration ranges from 6 to 99µg g^{-1} with an average of 35µg g^{-1}, and from 0.7–11µg g^{-1} as ROPME oil and Chrysene equivalents, respectively (Figure 5.11). These concentrations are similar to those reported for the same open area of the RSA in surveys undertaken in December 1994 (5.4–92µg g^{-1}, average 33µg g^{-1} as ROPME oil), (Al-Lihaibi and Ghazi, 1996) and lower than those measured in 1992 at the same sites (Massoud *et al.*, 1996). They are also significantly lower than those reported from coastal areas of the RSA that were affected by the 1991 War spill (Fowler *et al.*, 1993; Readman *et al.*, 1996; IAEA, 1996, 1998, 1999). According to some guidelines for contaminant levels in sediments on the bottom of the RSA (Massoud *et al.*, 1996), concentration levels lower than 15µg g^{-1} (as Chrysene equivalents) are considered the natural background level in this area.

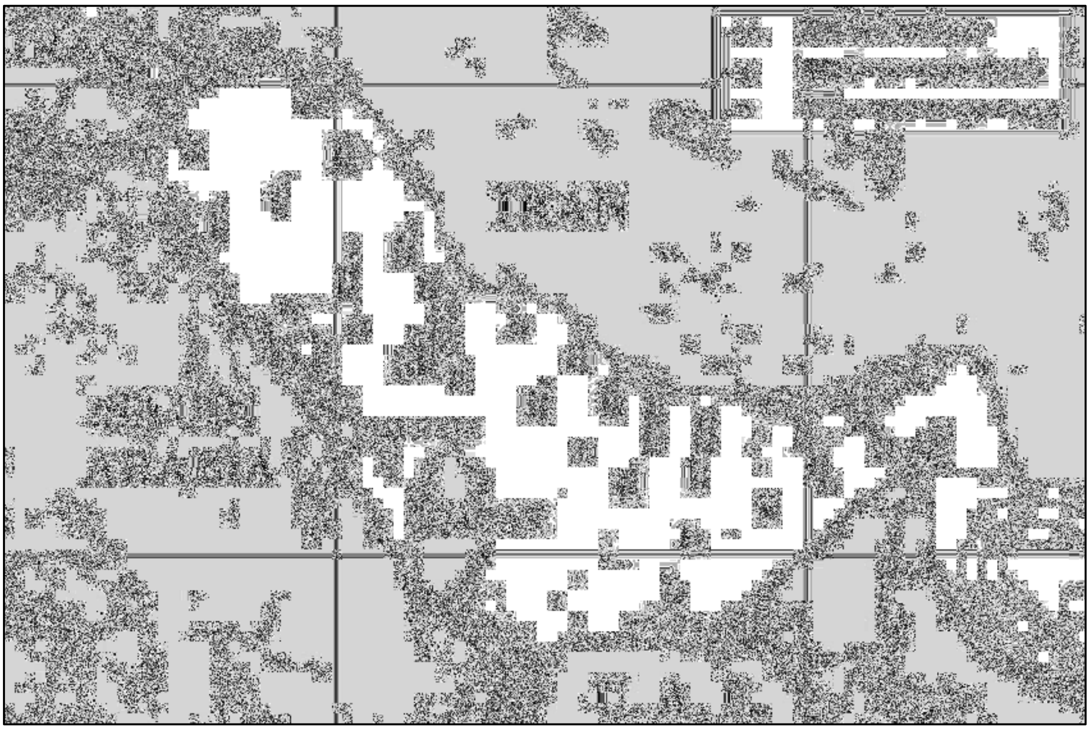


Figure 5.11 Total petroleum hydrocarbon concentrations in sediments from the inner RSA in 2001

As shown in Figures 5.11 and 5.12, total unresolved aliphatic concentrations higher than 10µg g^{-1} and/or total petroleum hydrocarbons as ROPME oil equivalents from 60–100µg g^{-1} indicated slight oil contamination. Affected sites were found in the offshore area of the Saudi Arabia stations (Station 23) to the Iranian coast (Stations 24, 25, 26), in the central coastal area of I.R. Iran (Stations 40 & 56), in the offshore Western Basin (Station 17) and at the Strait of Hormuz in the south-east (Station 78).

No correlation was observed between the percentage of fine-grained material and both concentrations of petroleum hydrocarbons and TOC. This result concurs with those of a previous investigation in the same area (Al-Lihaibi and Al-Omran, 1996), but contrasts with later studies (Massoud *et al.*, 1996) where a significant correlation was found between percentages of fine-grained materials and TPH. Nevertheless, none of these studies found a positive correlation between TOC and both grain-size and TPH contents, indicating that TOC cannot be used as an indicator for petroleum hydrocarbon pollution in the RSA.

Interestingly, the total concentrations of resolved n-alkanes (3.3–12µg g^{-1}) were consistently as high as those of the unresolved aliphatic compounds (unresolved complex mixture or UCM), with values ranging from 3–16µg g^{-1} (Figure 5.12).

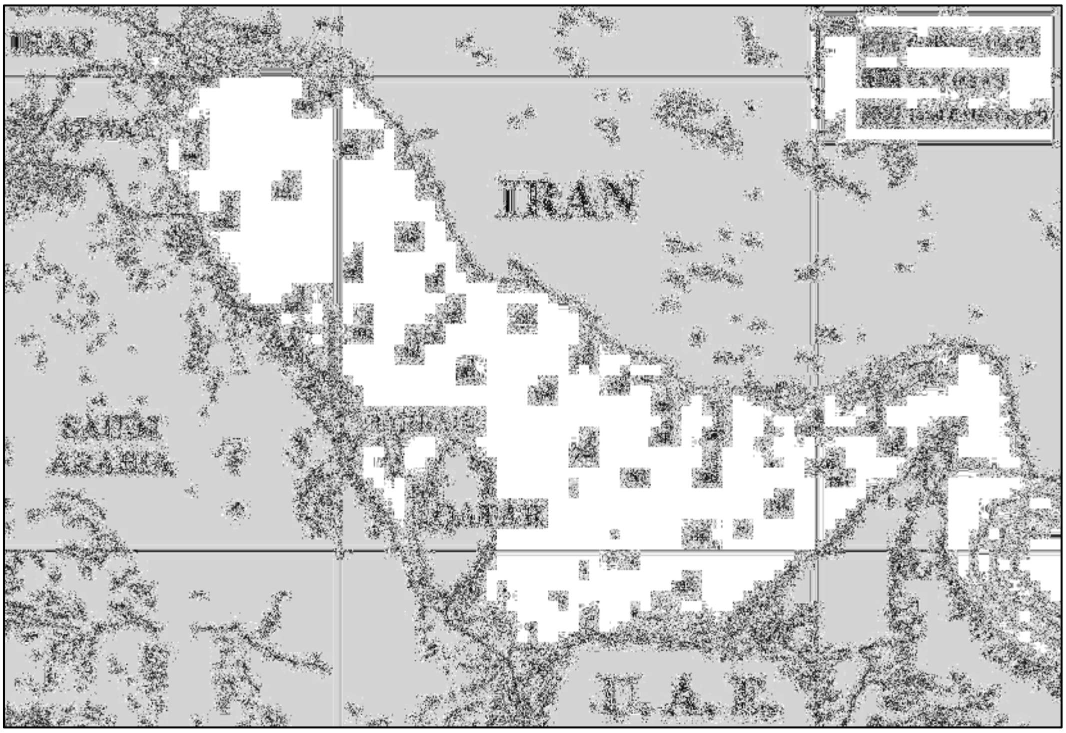


Figure 5.12 Concentrations of n-alkanes, unresolved complex mixture and total polycyclic aromatic hydrocarbons in sediments from the inner RSA in 2001

The low levels of UCM with minor amounts of specific petroleum biomarkers (hopanes) indicate little evidence of chronic degraded oil pollution. The pattern of n-alkanes showed an unusual distribution dominated by the even carbon number preference in the C_{12} to C_{22} n-alkanes, with a minor contribution of long-chain homologues (C_{27}, C_{29}, C_{31}), derived from terrestrial higher plant waxes. This strong preference for even carbon numbers of the C_{12}-C_{22} n-alkanes, which apparently is not directly related to petroleum sources, has only been found previously in a few surface sediments from the north-western RSA coast, the Omani coastal zone (Grimalt and Albaiges, 1985; Mille *et al*. 1992), and in ancient sediments from the RSA (Welte and Ebhardt, 1968). In contrast, this distribution was not found in the earlier surveys carried out at the same sites in December 1993–94 (Al-Lihaibi and Ghazi, 1996; Al-Omran and Rao, 1999). Although a few examples, such as seed oil from leguminosae species exist among living organisms and support the hypothesis of a predominant direct biological input (Lamarque *et al.*,1998), the widespread distribution of these compounds in all stations from the RSA can only be explained by the particular environmental conditions prevailing in the area during the summer. The restricted water circulation, the well-oxygenated bottom waters, the high temperatures (>30^{o}C) and salinities (up to 40‰) are known to be favourable conditions for oil degradation and therefore it is suggested that these n-alkanes might be the result of bacterial degradation of petroleum hydrocarbons. Although these compounds have not yet been identified in marine plankton, some authors (Al-Saad and Al-Timari, 1993) have suggested that diatoms might be responsible for the even carbon n-alkanes in these sediments. In other areas where anoxic conditions prevail, such as the Black Sea and Cariaco Trench, this particular n-alkane distribution was attributed to the bacterial reduction of autochthonous fatty acids maximizing at C_{16}-C_{18} (Debyser *et al.*, 1975; Dastillung and Corbet, 1978).

The distribution of total PAH concentrations throughout the sediments in the inner RSA is shown in Figure 5.12. Here, the range of values was also low, from 29 to 480ng g^{-1}, with a content 10 times lower than stipulated by the NOAA Sediment Quality Guideline value for Effects Range Low (ERL) of 4,000ng g^{-1} dry wt. (Long *et al.*, 1995). The overall trend mimicked that of the unresolved aliphatic hydrocarbons with highest PAH concentrations observed at Station 23 (480ng g^{-1}) in the centre of the inner RSA and Station 78 at the Strait of Hormuz (300ng g^{-1}) in the south-east.

With the exception of Stations 23, 78 and 1, pyrene concentrations were relatively low (0.78–8.5ng g^{-1} dry) and were at the lower end of the ranges measured in coastal RSA sediments collected after the 1991 War spill (1–450ng g^{-1}), (Fowler *et al.*, 1993) and in 1994 (1.6–510ng g^{-1}), (IAEA, 1996). Similarly, the extremely low benzo(a)pyrene levels, 0.1–1.2ng g^{-1} dry, are certainly some of the lowest concentrations reported to date in the Region (Saeed *et al.*, 1996).

Representative PAH sedimentary patterns show a typical profile of petrogenic PAHs, with a predominance of alkyl-substituted phenanthrenes and chrysenes. Pyrolitic sources, evident by the dominance of the unsubstituted PAH over their alkylated homologues and a dominance of 4–6 ring PAH over the low molecular weight 2–3 ring PAHs, were extremely low indicating a very low input of combustion-derived PAHs.

5.2.3 Organochlorinated compounds

The concentrations of total DDTs, total HCHs, and total PCBs for all stations are shown in Figures 5.13, 5.14 and 5.15, respectively. Except for a few stations, the concentrations recorded were relatively uniform. The only locations where comparatively high concentrations were exhibited were Station 20 for total DDT, Station 56 for total HCHs, and Stations 27 and 78 for Total PCBs.

Station 20, where a Total DDT concentration of 650pg g^{-1} was obtained, as compared to about 100pg g^{-1} for the other stations, is situated almost in front of Mond. This station was monitored in 1997 (IAEA, 1998) when it exhibited a concentration of 778pg g^{-1} dry wt. At Station 27, also close to Mond, the Total PCBs concentration obtained was about 700pg g^{-1} dry wt. (concentration found in 1997: 145pg g^{-1} dry wt.).

The highest Total PCBs concentration (about 900pg g^{-1} dry wt.) was obtained at Station 78, which is close to Hormuz Island. This site had also been sampled in 1997 and had a comparable Total PCBs concentration of 900pg g^{-1} dry wt.

In other remaining stations, the concentrations obtained are low when compared to the concentrations obtained in other areas of the world (ROPME, 2002).

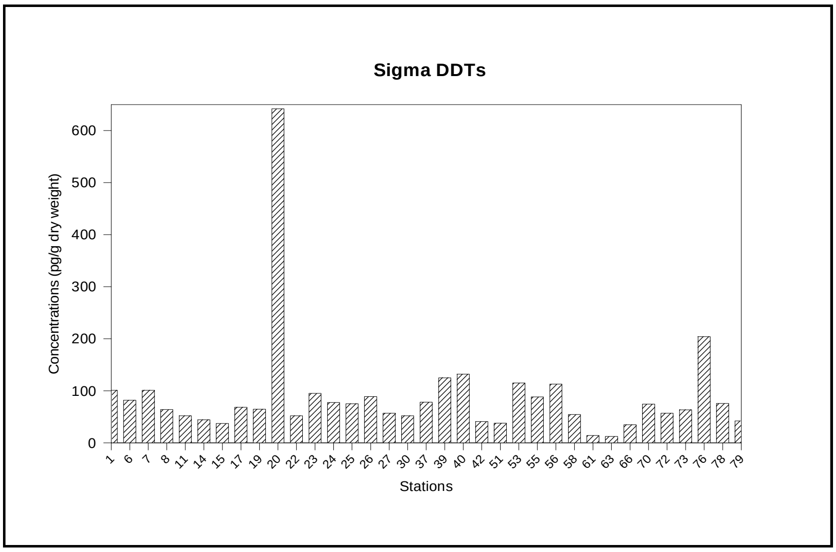


Figure 5.13 Total DDT in sediments throughout the inner RSA in 2001

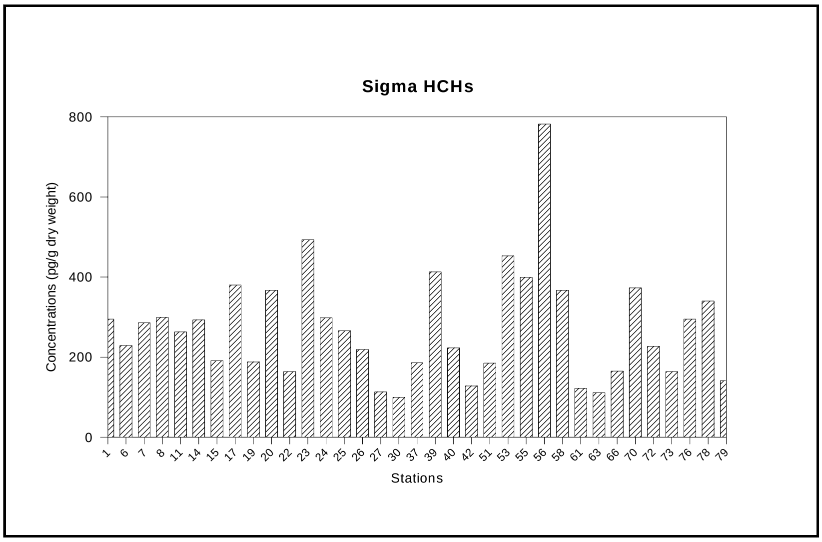


Figure 5.14 Total HCHs in sediments throughout the inner RSA in 2001

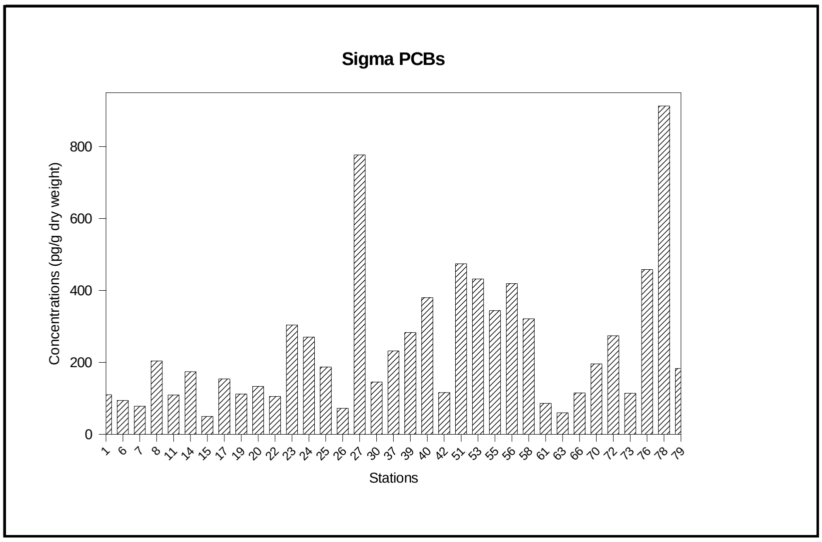


Figure 5.15 Total PCBs in sediments throughout the inner RSA in 2001

5.2.4 Trace metals

Following a standard protocol, the ROPME sediment samples were sieved at 1,000 micron to remove larger shell fragments, seaweed, etc. The basis for this protocol is to assess the entire sample, without preferentially selecting any particular size fraction in order to ensure adequate representation. The disadvantage of assaying the sample in this manner is that the sample collected may contain a significant fraction of silica-based (sand) and/or coarse material in addition to the finer sedimentary material. Silica generally does not contain significant concentrations of any other trace metals, so it in effect dilutes the sediments such that the trace metal concentrations are lower than they would be if just the sedimentary fraction were analysed. This characteristic plays an important role in interpreting the distribution of contaminants in the RSA sediments. Fine material, with a larger surface to volume (or weight) ratio, has a greater potential to scavenge both inorganic and organic contaminants from the water column. In general terms, fine mud/silt/clay sediments with high organic content retain more contaminants than relatively coarse sandy sediment. Thus, sites where fine materials are deposited are likely to exhibit a higher concentration of trace metals, for instance.

To account for this factor, it is common to normalize the trace metal results to a reference metal that is characteristic of the terrestrial material. This typically is an element found at high and relatively reproducible concentrations in sediments that behaves conservatively in the marine environment. The trace metals characteristically used for normalization are Al, Fe, or Li.

For this assessment, Al was selected as the trace metal to establish the normalization standard. All trace metals in each sample were normalized such that the Al concentration in that sample was set to 30,000 micrograms per gram (dry weight), which was an approximate average concentration. With few exceptions, the Al concentration was relatively constant across the suite of samples examined. After normalization, the mean and standard deviation were calculated for each trace metal. Concentrations greater than three standard deviations from the mean were flagged as end-points on the figures. The concentration means were also compared with accepted action levels and limits; concentrations were compared firstly to the NOAA Marine Sediment Quality Guideline values (Table 5.10) by designating an Effects Range Low (ERL) and an Effects Range Medium (ERM). In the absence of a NOAA-defined ERL for a substance, the Canadian Interim Marine Sediment Quality Guideline (ISQG) value has been used. This Table also presents the Probable Effects Level (PEL) given by Environment Canada.

Table 5.10 Sediment Quality Guidelines from NOAA (USA) and Environment Canada

Chemical	Units	ERL	ERM	ISQG	PEL
As	$\mu g\ g^{-1}$ dry	8.2	70	7.24	41.6
Cd	$\mu g\ g^{-1}$ dry	1.2	9.6	0.7	4.2
Cr	$\mu g\ g^{-1}$ dry	81	370	52.3	160
Cu	$\mu g\ g^{-1}$ dry	34	270	18.7	108
Pb	$\mu g\ g^{-1}$ dry	47	220	30.2	112
Hg	$\mu g\ g^{-1}$ dry	0.15	0.71	0.13	0.7
Ni	$\mu g\ g^{-1}$ dry	21	52	-	-
Ag	$\mu g\ g^{-1}$ dry	1	3.7	-	-
Zn	$\mu g\ g^{-1}$ dry	-	-	124	271

5.2.4.1 *Site-specific assessments*

There were only a few samples that showed what appeared to be significant contamination for at least two trace metals. The most notable of these was Station 73, off the coast of eastern UAE (near Dubai), which showed significantly elevated concentrations of V, As, Cd, Sn, Sb, and Pb, with a slightly elevated Cr concentration as well. It should be noted that the normalization factor for this sample was quite high, which account for the anomalously high values (Both Fe and Al were low in this sample, but most of the other elements were not; the resulting normalization meant that apparent concentrations seemed to be relatively high).

Relatively high normalized concentrations for As, Cd, and Sr were also observed in sample 15, collected off the coast of Saudi Arabia, possibly for the same reason; the sample had relatively low concentrations of Al and Fe, but not comparatively low concentrations of other trace metals. For these samples, it may be that the best way to determine whether or not there is a true contamination problem would be to process and analyse just a fine fraction of the sample.

Samples collected at Station 7, in the western RSA between Iraq and I.R. Iran, showed a very high Zn concentration, an order of magnitude of nearly one time greater than the Probable Effects Level (PEL) given by Environment Canada. The normalization factor for this sample was very close to 1; i.e., the elevated Zn was observed in the original sample and is not an anomaly.

One site off the coast of Saudi Arabia (sample 23) showed a slightly high Ag concentration (normalized), and two sites off the coast of UAE (61 and 72) showed marginally higher Hg concentrations, but these concentrations were only high relative to other samples and not significant with respect to the limits used for comparison in this study. With those exceptions, the samples appeared to be relatively similar to each other.

5.2.4.2 *Element-specific observations*

Based on all the measurements of trace metals and the findings, a discussion on element-specific observations follows.

5.2.4.2.1 Arsenic (As)

Figure 5.16 maps the distribution of total arsenic (e.g., not normalized to aluminium) found in sediments throughout the inner RSA. This illustrates the relative higher concentrations in sediments near the Strait of Hormuz. The NOAA ERL value (8.2µg g^{-1}) is exceeded for one site in Saudi Arabia, one site in I.R. Iran, and many sites in the UAE. The distribution of normalized arsenic concentrations for all sites sampled is presented in Figure 5.17.

5.2.4.2.2 Barium (Ba)

There was only one site in the RSA with an anomalously high level relative to other locations. This concentration, 1360µg g^{-1} for sample 63 collected off the coast of UAE, exceeds those found elsewhere. As barium is used in drilling mud, this may explain the high levels. However, this is not an element of concern with respect to environmental toxicity.

5.2.4.2.3 Cadmium (Cd)

Figure 5.18 presents the cadmium concentration for all samples. Concentrations never exceed the NOAA ERL value of 1.2µg g^{-1}.

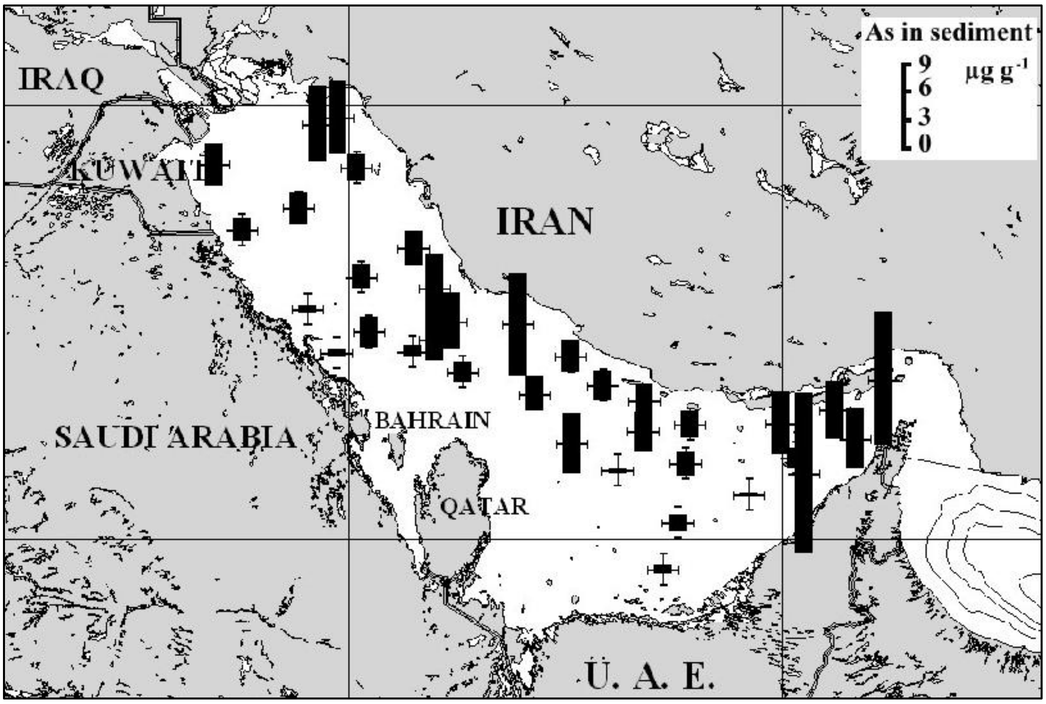


Figure 5.16 The distribution of arsenic in sediments from the inner RSA in 2001, whereby the mid-point of the bar designates the sample location

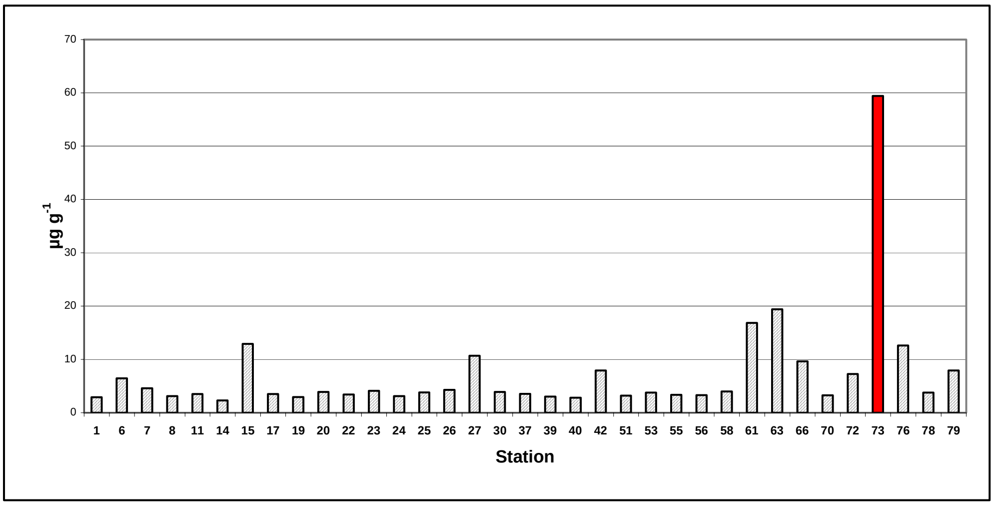


Figure 5.17 Arsenic concentrations normalized to aluminium for all stations in 2001

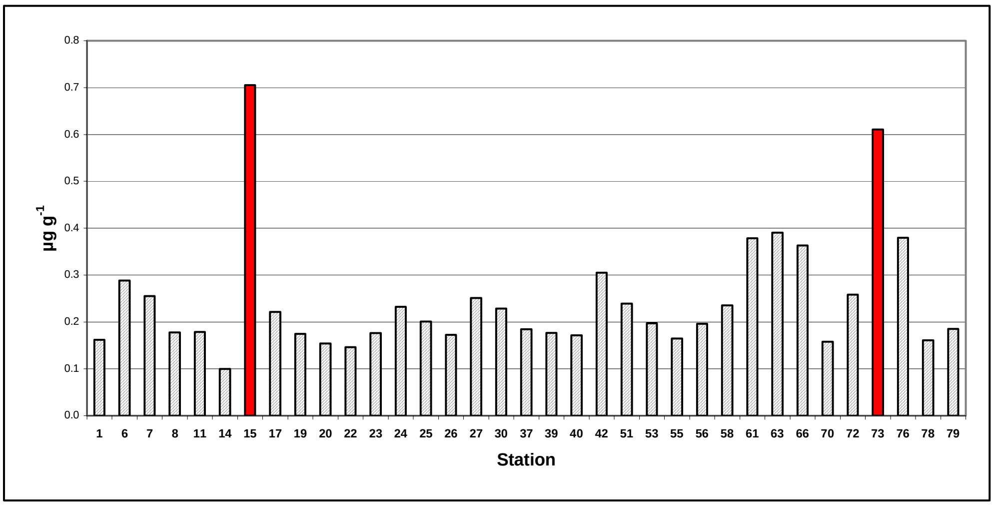


Figure 5.18 Cadmium concentrations normalized to aluminium for all stations in 2001

5.2.4.2.4 Chromium (Cr)

The distribution of chromium is relatively uniform throughout the inner RSA, with few significant variations (Figure 5.19); however, the normalized Cr content exceeds the NOAA ERL value at every location sampled. It is assumed that the high ERL value of 81µg g^{-1} and concentrations of Cr stem from its high rate of natural occurrence in the Region.

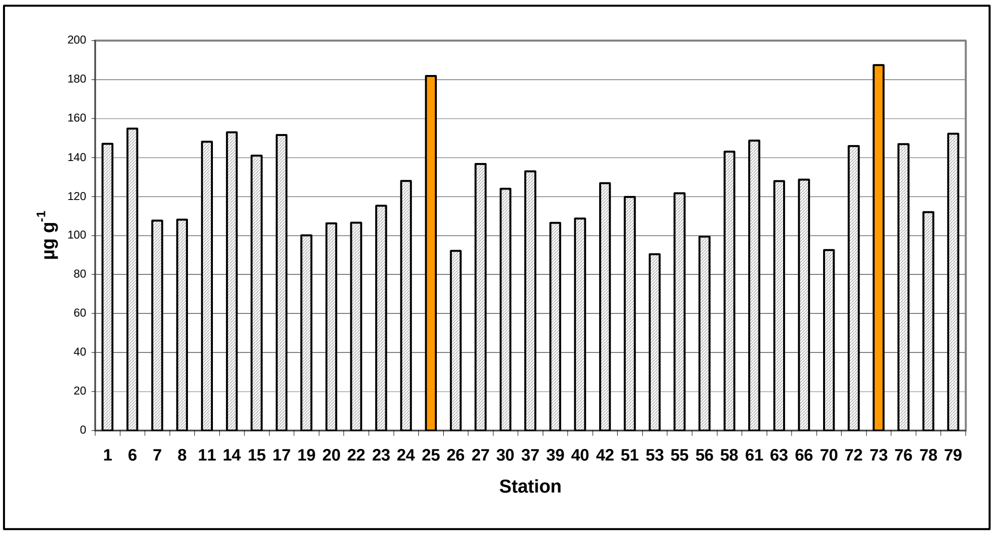


Figure 5.19 Chromium concentrations normalized to aluminium for all stations in 2001

5.2.4.2.5 Copper (Cu)

In general, the distribution of copper in the sediments, illustrated in Figure 5.20, is remarkable. It is relatively uniform in concentration, and never exceeded the NOAA ERL value of 34µg g^{-1}.

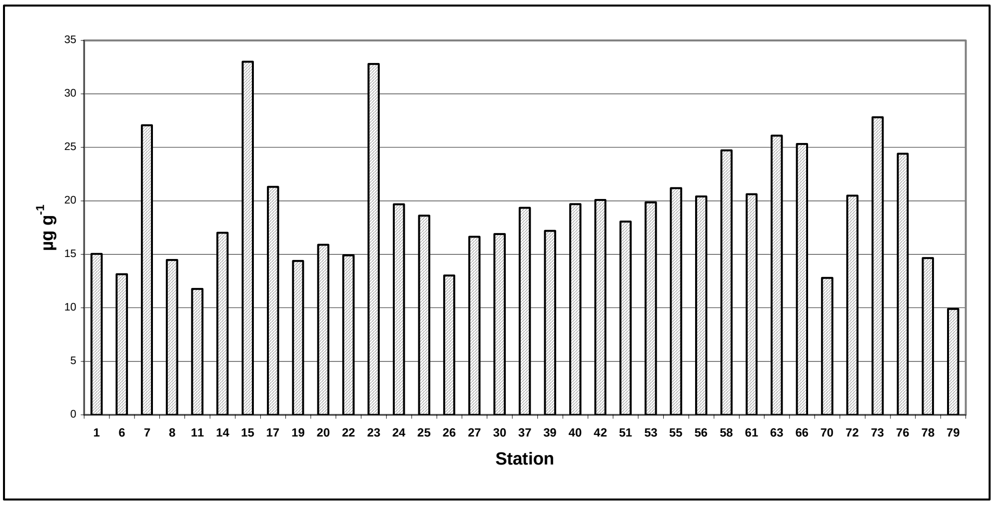


Figure 5.20 Copper concentrations normalized to aluminium for all stations in 2001

5.2.4.2.6 Lead (Pb)

Like cadmium and copper, the lead concentrations are not very high for the sites investigated in the RSA (Figure 5.21). The highest normalized concentration (~18µg g^{-1}) was found near Dubai at Station 73, however levels never came close to exceeding the NOAA ERL value of 47µg g^{-1}.

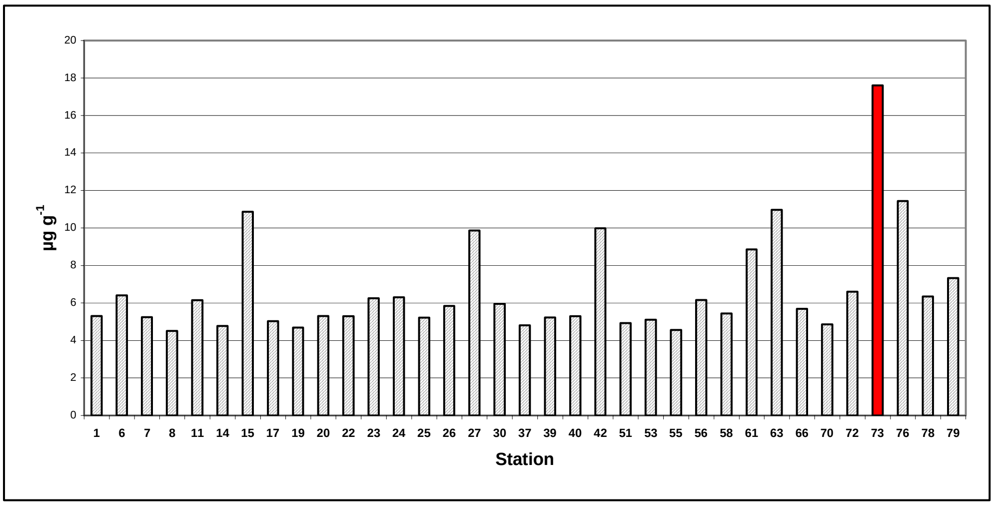


Figure 5.21 Lead concentrations normalized to aluminium for all stations in 2001

5.2.4.2.7 Mercury (Hg)

The distribution of mercury in sediments throughout the inner RSA is shown in Figure 5.22. As mentioned previously, there are two sample sites off the coast of UAE where relatively high levels of Hg were reported, however the concentrations at all sites never exceeded the NOAA ERL value of 0.15µg g^{-1}.

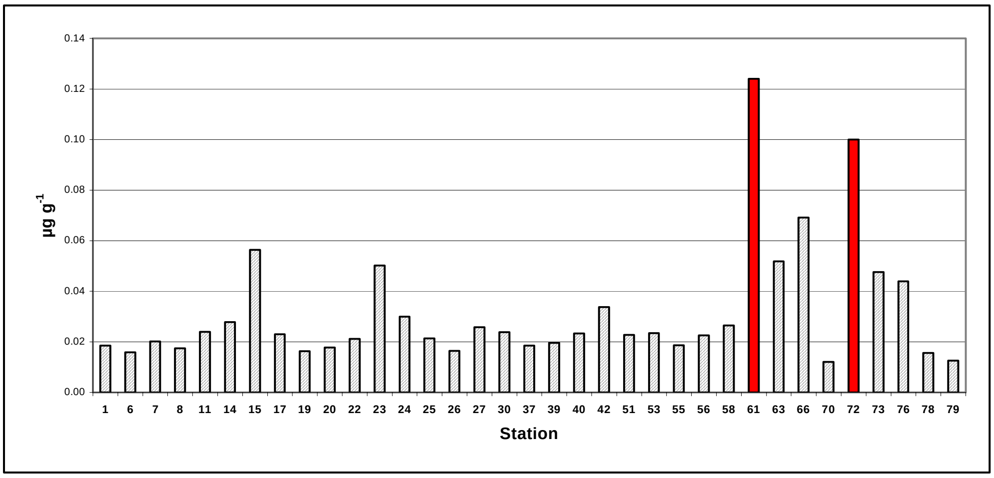


Figure 5.22 Mercury concentrations normalized to aluminium for all stations in 2001

5.2.4.2.8 Nickel (Ni)

Figure 5.23 depicts the normalized nickel concentration at all sites investigated in the inner RSA. The distribution is similar to that of chromium, reflecting a uniformly high natural occurrence due to the regionally high mineral content. The NOAA ERL (21µg g^{-1}) and the ERM (52µg g^{-1}) was always exceeded, but reflects a high natural occurrence.

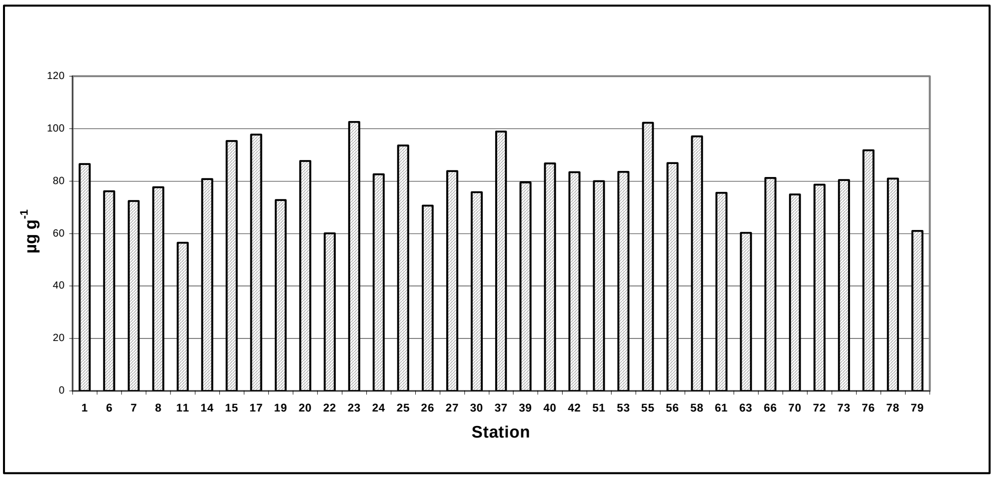


Figure 5.23 Nickel concentrations normalized to aluminium for all stations in 2001

5.2.4.2.9 Silver (Ag)

The silver content of sediments from all sites is presented in Figure 5.24. All sample concentrations were low. Although one sample (Station 23, off the coast of Saudi Arabia) appeared to contain a slightly higher concentration of Ag, a known indicator of an anthropogenic source, however, compared to the other samples, the level of all samples never exceeded one-tenth of the NOAA ERL value of 1µg g^{-1}.

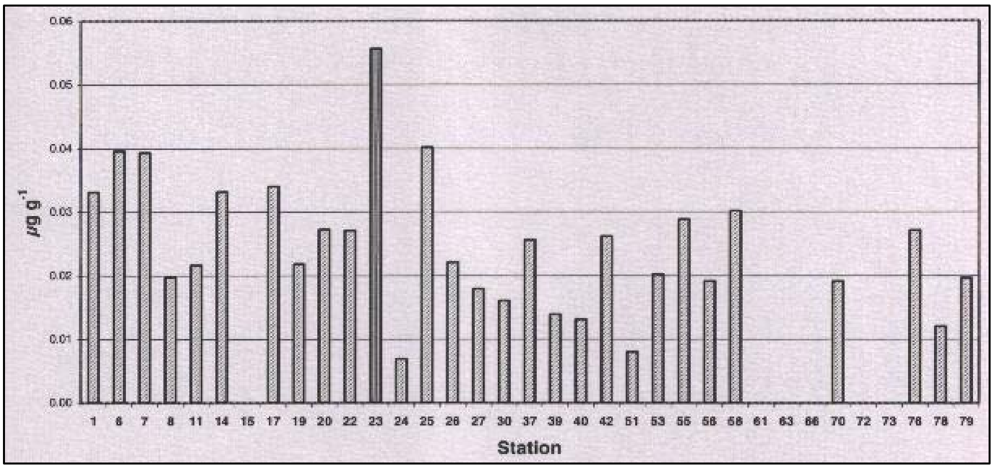


Figure 5.24 Silver concentrations normalized to aluminium for all stations in 2001

5.2.4.2.10 Vanadium (V)

Figure 5.25 shows the distribution of vanadium in sediments taken from the inner RSA. With only one exception (that of Station 73, which is low in Al), the V distribution closely mimics that of aluminium, as demonstrated by the relative uniformity observed between the normalized V concentration values.

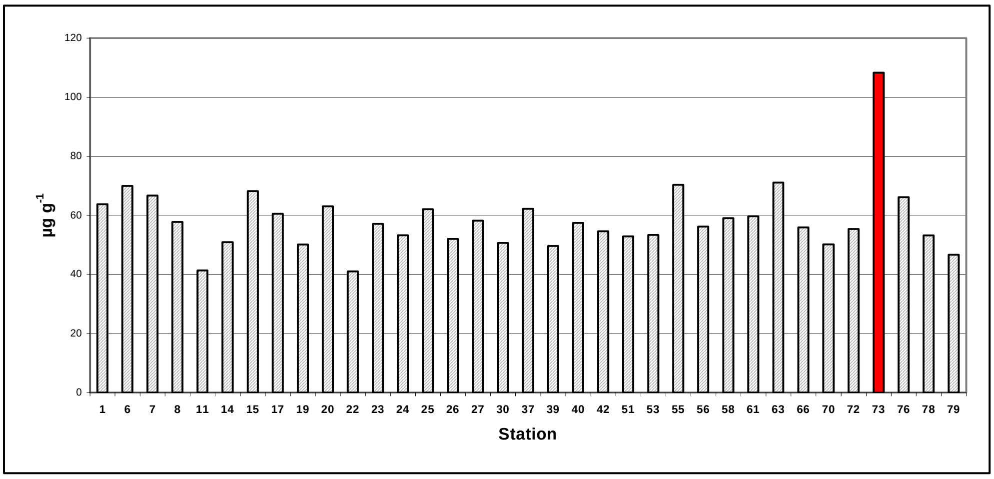


Figure 5.25 Vanadium concentrations normalized to aluminium for all stations in 2001

5.2.4.2.11 Zinc (Zn)

The distribution of zinc is presented in Figure 5.26, and in contrast to other figures, is expressed as a log scale. Generally the overall pattern of normalized distribution is relatively uniform, again due to the grain size. However, one important 'hotspot' is obvious in the western region of the RSA, between Iraq and I.R. Iran at Station 7. Here, the concentration, 2,200µg g^{-1} (with or without normalization the value was virtually identical), exceeded the Canadian PEL value of 271µg g^{-1} by an order of magnitude of nearly one.

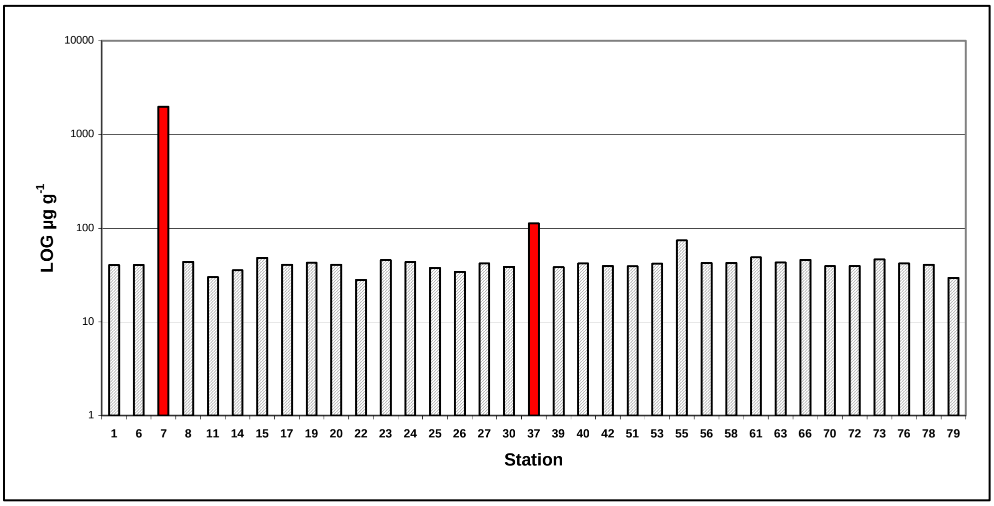


Figure 5.26 Zinc concentrations normalized to aluminium for all stations in 2001

5.3 Overall Conclusion on the Assessment of Contaminant Levels in the ROPME Sea Area

5.3.1 Coastal waters

Although the sampling coverage in some areas of coastal waters has not been comprehensive during the contaminant screening survey, several pertinent findings and general conclusions can be drawn based on the screening results from the four Member States surveyed in 2000 and 2001, as well as on previous data for the Region generated through surveys using similar sampling sites, sample preparation techniques, analytical methodologies, quality assurance measures and analyses.

Oil pollution continues to be a problem in various areas of the RSA. Approximately six years after a severe oil spill occurred in the Gulf of Oman off the east coast of UAE, relatively high petroleum hydrocarbon concentrations were still noted in the sediments and oysters around Akkah Head. The existing concentrations in sediments are much lower than those measured just after the spill, but nevertheless, attest to the slow process of environmental recovery from acute oil spills in the Region. Interestingly, sediment from this area also contained extremely high levels of trace metals (e.g., nickel) and high concentrations of certain organochlorine pesticides. In contrast, trace metal levels in oysters from Akkah Head and Akkah Beach were not particularly high suggesting that presently contaminant trace metals in sediments may be acting more as a sink than a source of contamination to the bivalves living near them. The source of this varied mixture of contaminants found at Akkah Head and Akkah beach is not known, but it is likely that it is not a direct result of the 1994 oil spill. Regular monitoring of the area and more specific analyses are necessary in order to determine if any dumping activities have taken place in this area.

Moreover, it has been over three years since the last time-series measurements of petroleum residues and related contaminants were made in specific areas of north-western Saudi Arabia and Kuwait which were heavily impacted by the 1991 War oil spill. In order to achieve a high resolution time-series data set which will allow better assessment of the ecosystem recovery potential in this impacted region, further screening measurements should be undertaken at the same locations in the near future. Such screening surveys in all the above-mentioned areas will continue to pinpoint local 'hotspots' as well as ensuring that a more synoptic coverage is obtained of spatially and temporary determined contaminant levels in the RSA.

Another location where chronic pollution involving a mixture of contaminants has occurred is off the BAPCO industrial complex in Bahrain. The highest concentrations of a variety of toxic substances were found there, and the extremely high levels of benzo(a)pyrene recorded off BAPCO and at Askar should be viewed with concern and warrant continued monitoring.

In particular, the new results on organochlorine compounds have proven useful in expanding the existing time-series data sets for the Region. Whereas PCB concentrations in oyster populations have appeared to decrease over the last two decades, concentrations of DDT compounds have varied little during this time. Such data sets are unique and should be extended to coastal water sediments in well-defined locations so that the countries can better evaluate temporal changes and recovery potential in areas that have been heavily contaminated, such as Akkah beach in UAE and off BAPCO in Bahrain.

The origins of high trace metals and organotin compound levels in rock oysters from certain locations on Masirah Island are not evident, but the high trace metal concentrations may be the result of natural geochemical and oceanographic processes. Likewise, the very interesting observation of very high Cd concentrations in the livers of some fishes from southern Oman may result from high levels of Cd accumulated in the food chain and introduced into the productive surface waters by the natural upwelling processes that occur in this region. Only more detailed spatial and temporal sampling will help to resolve such unexplained observations.

Detailed sampling of fishes (liver) in the south of Oman should be continued to try to explain the high concentrations of Cd observed in the samples (food chain bioaccumulation from natural upwelling, or other source).

Mercury concentrations generally continue to be very low in sediments, and total Hg levels in top predator fishes commonly consumed in the RSA were found to be below the 0.5µg g^{-1} wet threshold value set by many Member States and were similar to levels measured in the same species during earlier years.

Most interesting, and as yet unexplainable, is the observation of very high arsenic concentrations in certain bivalve species from the RSA when compared to those from other regions in the world. Again, it is not clear whether this is related to precise sources of contamination (unlikely) or to natural biogeochemical processes in the Region (more likely). It is evident that to properly interpret the sources of possible metal contamination, it is imperative to understand the natural bioaccumulation potential and natural occurrence of levels of elements like As in the species under study since content and ratios of trace metals vary greatly among the bioindicator species (particularly bivalves) used in the RSA.

Aside from the specific aspects discussed above, which should be given attention in future monitoring work, we still have gaps in our knowledge of the spatial (and local) distributions of some of these key contaminants in coastal waters of the RSA. Most existing reliable data have been obtained from the north-western region of the RSA. Areas around north-eastern Shatt Al-Arab have been little surveyed as have many locations along the eastern and south-eastern shores of the RSA. Because the Shatt Al-Arab drainage system is the most likely source of the large-scale introduction of agrochemicals and many other industrial and urban contaminants to the RSA, this is a critical area to screen for POPs as well as other potential contaminants originating from land-based sources.

It should be also noted that the last screenings in Kuwait and Saudi Arabia coastal waters were carried out in 1998, over 5 years ago. These countries were heavily affected by the 1991 War oil spill. In order to achieve a high-resolution time-series data set that will allow a better assessment of the ecosystem recovery potential in this impacted region, further screening measurements should be undertaken at the same locations in the near future.

Neither faecal sterols from sewage sources nor organotin compounds arising from biocide use appear to be major problems in the areas screened in these surveys. The environmental levels of organotins found in coastal sediments from the RSA are relatively low by global standards. Similarly, the organotin content of the marine biota is comparatively low which does not pose any immediate public health problems.

5.3.2 Open sea

The basin-wide contaminants study of the sediment samples by the Oceanographic Cruise – Summer 2001 disclosed that the open RSA is characterized by naturally occurring hydrocarbons derived from a mixture of autochthonous and terrestrial origins, and by low levels of anthropogenic introductions of degraded petroleum hydrocarbons. Since the high concentration and widespread distribution of the C_{12}-C_{22} n-alkanes with a strong even carbon number masked almost all evidence of spilled oil, it is suggested that a continued watch on the area should be maintained in order to follow any changes in the aliphatic distribution.

With the exception of a few stations visited by the Oceanographic Cruise – Summer 2001, the concentrations of total DDTs, total HCHs, and total PCBs are relatively uniform. The only stations where comparatively high concentrations were recorded are at Station 20 for total DDT, at Station 56 for total HCHs, and at Stations 27 and 78 for Total PCBs. Overall, the concentration of organochlorinated compounds in sediments in the inner RSA is relatively low by global standards.

The strength of local sources and the propensity of fine-grained material to accumulate influence the distribution of metallic contaminants in sediments in the inner RSA. The trace metal concentrations are strongly correlated to the aluminium concentration, a good proxy for terrigenous material, and the amount of fine-grained material present. Several trace metals (As Cr, Ni) exhibit concentrations sufficiently high to exceed sediment quality guidelines. Such trace metals, at least in the case of Cr and Ni, undoubtedly occur naturally in this mineral-rich Region. However, anthropogenic activities, notably mining, may have further increased the trace metal burdens in the sediments of the RSA, which could explain an apparent zinc ‘hotspot’ in one region. Several trace metals (Ag, Cd, Pb) occur in relatively low levels that pose no environmental concerns.

MAJOR ACCIDENTS AND EPISODIC EVENTS

CHAPTER 6

With its diversified oil operations, the RSA has the most crowded shipping routes in the world, with around 25,000 oil tankers carrying about 60% of the world's total crude oil exports by sea (UNEP, 1999). Accordingly, effective management for safety operations is critical for the protection of the marine environment. Heavy tanker traffic with its continuous oil spills, in the RSA has serious impacts on the marine environment. About 1.2 million barrels of oil are spilled into RSA every year (GEO, 2000). The source of oil pollution in this area is mainly operational discharges of shipping, river run-off, natural seeps, atmospheric inputs, coastal refineries, the petrochemical industry, offshore operations and tanker accidents which pose a great threat to the marine environment.

6.1 War-related Oil Spills

The ROPME Region has witnessed three wars since 1980. The war between Iraq and I.R. Iran, which started in 1980 and lasted for eight years, the 1991 War, which lasted for 35 days and the 2003 War in March-April 2003.

6.1.1 The Iraq-Iran War (1980-1988)

During the war, an estimated 1-4 million barrels of crude oil was spilled into the marine environment (Olfat, 1984; Reynolds, 1993). The major oil spill during the war took place in 1983 at the Nowruz offshore oilfields in the northern part of RSA and resulted in the release of 2-4 million barrels of crude oil. The main bulk of this oil spill was driven southward to the central part of the inner RSA (Massoud *et al.*, 1996). Tar balls resulting from the oil spills spread over the beach area and the highest recorded density of tar balls was found along the southern coastline of Kuwait (Literathy *et al.*, 1990).

6.1.2 The 1991 War

An initial survey of the period between 19-28 January 1991 (Gerges, 1993), estimated that a huge quantity of oil (6-8 million barrels) was spilled into the RSA from four sunken and leaking vessels, and as a result of the release of oil from the Kuwaiti Mina Al-Ahmadi Sea Island terminal and the Iraqi Mina Al-Bakr loading terminals. In addition, several hundred thousand barrels of oil seeped from damaged Kuwaiti and Iraqi oil facilities. Several small sunken Iraqi tankers in the northern part of the Sea Area contributed additional pollution during the spring and early summer of 1997. The final official estimate by the Kuwaiti authorities of the amount of oil discharged and spilled into the RSA was over 9 million barrels (PAAC, 1999).

The fires that burned in the Kuwaiti oil wells in the 1991 War had a significant environmental impact and adverse effects on the surrounding atmosphere and the marine and terrestrial ecosystems. Moreover, atmospheric fallout from the oil wells gradually led to the introduction of additional oil in the form of small droplets and oily soot. Several reports indicate that out of the 943 Kuwaiti oil wells, at least 700 wells were either set on fire or damaged (UN, 1991; Al-Besharah, 1992; Tawfiq, 1992). Official Kuwaiti reports indicate 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 (PAAC, 1999). This estimate puts the quantity of oil and gas burnt at 6 million barrels and 100 million m^3/day, respectively, thereby generating substantial emissions of sulphur dioxide, hydrogen sulphide and nitrogen oxides. 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 because of the presence of salt in the aerosols resulting from the release of associated brines and the use of seawater for fire fighting (Steven *et al.*, 1992). The oil well fires caused serious air and water pollution, which affected people's health, as well as the fauna and flora in many areas.

The recent report of EPA-Kuwait (2002) disclosed that during the Iraqi invasion, more than 730 oil wells were torched, many were set on fire and others were gushing oil in the desert forming more than 460 oil lakes of different sizes in the north and south of Kuwait. An estimated 13 million gallons were recovered despite the difficulty of treating such contaminated oil and the risks involved. Oil lake areas are still contaminated with the oil sludge that remained after the liquid oil was extracted. Sludge is difficult to vacuum using pumps and as a result, a heavily polluted soil remains. This area covers about $50km^2$ scattered over all the oil fields. In addition to the economic impacts of oil spills, the environmental impacts are enormous. More than $978km^2$ have deteriorated as a result of the formation of a tar layer from oil lakes. The war has affected about 30% of the Kuwait desert.

A large number of mines were also laid all along the coast in the intertidal zone and the deep-sea channel approaches to Kuwait by the Iraqi military as a defensive measure. Numerous trenches were dug along the coast and major damage was inflicted on coastal installations, facilities and infrastructure. The large number of land and sea mines (2 million mines) left over (Figure 6.1) have caused the loss of a number of lives and resulted in injuries among civilians and members of the armed forces. In addition, war activities such as bombing, shelling, placing of mines and digging of bunkers and ditches had a considerable effect on wildlife as well as causing extensive soil disturbances (Kuwait Times, 22 April 2003).

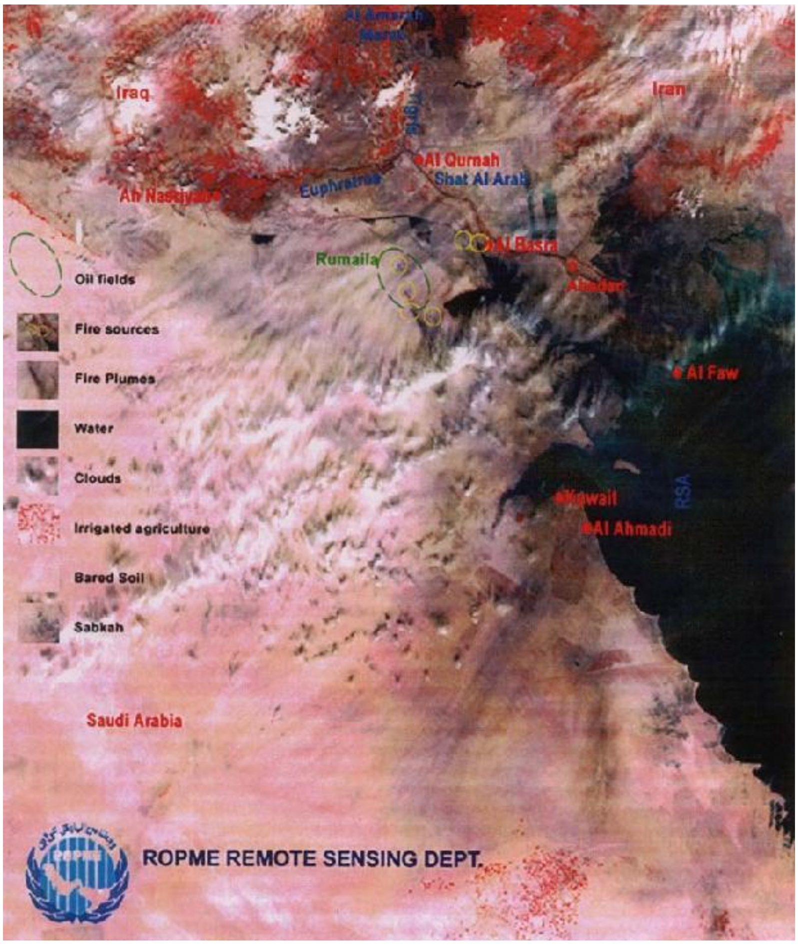
Figure 6.1 Recovered Iraqi mines left over from the 1991 War

6.1.3 The 2003 War

The recent war over Iraq (March-April 2003) also caused considerable damage to the environment in general and to the Rumeila, Zubair, Basra, Baghdad and Mosul oil fields, in particular. There were nine fires in the Rumeila, Zubair and Basra oil fields during 21-28 March 2003. Plumes of black smoke rose into the air from the burning oil wells which reached the Kuwait urban area and moved towards Saudi Arabia (Figure 6.2). Satellite images taken on 1 April 2003 show the oil well fires from Basra dispersing into a south-easterly direction towards Bubiyan Island and the open sea area. Very intense oil fire plumes are also conspicuous near Baghdad, however, the Rumeila oil fires died down significantly on 1 April 2003. The impact of the oil fires on the marine environment is evident from remote sensing observations. Particulate materials (black carbon particles, SO_2, etc.) from the fire plumes were deposited on land and sea. The particulates were transported by the prevailing sand storms over long distances and settled on a vast stretch of the terrestrial and marine environment of the Region.

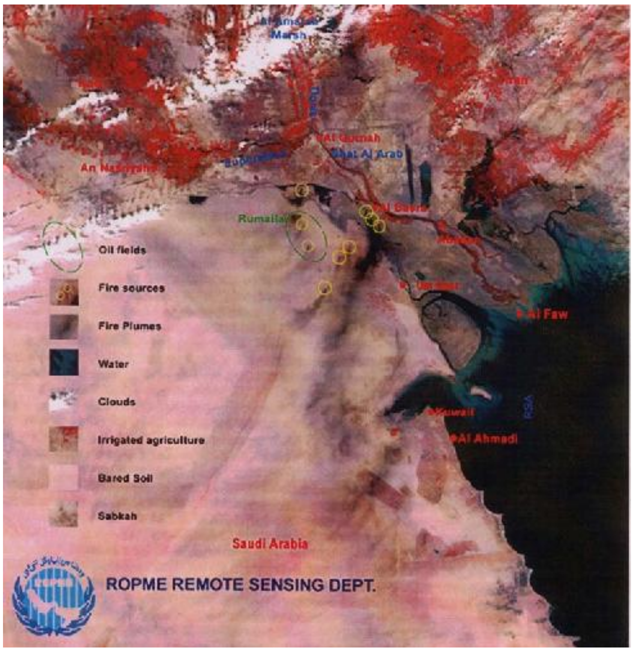
Military conflicts have also left behind hundreds of shipwrecks, which are seriously affecting the most north-western part of the RSA. The wrecks range in size from large tankers and container ships to barges, tugs and torpedo boats. Many were sunk in the port of Umm Qasr and in the navigational channel to the port. UNDP has begun efforts to salvage and remove the shipwrecks from the watercourses of Iraq and Kuwait in an environmentally acceptable manner with the participation of UNEP, IMO and IAEA-MESL, and in close cooperation with ROPME (ROPME/UNDP, 2004).

(a) An oil well set ablaze at the Rumeila oilfield, Southern Iraq on 28 March 2003

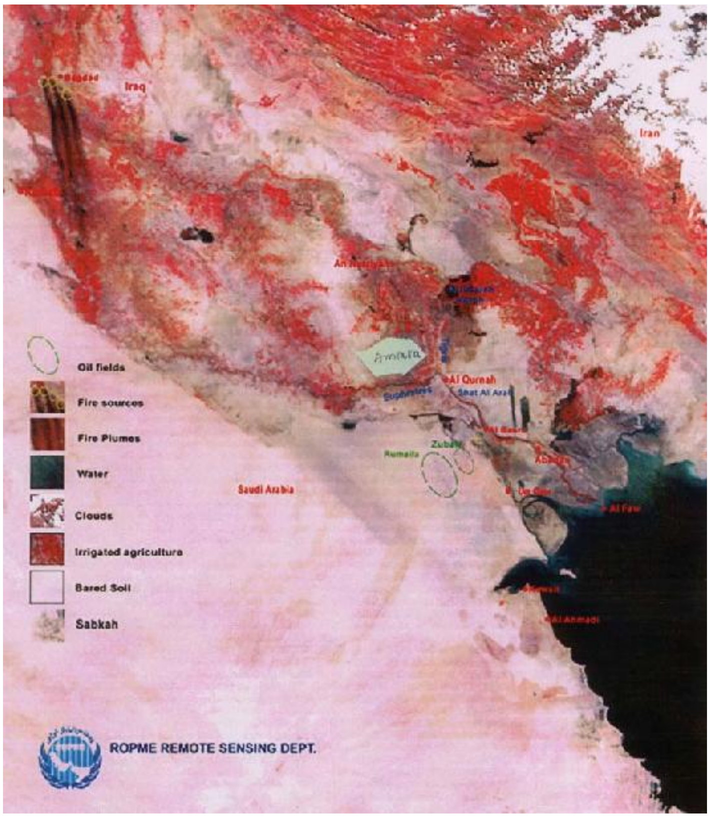


(b) Satellite remote sensing image shows Iraq, Kuwait, parts of Saudi Arabia and I.R. Iran. It depicts dust over the Middle East and the RSA, as well as several large plumes of black smoke, the locations are consistent with known oil field locations near Rumeila, Zubair and Basra. Smoke plumes are reaching Kuwait urban areas and Saudi Arabia. (The black / dark colors of the plumes depend on their density, while vegetation is shown in reddish. Cloud coverage over North West of Kuwait, I.R. Iran and Saudi Arabia. In the south, large intensive irrigated agriculture farms in Saudi Arabia are shown as red spots). 21 March 2003, MODIS / Terra1 (L2, 250m resolution, color combination channels 122).

Figure 6.2a&b Oil well fires recorded during the 2003 War, March-April 2003



(c) Satellite remote sensing image shows oil fire plumes rising from Rumeila, Zubair and Basra oil fields. Smoke plumes are reaching Kuwait urban areas moving towards Saudi Arabia (Black / dark colors of the plumes depend on soot density, while vegetation is seen in reddish color. Clouds are covering South West of Iraq). 23 March 2003, MODIS / Terra1 (L2, 250m resolution, color combination channels 122).



(d) Satellite remote sensing image shows the oil well fires visible near Basra and dispersing plumes into the southeast direction toward Bubiyan Island. It also shows the intense oil fires of Baghdad area. Rumeila oil fire plumes have shown a significant reduction. Following climatic conditions, still very dense Basra oil fire plumes are directed towards the open sea area (Oil fire plumes are in black-greyish, depending on soot density and cloud thickness). 01 April 2003, MODIS / Terra1 (L2, 250m resolution, color combination channels 122).

Figure 6.2c&d Oil well fires recorded during the 2003 War, March-April 2003

6.2 Tanker Accidents

In recent years, the RSA has fortunately not experienced any major oil tanker accidents with catastrophic results. Nevertheless, a few incidents with sub-standard barges have resulted in oil spills of various magnitudes between 1998 and 2002. The percentage of spilled oil during the period is given in Figure 6.3 (MEMAC, 2003a&b).

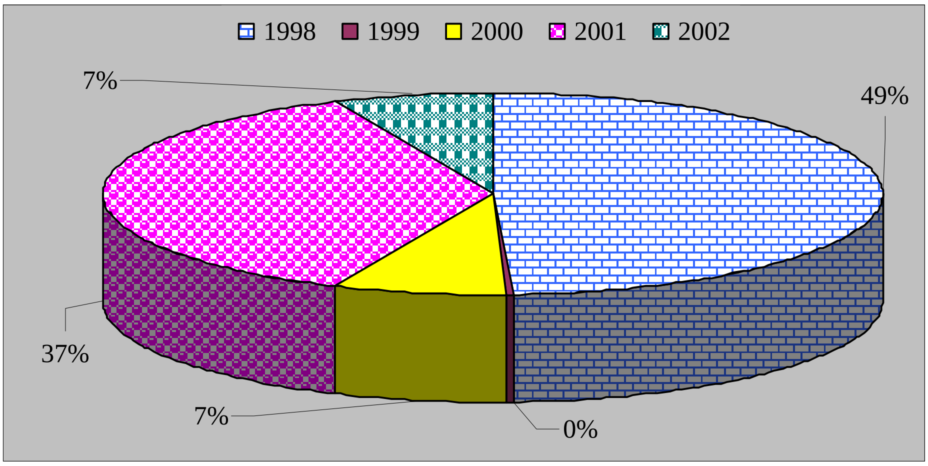


Figure 6.3 Percentage of oil spilled in the ROPME Sea Area during the period 1998-2002

The total oil salvaged by MEMAC from December 1997 to October 2002 was estimated at 46,330 metric tones (13,624,473 gallons) (MEMAC, 2003a).

6.3 Mass Mortality of Marine Organisms

A number of unusual environmental events have been noticed in recent years, particularly in the marine ecosystems of the RSA. The phenomena include a number of large-scale epidemics (disease events) and the mass mortality of a variety of marine and coastal organisms, and the proliferation of certain algal species (ROPME, 1999). The marine mortality events have occurred repeatedly causing economic losses in the fisheries sector and anxiety among fish consumers in the affected areas.

The mortality phenomena have been attributed to high levels of anthropogenic contaminants, unseasonably warm temperatures, disease agents, red tides, biotoxins and changes in food supply, which need to be investigated individually.

Several major cases of marine mortality reported in the Region (Khamdan, 2000; Thangaraja, 1990 & 1998a; Thangaraja *et al.*, 2001a&b; Al-Aisri *et al.*, 2001; Al-Ansi *et al.*, 2002) during the period 1986-2001 are noted in Table 6.1.

Table 6.1 Documented incidents of mass mortality of marine organisms in the ROPME Sea Area

Year of Incident	Member State	Organisms	Cause
September, 1986 (Massive)	Bahrain, Kuwait, Qatar, Saudi Arabia	Mammals, Fish, Turtles, Birds, Cuttlefish	Unknown
January, 1987	Bahrain, Saudi Arabia	Mammals, Birds, Starfish	Red and green algal bloom (KSA); *Gymnodinium* sp. (Bahrain)
February - April, 1988	Oman (middle RSA)	Fish	Red tide of *Noctiluca* sp. effect and bacterial infection
September, 1988	Oman (middle RSA)	Fish and a few shellfish	Red tide caused by diatoms and a few species of dinoflagellets (DO depletion)
February - April,	Oman (middle RSA)	Fish	Red tide of *Noctiluca* sp.
May, 1989 (Massive)	Oman (middle RSA) Naval Port	Fish (Sardines)	Death due to over crowd and suffocation (DO depletion)
May, 1990	Oman	Turtles	Fishing net entanglement
January, 1991	Oman (outer RSA) Dhofar Coast	Deep shrimp and fish species	Low DO
March, 1991	Oman	Turtles	Fishing net entanglement
April, 1991 (Massive)	Oman (middle RSA) Naval Port	Fish (Sardines)	Death due to over crowd and suffocation (DO depletion)
August, 1991	Bahrain, Saudi Arabia	Fish	Unknown, bleeding
April, 1992	Bahrain, Kuwait	Corals	Bleaching
September - December 1992	Oman (outer RSA) Dhofar Coast	Fish, Deep sea shrimps	Oceanographic changes (Low DO)
April, 1993	Oman (middle RSA)	Fish	Red tide of *Noctiluca* sp.
July, 1993	Bahrain	Fish	Elevated seawater temperature
August, 1993 (Masive)	I.R. Iran	Fish, Mammals, Turtles	Chemical pollution
August - October, 1993	Oman (outer RSA)	Fish, Deep sea shrimps	Oceanographic changes (Low DO)
August - October, 1993 (Massive)	Oman (outer RSA)	Fish (Sardines), Fin and Shellfish	Plankton blooms and DO depletion
September, 1993	Qatar, UAE	Fish	Chemical pollution
September, 1993	Oman (middle RSA)	Fish	Red tide of *Gonyaulax* sp.
October, 1993	Oman (middle RSA)	Fish	Red tide of *Dinophysis* spp., *Ceratium* spp.
October, 1993	Kuwait, Saudi Arabia	Fish	Unknown, Chlorine used at power station
April, 1994	UAE	Fish, Birds, Turtles	Oil pollution
August, 1994	Oman (middle RSA), inside Port	Fish	Red tide of *Gonyaulax* sp.
April, 1995	Kuwait	Fish	Chlorine used at power station

Table 6.1 Cont.

Year of Incident	Member State	Organisms	Cause
February, 1996	Kuwait	Fish	Chlorine used at power station
July-September, 1996 (Massive)	I.R. Iran	Fish	Elevated seawater temperature, low dissolved oxygen
September, 1996 (Massive)	Bahrain	Coral Bleaching	Elevated seawater temperature
August - September, 1996	Qatar	Fish	Elevated seawater temperature
October, 1996 (Massive)	Kuwait	Fish	Chlorine used at power station
February, 1997	Kuwait	Fish	Chlorine used at power station
June, 1997 (Massive)	Bahrain	Fish	Parasitic infection
Summer, 1997	Kuwait	Fish	Unwise use of fishing gear
August, 1997	UAE	Fish	Unknown
February, 1998	UAE	Fish	Deliberate discard
August, 1998	Bahrain	Fish, Coral bleaching	Elevated seawater temperature
August - September, 1998	Qatar	Fish	Elevated seawater temperature
September, 1998	Bahrain	Fish	Red Tide (*Gymnodinium*)
December, 1998	Oman (outer RSA)	Deep sea shrimp	Low DO
April, 1999	Bahrain	Fish	Red Tide (*Gymnodinium*)
September, 1999 (Massive)	I.R. Iran	Fish	Unknown
September-October, 1999 (Massive)	Kuwait	Fish	Red Tide (*Gymnodinium*)
October, 1999	UAE	Fish	Unknown
May, 2000	UAE	Fish	Red Tide (*Gymnodinium*)
September, 2000 (Massive)	Oman (middle RSA)	Fish	Phytoplankton blooms (mainly diatom blooms), DO depletion
March, 2001	Oman (middle RSA), inside fishing port	Fish	Accidental entry of large quantity of fish (DO depletion)
April, 2001	Oman (outer RSA)	Fish	Oceanographic changes (Low DO)
May, 2001	Oman (middle RSA), inside fishing port	Fish	Bacterial infection (*Streptococcus* and total coliform)
August-October, 2001	Kuwait	Fish	Bacterial infection (*Streptococcus agalactiae)*
November-December 2001	Oman (outer RSA)	Fish, turtles, dolphins, birds	Red Tide (*Karenia selliformis, Prorocentrum micans, P. minimum*)

6.3.1 Human interference

Marine organisms, including dolphins, dugongs, fishes and turtles were found dead on the western and eastern shores of the RSA between 23 August and 30 October 1986. The peak mortality occurred between late August and late

September 1986, resulting in the death of a large number of dolphins and fishes in the Mesaieed Area on the eastern coast of Qatar and the eastern coast of Saudi Arabia (ROPME, 1997b). 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, on the coasts of Qatar (358), Saudi Arabia (141), Bahrain (18), I.R. Iran (6), Kuwait (2), and UAE (2); seven dugongs and one whale of unknown species (20 feet long) were reported dead. In the fish category, the estimated number was 4,000—8,000 fishes of different species and lengths (generally greater than 60cm). In addition, 58 dead marine turtles, about 10,000 or more cuttlefish, a small number of dead crabs and a few dead birds were recorded. Subsequent to this event and on 10 November 1986, up to 2,000 terns were found dead off the Saudi Coast.

In Oman, during May 1990, 19 dead Hawksbill turtles were found at Barr Al-Hikman off the Arabian Sea coast during their nesting period. During March 1991, a total of 118 dead turtles were found between Ras Qumaylah and Ras Sirab. They died mainly as a result of entanglement in gill nets close to their nesting beaches. Records of the mortality of marine organisms especially the turtles in Omani waters were continued up to 1998. All of these Green turtles died as a result of dehydration or human activity (interruption) as they made their way back to the sea after laying eggs (SOMER, 2000).

6.3.2 Accidental fish kills

A huge number of fishes perished in Iranian coastal waters during the period from 15 August to 30 September 1993. This happened less than two months after the Russian merchant ship, Captain Sakharov, sunk offshore to the south-west of Lavan Island and its cargo of 40 containers spilled chemical substances. This resulted in the immediate death 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, yellowfin seabream and flathead) in August-September 1993 (DOE–I.R. Iran, 1998).

The occasional entry of large numbers of fish into a small enclosed area like a fishing port, leads to mass mortality of fish species. The entry of dense schools of sardines into the Sur fishing port in Oman, chased by schools of large pelagic predatory species caused massive fish kills inside the Sur fishing port on 28 February 2001. The dead fishes were floating inside the port and on 1 March 2001 the biomass of dead fish was estimated at 250 tons. The dead fishes belonged to 23 families and 33 species. The Indian oil sardine, *Sardinella longiceps* was the dominant species among the dead fishes accounting for 95%. The dead fish belonged to both pelagic and demersal groups. This indicated that all species that were trapped inside the port died, largely due to the low oxygen levels in the water. The oceanographic parameters measured inside the port were all at normal levels, except for dissolved oxygen measured on 28 February 2001.

It was 0.96 to 0.34mg/l from surface to 6m depth respectively which is a highly lethal level for all pelagic and demersal organisms. However, outside the port all the oceanographic parameters were at normal levels (Thangaraja *et al.*, 2001a).

The following day (1 March) the oxygen level started increasing to 3.63mg/l in the surface waters and to 3.27mg/l on the bottom at a depth of 2.4m, even though the decomposition of dead fish had started. This indicated that the oxygen was utilized more for respiration in the first day and less for the decomposition of the dead fish by bacteria on the subsequent day.

Similar incidents to that at Sur have resulted in other episodes of fish mortality. Fish kill episodes had previously been recorded at Wudam Sahil Naval Port in the Gulf of Oman, one in 5 May 1989 and another between 13-14 April 1991. In the first incident, 12 tons and in the second 10 tons of sardines died inside the port. In general, the surface water tends to be in equilibrium with the air above it so that the oxygen value is at or near to the saturation concentration level of 4 to 10mg/l for the existing conditions of temperature and salinity. But respiration and decomposition of large quantities of organisms tend to deplete the oxygen drastically (Thangaraja, 1998a).

6.3.3 Rapid changes in physico-chemical characteristics of the seawater column

Marine mortality occurred in several areas of Bahrain, I.R. Iran, Kuwait, Oman, Qatar, Saudi Arabia and UAE in the years 1993, 1994, 1996 and 1998 where thousands of fishes of many species, including some dolphins and turtles, were found dead on the coast of these countries. Between 1993 and 1994, a total of 22 dolphins, three whales, two whale sharks and many turtles were found dead on the shores of Bushehr Province in Iranian coastal waters (DOE-I.R. Iran, 1998). In the same area, again a large-scale fish kill of demersal fishes (silver seabream, yellowfin seabream and flat head) was observed from 22 July-7 September 1996. This event was attributed to unusually high water temperatures and the low dissolved oxygen content of Bushehr coastal waters at the time of the fish mortality. Also the density of phytoplankton was measured during this incident and the results indicated that the density of phytoplankton was a hundred times higher than during normal conditions in previous years (Valavi, 1998).

Fishermen observed fish kills (mainly sardines) in the offshore area near Abu Moosa Island in 1997. Similar observations were also reported on the Ajman coast and Umm Al-Qaiwain. High temperatures (33.5-34^{o}C) were suspected to be the main cause of the fish kill in that area.

In Bahrain, fish kills were reported in the coastal areas in August 1998. Investigating the possible reasons for this phenomenon, satellite images of the sea surface temperatures in the RSA were obtained and specimens of the dead fishes were analysed. It was concluded that the increase in the water temperature of the area and the fact that the fishes examined tend to congregate mainly in shallow waters, meant that thermal shock or lack of oxygen seemed to be the most likely possible cause of fish death. A high sea surface temperature (35^oC) was observed in August 1998.

In contrast, the physical process of upwelling at certain times leads to the mass mortality of marine organisms. When cold water from the deep is brought up to the surface, those stenothermal species inhabiting the top layers of the waters are unable to tolerate the thermal difference and perish rapidly. Coral reefs in the Gulf of Oman are often stressed because of irregular drops in temperature caused by upwelling. The upwelling waters generally have low oxygen levels which leads to the death of many species of marine life. During the process, the nutrients-rich bottom water is brought to the surface which causes an enormous production of phytoplankton and creates oxygen depletion during the night leading to the death of many species. Mortality due to a combination of many factors or a single factor has often been observed in the southern part of Oman (outer RSA) during the south-west monsoon period. Mass mortality (>1 ton) of fin and shellfish, representing over 30 fish species and three kinds of shellfish such as rock lobster, sand lobster and shrimp were observed at the Raysut Port on 4 August 1993. The depletion of oxygen (0.57-0.83 mg/l) was the cause of mortality at the Raysut Port in the southern most part of Oman. Again, 5-7 tons of fish were found dead as a result of low oxygen levels (1.2mg/l) on 23 November 1993 in the same Raysut Port (Thangaraja, 1998a).

Fish kills were observed along the Qatari coastline and offshore during the summers of 1996 and 1998 when about 40 tons of dead fish were found off the eastern coast of Qatar. Siganidae, Lethrinidae and Carangidae, coral reef inhabiting fish were the main species found dead along the beaches. During these periods, temperatures along the Qatari coast of 37^oC in the summer of 1996 and 38.6^oC in the summer of 1998 seem to be the main reason for fish kills. A temperature of 35^oC is the threshold beyond which fish kill phenomena take place (Al-Ansi *et al.*, 2002).

6.3.4 Eutrophication

Eutrophication is the process by which gradual increases in the concentration of nutrients such as phosphorous, nitrogen, and other nutrients occur in an aquatic system or shallow marine environment. When the body of water becomes excessively enriched with nutrients, such as nitrate fertilizers and phosphates, algae and bacteria develop which can lead to excessive algal blooms, oxygen depletion and fish kills. Many native fish species will disappear and be replaced by species more resistant to the new conditions.

The sources of excessive amounts of nutrients in the marine environment are diverse and include industry, agriculture, river run-off and sewage discharges. A number of industrial processes contribute to the problem such as methanol/ammonia production, oil refining, slaughter-house and livestock industries, sewage treatment plants, as well as the release of untreated wastewater. In addition, intensive blooms of pelagic algae in offshore areas appear to be becoming more frequent. This may be a sign of a more large-scale eutrophication in offshore areas as well.

Run-off from agricultural fields and rivers is a major contributor of nutrients to the sea, but such materials remain largely within the shelf areas and only a small fraction of the nutrients ultimately reach the open ocean, which remains oligotrophic. In certain areas, the increase in concentrations of dissolved nitrates and phosphates and of organic carbon, together with organic accumulations of sediments, have brought about changes in the structure of planktonic and benthic communities, often with substantial ecological and economic consequences. This increases the number of episodic events, such as enormous plankton blooms, which alter natural ecosystems and threaten the mariculture industry as well as 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 appropriate studies should be undertaken (GESAMP, 1990).

In the RSA, although limited scientific data are available on the biological effects of contamination of the marine and coastal environment by sewage and nutrients, there is enough evidence to show that eutrophication occurs in certain areas and particularly near to urban and industrialized areas. Linden *et al.* (1990) reported some signs of eutrophication on the northern coast of Bahrain where dense mats of filamentous green algae were observed in the intertidal zone showing obvious signs of organic pollution and increased levels of nutrients in the water. Similar problems from sewage and agro-based industries have caused increase growth of benthic algae in the north-west RSA off Shatt Al-Arab.

Signs of eutrophication were observed in Kuwait Bay and in the coastal waters of Muscat (Oman), Dhahran (Saudi Arabia) and Abu Dhabi (UAE). In Kuwait Bay, near Doha village where raw municipal wastewater is discharged, the intertidal area was found to be covered with algal mats; pond growth of reeds was also observed in the vicinity of other outfalls where oxygenation had taken place (Al-Bakri *et al.*, 1989; EES/FRD, 1986). Nutrient release from sewage discharges in the Bay may also have contributed to the extensive beds of *Enteromorpha* and other seaweeds around the Al-Akaz Islands (EES, 1998). The depletion of oxygen and high levels of hydrogen sulphate and ammonia coupled with large quantities of wastewater discharge in Kuwait Bay have led to several major incidents of fish mortality – fish kills – in 1983 and 1984 (Salama, 1986). A major fish kill recorded in Kuwait Bay, in 1999, was the result of anoxic conditions caused by massive algal blooms (EPA-Kuwait, 1999).

High nutrient levels have been reported occasionally in both Abu Dhabi and Dubai creeks with wide spatial and temporal variations suggesting anthropogenic sources of pollution (Banat *et al*., 1998). In Saudi Arabia, raw sewage is known to be deposited in the coastal areas of several small towns where eutrophication has been occurring and resulting in increasing BOD and algal blooms (Price, 1993). There are also reports of local 'red tides' in Bahrain and Saudi Arabia. This may be taken as a sign of abnormal conditions in the pelagic zone, possibly as a result of eutrophication (Linden *et al.*, 1990).

6.3.5 Harmful algal blooms

Huge fish mortality (about 60 tons of grey mullet *Liza macrolepis* and 150 tons of sobaity seabream, *Sparidentex hata*, from the fish farm cages) was reported in Kuwait Bay between 19 September and 25 October 1999. A similar event was reported by I.R. Iran. These incidents were accompanied by unusual occurrence of Harmful Algal Blooms (HAB), the so-called ‘red tides’ and other algal blooms. Algal blooms of dinoflagellates (phytoplankton with greater than one million cell/litre of *Gymnodinium* species) were observed to be the dominant species in the samples studied (EPA-Kuwait, 1999). A brownish ‘red tide’ bloom of *Gymnodinium* sp. was found along the northern part of the Hamriya Port waters of UAE from 2-5 May 2000. The blooms killed a few fishes (<20 fish) along the side of the northern part of the port (MNR-UAE, 2003). A high density of chlorophyll-*a* was observed during the period of fish morality in Kuwait, and I.R. Iran. The frequent occurrence of such incidents would suggest a deterioration in the water quality in the Region.

The most common and dominant red tide-causing dinoflagellate species in the middle RSA (Gulf of Oman) is *Noctiluca scintillans*. Red tides of this species were recorded along the coast of the Gulf of Oman from the Strait of Hormuz to Ra’s Al-Hadd. Blooms of this species cause patches of orange red colouration in the waters when they become fully matured and conspicuous as they reach the inshore waters (Figure 6.4A). This species has formed red tide blooms in the Gulf of Oman between January and May every year since 1988. In 1999, for the first time in Oman, this species formed a ‘green tide’ along most of the coasts in the Gulf of Oman (Figure 6.4B). The blooming intensity of this species is increasing year after year. *Trichodesmium* sp., *Dinophysis* spp., *Gonyaulax* spp., *Ceratium* spp. etc., are the other red tide causing species that occur in the Gulf of Oman (Thangaraja, 1998a, 2000).

Harmful algal blooms in Omani waters have led to the following:

- Abnormal production of phytoplankton of both toxic and non-toxic species depletes the dissolved oxygen of the water, which kills the marine organisms occasionally.
- Direct intake of toxic species kills marine organisms.

- Putrefaction of phytoplankton blooms lead to over-flourishing of microgerms in the area and infect other living fish species and cause various diseases.

A: Red tide bloom

B: Green tide bloom

Figure 6.4 Red and Green tide blooms in the Gulf of Oman

Discoloration of coastal waters followed by mass mortality of marine organisms was observed in the Muscat area between Seeb and Qurm on a 30km coastal stretch from 5 to 20 September 1988. The bloom was initially a pale greenish yellow, which turned to pale brown and putrefied subsequently to a dark brown. Diatom species dominated the bloom, and the dinoflagellates found in the bloom were non-toxic and less concentrated. Large blooms of diatoms first caused discoloration of the water and then mass mortality of marine life. Low oxygen levels were recorded (2.64ml/l and 1.87ml/l) at water depths of 2-3m and 8-10m respectively, on 14 September 1988 on the Al-Ghubrah coast. Other parameters recorded were: temperature 27.5^{o}C; salinity 35.9‰ and pH 8.31. The dead fishes strewn on the beach on 14 September (the peak mortality day) showed that demersal species dominated the pelagic species throughout the affected area. It was estimated that on that day alone 3 to 5 tons of dead fish were strewn all along the Al-Ghubra beach. Dead organisms found on the beach during that period were identified and classified into 42 families and 52 species (Thangaraja, 1990).

After the 1988 mass mortality incident, a second incident in Barka waters on 1 September 2000 was the next major fish kill recorded in the Gulf of Oman (Thangaraja, 2000). The estimated number of dead fish on 2 September alone, the peak mortality day, was between 15-30 tons (Figure 6.5). The mortality rate decreased the following day to 7 tons.

In the Barka incident about 95% of the dead fishes belonged to the group of demersal fish. Hydrographic measurements at the bloom area indicated the depletion of dissolved oxygen levels (5m depth: 2.23-2.6mg/l; 8-10m depth: 0.62-0.40mg/l; 12.8m depth: 0.18mg/l) in the bottom layers of waters. Low oxygen levels were the main cause of the heavy mortality of demersal fish species.

Figure 6.5 Dead fishes stranded along the beach of Barka, Oman in 2000

Fish kills through direct contact with *Noctiluca scintillans* (Figure 6.6) and red tide blooms were recorded three times (March 1988, April 1989 and 1993) during the period between 1988-2000. In the first incident, between 1 February and 19 March 1988, blooms of this species caused patches of orange-red colouration in the waters from Al-Bustan to Qurm. During the period, the red tide bloom killed a few species of fish namely, *Atherinomorus lacunosus*, *Odonus niger* and *Diodon histrix*, of which *A. lacunosus* was particularly affected. Hydrographic parameters measured at the area were: dissolved oxygen 3.26-6.51ml/l; temperature 22.48-24.92^{o}C; salinity 36.1-36.6‰; pH 8.38-9.00.

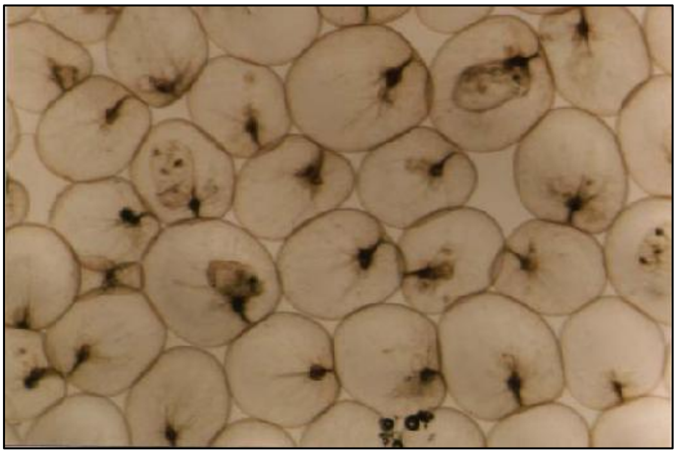


Figure 6.6 Microscopic view of red tide-causing *Noctiluca scintillans*

In the second incident, between 11 and 13 April 1989, dense red tide blooms of this species occurred. They killed seven species of fish and one species of mollusc on the Bustan coast. The dead fauna recorded included: *Sarda orientalis* (10), *Scomberoides commersonianus* (8), *Sphyraena acutipinnis* (1), *Sardinella* sp. (1), *Saurida tumbil* (2), *Epinephelus* sp. (1), *Alectis* sp. (1) and *Sepia* (1). Of these species, the queenfish *S. commersonianus* was particularly affected, a few hundred of this species died and were washed ashore over a period of one week.

During the third episode on 3 April 1993, red tide blooms of *N. scintillans* at the Al-Bustan coast killed the queenfish, *Scomberoides commersonianus,* 12 dead individuals were washed up on the beach.

The occurrence of red tide blooms of the toxic species, *Gonyaulax diegensis* (Figure 6.7) has been recorded twice since 1988 at the Mina Sultan Quboos Port, Muttrah in the area around the capital, Muscat, on 21 September 1993 and 16 August 1994. This species created pale reddish colouration and killed about 2-3 tons of fish in September 1993 and about 50kg in August 1994. Observations made on the dead fishes during the first episode revealed that the sardine fish, *Sardinella longiceps* dominated (about 99%) the dead fish. The other dead fishes found in the port were: *Selar crumenophthalmus*, *Mugil* sp., *Sarda* sp., *Mulloides* sp., *Platycephalus* sp., *Chilomycterus orbicularis*, *Leiognathus* sp., *Sphyraena* sp., *Apogonus* sp., *Brachypleura* sp. and *Scomberoides commersonianus*. During the second episode, the queenfish, *Scomberoides commersonianus* and other carangid, *Selar crumenophthalmus* dominated the dead species (Thangaraja, 1998a). After this 1994 bloom, this species formed a red tide bloom in August and September 2000 in Sidab and Bustan coast in the Muscat area. But no fish kills were seen.

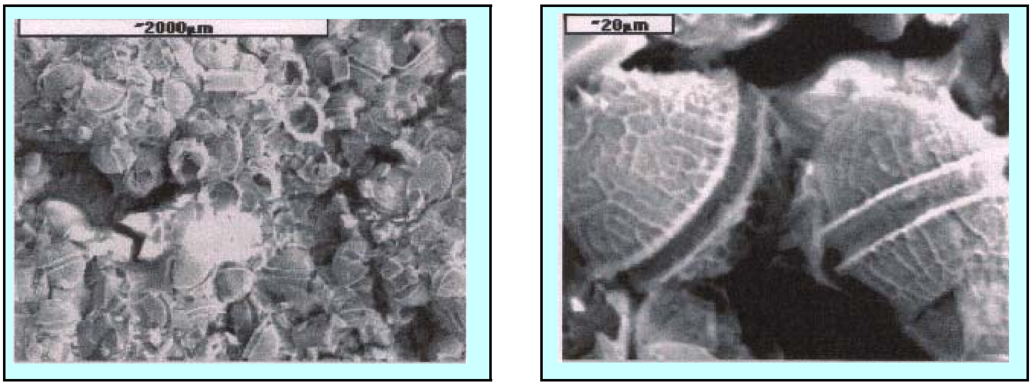


Figure 6.7 Electron microscopic views of *Gonyaulax diegensis*

Blooms of *Dinophysis cuneus* caused pale yellowish brown colouration in the Barka waters in the Gulf of Oman from 26 to 31 October 1993. The other (non-bloom) dinoflagellates that occurred in the area were *Pyrophacus horologicum*, *Ceratium trichoceros*, *C. furca*, *C. massiliense* and *C. tripos*. Impacts of the bloom were felt particularly acutely by the trap fishery in Barka waters.

Fishermen from Barka village found dead and decomposed fishes in their traps during the bloom of this species.

6.3.6 Outbreak of bacteria, viruses and parasites

Organic pollution caused by domestic sewage, and the decomposition of phytoplankton blooms, etc. trigger the outbreak of microgerms and cause severe environmental impacts on marine life. The fish kill incident in Kuwait Bay on 10 August 2001 is one among them. During the incident, thousands of dead fishes were washed ashore at Bneid Al-Gar, Shuwaikh Port and in the south of Kuwait near the chalets. The mullet fish, *Liza microlepis* was the most affected species. Since 18 August 2001 other deep-sea fishes have also been affected. About 99% of the dead fish were mullets. The mullets exhibited symptoms of bacterial infection such as pop eye, and haemorrhaging in the inside of the gill-cover and around the mouth. A total of 2,000—3,000 tons of fish were reported killed. However, three dolphins were also found dead on 12 September 2001.

The fish kill event in Kuwait Bay could be the result of extreme water temperatures (36-37^{o}C) coupled with high salinity and low oxygen that led to reduced immunity in the fishes, making them susceptible to infections from marine bacteria, particularly by the species, *Streptococcus agalactiae*, which was isolated from the dead fish. Sewage discharge is believed to be the main cause of the proliferation of the bacteria.

The decomposition of phytoplankton after a huge bloom produces enormous microgerms. These micro-organisms subsequently spread to the surrounding areas, attack the living organisms, and become epidemic. This is evidently what happened in Muscat waters at the time of a huge red tide bloom of *Noctiluca scintillans* in 1988 which caused 'fin and tail rot' disease (Figure 6.8) and killed a large quantity of pelagic fishes, *Atherinomorus lacunosus* (Thangaraja, 1998a).

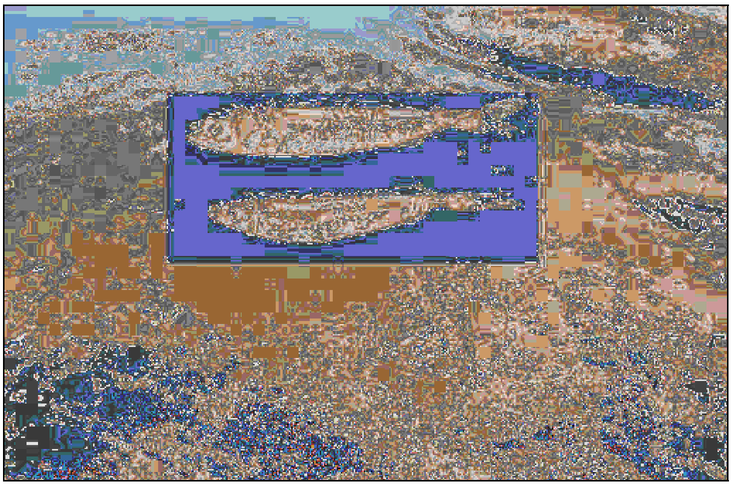


Figure 6.8 Bacteria-infected pelagic fishes, *Atherinomorus lacunosus*

Mass kills of the Birdbeak burrfish, *Chilomycterus orbicularis* caused by a mysterious (probably a viral) epidemic were recorded in waters between Muscat and Masirah between 25 June and 22 July 1991. Thousands of these fishes died during the period and were strewn sporadically along the beaches. A mysterious disease possibly caused by bacteria or fungus killed scores of groupers in Bahraini waters in 1991. The dead fishes had red spots on their stomachs, gills and near the tail and dorsal fins (Khaleej Times, 1991).

The small pelagic Indian oil sardine, *Sardinella longiceps*, began to die inside the Quriyat fishing port of Oman on 20 April 2001 and continued till the second week of May 2001. During the period, the daily biomass of dead fish was estimated at 150-200kg. Interestingly, only the fish living inside the port were infected and started dying (Figure 6.9).

Figure 6.9 Affected fish struggling for life

The affected live fishes had bacterial infections in the forebrain area with reddish markings, and swollen eyeballs and dorsal sides of the head. The dead floating fishes had reddish patches on their heads, abdomen and lateral sides of the body and blood was oozing through their mouths as a result of internal haemorrhaging (Figure 6.10). The laboratory study indicated that the fishes were infected with *Streptococcus* and coliform bacteria (Thangaraja *et al.*, 2001b). The source of the contamination was found to be organic pollution from large quantities of discarded fish thrown into the port water by the fishermen as they were sorting commercially important species.

Ecto and endoparasites are found in many fin and shellfish species in the Gulf of Oman and the Arabian Sea (middle and outer RSA). Although they are not epidemic like bacteria and viruses, the affected organisms become weak and die at a later stage. Endoparasites are common in many species of tuna and a few demersal fish species. The worm like helminthes such as cestodes and nematodes are common parasites of marine fish. The cysts and larvae of these parasites form in the muscle tissues of different species of tuna such as *Euthynnus affinis, Sarda orientalis, Thunnus albacares* and *T. tonggol*; the Indian halibut, *Psettodes erumei*; and the Grunts, *Pomadasys* spp. that were collected from Oman. The infection of cestode larvae, *Poecilancistrium* sp. in the muscle tissues of sciaenidfish was also recorded in 1997. The infection may be seasonal in Omani waters because the cysts and larvae are found more commonly in winter (Thangaraja, 1997).

Figure 6.10 Reddish patches indicating the bacteria infected areas of the fish

The adult parasites live mainly in the digestive tracts of fish, but larvae are usually found in the flesh or the viscera. Usually the larvae create more problems for the host. The infestation of the worm larvae in the muscle tissues and viscera of the host causes growth retardation, tissue damage, metabolic disturbances and death of the host. From an economic perspective, the results of heavy infestation by larvae include the discarding of edible fish products, loss in oil yields and delays in processing.

Ectoparasites are found in many species of small pelagic fish especially sardines. Certain parasites embed themselves inside the carapace of shrimps, suck their body fluid and subsequently destroy their gills. Leach-like ectoparasites are often found on the soft exposed part of the body of turtles especially around the neck.

6.4 Invasive Marine Species

The term ‘Invasive marine species’ describes marine organisms that are alien, non-native, or exotic or introduced species that are purposely or accidentally relocated. While some species enter into new habitats on their own by various natural ways, others are introduced by human beings, knowingly or unknowingly. When alien species find no natural enemies in their new environment, they spread quickly in a short time and pose a real threat to the species in their new environment and to the economy of the area.

Thousands of marine species are transferred around the world on ship bottoms and ballast water. It is estimated that each day more than 10,000 marine species are transferred around the globe in the ballast water of cargo ships (ESA, 2003). Mariculture with exotic species of fish and bivalves is a potential cause of the spread of alien species and associated disease-causing bacteria and virus pathogens and parasites.

Invasive marine species have negative impacts on the local species in many ways. They may remove the native species by preying on them, competing with them for shelter, food or both, introduce harmful germs and parasites and utilize the available nutrients of the local marine environment. The exotic species may also change the total ecosystem by changing the species composition, destroy rare local species, and change the normal function of the ecosystem.

The invasive species must be prevented before they establish themselves in a new environment; however, sometimes certain species take a long time to establish themselves in a new area. Until they pose a threat to the new environment it is difficult to detect their presence, especially if they are in microscopic forms.

In the RSA, although the harmful effects of invasive species have not been reported, there are three records of exotic species in the inner RSA: the mysidacean *Rhopalothalymus tattersallae*, the decapod *Exopalaemon styliferus* from the Indian Ocean, and the fish *Pterorhinus marmoratus* from Japan (Carleton and Geller, 1993). However, the occurrence of certain problematic species noticed in recent years is of great concern and their origin is believed to be exotic. Research on the origin of those species is necessary to confirm whether they are invasive. Continuous regional monitoring and research in coordination with international organizations and also the local coastal public and fishermen are essential to identify the invasive species and to control their spread. Therefore, it is important to publish up-to-date information with accurate facts on all incidents. The following are some of the records of the occurrence of unconfirmed 'invasive species' and their negative impacts in the RSA. Further research on these species is essential, and it is the responsibility of the scientists of the Region to carry out this important task. The occurrence of 'Invasive species' (unconfirmed) and their impacts on the RSA are described below.

6.4.1 Microalgae

Phytoplankton includes a variety of organisms such as diatoms, dinoflagellates, blue green algae, silicoflagellates, cocolithophores, etc. with sizes ranging between 0.001-0.2 mm. Knowledge about its taxonomy, species occurrence and distribution in RSA is very limited and scant. Everyday thousands of species of these microalgae are transported from other regions to the RSA through ballast water and sediments of ships. Since historical records on the list of native species of phytoplankton in RSA are not available, it is difficult to distinguish the new additions of invasive species to this group. However, the occasional outbreak of harmful algal blooms of certain species in recent years is an alarming indication of the presence of certain new species in regional waters. One example is the occurrence, hitherto unknown, of the 'green tide' bloom of *Noctiluca* (Figure 6.11). The green tide has a devastating impact on the environment and has become a common phenomenon in regional and coastal waters since 1999 (Thangaraja, 2000). Like the dense green tide causing dinoflagellate *Noctiluca*, many species of unknown phytoplankton signal their presence through the occasional 'outbreak' of blooms. These species need to be studied thoroughly to discover their origin and their impacts on the new environment.

A: Green tide bloom of *Noctiluca*

B: Microscopic view of green tide causing *Noctiluca*

Figure 6.11 Dense 'Green tide' bloom of *Noctiluca* in 1999

6.4.2 Jellyfish

Jellyfish flock to the coastal waters of the RSA seasonally. Many are of Indo-Pacific origin and come to the RSA either through water currents, or their planktonic eggs and young ones are brought in via ballast water. The occurrence of little mauve stinger jellyfish, *Pelagia noctiluca* (Figure 6.12) is one of the examples which was found for the first time in October 1999 in Muscat waters, more than a decade after monitoring surveys began in the middle and outer RSA. Between 7 and 8 October 1999, the inshore waters of the Muscat coast had large numbers of this jellyfish, both young and adult, which severely affected those who ventured into the waters, especially swimmers. Although their sting is not fatal, the pain can last for at least for two days after medication. The pinkish patches of the jellyfish which look like 'red tides' of phytoplankton bloom, consist of thousands of live jellyfishes. Since the jellyfish spawn in the local water, numerous young ones have been seen on the coasts and the population has established itself in local waters since October 1999 (Thangaraja *et al.*, 1999).

The species occurs in Australian waters, where large numbers are found in the coastal waters during the latter half of the summer because of onshore winds. The appearance of large numbers at certain times has resulted in economic loss because of the cancellation of Surf carnivals in Australia. In 1985, it was also found in plague proportions in the Mediterranean Sea.

Figure 6.12 Jellyfish, *Pelagia noctiluca*

6.4.3 Crown of Thorns

The destruction of coral reefs in Oman and UAE by the Starfish, Crown of Thorns (*Acanthaster planci*) (Figure 6.13) is of concern in the RSA. Its negative impacts on the coral reefs have been enormous in recent years and the authorities have taken various steps to reduce their number to ensure an acceptable ecological balance with coral reefs. It is said to be an invasive species, however, only genetic and other taxonomic studies will prove its place of origin. This is also a native and problematic species in Australia.

Figure 6.13 Crown of Thorns, *Acanthaster planci*

6.4.4 Gilthead seabream

The introduction of exotic species of fish or bivalve or crustaceans for mariculture is a real concern, not only because of diseases or parasites carried by these species, but also from the culture of the species itself. The best example of this in the ROPME Region is the cultured gilthead seabream (*Sparus auratus)* (Figure 6.14) which is not a native species of the RSA, but from the Mediterranean region. They are cultured in cages in the RSA. The gilthead seabream has already escaped from its cages into the wild, and fishermen have reported catching specimens in Kuwait Bay (Al-Husaini, 1999). A study of the breeding and spawning of the species in the RSA has not been carried out yet, but the threat is real. Alien species intentionally introduced in the RSA for commercial purposes, may become a threat to the native species. Under these circumstances and given the inherent risks, only cultivation of native species is encouraged in cage culture conditions where escape is almost a certainty (Bishop, 2002).

Figure 6.14 Gilthead seabream, S*parus auratus*

6.4.5 Management initiatives

Given that ballast water from oil tankers and cargo ships is the main source of the introduction of invasive species into the RSA, GloBallast designated Kharg Island as one of six demonstration sites for a study of alien/invasive species carried by ballast water of ships into the Region. The First IMO Regional Conference on Ballast Water Management and Control in the RSA, was held in cooperation with ROPME in Tehran, I.R. Iran from 17 to 19 June 2002. The objectives of the Conference were to enhance regional cooperation and coordination of ballast water management and control, and to finalize a Regional Action Plan to minimize the transfer of Harmful Aquatic Organisms and Pathogens in Ships' Ballast Waters.

ROPME has welcomed the initiative of the Global Ballast Water Management Programme (GloBallast) in designating Kharg Island as one of the six global demonstration sites for the study of invasive species carried in the ballast water of ships into the Region. ROPME has adopted the Regional Action Plan to minimize the transfer of Harmful Aquatic Organisms and Pathogens in Ships' Ballast Waters, and is collaborating with IMO-GloBallast to facilitate its implementation.

MARINE POLLUTION CONTROL, EMERGING ISSUES AND STRATEGIES FOR SUSTAINABLE DEVELOPMENT

CHAPTER 7

The previous Chapters of this Report reviewed the current state of the marine environment of the 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. The present Chapter summarizes and updates the information on measures, policies and strategies for sound environmental management and sustainable development in the RSA.

7.1 Environmental Challenges

The following current and emerging environmental issues need to be addressed. These are discussed below:

(i) Degradation of major wetlands or habitats
(ii) Pollution from river basins, coastal areas, offshore operations, and ships
(iii) Lack of harmonization of environment regulations
(iv) Lack of updated well-defined Regional Environmental Quality Objectives and Environmental Quality Standards (EQO/EQS) as a powerful tool to assess the environmental changes and trends for sound environmental management
(v) Lack of continuity in regional monitoring programmes to fill the data gaps, improve the consistency, quality and reliability of data and information
(vi) Lack of political will in participation and follow-up of international conventions.

Based on current and emerging environmental issues, the specific environmental challenges that face the Region can be described as follows:

7.1.1 <u>Conservation and restoration of marshlands of Mesopotamia</u>

The draining of the Marshlands of Mesopotamia in Iraq by drying up and diverting the feeder streams and rivers, has posed serious threats to the ecological balance of vast areas, affecting water quality of Shatt Al-Arab and the spawning grounds of shrimp and migratory species of fish at the river delta.

Given the extent of the environmental impact of the river discharge in the north-western part of the RSA, a river basin management programme should be developed for the Shatt Al-Arab and its entire basin, in cooperation with UNEP and other concerned UN and non-UN international organizations. Plans are currently under way in Iraq to develop a national strategy for marshland restoration and substantial areas have already been re-flooded in 2003. At the regional level, ROPME could provide an important forum for transboundary cooperation to rehabilitate the Mesopotamian Marshlands. Restoration would substantively contribute to the implementation of relevant ROPME protocols aimed at reducing land-based sources of marine pollution and support revitalization of fishery resources and biodiversity conservation. There is also a need for international support and UNEP is to assist in facilitating a process of regional dialogue between Member States to pursue a successful programme in addressing this environmental catastrophe.

7.1.2 Pollution from land-based activities

The ROPME Region has witnessed one of the highest rates of economic growth in the world over the last three decades. The rise in industrialization together with a high population growth and rapid urbanization, have resulted in ever-increasing environmental problems in the Region. Almost all development projects have been established on the coasts, taking advantage of access to sea for transportation, obtaining water for cooling and other uses, or for discharging the effluents from these activities, thereby affecting the most productive areas of the marine environment.

The impacts of municipal sewage and industrial effluents, particularly those of petroleum refineries and the petrochemical industry are significant. Power plants cause thermal pollution and desalination plants release chlorine, brine and thermal loads into the seawater. Dredging and land reclamation are also a permanent feature in many coastal areas of the Region with significant damaging effects on the environment.

ROPME has developed guidelines on Integrated Coastal Area Management (ICAM) to harmonize development activities in the coastal zone. Member States are also taking appropriate measures to develop ICAM plans, and to prevent, abate and combat pollution from land-based activities.

7.1.3 Pollution from ships

The RSA has one of the highest oil pollution risks in the world. This is mainly because of the concentration of offshore installations, tanker loading terminals and the huge volume and density of marine transportation of oil. According to the Oil Spill Intelligence Report, out of 20 cases of oil spill greater than ten million gallons worldwide, six cases have taken place in the ROPME Region. Smaller scale oil pollution incidents such as submarine pipeline rupture and well blowout are more frequent in the RSA.

ROPME is supporting every effort to encourage ratification of the MARPOL Convention and to ensure that requirements for adequate reception facilities in the

Region are met so that the RSA can be declared a Special Area. There is an urgent need to establish reception facilities and protect our marine environment from the operational discharges from oil tankers, commercial ships and port facilities. We are also concerned about the introduction of alien species by ballast water and have initiated a project to tackle this.

ROPME has made every effort to carry out a Feasibility Study on regional requirements for establishing reception facilities. The project was supported by the European Union, GCC Secretariat, IMO, oil companies, ROPME Member States and UNDP. The Final Report of the Feasibility Study has been approved by the ROPME Executive Committee and every effort is being made to ensure its implementation at an early date.

Recent military conflicts and remnants of hundreds of shipwrecks have seriously affected the northern part of the RSA. This pressing environmental challenge should be urgently addressed in a concerted effort with international support and cooperation.

7.1.4 Pollution from offshore operations

Offshore oil and gas installations are located in the inner RSA, which suffer from extremes of salinity, temperature and oil pollution. Evaporation is high, precipitation is poor and the volume of water in rivers is decreasing. The water lost by evaporation of the sea is mainly compensated by water exchange through the Strait of Hormuz. However, the rate of water exchange is low and the retention of pollutants is prolonged. Given this situation, the impact of offshore operations on the marine environment, especially in shallow waters or near to ecologically sensitive areas is more noticeable.

High salinity, temperature and oil content of water produced from offshore oil wells are among the main causes of stress for marine life. To this end, ROPME is making every effort to address all aspects of such water in a comprehensive way so as to minimize its detrimental impact on the marine environment.

7.1.5 Conservation of biodiversity

Marine life in the RSA suffers particularly from extremes of temperature, salinity, sedimentation and pollution. The stress factors, both anthropogenic and climatic, are the main threat to marine ecosystems and to the great biodiversity of species that depend on them. The fish and corals are more susceptible to such stress factors and respond to changes quickly.

Marine mortality episodes are familiar phenomena in the Region and the toll on fish, dolphins, dugongs, whales, waterfowl, algae and corals has reached record proportions in the past two decades. The mortality phenomena have been attributed to high levels of anthropogenic contaminants, unseasonably warm temperatures, disease agents, biotoxins and changes in food supply.

ROPME has initiated a Plan of Action on Marine Mortality (PAMM) and has established a permanent Regional Group of Experts to address the mortality events. There is a need to protect, preserve and restore the valuable marine ecosystems in this Region. Also there is a need to develop a number of marine protected areas and register the representative marine and coastal ecosystems on the lists of Biosphere Reserves and World Heritage sites.

ROPME Member States, recognizing the need to provide necessary protection for the natural biodiversity and habitats of the Region, within a framework of sustainable development, have agreed to develop a Protocol concerning the Conservation of Biological Diversity and the Establishment of Protected Areas. In this respect, the European Union, GCC Secretariat, PERSGA and UNEP/ROWA agreed with the ROPME Secretariat to prepare the Protocol and Concept Paper. The European Union hired an international consultant to draft the text of the Protocol, as well as to prepare a Concept Paper on Biological Diversity. The Legal/Technical Expert Meeting reviewed the draft text of the Protocol as submitted by the EU Consultant and made necessary amendments to the text.

7.2 Mechanisms for the Prevention and Control of Marine Pollution

The mechanisms for prevention and combating marine pollution start with the adoption of policies and preventive measures, establishment of environmental legislation and development of necessary institutional arrangements for implementation and enforcement.

7.2.1 Policies for pollution prevention and control

Policies for pollution prevention and control address national policies and initiatives, regional initiatives and policy instruments, protected areas and marine parks, contingency plans and emergency response, precautionary environmental protection policy, public awareness and implementation procedures. The latter encompasses an overview of Environmental Impact Assessment (EIA) procedures and the necessity to adopt the ambient coastal and marine water quality criteria.

7.2.2 Environmental legislation

Environmental legislation includes principal issues such as, national legislation/ regulation, the Kuwait Regional Convention and its Protocols, and the international conventions and programmes relevant to the protection of the marine environment.

More recent attempts at harmonization of environmental legislation and institutions have taken place. 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 wastes in territorial waters from ships or land-based sources is liable to large fines. In Kuwait, the resolution to establish the so-called Environmental Court has been adopted by the government. 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 of the Region obviously need updating and revising, particularly with reference to acceptable and adequate norms and standards.

Although ROPME members adhere to the ROPME legal instruments (Kuwait Convention and various protocols dealing with different sources of pollution), they contain only very general provisions on the question of civil liability and compensation. The ROPME Member States also actively participate in international conventions and agreements dealing with the marine environment.

The Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978) has four related protocols that were developed in accordance with the recommendations of the Legal Component of the Kuwait Action Plan. These protocols are:

(i) Protocol concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency, 1978;
(ii) Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf, 1989;
(iii) Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources, 1990; and
(iv) Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes, 1998.

The status of signature and ratification of the Convention and its protocols by the Member States is presented in Table 7.1.

The international agreements relevant to the protection of the marine environment are divided into international conventions and global programmes. 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 and control of marine pollution.

Table 7.1 Status of signature and ratification of the Kuwait Regional Convention and its Protocols by ROPME Member States

Member States	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	16.05.1990	21.02.1990	16.05.1990	17.03.1998	11.07.2001
I.R. Iran	24.04.1978	03.03.1980	29.03.1989	01.04.1992	21.02.1990	14.06.1993	17.03.1998	28.08.2001
Iraq	24.04.1978	04.02.1979	29.03.1989	11.11.1989	---	---	---	---
Kuwait	24.04.1978	07.11.1978	29.03.1989	31.10.1989	21.02.1990	23.05.1992	17.03.1998	22.02.2000
Oman	24.04.1978	20.03.1979	---	19.11.1989	---	09.12.1991	17.03.1998	---
Qatar	24.04.1978	04.01.1979	29.03.1989	21.05.1989	21.02.1990	23.02.1992	17.03.1998	28.07.1998
Saudi Arabia	24.04.1978	26.12.1981	29.03.1989	04.11.1989	21.02.1990	04.10.1992	---	30.01.2000
United Arab Emirates	24.04.1978	01.12.1979	29.03.1989	17.04.1990	21.02.1990	---	17.03.1998	---

The following are the main conventions and associated legislation relating to marine pollution by oil:

(i) 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);
(ii) 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);
(iii) International Convention on Civil Liability for Oil Pollution Damage, 1969, as amended by Protocols 1976, 1984 and 1992 (CLC Convention);
(iv) International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969 (INTERVENTION Convention) – Protocol relating to Intervention on the High Seas in cases of Pollution by Substances other than Oil, 1973 (INTERVENTION Protocol);
(v) International Convention for the Prevention of Pollution from Ships, 1973 and Protocol 1978 (MARPOL 73/78); and
(vi) International Convention on Oil Pollution Preparedness, Response and Cooperation 1990 (OPRC).

The status of participation of ROPME Member States in the international conventions dealing directly or indirectly with the marine environment is summarized in Table 7.2.

7.2.3 Institutional arrangements

Institutional arrangements are made at the regional level, as well as the national level, in the form of government and non-governmental bodies dealing with environmental issues or through follow-up with the overall coordination bodies.

All ROPME Member States now have environmental ministries or institutions in place. Some countries have restructured these institutions in recent years to give them higher political standing. At present, two Member States have ministers of environment in the cabinets, namely, Iraq (Ministry of Environment) and Oman (Ministry of Regional Municipalities, Environment and Water Resources). I.R. Iran has established the post of Vice-President for the environment. Bahrain has a Public Commission for the Protection of Marine Resources, Environment and Wildlife, Kuwait has the Environment Public Authority, Qatar has the Supreme Council for the Environment and Natural Reserves, Saudi Arabia has the Presidency of Meteorology and Environment, and the UAE has the Federal Environmental Agency (Table 7.3). However, Iraq has been absent from ROPME for more than a decade and needs to be re-engaged in ROPME programme activities as soon as possible.

The role of non-governmental organizations (NGOs) is becoming increasingly important particularly in areas that require active public participation, and in raising public awareness of environmental issues. In almost all ROPME Member States, environmental NGOs are operational and have a wide range of activities, many of which are related to the marine environment. A good example to note is the Environmental Protection Society of Kuwait which has recently formulated a diver team that helped with some diving activities for the cleanup of contaminated sites (SOMER, 2000). EPA-Kuwait adopted a method to enhance and promote the concept of environmental protection among all sections of society, by selecting an environmental lady-mayor for each residential area, to look after environmental issues (Kuwait Times, 24 July 2003).

The overall coordination bodies for environmental protection can be divided into three categories: national level, regional level and international level. The creation of these bodies and their cross-cutting nature are fully addressed in SOMER (1999).

7.3 Strategies and Priority Action for Sustainable Development

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

Table 7.2 Status of participation of ROPME Member States in international environmental agreements

No.	International Conventions/Protocols	Bahrain	I.R. Iran	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
1	United Nations Convention on the Law of the Sea, 1982 (UNCLOS)	X	*	X	X	*	X	*
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)				X		*	
3	International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 with the Amendments 1978/80 (LONDON Convention)	X	X	*	X			X
	* 1996 Protocol to Amend the Convention (LC Protocol)						X	
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)	X		X	X	X		Withdrawn 2001
	* 1992 Protocol to Amend the Convention (FUND Protocol)	X			X	*		X
5	International Convention on Civil Liability for Oil Pollution Damage, 1969, as amended by Protocols 1976, 1984 and 1992 (CLC Convention)	X		X	X	X	X	X
6	International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualities, 1969 (INTERVENTION Convention)		X	X	X	X		X
	* Protocol Relating to Intervention on the High Seas in Cases of Pollution by Substances other than Oil, 1973 (INTERVENTION Protocol)		X		X			
7	International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990 (OPRC Convention)	*	X					
8	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1989 (BASEL Convention)	X	X	X	X	X	X	X
	* 1995 and 1998 Amendments					X		

Table 7.2 Cont.

No.	International Conventions/Protocols	Bahrain	I.R. Iran	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
9	Convention on Wetlands of International Importance, Especially as Waterfowl Habitat, 1971 (RAMSAR Convention)	X	X					
	* Protocol to amend the Convention, 1982 (RAMSAR Protocol)	X	X					
10	Convention on the Conservation of Migratory Species of Wild Animals, 1979 (BONN Convention - Migratory Species)		X				X	
11	Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (WORLD HERITAGE Convention)	X	X		X	X	X	X
12	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973, as amended		X	*		X	X	X
13	Convention on Biological Diversity, 1992 (BIODIVERSITY Convention)	X	X	X	X	X	X	X
	*Cartagena Protocol on Biosafety to the Convention on Biological Diversity, 2000				*			
14	Framework Convention on Climate Change, 1992 (Convention on CLIMATE CHANGE)	X	X	X	X	X	X	X
15	Convention for the Protection of the Ozone Layer, 1985 (OZONE LAYER Convention)	X	X	X	*	X	X	X
	* Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, with Amendments and Adjustments (MONTREAL Protocol)	X	X	X	*	X	X	X

X - Ratified / Acceded to * - Signed but not Ratified

Table 7.3 Governmental environmental institutions and agencies in ROPME Member States

Member States	Policy Institutions	Executive Agency
Bahrain	Environment and Wildlife Affairs	Public Commission for the Protection of Marine Resources, Environment & Wildlife
I.R. Iran	Environmental High Council	Department of the Environment
Iraq	Ministry of Environment	Ministry of Environment/ Marine Science Centre
Kuwait	Environment Public Authority (EPA)	Environment Public Authority
Oman	Council of Ministers	Ministry of Regional Municipalities, Environment and Water Resources
Qatar	Council of Ministers (Permanent Commission for Environmental Protection)	Supreme Council for the Environment and Natural Reserves
Saudi Arabia	Ministerial Committee on Environment	Presidency of Meteorology and Environment (PME)
United Arab Emirates	Council of Federation	Federal Environmental Agency(FEA)

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.

ROPME can act as an interface between 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 section identifies some of the priority issues to be included in strategies for environmental protection in the Region.

7.3.1 Integrated Coastal Area Management (ICAM)

National ICAM plans may be developed with a regional perspective 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.

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. EIA procedures are required in all Member States to facilitate sound environmental management and more effective economic development.

7.3.2 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 for 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. National and regional conservation strategies are complementary and should be developed for key habitats such as, coastal wetlands, mangroves, seagrass beds, coral reefs and oyster banks in the RSA.

7.3.3 Strengthening the implementation of ROPME Protocols

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

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

7.3.4 Capacity building

An important factor in achieving the environmental objectives and in effectively addressing the prescribed concerns is building the national and regional capacities that enable 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 in this Report. ROPME programmes for in-house training, short courses, or visits to 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 in order to train specialists in various fields of the environment to face the future challenges of the Region.

7.3.5 Enhancing public awareness, information sharing and networking

Environmental public awareness is an essential component of any national policy for the protection and conservation of the environment. 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.

7.3.6 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 areas of ROPME's programme. The NGOs themselves also need to ascertain their objectives and roles in the development of national policies and to provide advice, constructive criticism and assistance to national environmental authorities.

7.3.7 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 and has gained momentum ever since. Cooperation with the GCC on issues such as conducting the study on reception facilities, development of port state control and the preparation of a regional protocol on biodiversity and the establishment of protected areas is another example of regional cooperation.

The MoU between CAMRE, PERSGA, ROPME and UNEP, which was signed in 1999, provides for regional cooperation with full transparency, avoidance of duplication and sharing of experience and information. ROPME has also established close working relations and collaboration with many international organizations and their related conventions/ programmes particularly with FAO, IAEA, IHB, IMO, IOC, ISO, IUCN, OPEC, UNEP, UNDP, UNESCO and WHO. Similar activities between ROPME and other regional environmental bodies and between regional and international environmental organizations are required and should be encouraged and formalized. In this regard, UNEP's Regional Seas Programme which brokers 'twining' arrangements between sister regional seas programmes offers and important window for increased collaboration.

7.3.8 Harmonization of legislation

ROPME Member States as members of the international community collectively have a significant role to play in 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. Member States should therefore continue to be involved in the development of global conventions to ensure that they take into consideration the needs and opportunities afforded by the Region.

7.3.9 Environmental assessment and monitoring

Although much progress has been made since 1999 in the development of regular state of the environment assessments and monitoring systems, a strengthened monitoring and assessment programme is required to address new challenges in the Region. This programme will be integrated with larger global assessments such as the United Nations Global Marine Assessment and the Global Environment Outlook process and will be developed with regional and international scientific institutions and with relevant United Nations agencies.

ROPME has already made considerable efforts to adapt advanced space age-based technologies for monitoring efforts and to obtain 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 are to support this major regional effort towards a more achievable goal.

Satellite-based technologies are widely used in environmental monitoring and research activities. To this effect, ROPME has established a Remote Sensing Laboratory to acquire the existing aerospace remote sensing materials and to prepare the satellite thematic mapping and habitat characterization and distribution in the Region.

ROPME upgraded the satellite capabilities and acquired a Satellite Receiving and Processing System for monitoring of marine and coastal areas in early 2003. Member States and the concerned regional and international organizations supported ROPME in acquiring the satellite receiving station (Figure 7.1).

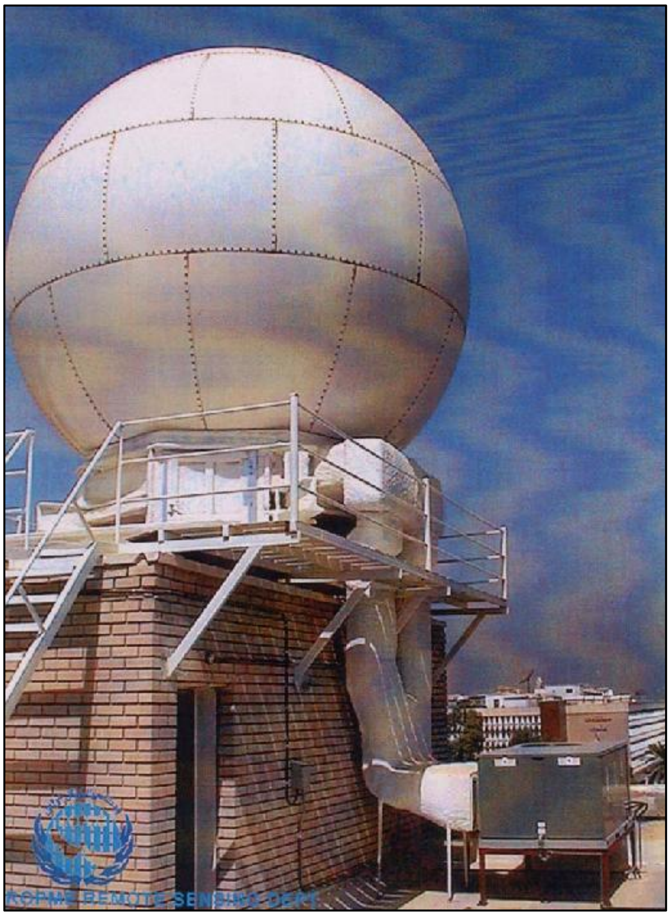


Figure 7.1 Remote sensing ground station at ROPME Secretariat for receiving NASA EOS family, MODIS data

7.3.10 Control and management of oil spills

As elaborated, oil pollution is the most significant form of pollution in the RSA, and oil spills with their visible and invisible impacts have long constituted a serious threat to the Region.

In spite of extremely heavy traffic of oil tankers through the RSA, only a limited number of reception facilities exist 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, further contributing to the observed high level of oil pollution in the Region.

Implementing the recommendations of the Feasibility Study on Reception Facilities, which was finalized by national and international experts working under the auspices of ROPME/MEMAC, the RSA could be declared as a Special Area under MARPOL 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 establishing reception facilities would also require the adoption of Port State Control procedures according to which vessels transiting through waters within the Exclusive Economic Zone (EEZ) of a sovereign State could be inspected to ensure their compliance with international agreements that are in force in the Region. The Port State Control provides for standardized procedures and fees in order not to allow vessels to call at ports where regulations are less stringent and reception facilities are inadequate.

7.3.11 Control of land-based sources of pollution

ROPME Member States should seriously pursue the implementation of the ROPME 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 surveys of land-based activities, pilot studies on pollutants, development of technical guidelines for the management of LBA, training programmes, establishment of database systems and development of a river basin management plan for the Shatt Al-Arab and other rivers in the RSA. Such efforts will require potential cooperation and relationships with countries outside the RSA, and the diplomatic skills and the ability to draw on the support and cooperation of the international and regional organizations concerned. To this effect, one of the key areas emphasized in the WSSD Plan of Implementation is an advance response to pollution caused by municipal wastewater in the period 2002-2006. ROPME has expressed willingness and begun cooperating with UNEP/GPA in their Strategic Action Plan on Municipal Wastewater.

7.3.12 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 exists, it 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 permits obtained prior to the initiation of any small- or large-scale project requiring dredging or filling, particularly those 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 need to be evaluated from a regional perspective through ROPME in order to avoid major ecological changes in the Sea Area.

7.3.13 Restoration of mangroves and coral reefs, protection of wetlands

Mangroves, coastal lagoons, seagrass beds and coral reefs represent important components of the ecological systems of the RSA, which have been subject to rapid deterioration. The restoration of damaged ecosystems and re-introduction of lost species or populations through cooperation between research institutions, fisheries and environmental protection authorities are essential steps towards pushing back the tide of destruction and moving towards recovery of our habitats. In the meantime, since the restoration projects are extremely costly, governments, development and finance funds/banks and the private sector are to support such an important regional effort.

7.3.14 Development of an Environment Information System and reporting programme

The amount of data that are available from monitoring programmes as well as the results from cruises and other literature can be increased and utilized to develop an environmental information system with geographic information system capabilities. Such an information system can be extensively used by and benefit all the concerned scientists and authorities for the cause of our marine environment. It is equally important that scientific data be communicated in a meaningful and timely manner to policy and decision-makers as well as the general public to assist their action planning. To this end, ROPME's environmental reporting capacity needs to be strengthened and its reporting outputs disseminated in printed and electronic formats, including through the upgrading of its Website.

7.4 Recommendations

Several steps needs to be taken at the national and regional levels to support the National Focal Points (NFPs) in implementing the provisions of regional and global conventions and programmes.

At the national level, the following is required:

(i) Strengthening NFPs through the provision of technical, administrative and legal support;
(ii) Updating and advancing monitoring programmes and quality assurance;
(iii) Monitoring close relationships with the political and social structure;
(iv) Adoption of regional approaches;
(v) Carrying-out environmental impact assessment as a useful tool for good preventive approaches; and
(vi) Pursuit of integrated approaches to coastal area management.

At the regional level, the following are of significance and should be attentively addressed:

(i) Marine pollution resulting from oil production and transportation;
(ii) Increase of land-based activities affecting the marine environment;
(iii) Increase of pollution from municipal releases and low percentage of treatments;
(iv) Loss of fisheries, biodiversity and ecosystems as a result of over-fishing and the use of illegal ways or means; and
(v) Huge amounts of marine contaminants from industrial sources.

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