STATE OF THE COAST ENVIRONMENT, REPORT FOR AQABA

MARCH

2015

ASEZ- "The Aqaba Special Economic Zone" was created in the year 2000 with an empowered Authority known as "The Aqaba Special Economic Zone Authority" **(ASEZA)** with regulatory, administrative, fiscal and economic responsibilities. The empowering legislation is the Aqaba Special Economic Zone Law for the Year 2000 (No. 32) and its amendments. The legislation consists of 58 articles with article 52 is devoted for the protection of the environment. Environmental protection was further strengthened with the ASEZ Environmental Protection Regulation No. 21 for the year 2001 which requires that all investors satisfy the Authority with regard to environmental effects and their capacity to comply with all the relevant environmental requirements, rules and instructions within the zone.
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This report is based on the data collected by the participant scientists, in addition to the published and unpublished data, the results and analysis of the surveys, and research and monitoring programmes and various activities carried out by the staff of the Faculty of Marine Sciences, researchers of the Marine Science Station, and researchers from Europe and United States universities who conducted research in cooperation with Jordanian scientists from the University of Jordan, Yarmouk University, and other Jordanian universities. Data from many published and unpublished official reports have also been used. Related data published in the international Journals on the Gulf of Aqaba and Red Sea, whether on local or regional scale was included in this report. Most of previous reports and activities of PERSGA were reviewed thoroughly and referred to wherever it necessary.

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FOREWORD

Human population in coastal areas and the rapid rise in economic growth have resulted in huge pressures and impacts on the coastal and marine environment including destruction of coastal ecosystems through human and development activities including among others, recreational activities, maritime activities, dredging, land-filling and the disposal or dumping of industrial and domestic wastes into the marine environment.

In 1982 Jeddah Convention, was signed by the Arab countries bordering the Red Sea and Gulf of Aden. Later in 1995 the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) was established as a secretariat for the Convention to enhance cooperation between member states in various marine environment issues.

Jordan represented by Aqaba Region Authority since 1984, and its successor Aqaba Special Economic Zone Authority (ASEZA) since 2000 was always an active state on the Red Sea and among the pioneer countries in signing Jeddah Convention and as a Member of PERSGA. The Aqaba Special Economic Zone Authority (ASEZA) is mandated to oversee the well being of the state of coastal and marine environment in the Aqaba Special Economic Zone (ASEZ).

The Aqaba Special Economic Zone Authority (ASEZA) in cooperation with United Nations Development Programme (UNDP) is currently implementing a project titled "Mainstreaming Marine Biodiversity Conservation into Coastal Zone Management (CZM) in The Aqaba Special Economic Zone". The main goal of this project is to internalize biodiversity as an asset and value for economic development and promoting more effective and integrated management of the coastal zone in Aqaba (UNDP 2011). One of its activities in this direction is the preparation of State of the Marine Environment Report (SOCR) by a team of academic staff and researchers specialized in marine sciences and coastal management. SOCR is structured to evolve as a basic reference material for a large class of individuals and institutions that have responsibility and/or interest in the marine environment and whose collective actions, based on the knowledge drawn from SOCR, should enable sustainable development of this region. It is hoped that SOCR caters to a large target audience, beginning from decision makers down to involved researchers. Further, the report will be suitable to bring out several spin off products in the form of, case studies, success stories, guidelines, brochures and such other material to enhance the awareness as well as penetrate all sectors of the society that are required to be addressed.

This publication—*State of the Coast Environment Report for Aqaba (SOCER)* will contribute to the continued efforts for sustainable use of marine and coastal resources.

……………………………………..
Chairman,

PREFACE

The Gulf of Aqaba which is part of the Red Sea contains unique coastal and marine environments. Both are famous for their globally important marine biodiversity, within their coral reefs and associated fauna and flora.

The protection of the unique environment of the Jordan Gulf of Aqaba began in the mid seventies earlier than the initiation of the *Programme for the Environment of the Red Sea and Gulf of Aden* (PERSGA) and before Jordan signed the Jeddah Convention (1982), Emergency Protocol, and the Action Plan. The efforts of Jordan to protect the environment of the Gulf of Aqaba continued after the establishment of PERSGA in 1995, which was mandated to perform the functions necessary for the management of the Jeddah Convention and its Action Plan.

During the last four decades, Jordan alone, and in collaboration with relevant regional (PERSGA) and international organizations, institutions and agencies began implementing activities and monitoring, protection and management programmes to deal with the various threats facing the coastal and marine environments of the Gulf of Aqaba and the Red Sea region. Among the significant issues and threats are urban and industrial development, tourism, non-sustainable use of living marine resources, maritime traffic, and oil transport. The Gulf of Aqaba Environmental Action Plan (GAEAP) which was supported by the Global Environment Facility (GEF), UN Development Programme (UNDP), The World Bank (WB)) contained activities and programmes which was implemented in 1995 with support from the WB, JEF, EU, and USAID. Among these activities and programmes are Marine Park management; environmental monitoring; public awareness and environmental education. The implementation of the GAEAP has helped in the preparation of guidelines for EIA; CZM; oil spill contingency plan; establishment of Prince Hamzah Centre for combating oil spills; and the development of the Aqaba Marine Park project.

The ongoing United Nations Development Programme (UNDP) Project "Mainstreaming Marine Biodiversity Conservation into Coastal Zone Management in The Aqaba Special Economic Zone (ASEZ) is another important addition to Jordan efforts to conserve the biodiversity of the Gulf of Aqaba, achieve sustainable economic development, and promote more effective and integrated management of the coastal zone in Aqaba. The results of the scientific research, environmental monitoring programmes, and reports on the activities of the GAEAP formed an excellent basis for the production of the *State of the Coast Environment Report (SOCER), for Aqaba.* The *SOCER* aims to support efforts towards the sustainable use and conservation of the Gulf of Aqaba. It is hoped that this report will provide a foundation for improved decision-making, and increase awareness and understanding of environmental conditions, issues, trends, their causes and consequences among stakeholders. The report will be a source material for academic studies and a baseline of integrated information against which future assessments can be compared.

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ASEZA

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ABBREVIATIONS AND ACRONYMS

ACT	Aqaba Container Terminal
ADC	Aqaba Development Corporation
ADCP	Acoustic Doppler Current Profiler
AFS	Aqaba Fishers Society
AIIE	Aqaba International Industrial Estate
ALECSO	Arab League Education, Cultural, and Science Organization
AMP	Aqaba Marine Park
ARA	Aqaba Regional Authority
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
BPD	Barrel oil production per day
BWM	International Convention for the Control and Management of Ships' Ballast Water and Sediments
CBD	Convention on Biological Diversity
CCL	Curved Carapace Length of Turtle
CITES	Convention on International Trade in Endangered Species
ICCL	International Convention on Civil Liability for Oil Pollution Damage
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COT	Crown of Thorn
CZM	Coastal Zone Management

DAP	Diammonium phosphate
DEM	Digital Elevation Model
DoS	Department of Statistics/Jordan
DPSIR	Drivers-Pressure-State-Impact-Response
DST	Dead Sea Transform fault system
DWT	Dead weight tonnage
EIA	Environmental Impact Assessment
EIS	Environmental Information System
ENC	Electronic Navigation Chart
EU	European Union
FAO	Food and Agriculture Organization
GAEAP	Gulf of Aqaba Environmental Action Plan
GBP	Gross Domestic Production
GDP	GloBallast Partnerships
GEF	Global Environment Facility
GEO	Global Environment Outlook
GLOSS	Global Sea Level Observing System
GoA	Gulf of Aqaba
GPA	The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities. Adopted in Washington DC, November 1995
GPS	Global positioning system
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
IAS	Invasive Aquatic Species
ICG	International Court of Justice
ICZM	Integrated coastal zone management
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change (UN)
ISPAN	Irrigation Support Project for Asia and the Near East
ITOPF	International Tanker Owners Pollution Federation
IUCN	The World Conservation Union (The International Union for the Conservation of Nature)
	Jordanian Dinar
	Jordan Industrial Estates Corporation
	Jordan Phosphate Mines Company
	Joint Team of Experts
	Kemira Arab Potash Company
	King Hussein International Airport
	Land-based sources and activities
	Living marine resources
	Liquefied natural gas
	Length of Stay
	Liquefied petroleum gas
	Mean Absolute Cover
	Multi-Annual Mean
	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978
	meters above sea level
	Million Cubic Metre

	Monitoring control and surveillance
	Marine Emergency Mutual Aid Centre
	Middle East Regional Program
	Ministry of Tourism and Antiquities
	Memorandum of understanding
	Marine Protected Area
	Mean Sea Level
	Marine Science Station/Aqaba
	Million Tonnes
	Non-governmental organization
	North Indian Ocean Hydrographic Commission
	Nitrogen oxides
	National Programme of Action for the Protection of the Marine Environment from Land-Based Activities
	Nitrogen Phosphate Potash
	National Research Centre
	National Tourism Strategy
	International Convention on Oil Pollution Preparedness, Response and Co-operation
	Poly Chlorinated Biphenyls
	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
	Particulate Matter 10
	Parts per million
	Port State Control
	Permanent Service for Mean Sea Level
	Qualified Industrial Zone
	Regional Organization for the Protection of the Marine Environment
	Roll on-Roll off
	Red Sea and Gulf of Aden
	Strategic Action Programme for the Red Sea and Gulf of Aden
	Segregated ballast tanks
	Suez Canal Authority
	State of Coast Environment Report, for Aqaba
	Safety of Life at Sea (Convention)
	Suez to the Mediterranean Pipeline
	Twenty-foot Equivalent Unit, a standardized shipping container size based on overall length
	Terms of Reference
	Traffic separation schemes
	Total Throughput
	United Kingdom Hydrographic Office
	United Nations
	United Nations Conference on Environment and Development , held in Rio de Janeiro, June 1992
	United Nations Development Programme
	United Nations Environment Programme
	United Nations Educational Scientific and Cultural Organization
	United Nations Framework Convention on Climate Change
	United States Agency for International Development

JD **JIEC** **JPMC** **JTE** **KEMAPCO** **KHIA** **LBSA** **LMR** **LNG** **LOS** **LPG** **MAC** MAM **MARPOL73 /78** **mASL** **MCM** **MCS** **MEMAC** **MERC** **MoTA** **MoU** **MPA** **MSL** **MSS** **MT** **NGO** **NIOHC** **NOx** **NPA** **NPK** **NRC** **NTS** **OPRC** **PCBs** **PERSGA** **PM10** **ppm** **PSC**	United States Dollars Volatile organic compounds World Geodetic Systems World Wide Fund for Nature Parts per thousand

PSMSL	
QIZ	
ROPME	
RoRo	
RSGA	
SAP	
SBT	
SCA	
SOCER	
SOLAS	
SUMED	
TEU	
TOR	
TSS	
TTL	
UKHO	
UN	
UNCED	
UNDP	
UNEP	
UNESCO	
UNFCCC	
USAID	
US$	
VOCs	
WGS	
WWF	
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STATE OF THE COAST ENVIRONMENT, REPORT FOR AQABA

EXECUTIVE SUMMARY

The Gulf of Aqaba as part of the Red Sea is scientifically and globally recognized for its great diversity of marine and coastal environments, the high percentage of its unique and endemic species, and the importance of its marine resources to the social and economic development of the region. During the 1960s and 1970s the northern coasts of the Gulf of Aqaba have experienced destructive military (depth charges) and tourism practices (Souvenirs collection) in Eilat, and destructive fishing practices (dynamiting and spear fishing) in Aqaba. Since the 1980s, this part of the Gulf has experienced a great development in the whole coastal zone which caused clear degradation of its marine and coastal environments.

However, because of the importance of the Gulf of Aqaba for Jordan, the successive authorities in Aqaba have worked hard to protect this unique environment. It is a fact that the authorities have achieved a great success during the last three decades and scientists gained a good knowledge about the marine environment of the Gulf of Aqaba.

The data collected during the preparation of this report show that significant progress has occurred and still occurring in Jordanian coast which include but not restricted to:

- scientific understanding of many species, habitats and ecosystems;
- environmental capacity building and management experience; and
- establishment of a marine protected area; the Aqaba Marine Park.

This review of the available information on the state of the marine environment of the mostnorthern sector of the Gulf of Aqaba provides an assessment of its present status and the factors and drives behind it, the current environmental issues and threats facing this environment, the needs for additional actions, and the recommendations to achieve more progress in coastal and marine environment understanding and management.

As a result of the scientific and management information it is possible to conclude that the emerging issues for the environment of the Gulf include:

- scientific knowledge and monitoring of key habitats, species, and activities (especially fisheries-related data);
- habitat degradation and destruction by pollution, tourism, and coastal development;
- over-fishing and its associated socioeconomic consequences for coastal populations;
- the risk of ocean acidification on coral reef ecosystem of the Gulf of Aqaba

- the risks of coral bleaching events and coral diseases outbreaks;
- the risks of sea level rise and impact of global climate change and warming;
- the spread of invasive marine species;
- The lack management action, and the implementation and enforcement of management;
- technical capacity and management experience;
- the implementation and enforcement of management; and
- protection and conservation of some of the uplifted terraces;

CHAPTER ONE: PREPARATION OF THE REPORT AND PREVIOUS ASSESSMENTS AND REPORTING OF THE STATE OF JORDAN'S COASTAL ENVIRONMENT

The Aqaba Special Economic Zone Authority (ASEZA) in cooperation with United Nations Development Program (UNDP) is implementing a project titled "Mainstreaming Marine Biodiversity Conservation into Coastal Zone Management in the Aqaba Special Economic Zone" (ASEZ), the main goal of which is to internalize biodiversity as an asset and value for economic development and promoting more effective and integrated management of the coastal zone in Aqaba

Outcome1.1 of the project: "Spatial planning and sharing of benefits from marine resources informed by sound knowledge", seeks to provide a high level of understanding of the local environment as a prerequisite for effective planning that leads to good environmental management.

According to the Terms of Reference (TOR) of the project, one of the outputs of the above outcome is "Prepare a ***State of the Aqaba Coast Environment Report*** (SOCER)" which includes an analysis and discussion of the current state of the coastal and marine resources in Aqaba.

The report is to provide comprehensive baseline information on environmental status, socioeconomic aspects, existing governance mechanisms and arrangements related to coastal management, and critical data gaps that need further research and monitoring.

A specialized team from the staff of the Faculty of Marine Sciences at "The University of Jordan/ Aqaba Branch" and researchers from the Marine Science Station/Aqaba, have carried out the assignment and prepared this report.

This chapter describes the steps followed in preparing the state of coastal environment and the steps adopted in the production of the report which includes: Preparation step; Planning step; Information assembly and organization; Compilation of chapters and sections; Report consolidation; and Publication and dissemination of the report

The chapter points out the previous assessments and reporting of the state and management of the Red Sea and Gulf of Aqaba in general (regional), and the Jordan Gulf of Aqaba coastal and marine environment in details. It focuses on the coastal and marine environment protection and management efforts along the Jordan Gulf of Aqaba; the research and monitoring programmes in support of coastal zone management (CZM) in ASEZ; and the environmental priorities in research, monitoring and management on regional (Red Sea and Gulf of Aqaba) and national scale (Jordan Gulf of Aqaba). In addition, this chapter gives a brief account of the contents of each chapter of the seven chapters that constitute the report.

The chapter points out that in the process of preparation of the report, the scientific team have surveyed the related literature and reviewed a large number of papers from the published literature, data collected as part of the national, regional and international environmental research and monitoring programmes, and almost all published reports of PERSGA.

CHAPTER TWO: THE PHYSICAL ENVIRONMENT OF THE GULF OF AQABA

The Gulf of Aqaba is the north-eastern extension of the Red Sea. The water of the Gulf of Aqaba is the warmest among the world's seas due to the climate of the region.

The Gulf of Aqaba is located in the sub-tropical arid zone between 28–29◦30N and 34◦30–35◦E. It is a semi-enclosed basin that extends over a length of 180 km with a width between 5 and 25 km (average of 16 km).

The deepest point in the Gulf reaches 1825 m with an average depth of 800 m. The bathymetry of the Gulf is arranged in three deep elongated basins separated from each other by relatively low sills. The Gulf is connected to the Red Sea by the Strait of Tiran, which has a sill depth of about 265 m.

The topography of the Gulf of Aqaba has been described as a regional north-south directed graben, bounded by two major flanks of higher elevations and cut with east-west directed wadis. The elevations start from values approaching zero nearby the sea zone, and start to increase gently to reach in the upper part of Wadi Al Yutum more than 350 meters above sea level and at the southern Wadi Araba more than 80 meters.

The coasts of the Gulf of Aqaba are steep all along the Gulf with very narrow or missing coastal plains. The bordering mountains rise up abrupt from the water edge. However, the head of the Gulf is low lying; only rises 2 m above sea level.

Along the Jordanian Gulf of Aqaba the following morphological features and land forms have been distinguished: the complex granite series, the active side wadis and their deposits, coastal wadis, alluvial fans, flood plains, and coastal zones.

The Gulf exhibits a seasonal cycle of stratification in spring, maintenance of a shallow thermocline in summer, and subsequent deepening of the thermocline to produce deep mixed layers in winter. Much of the seasonal stratification variability is determined by exchanges with the rest of the Red Sea. Nonetheless, inter-annual variability in winter time temperatures appears to set the depth of maximum mixing.

Because of being generally warm (T>21 ºC), and subject to dry winds much of the year, the Gulf is a site of high evaporation rates, estimated at 0.5-1.0 cm/day, with recent estimated values lower than earlier ones. Given a surface area of the Gulf of ca. 1.7 x 109 m2, this implies a net inflow to the Gulf of ca. 54 m3/s.

Because the densities of the Gulf are different from the rest of the Red Sea, there are strong density-driven flows. These exchange flows through the Straits of Tiran are substantially larger than the net flows through the Straits. About 3 x 104 m3/s is entering (near the surface) and leaving (at depth) the Gulf through the Straits. The exchange varies annually with an annual mean of 1.8 x 104 m3/s.

Since the Gulf is a semi-enclosed concentration basin, the combined effects of exchange flow through the strait and evaporation produce a characteristic salinity profile with a noticeable subsurface salinity minimum in summer. The high salinity levels are very close to the physiological limits of many species, which highlights the potential sensitivity of its biota to any localised anthropogenic increases.

Surface water temperature may approach 28 ºC during summer months and fall to just above 20 ºC in winter. Temperatures within the water mass reflect a degree of stratification versus vertical and lateral mixing by water currents. Vertically, temperature falls with depth in summer although there appears to be an inversion at certain depths in winter months because the deep water mass has a temperature reportedly above 20 ºC.

The general weak currents (10 cm/s) in the northern Gulf are largely driven by the prevailing down-Gulf winds and by the semi-diurnal internal tides generated in the Straits of Tiran. Notably, surface (barotropic) tides are negligible. These internal tides vary annually and are stronger in deep water than nearshore.

The renewal time for the Gulf of Aqaba is one to two years compared to 200 years for the entire water body of the Red Sea.

The combination of winds and buoyancy forcing as modified by the earth's rotation produces a series of horizontal eddies throughout the Gulf, although in the narrower northern Gulf, they tend to be less organized and more variable than in the south. The associated velocities are relatively high, and can reach 100 cm s-1 near edge of the eddies compared to the average velocities of 15 cm s-1 observed over most of all seasons. In addition, such horizontal eddies appear usually under calm condition, when the wind is relatively weak. Large velocities occur also during strong storms.

There are no known upwellings in the Gulf of Aqaba.

The annual meteorological measurements demonstrate that the wind speed fluctuates within a range of 0-12 ms-1 (mean: 4.5 ± 2.4 ms-1). Occasionally, wind speed reaches more than 15 cms-1 but just for few hours. Moreover, a harmonic change of wind speed appears during summer causing a diurnal cycle that is represented by strong winds during daytime and relatively weaker winds during nighttime. Meanwhile, northerly winds (NNW-NNE) dominate over the study area and represent about 85% of total measurements.

A typical daily cycle of air temperature variations occur during the whole year. Mean air temperature values range between 32.2 ± 3.16 °C in summer and 17.6 ± 3.46 °C in winter. In general, winds and air temperature have obvious effect on humidity; therefore, relative humidity shows periodic variation following the daily cycle of air temperature and wind speed. Minimum humidity recorded in summer is 13% compared to a maximum of 83% in winter. The recorded wind speed and direction, air temperature and relative humidity for the years 2010-2013 in the northern Gulf of Aqaba show that most of the values for each year are comparable with year 2013 values.

The maximum sea level range related to Global mean sea level (MSL) during the year 2013 was 154.3 cm. The highest value was 101.7 cm observed on December 12th, and the lowest value was -52.6 cm recorded on April 23rd. The seal level anomalies mostly depict a clear yearly cycle, where the lowest and highest monthly mean anomaly usually recorded in summer and winter, respectively.

Until now, there had been little evidence of climate change impacts on coral reefs of the Gulf of Aqaba. However, thermal stress and ocean acidification are anticipated to increase threat levels to the reefs in the whole region. Climate change and the sea level rises are topics of concern to the countries bordering the Red Sea and Gulf of Aqaba. Rising sea levels may pose a threat in the Red Sea in a number of low-lying areas. These include large areas close to the coast; ports; sewage, desalination, power, and industrial plants built at sea level.

The pH at coastal and offshore waters of the Jordan Gulf of Aqaba fluctuate around 8.3 with very minor temporal and spatial variations. This is typical for all coral reef waters because these waters are always saturated with calcium carbonate, which acts as a buffer and resists change in the pH.

Primary productivity throughout most of the Gulf of Aqaba is low, relative to other seas and oceans, due to the thermocline preventing the recycling of nutrients from deeper water to the euphotic zone.

Inorganic nutrients (ammonia, nitrate, nitrite, phosphate and silicate) are essential for marine phytoplankton productivity and growth. Higher concentrations of nutrients, chlorophyll a concentrations, and primary productivity in the shallow waters occur during winter. This may be attributed to deep-water vertical mixing during winter in which deep water of high nutrients concentrations comes up to the surface.

Cross-shore mixing (from shallow to offshore waters) due to density currents (gravity currents) has been recently documented. This process drives coastal water down slope offshore when it gets cooler at night. The increased nutrient concentrations in the euphotic zone enhances primary productivity resulting in higher phytoplankton abundance and increased chlorophyll a concentrations

Water column stratification and high irradiance during summer result in a depletion of the inorganic nutrients in the upper waters by enhanced primary productivity at the subsurface level (50-75m). Ammonium concentration is fluctuated irregularly with a tendency to higher concentrations during the winter months (January-March). Nitrate and nitrite concentrations during the last five years showed a regular shift from a summer low to relatively high early winter values. Phosphate concentrations are generally low during summer and high during winter. Silicate concentrations show the same trend during summer and during winter.

The surface waters of the Red Sea and the Gulf of Aqaba are mostly oligotrophic (nutrient-poor), except in polluted areas (see Table 2.16). Nutrient distribution shows variations from north to south and with depth and season. The concentrations in the southern Red Sea are higher than those of the northern part, which can be attributed to the richer nutrient water inflow from the Gulf of Aden into the southern Red Sea during late summer.

Dissolved oxygen concentrations at the Gulf of Aqaba show a regular pattern inversely proportional to that of temperature with a range of 6.4 to7.4 mgl-1, indicating that the effects of the other ecosystem variables are masked by that the of temperature. Waters of the Gulf of Aqaba are very well balanced in terms of respiration and photosynthesis and well ventilated due to the annual deep mixing. Most of the time a100% saturation is found.

CHAPTER THREE: SOCIO-ECONOMIC DEVELOPMENT AND LAND-BASED SOURCES OF POLLUTION

The population of Aqaba (and Jordan) is growing at a rate of 2.2%. Such increase in the population growth puts a lot of pressure on the coastal environment resources and coastal cities infrastructure. This fast growing coastal town is considered the heart of the Aqaba Special Economic Zone (ASEZ). By the end of 2010, the population of Aqaba was 103,000 and its estimated population by the end of 2012 was about 139,000 (DoS/Jordan)

The economy of Aqaba has increased after the establishment of the ASEZA in 2001. The main economical activities in Aqaba are associated with the port, some industries, tourism and re-export activities. New resorts and tourism projects are being constructed. Along with tourism projects, Aqaba has also attracted global logistic companies to invest in logistics, which boosted the city's status as a transport and logistics hub.

Many industrial activities are located in the South Coast Industrial Zone adjacent to Saudi Border. The main activities are: the Jordan Phosphate Mines Co. Industrial Complex, the Thermal Power Plant, the Arab Potash Corporation and the Arab Gas Pipeline, Aqaba International Industrial Estate (AIIE) that will serve as a hub for fully serviced light manufacturing and logistics.

The capacity of the port has been increased significantly over the years. Since 1979 the traffic through Aqaba port has grown at high rates (see Table 3.8). Aqaba port has received 32026 vessels during the last eleven years (2003-2013) with an annual average of 2912 vessel.

The number of passengers between ranged between a maximum of 1,375,411 in 2006 and a minimum of 726,920 in 2013 (annual mean 986,650 passenger) (see Table 3.8).

Exports ranged between 6 million tonnes (MT) in 2009 and about 9 MT in 2011. By comparison, imports ranged between a minimum of 8.3 MT in 2009 and about 12 MT in 2012 (see Table 3.8).

The total cargo handlings (imports and exports) via the port varied from 6600 tonnes (T) in 1952 to 20 MT in 1988 with revenue of JD 40.5 million. The revenue reached maximum of JD 83 million in 2012 (see Table 3.11).

The main exported items include fertilizers, raw phosphate, potash and cement. The main imported industrial items are ammonia, sulphur and gas in addition to crude oil and oil products. The imported oil is mainly crude oil (3.7- 4.0 MT). The official figures of the 2012 annual report showed a general trend of increase in the imports of the liquefied gas, diesel and gasoline.

By 2013, the port was the largest employer in the ASEZ with over 3100 employees and a revenue of more than JD200 million.

A new Port of Aqaba project will cost 5 billion dollars, and includes Liquefied Petroleum Gas Terminal (LPG) Jetty, and Liquefied Natural Gas Terminal (LNG) Jetty and the rehabilitation of the Oil Terminal, New Phosphate Terminal, Industrial Port, Miscellaneous Liquids Jetty, General Cargo and Ro-Ro Terminal, the Grain Terminal, and the New Ferry (Passenger) Terminal.

The mineral resources production, sales, revenues, and social and environmental impacts constitute very important issues to Aqaba and Jordan. Official reports of the Arab Potash Company (APC) show that the production increased after 2009. The company sold 1.8 million tonnes in 2013. The revenues increased from JD 373,700 in 2009 to JD 521,209 in 2013. The number of employees of the APC and other related subsidiaries companies is 2427.

The company and other related subsidiaries companies a provided Jordan with JD175 million in 2011, JD100 million in 2012, and JD 75 in 2013 as percentage of the net profit of each of these years. In addition, APC provided more than JD 10 million to support development projects with a focus on vital sectors that include water, education, health and infrastructure.

The Jordan Phosphate Mines Company production of the Rock Phosphate in the last five years exceeded 5 MT per year. The production in 2013 was about 5.4MT. The revenues had increased to JD 521 millions in 2012 and the profits had increased in parallel to sales revenues from JD 131,800,000 in 2009 to JD 198,822,000 in 2012.

The annual phosphate exports ranged between 3.5-4.0 MT during the past five years. In average 3.5 MT are exported through Aqaba port. During 2013, the quantity of Rock Phosphate exported reached to (3,245) MT. The company sold 483,000 tonnes of diammonium phosphate (DAP) fertilizer. The net sales revenues reached JD 574.4 million. This is compared to JD 759.4 million in 2012. The net profits after deducting income tax and distributions reached JD 131.7 million in 2012.

From this income, the company which is employing 4056 with 1194 of them in Aqaba is contributing to the development of the local society and support of various activities. The financial donations, given by the company, during 2013, exceeded JD 4.3 millions.

However, the activities of the company are not without environmental effects in Aqaba. During transportation, storage, and loading some phosphate is lost to the atmosphere, to the land around the storage areas, under the ship loader, near the berth, and to the sea. The environmental effects of the dust include increasing of suspended solids and water turbidity, reduction of water clarity and light penetration, siltation on the coral reef and depression of coral growth, and increasing the levels of dissolved phosphate nutrients and other toxic heavy metals.

It is anticipated however, that the problem of phosphate dust and its impacts on the environment will be overcome in the new Aqaba Ports Relocation and Development Project. This can be achieved by the development of adequate mitigation measures to reduce or eliminate emissions.

Water consumption and increasing demand in Aqaba region is a foreseen problem. Economical growth over the past four decades has been accompanied by a parallel growth in population which is expected to reach approximately 250,000 by the year 2020. The high growth rate of economical development which include expansion in the tourism and resort hotels, maritime and land transportation, and industrial and commercial activities will increase the demand for water.

In 2005, the water consumption in the region was estimated at 14.94 million cubic meters (MCM) plus 2 MCM of treated wastewater which is used for irrigating some 200 ha of palm farms and the green areas project. Demand for water will increase to reach about 33.5 MCM on the average by the year 2020 and will be 43.00 MCM (about three times than the demand of 14.94 MCM in 2005) if the high growth model (7.3 % population increase) is considered. Consequently, the effluent from the tertiary treatment plants is expected to increase and reach 7 MCM by the year 2020.

These conditions will create water and environmental problems in Aqaba. Aqaba will suffer shortages of water supply that has to be overcome by supply and demand management options. Since current supplies from Disi aquifers are limited, new supplies would depend on the desalinated sea water. This source will also have environmental and socioeconomic impacts.

The other potential environmental problem associated with increasing demand and consumption of water is the problem of the increased domestic wastewater treatment, use and loss. Wastewater losses can reach 20 to 25% of the effluents used for irrigation. These lost quantities will percolate to shallow groundwater and eventually reach the Gulf of Aqaba. The semi-enclosed nature of the Gulf of Aqaba makes it more susceptible to pollution with nitrates.

The most anticipated change in the percentage land-use between 2004 and 2018 will be in urban areas, industrial or commercial areas, port areas and airport area. The land-use changes for ASEZA area of about 375km^2 between 1990 and 2004 showed that continuous urban fabric was expanding and about 46% of discontinuous urban fabric has changed to urbanized areas **(**see Table 3.33**)**. Assuming that similar trend of land-use changes will take place in the future, the predicted land-use by 2018 shows most changes will be in the urbanization and in the industrial and commercial areas.

Tourism is very important to the economy and social development of Jordan who experienced a steady increase in tourism during the first decade of the 21st century. Jordan first National Tourism Strategy 2004-2010, had led to great economic advantages. During 2010 Jordan recorded over 8 million tourism arrivals and tourism expenditure reached more than JD 2.4 billion which contributed 12.4% to the national gross domestic production (GDP), direct employment reached 41,900, and hundred thousand full time-equivalent jobs. The 2011-2015 National Tourism Strategy targets an increase of total arrivals to 9.4 million; grow tourism receipts to JD 4.2 billion; and grow domestic tourism receipts by 30% over the period.

ASEZA reported that the number of tourists visited the ASEZ in 2006 rose to about 432,000, an increase of 5% over previous year. In 2010 the number of tourists was 503,551 including 294,592 (59%) incoming tourism. More than $20 billion has been invested in developing Aqaba’s massive Mega Projects in tourism infrastructure and logistics. ASEZA targeted occupancy of 67% in 2014 and 70% in 2015 compared to 45% in 2009 (see Table 3.35).

According to one report, the rapid increase process of hotel-rooms development, Aqaba moved from a "RESPONSE" strategy experienced until 2004, into a "LEVERAGE" strategy until 2011, followed by a possible "GROWTH" strategy towards 2015–2017.

General trend of increase is expected in other countries on the coast of the Gulf of Aqaba if the political conditions were to improve, ‘Eilat 2030’ strategic plan, tourist development will cause an increase in number of visitors to 7 million visitors, hotel-rooms to 35,000 and a local population of approximately 150,000 inhabitants. In Egypt where tourism is considered one important factor of economic growth, tourism generates estimated revenue of US$ 10.8 billion annually. This is equivalent to approximately 6% of national GDP if the direct and indirect activities related to tourism are considered. The Red Sea Governorate represents about 33%, and South Governorate (North Sinaï) at about 32% of the total hotel capacity in Egypt. Together they represent 65% of the total capacity. Tourists are attracted to these governorates because of the coral reefs.

Coral reefs are an important component of nature-based tourism and sustainable tourism is a crucial component of tourism strategy in Egypt, Aqaba in Jordan and Eilat for Israel. Almost 75% of tourism activity in Egypt is concentrated on the Sinai and Red Sea.

Tourists ranked coral reefs at the first place (73%), before climate, beauty of landscape and beaches. Unfortunately, the relationship between tourism and the environment is unbalanced: tourism is environmentally dependent and the environment is vulnerable to the impact of tourism.

The construction and operation of tourist facilities and tourist activities have significant impacts on the marine environment but particularly on coral reefs. It has been estimated that 73% of the coral along the Egyptian coast has suffered damaged as a result of coastal constructions. Overfishing is also a major local threat affecting 55% of reefs, particularly in the Gulf of Aqaba. Therefore, ecotourism along the coral reefs of the Red Sea represents a challenge to sustainability

Marine protected areas (MPAs) are also affected by the continued development of the tourism industry. Pollution caused directly by tourists includes littering caused by divers, snorkelers and anchor chains in coral reef areas. Accordingly, the conservation and management of coral reefs is a priority issue in Egypt and Jordan.

Land-based sources of marine litter account for up to 80% of the world's marine pollution. Marine litter of diverse types were reported from the coastal and marine environment of the RSGA region including the waters and beaches of Jordan, Egypt, Saudi Arabia, Yemen, Djibouti, northern coast of Somalia and Sudan. It has been reported from MPAs in Egypt, Sudan and Djibouti.

Among the types of marine litter reported in Aqaba and RSGA are plastics (fragments, sheets, bags, containers); polystyrene (cups, packaging, buoys); rubber (gloves, boots, tyres); wood (construction timbers, pallets, fragments of both); metals (drink cans, oil drums, aerosol containers, scrap); paper and cardboard; cloth (clothing, furnishings, shoes); glass (bottles, light bulbs); fishing gear (nets, abandoned/lost fishing gear); and plastic pellets. In almost all reports plastics were by far the most abundant.

Most of the litter on the Jordanian beaches and in coastal waters of the Gulf of Aqaba results from recreational and shipping activities. The cargo and passengers' ships are a major source of debris. About 19 million items are reaching the marine environment in front of the Marie Science Station (MSS) from the ferry boat at Aqaba passengers' port each year. Other sources of debris are fishing activities and input from several wadis and small valleys during the occasional but very strong floods caused by rain storms common to the region. The origin of the debris is mainly local, but some debris from Egypt, Eilat, and Saudi Arabia was found on Aqaba Beaches.

Management activities in Jordan include visual monitoring; daily beach clean-up activities; monthly clean-up dive campaigns in the Aqaba Marine Park (AMP) and other sites; participation in the International Coastal Cleanup Campaigns; "Clean-up the World"**;** and public awareness activities and programmes for management of marine litter. In addition, ASEZA is implementing legislations and coastal management policies such as the Aqaba Marine Park Regulation No. 22 year 2001, and the Environmental Protection Regulation No. 21 year 2002. However since the early sixties, protection of the marine environment of the Jordanian Gulf of Aqaba has been the subject of many articles in many national laws, by-law, and regulations since 1961. All of them contain articles on prohibiting dumping of litter in the marine environment.

The Gulf of Aqaba as part of the Red Sea, has been designated under the terms of regulation (10) of MARPOL and its annexes as a ''Special Area''. Annex V, in particular prohibits and restricts the disposal of all garbage, ropes, fishing gear and plastics from ships in any special area. Consequently, Jordan became a party to many regional and international environmental conventions, protocols, treaties, and agreements pertaining to marine litter issues.

According to PERSGA however, the implementation of the national regulations and other regional and international conventions by member states is inadequate, mainly due to lack of sufficient capacities and coordination between different authorities, in addition to a lack of sufficient updating of the laws.

The following actions are suggested to limit, reduce, and enhance the appreciation of the litter problem along the Gulf of Aqaba.

- initiate local and regional research and long-term marine litter monitoring. The scientific information would provide input for conservation;
- assist passengers and merchant shipping lines to comply with MARPOL 73/78 and its annexes;
- develop a strategy that integrates land-based solid wastes management issues with those associated with ship and boat generated marine litter;
- increase of existing co-operation among scientists, decision makers, general public on local, national, regional and international scales ;
- implement a solid waste management plan and enforce a Marine Park management plan that will help to control the transboundary solid waste impacts on the marine and coastal water resources of the area;
- promote sound solid waste management practices in Aqaba town, Aqaba ports and in the whole region of the Gulf of Aqaba and the Red Sea;
- Develop a long term strategy for conducting a marine litter cleanup and outreach campaign and establish a public education programmes that target local and international tourists, Aqaba town citizens, students, ports corporation employees and all workers involved in shipping, industry and transport activities;
- Review, develop, implement and enforce a legislative and regulatory framework for the management protection and control of pollution including monitoring with a regional focus; and
- Take measures by the Jordan Ports Corporation and similar port authorities along the Red Sea and Gulf of Aqaba and make available adequate port facilities in all ports of the region to ensure the compliance of vessels, ships and boats with MARPOL 73/78.

CHAPTER FOUR: SEA-BASED ACTIVITIES AND SOURCES OF POLLUTION

The numbers of ships that visit Jordan ports on the Gulf of Aqaba is increasing with time. Consequently, ports development is increasing very fast to accommodate for the vast growth in trade, cargo, container, and tanker shipping activities.

Because of the small width and semi-enclosed nature of the Gulf of Aqaba, any spill of oil or chemicals will have detrimental effects on its coastal waters, ecosystem, habitats and flora and fauna.

In addition to land-sourced marine pollution, over-exploitation of living marine resources (LMR), and physical alteration or destruction of habitat, invasive species in ballast water has been considered the fourth greatest threats to the world's oceans. Ballast water on container ships, bulk carriers, and tankers, visiting the ports in Jordan and the neighbouring countries in the Gulf of Aqaba region, is a potential source of pollution that can carry and seriously pollute the marine environment of the Gulf in addition to the Red Sea with invasive species. Therefore, Port`s managers and other official responsible authorities should take all measures to deal with this threat.

Pollution from maritime transport to and from the ports in Jordan and neighbouring countries in the Gulf of Aqaba region that receive or export chemicals, oil and liquefied natural gas has to be monitored and carefully managed and controlled in case of pollution event.

To be able to combat such pollution, the countries in the region have witnessed many activities in connection with this subject. According to PERSGA, capacity building in combating oil pollution, in port state control, navigation safety, contingency planning and ballast water management has been improved through training workshops held throughout the region.

Jordan who is a party to the 1972 London Dumping Convention has already adopted a National Contingency Plan and national plans are now in place in Saudi Arabia. The Maritime Authority in Aqaba has built up its capacity to carry out Port State Control of ships.

Still however, the capacity for monitoring oil and chemical spills in the Gulf of Aqaba region remains limited and there is an urgent need to build up and strengthen the capacity, improve the level of understanding of the potential impact of ballast water and take actions to prepare the region to deal effectively with invasive aquatic species (IAS).

CHAPTER FIVE: COASTAL AND MARINE RESOURCES

The beaches along the north coast are consisted of varying amounts of fine-grained, wind-blown sand, in addition to larger-sized particles. The northern part of the Jordanian coastline is characterized by sandy and seagrass meadows, especially in the hotels area, and the public coffees' area. In the east-northern coast of Aqaba, high mountains produce a shoreline largely comprised of rocky shore and cliffs plunging directly into the sea.

There may be flat terraces extending out to fringing reefs, rock platforms, cobble beaches, or 1,000 m high vertical cliffs. Major groups of invertebrates occupying this zone include gastropod molluscs, rock oysters, barnacles, and chitons.

The sand beaches along the southern coast of Aqaba are composed of coarse particles, originating from the disintegration and decomposition of terrestrial rocks, and varying amounts of calcareous, sand sized particles of biological origin. The animals living in the intertidal sand include various species of macrofauna; meiofauna, and microfauna.

The Jordanian coast of the Gulf of Aqaba is relatively small with much of the sea-related activities are focused. About 30% of the coastline is used for port activities, while 7 Km of the coast has been declared as marine protected area (About 25% of the total coast area). The Jordanian Gulf of Aqaba coast supports relatively small total coral reef area, composed entirely of narrow and steep fringing reefs.

Though, the Gulf of Aqaba is among the most diverse high latitude reefs in the world, with about 200 species of hard corals and more than 500 fish species. Jordan's coral reefs were maintained in relatively good conditions during the past period, before the most recent developments of sea ports. No major bleaching events were recorded in the past.

At present, the most important threats to coral reefs in Jordan are the constructions of new ports and the expansions of existing ports that took place in the past years. This sector is still fast growing, as many new ports are being constructed, especially in the southern part of the coast. Massive death of corals and its associated fauna and flora have resulted from the construction and expansion of ports.

Additional and significant threats resulted from flooding, which happens every few years. The amount of coral death occurring upon such event is detrimental to the coral reefs, where a whole reef flat can be killed as a result of the heavy load of sediments, which remain suspended in the water for about two weeks after the flood.

Adding to the above mentioned threats, the coral diseases, souvenir collections, damage by recreational diving, drifting of some ships by accidents, accidental oil spills, damaging fishing methods are the most important.

A long-term monitoring for basic coral reef ecosystem parameters such as percent cover and diversity of corals, as well as assessment of the associated fauna like sponges, algae and macro-invertebrates has been implemented as part of an overall monitoring programme during the past years. Other benthic habitats such as the seagrass meadows and the sandy bottoms are also included in the monitoring programme. Additional monitoring includes those that are associated with certain coastal projects, such as the industrial complex and the Ayla project. Additional studies are carried out according to the needs of some facilities before and after construction of the project.

From the national monitoring programme results, the benthic habitat in the Jordanian Gulf of Aqaba can be described as follows: In general, the southern sites of the Jordanian coastline have more coral cover compared with the northern sites. The deeper transects in all sites have more percent cover of corals compared with the shallower transects.

The deep transects contained higher percent cover of healthy corals, due to the better protection from possible damaging factors, which affect the shallower reef corals. Other species such as sponges, clams, sea anemone, ascidians, algae and others are less significant in terms of their distribution along the Jordanian coast of the Gulf of Aqaba.

The recently killed corals, as the most important indicator for reef destruction were low in all sites with a percent cover of less than 1%. But this does not imply that there is no coral death on the other parts of the coast. In fact significant coral damage was seen in other areas which were impacted by the floods.

Eighteen genera of benthic macroalgae were identified in the Gulf of Aqaba coast including seven chlorophytes, eleven rhodophytes, and ten phaeophytes. Both biomass and mean absolute cover (MAC) were high for the brown algae (Phaeophyceae). The industrial complex has the highest cover and biomass and is significantly different from those observed at the phosphate port. The highest cover and biomass are in spring.

No significant differences in biomass were observed among seasons, but there are distinct seasonal shifts, in which, genera are dominant and habitat is the most important factor determining algal composition, followed by season and site. However, the yearly fluctuations of algal community pattern do not show any clear trend.

Along the coastline of the Jordan Gulf of Aqaba, turf algae exhibits higher cover in the shallower depth (8 m), and more live reef occurs at the deeper water (15 m). Sites with the most turf algae and least live reef coverage are within close proximity to heavy industrial developments, while the site with the least turf algae and most live reef cover lies within a public beach, inside the Aqaba Marine Park, which prohibits fishing.

The average turf algae cover in relation to the total reef area for all the sites and both depths is 28%, while bare dead coral to total reef proportion constitutes greater percentage 40%). This may indicate that the potential phase-shift from coral reef to turf algae is not yet incurable; but with significant action, it can be slowed, halted, or even reversed specially at sites in close proximity to anthropogenic influences such as construction activities and nutrient (i.e. Phosphorus and Nitrogen) over-enrichment.

The foraging sea turtles at all diving spots along the coastline of the Jordanian Gulf of Aqaba revealed that all turtle captured as well as those observed in the field were Hawksbill. The majority of the turtle population was at sub adult stage (45-60 cm CCL; curved carapace length). The highest abundance of turtles is at the Black Rock, compared with other sites such as the Moon valley, Seven Sisters, and Oliver Canyon. The gender ratio of population showed variation throughout a one-year cycle with males consistently more abundant between July and December. In January-February only females were seen. An overall estimation of the total number of both genders in one year indicated that there are superiority of females over males. The majority of turtle population (85%) was observed in the coral reef habitat.

Turtle population along the coast is suggested to be present solely to forage and then migrate for nesting to Saudi Arabian or Egyptian coasts or even farther. Rapid urbanization have reduced nesting habitat at the Jordanian coast. The Jordan's National Action Plan for Conservation of Marine Turtles suggested actions for management, enforcement of legislation and securing funding for successful conservation measures.

CHAPTER SIX: LIVING MARINE RESOURCES

The Jordanian coastline is very short (27km), of which about 12 km is occupied by the industrial establishments, ports, resorts and hotels. The fishers are not allowed to fish in many of these areas as well as in the protected areas or the areas used for ship anchorages. Therefore, most of the catch is restricted to the northern part of the coast, which is characterized by sandy bottoms and seagrass meadows, where more fish species can be found.

The short coastline of Jordan has a narrow continental shelf which certainly limits the commercial fishing to artisanal methods. About 230 fishers are licensed but only 26 of them renew their licenses, and all of them focus their effort on reef associated species and some pelagic species.

Fishers use small fibreglass boats 2.5-9m long, equipped with outboard engines, mostly of not more than 60 HP. The number of boats which were operating during the period 2008 - 2012 range between 58 in 2009 and 28 in 2011.

Fishers use various types of fishing gears including fish traps (local name: Sakhawah; plural Sakhawi), gill nets, seine nets (local name: Shwar) and hooks and line (local name: Khait-Wa- Sinnara), long line (local name: Sharak) and short long line (local name Amra).

Fishing methods like trolling and line do not have significant impacts on the fisheries or environment. By comparison, other methods (for example fish traps and gillnets) are associated with high number of incidental captures of non-target coral reef fishes and sea turtles, and cause adverse impacts on the environment and on this limited coastal resource. In addition, lost traps and gill nets are known as ghost traps continue to catch non-target fishes.

There is only one landing site in Aqaba where all of the fishers bring their catches near the end of their fishing day to sell it at this site. The site is located in the fishers' port in front of the Royal Navy check point. However, some fishers sell their catches directly to fish shops in Aqaba.

The larval abundances of fishes varied seasonally, reaching maxima during July and minimal abundances during winter months (November-February). If larval abundance reached its maximum during July, the fishes may reproduce in April, May or even in June.

Scombridae represent the most important commercial species in Aqaba. It represents more than 70% of the Jordanian marine fish catch, especially the most abundant migratory species *Katsuwonuspelamis* and *Euthynnusaffinis*. Other important commercial fish species are *Decapterusmacarellus, Decapterusmacrosoma*n which belong to the family Carangidae*;* followed by other species of the Xiphiidae and Istiophoridaefamilies.

Local fish consumption varies from year to year. The average fish consumption per capita was (2.7) kg in 1998 and (2.8) kg in 1997. The maximum consumption was highest in 2011(32,902 tonnes). This increase can be attributed to the millions of refugees who came to Jordan from Syria and Iraq as a result of the political conflicts in the region. The ratio of the local fish production to the imported fishes is very small as it ranges between 0.02 in the year 2011and 0.05 in 2012.

The Ministry of Agriculture Jordan started collecting data on fisheries during the fifties, sixties, seventies and mid eighties (1985) of the last century. Unfortunately, after then, this effort has been stopped. Recently however, Department of Statistics started new efforts to collect such useful data which covers the period from 2008 to 2012.

There are two Cooperative Fishers' Societies in Aqaba. The first society with 139 members has cool storage room just near the Royal Navy check point at the fisher' port and another cool room near the town centre. The second Cooperative Society is the "Thagher Jordan Cooperative Fishing and Agriculture Society" with 89 members. The two societies rarely receive financial support from the government or from other funding agencies. Therefore, they cannot provide their members with financial loans or any other type of support.

Fisheries are considered important renewable natural resources, which have important economic role and therefore, it is important to enforce fishing regulations pertaining to nature conservation and place increased emphasis on marine species of fishes. This should include the development of marine environment strategies that guarantee the protection of marine environment in general, and fishes in particular.

Fisheries in Jordan are facing increasing pressure from the demand created by the continued population increase, habitat degradation, pollution and global climate change. The main areas that can be identified as requiring action to facilitate the conservation of marine biodiversity are the promotion of the conservation and sustainable use of fish stocks and feeding grounds through control of exploitation rates and the establishment of technical conservation measures, reduction of the impact of fishing activities and other human activities on non-target species, avoidance of aquaculture practices that may affect habitat conservation through occupation of sensitive areas (coral reef), improved target species size selectivity to reduce discards of juveniles, temporal or spatial closures, and introduction and promotion of fishing methods that have a reduced physical impact on the environment.

Though Jordan has issued many laws, regulations, and instructions that pertain to the protection of the coastal and marine environment of the Jordan Gulf of Aqaba and its resources, it is however, of utmost importance to firmly enforce these legislations. In addition, it is important to develop a management plan for fishery resources based on outputs of scientific research and on consultation with the local scientific community. The management plan should include monitoring, control and surveillance (MCS) of fish stock.

Conservation of fishes is a multi-disciplinary task, and cooperation at the regional level is important. It is also very important for Jordan to conserve its marine resources through education and awareness and implementation of legislations.

The current national fish production from fresh and marine water resources is about 300 tonnes per year which comprises only about 1% of the national fish consumption. Thus, environment friendly aquaculture may be a future choice to increase fish production. Since Jordan is depending heavily on healthy coral reefs for the development of their growing tourist industry, researchers in the MSS are attempting to develop an integrated aquaculture system in which minimum wastes go into the natural marine environment, in addition to the development of low cost waste treatment technology for use in intensive land-based coastal aquaculture.

CHAPTER ONE

1 GUIDING PRINCIPLES IN THE PREPARATION OF THE REPORT AND PREVIOUS ASSESSMENTS AND REPORTING OF THE STATE OF THE JORDAN'S COASTAL ENVIRONMENT

1.1 SUMMARY

The Aqaba Special Economic Zone Authority (ASEZA) in cooperation with United Nations Development Programme (UNDP) is currently implementing a project titled “Mainstreaming Marine Biodiversity Conservation into Coastal Zone Management in the Aqaba Special Economic Zone” (ASEZ), the main goal of which is to internalize biodiversity as an asset and value for economic development and promoting more effective and integrated management of the coastal zone in Aqaba.

Outcome1.1 of the project: "Spatial planning and sharing of benefits from marine resources informed by sound knowledge", seeks to provide a high level of understanding of the local environment as a prerequisite for effective planning that leads to good environmental management.

According to the Terms of Reference (TOR) of the project, one of the outputs of the above outcome is “Prepare a ***State of the Aqaba Coast Environment Report*** (SOCER)” which includes an analysis and discussion of the current state of the coastal and marine resources in Aqaba.

The state of the coast report (SOCER) provides comprehensive qualitative and quantitative baseline information, where changes can be compared over time, on environmental status, socioeconomic aspects, existing governance mechanisms and implementing arrangements related to coastal management, and critical data gaps that need further research and monitoring.

A specialized team from the staff of the Faculty of Marine Sciences at "The University of Jordan/ Aqaba Branch" and researchers from the Marine Science Station/Aqaba, carried out and completed the assignment and prepared this report.

This chapter describes the steps followed in preparing the state of coastal environment such as: the establishment of institutional framework andappointing the leader of the tea; determine which groups and individuals will participate in the production process; determine who or which unit in the mandated institution will be the focal point for the process; and who will address policy issues on behalf of the institution.

Also, this chapter describes the six steps adopted in the production of the report which includes: Preparation step (informing stakeholders about the process, identifying responsibilities of the participants, identify expert drafters (authors), researchers and editors); Planning step (preparing the report structure and scope, and developing table of contents); Information assembly and organization (obtaining institutional and organizational cooperation in availing data and information, and identifying

appropriate indicators (for pressure, state, impact and response); Compilation of chapters and sections (producing, reviewing, and revising the draft report, and submitting the revised report for editing; Report consolidation (preparing and approving the final report by the relevant authorities); and Publication and dissemination of the report (arranging for printing of the report, media release, and dissemination of the report).

The chapter points out the previous assessments and reporting of the state and management of the Red Sea and Gulf of Aqaba in general (regional), and the Jordan Gulf of Aqaba coastal and marine environment in details. It focuses on the coastal and marine environment protection and management efforts along the Jordan Gulf of Aqaba; the research and monitoring programmes in support of coastal zone management (CZM) in ASEZ; and the environmental priorities in research, monitoring and management on regional (Red Sea and Gulf of Aqaba) and national scale (JordanGulf of Aqaba).

In addition, this chapter gives a brief account of the contents of each chapter in the present report. It indicates that Chapter 2 is a review of the geological, physical and chemical characteristics of the coastal and marine environment of the Red Sea in general and the Gulf of Aqaba in details, while Chapter 3 is a review of the most important aspects of the socio-economic growth and development activities. It focuses on the pressures and impacts of the existing and potential land-based sources of pollution affecting the environment of the Gulf of Aqaba. Chapter 4 reviews the sea-based activities and sources of pollution in the Red Sea with emphasis on the Gulf Aqaba. It reviews oil and gas activities, shipping and navigation, port activities, and the issue of ballast water and its role in carrying invasive alien species from one region to another. Chapter 5 is a review of the current knowledge and information, and gives details on the current status of major ecosystems and habitats, such as coral reefs and seagrass beds, important groups of organisms (algae, fishes, some marine mammals, some invertebrates, turtles, and seabirds), and endemism. Chapter 6 covers the status of fisheries and the most important species and the socioeconomic significance of fishing activities and its social, economic and environmental impacts. Chapter 7 pinpoints the priority actions that are required on the future decision-making based on the information gathered in the previous chapters.

In the process of preparation of this report, the scientific team have surveyed the related literature and reviewed a large number of papers from the published literature, data collected as part of the national, regional and international environmental research and monitoring programmes, and almost all published reports of PERSGA.

1.2 INTRODUTION/BACKGROUND

The most significant feature of Jordan's marine environment is the coral reef ecosystems. The Jordanian reefs lie within the Red Sea which is designated as a World Wide Fund for Nature (WWF) Global 200 Ecoregion on account of its unique marine biodiversity. The Gulf of Aqaba (GOA) is a separate biogeographic zone within the Red Sea, and is of global significance in having the northern-most latitude reefs in the Western Indo-Pacific. Reefs in Jordan are among the most threatened in the Red Sea because they are shallow, easily accessible, and adjacent to a major population and industrial centre. They are suffering from a combination of factors common to reefs worldwide, that includes sedimentation caused by construction, physical damage from divers, boats and other recreational activities, and pollution from toxic industrial waste.

The Aqaba Special Economic Zone Authority (ASEZA) is mandated to oversee the well being of the state of coastal and marine environment in the Aqaba Special Economic Zone (ASEZ) (See Box 1.1). One of its activities in this direction is the preparation of State of the Marine Environment Report (SOCER). Within this context, the Aqaba Special Economic Zone Authority (ASEZA) in cooperation with United Nations Development Program (UNDP) is currently implementing a project titled "Mainstreaming Marine Biodiversity Conservation into Coastal Zone Management in The Aqaba Special Economic Zone". The main goal of this project is to internalize biodiversity as an asset and value for economic development and promoting more effective and integrated management of the coastal zone in Aqaba (UNDP 2011).

Box 1.1: GOVERNANCE/INSTITUTIONAL AND REGULATORY FRAMEWORK IN AQABA/AQABA SPECIAL ECONOMIC ZONE AUTHORITY (ASEZA)

Aqaba Special Economic Zone Authority (ASEZA)

The ASEZ was established in 2001 to attract and facilitate investment in Aqaba in the areas of tourism, industry, port development, infrastructure, utilities and commercial services. The ASEZ is governed by the Aqaba Special Economic Zone Authority (ASEZA), which acts both as a municipal government regulator, as well as a regional development agency, investment promoter and facilitator.

The ASEZA is the financially and administratively autonomous institution responsible for the management, regulation, and the development of the ASEZ. ASEZA is a service – oriented organization offering one – stopassistance covering all investment needs (ASEZA Law 2000).

ASEZA has a juridical personality with financial and administrative autonomy. The Authority may perform alllegal acts necessary to achieve its objectives. The Authority is associated with the Prime Minister.

The Authority is administered and supervised by the "Board of Commissioners", which is composed of six fulltimemembers, including the Chief Commissioner and the Vice-Chief Commissioner who is appointed by adecision of the Council of Ministers upon the recommendation of the Prime Minister for a renewable four-yearterm, provided that such a decision shall be endorsed by a Royal Decree.

The Commission has the task of running the ASEZ, and is vested with zoning, licensing, and other regulatorypowers that distinguish it from the rest of Jordan. Wages, allowances and all financial entitlements of the ChiefCommissioner and the Board members shall be determined by the Council of Ministers decision upon therecommendation of the Prime Minister. The Board shall issue its resolutions by a majority vote of the attendingmembers, provided that it is not less than three votes.

The Governor's powers in the Governorate of Aqaba pursuant to the legislation in force. If the Minister of Interior, upon the approval of the Council of Ministers, does not appoint a Governor for such, whereby in the event of his appointment, a memorandum of understanding shall be prepared between the Minister and the Chief of Commissioners, which shall be approved by the Council of the Ministers. The Governor shall, when performing his functions in accordance with the enacted legislation, take this memorandum of understandinginto consideration. In the event a dispute arises between the two parties when implementing the memorandum, the matter shall be referred to the Prime Minister for resolution.

The five commissions of ASEZA are:
1. Environmental Affairs Commission.
2. Administrative and Financial Affairs Commission.
3. Customs and Revenue Affairs Commission.
4. Economic Development and Investment Affairs Commission.
5. Infrastructure and Services Affairs Commission.

ASEZA has an independent budget, which is endorsed by the council of ministers. Any budget surplus istransferred to the national treasury. To benefit from the financial incentives, companies should register at theASEZA, in which case they do not have to register with the Companies Comptroller at the Ministry of Tradeand Industry.

The ASEZA tasks are to include developing the area for investments, increasing job opportunities and givingpriority to Jordanians, and preventing monopoly of economic activities. To achieve those objectives, the authoritywould have command over a wide range of affairs including financial regulations in the region, labor issues, healthinspection, environmental protection, and project licensing as well as municipal affairs.

The ASEZA is invested with authority over legal and administrative affairs as well promoting the ASEZ bothat home and abroad. The ASEZA also shares power with some service ministries in Amman. For example, theASEZA is responsible for the provision of healthcare, in accordance with a memorandum of understanding(MOU) signed with the Ministry of Health (MOH). According to the MOU the ASEZA is responsible forupholding national health and safety standards throughout the Zone, and this applies to new investment projects -the maintenance of recognized standards is intended to attract investors. Yet another example of good governanceis the three-year experience of the ASEZ Customs Department -a unit that is totally autonomous from theNational Customs body (ASEZA Law 2000).

Jordan`s entire coastline lies within one national and municipal jurisdiction - that of the Aqaba Special Economic Zone (ASEZ). One of the ASEZA Commissioners has particular responsibility for Environmental Protection. ASEZA is responsible for the environmental management of the Zone as well as the regular monitoring and auditing of industrial activities and other activities which may affect the environment of the zone, and ensuring the development of and compliance with current standards.

ASEZA‟s Directorate of Environment includes a division responsible for the planning and implementation of environmental inspection and audit activities within the Zone, including the ongoing assessment of both industrial and tourism enterprises, to ensure compliance with environmental standards and regulations.

Within the Directorate, there is a division responsible for the development and ongoing assessment of environmental codes and standards to be adopted by ASEZA in order to govern environmental performance within the Zone. Also there is a department that deals with education and public awareness, consumer protection, legal issues, and maritime operations ASEZA also has a division responsible for reviewing and analyzing the environmental implications of potential investments and projects in the Zone. Specifically, this division will supervise and manage the implementation of both preliminary and comprehensive EIA studies, required as part of the environmental clearance procedure, as well as holding public hearings. This division recommends the acceptance/rejection of EIAs and the project classification with regard to the environmental clearance request.

An additional division is responsible for environmental monitoring programmes and studies that provide baseline information on the Aqaba environment. This will include the implementation and maintenance of monitoring networks to cover air and water quality, groundwater quality and quantity, marine currents, fish, corals, and other key parameters. Its responsibilities also include the implementation and maintenance of an environmental database, and development of predictive computer models, and commissioning of new research on the state of the environment.

1. Environmental Clearance

As noted above, environmental clearance in Aqaba is governed by the Regulation for the Protection of the Environment in the ASEZ - Regulation No. 21 for the year 2001. According to this Regulation, any project that may have significant effect on the environment according to its location, nature and effects will require a full EIA, to be provided by the project owner as explained in Section 1.

The Directorate of Environment will review the submitted EIS report, and make a decision on environmental clearance. The Commissioner shall issue the final decision, in writing, If Environmental Clearance is to be granted, the EIS report, together with the proposed mitigation and monitoring plans shall be considered an integral and binding part of the clearance agreement.

2. Post Clearance

All economic activities within the Zone are subject to periodic environmental inspection to ensure their compliance with environmental regulations and requirements. An inspection program is implemented throughout the Zone by the Directorate of Environment. This inspection program is prioritized to concentrate on those facilities or activities which pose major threats to the environment. The inspection plan covers five main categories: hotels and tourism resorts, industrial facilities, hospitals and medical facilities, storage facilities, port facilities, and other services that have a significant effect on the ASEZ environment. The inspections focus on pollutant effluents, emissions, or wastes resulting from any activity or service in the area.

Given the relatively small scale of the Zone and the limited number of large industries in the large-risk category, in terms of their ability to damage the environment, ASEZA has adopted a participatory approach of working alongside industries, persuading them of the need to ensure compliance. In addition to the regular environmental inspection program, ASEZA has the authority to initiate an environmental audit of any public and private enterprise in the ASEZ. The purpose of the audit is to ensure that the establishment is complying with environmental rules and regulations, and to ascertain that the best available technologies and practices for the control and prevention of environmental pollution are being utilized.

An environmental audit may be initiated in the following cases:

- Where complaints are received from residents or workers in a particular facility about any harm or pollution resulting from the operations conducted therein;
- In case of an accident related to the facility's operations, regardless of whether this occurred within or outside the facility, where such accident resulted or may have resulted in environmental harm;
- If the environmental inspection or monitoring results show that the project's activities are causing the release of pollutants into air, soil or water in excess of permitted levels according to adopted standards in ASEZ, or in amounts that may cause direct harm to the Environment.
- Where a periodical inspection shows the necessity of conducting an environmental audit.
- Where an audit is required to monitor the facility's compliance with mitigation measures or management plans that have been established by the operator in accordance with a previous EIA. In practice, ASEZA relies on the industries to carry out their own monitoring and report the results to ASEZA.

Source: ADC 2008; ASEZA Law 2010; DRMP-ASEZP 2010)

Based on an agreement between the UNDP and the University of Jordan/ Aqaba Branch, the University established a specialized team from the staff of the Faculty of Marine Sciences and researchers from the Marine Science Station/Aqaba to carry out and complete the assignment. A team leader was appointed to lead the team and communicate with the UNDP Project Manager of Marine project who will follow up the stages of the work and to whom all deliverables will be presented. In addition, he will communicate with ASEZA's Commission for Environment and its related directorates including the Directorate of Environment and the Aqaba Marine Park.

It is hoped that SOCER caters to a large target audience, beginning from decision makers down to involved researchers. Therefore, SOCER will be structured to evolve as a basic reference material for a large class of individuals and institutions that have responsibility and/or interest in the marine environment and whose collective actions, based on the knowledge drawn from SOCER, should enable sustainable development of this region. Further, the report will be suitable to bring out several spin off products in the form of, case studies, success stories, guidelines, brochures and such other material to enhance the awareness as well as penetrate all sectors of the society that are required to be addressed.

The project main components include: knowledge management systems for planning and investment; promotion of biodiversity friendly investment and development; institutional capacity for Integrated Coastal Zone Management and biodiversity conservation; and coral reef protection (UNDP 2011). The Outcome1.1 of the project: "Spatial planning and sharing of benefits from marine resources informed by sound knowledge" seeks to provide a high level of understanding of the local environment as a prerequisite for effective spatial planning that leads to good environmental management. Such an understanding is necessarily based on actual data on the state of the Jordanian coastal environment. Output 1.1.1.8 of the above Outcome; "Prepare a State of the Aqaba Coast Report for public use (SOCR)" requests the analysis and discussion of the current state of the coastal and marine resources in Aqaba (TOR 2013).

The state of the coast report (SOCER) provides comprehensive qualitative and quantitative baseline information (where changes can be compared over time) not only on environmental status but further on, socioeconomic aspects, existing governance mechanisms and implementing arrangements related to coastal management and critical data gaps that need further research and monitoring. SOCER is intended to capture and present in accurate, useful and practicable format key information on the state of the coast in terms of: its current condition; the pressures on it; the drivers of those pressures; management initiatives in place to address environmental concerns, and the impacts of those initiatives. The report is intended to clarify if the coastline resources in Aqaba are still being used in a sustainable manner or away from this approach. It will be the first example of a comprehensive ecological and indicators-based assessment of the condition of the coastal resources. It will mark the development of reporting process from now on i.e. series of reports that shall occur in five-year cycles (TOR 2013).

The specific objective of State of the Coast reporting is to make relevant and useful information on the state of the Aqaba's coastline available to all concerned agencies and individuals. It will help supporting sound decisions about environmental policies and management that lead to more sustainable use and effective conservation of coastal assets in Aqaba. Furthermore, it gives an access to accurate, up-to-date information on the state of Aqaba's coastline and increase awareness among decision-makers and the public, of the status and implications of the condition of the coastal environment and pressures on it (TOR 2013).

The SOCER will contribute along with other instruments to make such data and information available for sound management of the coast. Therefore and while the preparation of the report will benefit from any available data particularly from the monitoring programmes, its findings will provide an input to the proposed GIS-base database system in ASEZA. Furthermore, the findings of the SOCER will provide guidance to the marine spatial plan intended to be developed as part of the above mentioned component. The report will provide the foundation for the development of an Integrated Coastal Zone Management (ICZM) Plan for Aqaba (TOR 2013). It is hoped and envisaged that the state of coast reporting process gets further support from ASEZA by setting out a legislative framework within the relevant legislations so it is conducted and updated every five year.

1.3 GUIDING PRINCIPLES IN THE PREPARATION OF THE REPORT

In the process of preparing the SOCER, it is required to provide an integrated assessment report on the state of the marine environment in respective national context. Accordingly, this present national report is intended to be based on the common guidelines used for the preparation of state of the marine environment (SOMER**).** SOCER is an embodiment of information and analysis on the current status of the marine environment of the Jordanian Sector of the Gulf of Aqaba as portrayed through consultative and consensus mechanism. It is prepared based on the data and information available on the state of the marine environment, in addition to findings of oceanographic studies, monitoring programmes results, and the published articles from national, regional and international scientific literature. Conscious efforts were made to present the latest information on the marine environment in the report. In summary, SOCER covers comprehensive information from various sources together with recommendations of experts, and as such is maintained truly of consensus standards.

SOCER aspires to present an in-depth analysis of the results from above sources and bring to the fore the important trends, issues and future scenarios that concern GOA.

The preparation of the present State of the Coastal Environment Report was guided by the following principles (NIEAR 2004; SOMER Australia 1994; SOMER 2014).

- Rigour/Credible: The work was always be guided by the best available scientific information resulted from scientific research and monitoring programmes, and it will present accurate data and information in a balanced and accessible way.
- Objectivity and Trustworthy data and information: All efforts were made to present data and information without bias or modification and independent to avoid any perception of political interference in report content or messaging.
- Cooperation: The work was made on the basis of partnerships with the community, industry and official governmental institutions, to facilitate the sharing of information, expertise and resources.
- Openness: The work will always seek to ensure open access to information about the environment of the Gulf of Aqaba.
- Practical: The framework and underlying indicators took into account information that is currently available. The data sets which can enrich reporting and help prioritise environmental issues were identified.
- Relevancy: The scope of reporting encompasses the state and trends in the environment, the relationship with society's use of, and impact upon, natural resources. Therefore, reporting has integrated environmental information with social and economic information, to allow the public and decision-makers to consider the trade-offs inherent in policy making, and incorporate these considerations into broader policy decisions.
- Efficiency: Information sharing was intended to facilitate to maximise data value and to ensure clarity and consistency of messaging.
- Global vision /International comparability**:** Wherever possible, the work reported information in a comparative manner, seeking to place local and regional information in national and international contexts.
- Ecological sustainability: Efforts were made to assess environmental information and issues against the principles of ecologically sustainable development.
- Maintenance of biological diversity: It has been tried to assess environmental information and issues against the principles of biodiversity conservation.

For purposes of making the report compatible with the "Global Environment Outlook (GEO)", the present report adopted a structure and used the indicators as those applied at regional level (PERSGA 2006). This will help all countries to easily access useful data and information about other countries (on regional and sub-regional levels) for comparison in their reports. Generally, the components of the national state of environment report structures include:

- Information on "Environment and Development": The purpose of this section is to explore the relationship between environmental stewardship and economic development. It focuses mainly on how environmental resources are a key engine to economic development. It also establishes the basis for the pursuit of the sustainable development paradigm.

- Information on and discussion of the issues of "natural resources characteristics and management".

- Information on and discussion of the "response to environmental change". It is aimed at identifying and describing the different types of responses that are being used to address environmental issues, and also tries, where possible, to assess their success or failure.
- A "look into the future". This is done for two reasons. First, it is evident that present day actions have consequences that reach far into the future. Second, there is need to look at the environmental issues that are likely to require priority attention in the future – those that affect resources irreversibly, or result in having a significant impact on the population.

1.4 STEPS IN PREPARING THE STATE OF COASTAL ENVIRONMENT

The beginning point in the production process of a SOCER was to get started which is considered a critical stage in the process. During the "getting started" stage, the following considerations have been addressed:

a) Establish the institutional framework;
- Appointing the leader of the team; and
- Determine who has the mandate to prepare the report.

b) Determine which groups and individuals will participate in the production process
- Who should be involved?
- When do the various interests get involved?
- Which institutions/organizations are expected to play roles?
- How can they be involved?
- What mechanisms best foster their involvement?

c) Establish or use existing relevant institutional structures to manage the production process:
- Focal point: Determine who or which unit in the mandated institution will be the focal point for the process; and
- Policy issues: Determine who will address policy issues on behalf of the institution.

1.5 STEPS OF PRODUCTION OF THE REPORT

The production of the report is a step process as described below:

***Step 1: Preparation*: this step includes but not limited to the following:**

- Informing all stakeholders about the process;
- Orientation for all those to be involved;
- Identifying responsibilities for those participating in the process;
- Set up the report Task Force or Committee, identify expert drafters (authors), researchers, reviewers and editors;
- Bringing all these into the process with clear Terms of Reference (TOR); and
- Consensus building;

Step 2: Planning

- Identifying client needs;
- Defining conceptual approach and orient task force/committee on concepts;
- Preparing the report structure and scope; and

- Developing table of contents.

Step 3: Information Assembly and Organization

- Obtaining institutional and organizational cooperation in availing data and information;
- Identifying data sources and availability;
- Identifying appropriate indicators (for pressure, state, impact and response);
- Select key policies for analysis; and
- Carry out literature search.

Step 4: Compilation of Chapters/Sections

- Producing the draft report;
- Reviewing the draft report by a technical task-force;
- Revising the draft report; and
- Submitting the revised report for editing.

Step 5: Report Consolidation

- Carrying out chapter integration;
- Preparing the final report'
- Approving final report by relevant authorities; and
- Finalizing the report.

Step 6: Publication and Dissemination: (UNDP and ASEZA)

- Arranging for printing of report;
- Preparing a communication plan for the dissemination of the report;
- Prepare a media release package for the announcement of the report;
- Launching of the report;
- Arranging for the dissemination of the report; and
- Arranging for production of supporting products; Non technical summary, popular versions, youth version, children's version, etc.

1.6 PREVIOUS ASSESSMENTS AND REPORTING OF THE STATE AND MANAGEMENT OF THE COASTAL AND MARINE ENVIRONMENT

1.6.1 REGIONAL/RED SEA

Earlier assessments of the state of the marine environment on regional scale (RSGA) include those of Ormond (1987), Sheppard et al. (1992), Halim et al. (1994) and Abu-Gideiri (1997). According to Ormond (1987), in the late 1960s, about 98% of the total Red Sea coast was almost virgin, but the situation has changed very rapidly as intense population growth, and commercial and industrial development has taken place along many coastal sections. These changes have led to threatened environments. The main threats were from pollution, sedimentation, coastal construction, fishing and other exploitation, and visitor impacts (Ormond 1987). In his report in the early nineties, Sheppard et al. (1992) listed the sources of the main threats and impacts which include: pollution (from oil, domestic, urban and industrial sources); loss and degradation of productive coastal habitats (from dredging, landfill, and sedimentation), collecting, tourist activities, and inland agriculture.

However, since the assessment by Sheppard in 1992, many reports have dealt with many environmental issues in the Red Sea region. The threats and impacts of land-based sources and activities (LBSA) were reviewed by UNEP/ PERSGA (1997). Gladstone et al. (1999) pointed out other concerns that include the illegal disposal of toxic substances by foreign vessels in the Gulf of Aden; sedimentation from agriculture and grazing; and the introduction of pesticides and fertilizers in some locations. The Strategic Action plan (SAP) for the Red Sea and Gulf of Aden (PERSGA 1998) identified five major threats to the environment and coastal and marine resources of the RSGA: habitat destruction; non-sustainable use of living marine resources; navigation risks, petroleum transport and petroleum production; urban and industrial development; and the rapid expansion of coastal tourism. Mistafa and Ali (2005) concluded that the major threats to the marine environment of the Red Sea and Gulf of Aden are related to land-based activities which include urbanization and coastal development (for example, dredge and fill operations); industries including power and desalination plants and refineries; recreation and tourism; waste water treatment facilities; power plants; coastal mining and quarrying activities; and oil bunkering. The Global International Waters Assessment reviewed the impacts of fisheries, pollution and habitat modification on the Red Sea large marine ecosystem (UNEP 2006). It concluded that there were severe environmental impacts from habitat modification, moderate environmental impacts from pollution and over-exploitation of fisheries, and slight impacts from excessive by-catch and destructive fishing practices.

1.6.2 JORDAN GULF OF AQABA

Few years before the Jeddah Convention in 1982 and seventeen years before the Establishment of PERSGA in 1995, the Arab League Educational, Cultural, and Science Organization (ALECSO) funded a study on the coast of the Jordan Gulf of Aqaba to investigate the possibility of protecting some sections of this Jordanian stretch and the establishment of a marine park, and of ensuring marine environmental conditions compatible with scientific, recreational and touristic use. The report on this study was prepared by Ormond (1978) who conducted a biological survey and recorded indications of adverse impact upon marine life. He attributed the destruction, he found in some locations to infilling in extending port facilities, dynamiting by fishers, shell and coral collections, and spearfishing by visitors. He listed other environmental stresses which include sedimentation due to port construction and occasional heavy flash floods, phosphate dust lost to marine water from the phosphate loading berth, and oil spills from Eilat. Ormond (1978) listed the major species occurring in the non-reefal communities of the Gulf (after Fishelson1973) and different species in different reef zones in Jordan waters of the Gulf of Aqaba (after Mergner and Shuhmacher 1974). He listed 112 species of fish and 43 species of hermatypic corals which he found during his survey in 1977. In part of his report Ormond (1978) assessed endemism in the Gulf of Aqaba and he concluded that 10 -15% of species may be endemic to the Gulf of Aqaba. At a later date Shuhmacher (1982) conducted an environmental survey in developmentareas on the south coast of Aqaba. He reviewed the conditions of the coast of Aqaba and suggested actions to protect the marine environment of the area. At that time the on-going development plans divided Aqaba coast into four sections; (a) The north coast between the King’s Palace on the northwest and the classified hotels on the northeast; (b) The eastern stretch of coast that includes the Aqaba main (cargo) port, phosphate loading berth until the site of the ferry (passenger) port just north of the Marine Science Station (MSS); (c) Middle stretch; the tourist zone from the MSS to the site of the Royal Navy port; and (d) The most southeastern stretch; the industrial area down south to the border with Saudi Arabia.

During and after 1984, intensified efforts to manage and protect the marine environment have been administered by the Aqaba Region Authority (ARA). In 1984 Mahasneh and Meinesz (1984) reported on the effect of eighteen developments on the Jordanian coast between 0 and 50m depth, totalling are of 734.65 ha. They concluded that these developments have altered 29.4% of the coastline and resulted in serious damage to 35.71 ha. Most constructions affected the first 5m of the sea floor and more than 85% of that total damage occurred between the old Aqaba main (cargo) port and the Marine Science Station (MSS). An important result of the study is their conclusion that the 8 km of coastline (now the Aqaba Marine Park) between the MSS and the Royal Navy port was still in its natural state.

In 1985, the zero sewage discharge concept was adopted by the construction and operation of the new oxidation ponds treatment plant and the use of the treated sewage effluent in the irrigation of a green belt at the northern side of Aqaba town. The same period has witnessed the installation of phosphate dust traps (choke feeders) in the phosphate loading berth, which reduced exposure to winds and limited the release of dust to a great instant (Abu Hilal 2009). In 1989 the Marine Science Station, within its effort to gather all information about the state of the environment of the Jordan Gulf of Aqaba which has been studied extensively, prepared an excellent review (Hulings 1989) of all published scientific works in the whole Gulf of Aqaba. The review pointed out the gaps in the knowledge of the marine ecosystems of the Gulf.

The period between 1993 and 1999 is considered the stage of Aqaba Master Plans during which ARA gave special attention to producing and implementing land-use master plans which can help protecting and managing the Jordanian coast of the Gulf of Aqaba. At this stage Tom van`t Hof (van`t Hof 1992) conducted a survey similar to that of Ormond (1978). In his report van`t Hof discussed previous literature on the number of species and endemism of various groups in the Gulf of Aqaba including corals, molluscs, crustaceans, echinoderms, amphipods, fish and algae. He reported a decline percentage of live coral cover of 10 to 15% compared to 20 to 25% by Ormond (1978). Based on the results of this environmental survey, van`t Hof suggested an action plan to protect the marine environment of the Jordan Gulf of Aqaba and a plan for the establishment of a marine park on sections of the south coast of Aqaba.

In 1992 the Irrigation Support Project for Asia and the Near East (ISPAN) conducted a study to assess the status of environmental data concerning the Gulf of Aqaba. The study included intensive literature review and field visits to the countries bordering the Gulf in order to compile published data about the area, identify environmental issues, determine what additional information that might be needed for planning, and acquire suggestions for future work in the area(ISPAN (1992). The contents of the report detailed the most important findings of the survey and include:

1. The physical, chemical, geological and biological characteristics of the Gulf of Aqaba;
2. Human activities and development along the coasts of the Gulf of Aqaba including, coastal development, industries. shipping, fishing, mariculture, and recreation;

3. Environmental impacts resulting from human activities such as tourism and sport fishing, commercial fishing, spills of oil and other hazardous materials, wastewater disposal,maritime activity, and mariculture;
4. Previous, current and future research, monitoring and management: including ICZM, hazardous material, marine reserves, environmental impact assessments (EIA), fisheries management, education, and enforcement;
5. Scientific information gaps concerning water quality, sediments, flora and fauna, fisheries, monitoring of pollution effects, oceanography, coral reef, sand communities, deep-sea environment, mariculture impacts, primary production, microbial studies, and geological research;
6. National and regional coordinated coastal management including marine reserves, information exchange, coordination of environmental laws, marine debris, geographical information systems, coordinated emergency response programme, navigation systems, reducing bulk material dust, mooring buoys, and fisheries; and
7. Environmental education of the general public and tourists.

It seems that this report has been used in formulating the components of the "Gulf of Aqaba Environmental Action Plan" (GAEAP).

In 1997 Abu Hilal (1997) reported on the land-based and other sources of marine pollution and threats related to development along the northern end of the Gulf of Aqaba which include: coastal constructions and related pollutants and impacts that include suspended matter, turbidity, siltation and sedimentation, organic matter, and heavy metals; industrial related threats and impacts that include physical, chemical, biological, and thermal impacts from fertilizer plants and their products of fertilizers and fertilizers related chemicals; spills from potash transportation, handling, storage and exporting; thermal and other types of pollution from power plants; phosphate dust from storage and ship loading facilities in the phosphate loading port; solid waste from Aqaba town and Aqaba ports; oil spills from Aqaba and Eilat ports; and reef damage by international and local tourism activities. Reporting on the status of the environment within the Jordanian sector of the Gulf of Aqaba has been continued since 1998 and includes the results of the National Monitoring Programme conducted by the MSS and submitted to ASEZA in monthly, semi-annual and annual reports. The report pointed out all the major threats to the coastal and marine environment and its resources. It reviewed the progress and achievements in dealing with these threats. It pointed out the required actions in many priority areas.

1.6.2.1 Environmental Priorities in Research, Monitoring and Management on Regional and National Scale (Red Sea and Gulf of Aqaba)

The priorities of environmental issues along the Gulf of Aqaba and Red Sea region have been defined in many scientific publications and workshops and many environmental Action Plans (GAEAP, 1995 ICZM, 1995; IOC– PERSGA–ACOPS, 1995; AREN, 1995; EURO-MEDITERRANEAN WORKSHOP, 1996; Abu-Hilal, 1997; PERSGA/GEF, 1998; PERSGA/GEF, 2001).The priority issues include:

a) Oil spills and national and regional contingency planning;
b) Industrial pollution prevention, measures and regulations;
c) Solid waste and marine debris collection, storage, and disposal;
d) Coastal zone degradation and physical damage to coral reef ecosystem;
e) Biodiversity and conservation measures, and designate marine protected areas;

f) Institutional capacity build-up;
g) Tourism impacts and development approaches; and
h) Fishing method, fishing impacts, and fisheries development and management.

1.6.2.2 Coastal and Marine Environment Protection and Management Along the Jordan Gulf of Aqaba

In 1960`s Jordan shorelines with Saudi Arabia was extended southward for about (18) km. The extension was called "South Coast". In the late seventies report on a study on the possibility of establishment of a marine park (Ormond 1978) appeared under a title "A Marine Park for Jordan". Later in 1982 another report on environment and development of the southern coast of Aqaba was prepared by Shuhmacher, (1982). At that time previous development plans divided Aqaba coast into four sections; (a) The north coast between the King's Palace and the classified hotels; (b) The stretch of coast that includes the Aqaba main port, phosphate loading berth until the site of the ferry (passenger) port just north of the MSS; (c) The tourist zone from the MSS to the site of the Royal Navy port; and (d) The industrial area.

Since 1984 environment has been considered an important issue while planning for development of Aqaba region including the south coast. The Aqaba Region Authority (ARA) implemented the first Master Plan in 1987 which was prepared by a consultant agency (Dar Al- Handasah, 1987). The second Master Plan was adopted in 1995 as the "Revised Master Plan 1995-2020". During this period and in 1992: an action plan for Aqaba Marine Park was prepared by Tom van`t Hof. The plan divided Aqaba into four areas of development; Residential area, Port area; Industrial area and Tourism development area which include a Marine Park that was divided into five zones;Strict Reserve (Scientific Reserve) Zone, Beach Recreation and Swimming Zone, Boat Access Corridor, Diving and Snorkelling Zone, and Multi-Use Zone.

During the 1990`s, the Gulf of Aqaba Environmental Action Plan (GAEAP 1995) was initiated and implemented. The Action Plan included the preparation of: an oil spill contingency plan; guidelines for EIA, CZM, Industrial Environmental Auditing and Pollution Prevention, Aqaba Marine Park. The GAEAP included actions that deal with transboundary (regional) issues such as environmental management of international waters; legislative framework for the control and management of transboundary pollution;environmental monitoring; integrated marine and land-based solid waste management strategy in Jordan; and development and implementation of the Aqaba Marine Park to protect the globally important coral reefs (See Box 1.2).

Box 1.2: The AQABA MARINE PARK

The protected area of the Aqaba Marine Park was created to "conserve and manage the natural near-shore marine environment of the Aqaba south coast region with its rich biodiversity, while allowing for certain touristic uses at sustainable levels, for the benefit and enjoyment of the present and future generations of Jordanians and the global community."

The Aqaba Marine Park is located south of the city of Aqaba. The park is about 7 km in length, stretching from the Passenger Terminal in the North to the Police Officers'

Club in the South. The park's terrestrial boundary lies 50 m east of the Mean High Water Mark and the marine boundary lies 350m west of the Mean High Water Mark. The inter-tidal zone of the AMP is generally a sandy area or solid strata composed of coral reefs. While the tidal range in Aqaba is only about 1 m high, the inter-tidal area along the AMP hosts a dense community of invertebrates.

Extensive coral communities in the form of fringing reefs dominate the 7 km long Marine Park coast-line, from the Marine Science Station to the Public Security Officers' Club. Over 127 species of hard coral have been noted. The distribution of the reefs is discontinuous due to embayments at the outlets of wadis which form drowned canyons seaward.

The typical reef structure within the park is composed of the reef flat, which is often separated from the shore line by a shallow sandy lagoon. The back reef which extends from the shallow lagoon to the reef flat and the reef crest. The reef face is a steep drop-off seaward from the reef crest. The fore-reef extends from the reef-face and slopes seaward

Within Jordanian waters 118 genera and 161 species of fish have been noted. A number of molluscs, echinoderms, algae, amphipods and fish are endemic to the Gulf of Aqaba. The shallow reef structures provide habitats for a multitude of reef fish and benthic organisms. Dense reefs are observed to a depth of 70m. In addition, the Jordanian Gulf of Aqaba has seen repeated visits of whale sharks, barracuda, and jacks.

Three main species of seagrass communities exist in the shallow waters of the AMP, ranging from depths of 0.5m to approximately 40m. The beds provide habitats for a variety of fish and invertebrates.

The Park is divided into four zones which include:

1. **A Strict Reserve Zone**:
The objective is to preserve a marine community in its natural state by eliminating or reducing anthropogenic impacts on the zone area. These areas are to be used for scientific research and to promote sustainable management of the existing marine resources. All activities are prohibited within the AMP without a written permit from the park authority.
2. **Beach Recreation and Swimming Zone**:
Permitted activities include swimming, snorkelling, wading, and diving provided that proper access points are demarcated. Prohibited activities include general boating (with the exception of dive boats which may moor on designated mooring buoys), jet skiing, water-skiing, fishing and anchoring.
3. **Diving and Snorkelling Zones :**
Permitted activities include diving and snorkelling with the purpose of observing, studying or photographing marine life. Access to dive sites is restricted to demarcated shore entry points and to pre-determine mooring points for boat access. Prohibited activities within this zone include jet-skiing, water skiing, fishing, anchoring, and boating.
4. **Beach Zone :**
The beach zone encompasses the terrestrial territory of the AMP and is demarcated by 40 cm high natural stone markers 50 m east of the MHW mark. All activities within this area are controlled by the park management and special permits have to be secured

from the park management for any activities other than simple beach use by individuals.

The Park staffs are trained in the enforcement of park regulations. Park Officers have the legal authority to arrest violators of the park regulations. the AMP staff duties include but not restricted to public awareness of park regulations to protect the environment; patrol the park and to enforce park regulations; maintain and ensure the proper use of park facilities by visitors; ensure the cleanliness of the beaches and water; and management of a public outreach and education campaign to generate awareness about the marine environment.

A series of facilities have been set up by the park to serve the park visitors which include public Toilets and showers; camping area serviced by water, electricity, toilets and showers, as well as kiosks and car parks; three kiosks (run by non-profit organizations) to provide additional services to visitors; sun shades; garbage bins; first aid stations; park signage to acquaint visitors with park regulations; and watch towers to ensure visitor safety.

The park's visitor centre was established to be the focal point of the park's public environmental education and outreach programs. Environmental awareness activities such as lectures, audio-visual shows and interactive exhibits are part of the park's efforts to An important part of the park's management philosophy is to involve local environmental NGOs in its activities to reach out as many as stakeholders as possible. The centre campus includes an auditorium, a diving unit, exhibition halls, a gift shop, an out-door amphitheatre, playgrounds and sports fields.
The marine facilities includes: mooring buoys; park boundary buoys; zoning buoys which demarcate the boating and non-boating zones in the park; and wooden Jetties.

The Aqaba Marine Park is home to 21 of the 23 dive sites in Aqaba and they are 18 scuba diving centres in Aqaba. The Park has developed a comprehensive dive management policy to protect the underwater habitats while permitting access to the various dive sites. The dive management policies include:
1. Inspecting and certifying all dive centres in Aqaba;
2. Developing and enforcing diving regulations throughout the marine park;
3. Designation of dive sites and establishing safe entry and exits;
4. Installation and maintenance of mooring buoys for boats;
5. Monitoring of dive sites to estimate carrying capacities and to initiate rotation of dive sites.

The AMP has designed and implemented public awareness and educational programmes which aimed at the local civil community, business community, government people from all over Jordan and foreign tourists through holding workshops for stake-holders; participation in local and international exhibits; distribute hands-out on beach clean-ups and mobilizing students, dive centres, businesses, government agencies and others to participate in such activities; and promotion and supporting the activities of environmental NGOs and increasing their role in the park's activities.

In support of the park's awareness activities a series of publications including videos, posters, brochures, photo libraries …etc., has been compiled in the park to act as a resource centre for the advancement of marine conservation activities in Aqaba and the regionwww.aqabamarinepark.jo.

In October 1999 the by-law (No. (51) of 1999) was issued to address the marine environment protection in detail. In accordance with article (56) of the ASEZ law no. (32), the environment By-Law no. (21), and the Aqaba Marine Park By-Law no. (22) were issued in 2001. These regulations are dealing with various issues and activities in the park, including boating and water sports. More information on the AMP can be found in the website: www.aqabamarinepark.jo.
Source:http://www.aqabazone.com/?q=node/193. The Aqaba Marine Park

In 2001 the Aqaba Special Economic Zone Authority (ASEZA) as the legal and factual successor of the ARA and the Municipality of Aqaba became responsible for the development of the zone and for the protection and maintenance of the environment and for ensuring sustainable development according to regulations. ASEZA revised the previous Aqaba Master Plan and produced and implement a new revised master plan 2000-2020. Today, ASEZA is giving high priority to the protection of the general environment in the zone and to the environment of the Gulf of Aqaba on both national and regional levels.

1.6.2.3 Research and Monitoring Programmes in Support of Coastal Zone Management (CZM).

A literature search on research and monitoring programmes along the Jordanian coast of the Gulf of Aqaba indicates that scientists have provided important invaluable information and contributed to the knowledge of the ecosystems of the Gulf of Aqaba as well as on environmental stresses and sources of pollution and its effects on the Gulf ecosystems. The research and monitoring programmes during the past four decades have covered many important environmental topics such as pollution sources, distribution, magnitude and potential effects.

Many studies have conducted on pollution by the dust particles of the exported phosphate, sewage effluents, nutrients, heavy metals, hydrocarbons, marine debris, solid waste, and plastic pellets. Taxonomy of flora and fauna of the Gulf of Aqaba particularly corals, algae, seagrass, mollusks, sponges have been important areas for scientists (Abu Hilal, 2009).The results of fish taxonomy studies have been published in a book “Fishes of the Gulf of Aqaba” by Khalaf and Disi 1997). Coral transplanting and restoration projects are ongoing within the Jordanian coastal water. In addition, land-based sources of pollution are monitored continuously and the results are made available for the related official institutions and decision makers in ASEZA. Among these sources are phosphate fertilizers and other industrial and power plants, and all ports of Aqaba.

The search for potential bioindicators for pollution has also been ongoing research topic for scientists along this part of the Gulf of Aqaba (Abu-Kharma, 2006; Bani-Fawaz, 2006; Tawaha, 2007; Al-Qatamin, 2009; and Al Shabi, 2010). The use of such bioindicators has been justified in marine pollution monitoring programmes (Maher and Norris 1990) to monitor conditions of the coastal environment on an ongoing basis to assess impacts and requirements for management and to monitor the effectiveness of an ICZM process (Linton and Warner 2003).

The results of the scientific studies that were conducted before 1990 have been summarized in Hulings (1989) and published in five volumes of the "Collected Reprints of the Marine Science Station" (Wahbeh and Hulings, 1987 and 1988). The studies that were conducted between 1990 and 1997 have been collected in two volumes (Abu Hilal and Almoghrabi, 1999; Almoghrabi and Abu-Hilal, 1999). The studies conducted between 1998 and 2012 have been collected in five additional volumes by Abu-Hilal and Al-Rousan (2014) for the periods (1998-2003, and 2006-2007) and by Al-Rousan and Abu-Hilal (2014) for the periods (2004-2005, 2008-2009, and 2010-2012. According to an agreement signed in 1997 between the MSS and ARA and its successor ASEZA, the MSS is to produce semi-annual as well as annual reports to ASEZA on the results of an ongoing monitoring programme of the national Jordanian coastal environment of the Gulf of Aqaba. The report includes the quality of water and sediments as well as the health of coral reefs of selected sites along the Jordanian coast. Examples of other reports are Abu-Hilal and Al-Moghrabi (1994 and 1995); Abu-Hilal (1995, 1996, 2004a, 2004b, 2005, 2007, and 2008); Badran and Abu-Hilal (1998), Abu-Hilal et al. (1997, 1999, MSS (2000-2013).

1.7 CHAPTERS OF SOCER

Chapter 2 is a review of the geological, physical and chemical characteristics of the coastal and marine environment of the Red Sea in general and the Gulf of Aqaba in details. Such review is a necessary foundation for understanding the processes that shape the marine and coastal habitats, the potential for pollutant dispersal, and the modifications that have occurred to the natural coastlines from human development in the coastal zone (PERSGA 2006).

Chapter 3 is a review of the most important aspects of the socio-economic growth and development activities, and the pressures and impacts of the existing and potential land-based sources of pollution affecting the coastal environment of the Gulf of Aqaba. In addition to chapter 2, this chapter provides information on the current status of a number of chemical and physical indicators.

Chapter 4 reviews sea-based activities and sources of pollution. The chapter reviews oil and gas activities, shipping and navigation, port activities, and the issue of ballast water and invasive alien species.

Chapter 5 is a review of current knowledge and information and details the current status of major ecosystems and habitats such as coral reefs, seagrass beds, important groups of organisms (algae, fishes, some marine mammals, some invertebrates, turtles, and seabirds), endemism and biogeography. The available information will be assessed.

Chapter 6: the "living marine resources", covers the status of fisheries, overfishing and the most important species and the socioeconomic significance of fishing activities and its social, economic, and environmental impacts.

Chapter 7: pinpoints the emerging issues and priority actions that are required based on the future decision-making, and recommendations for additional actions and information.

To prepare the present state of the coast environment report for Aqaba, the authors and scientific team have surveyed the literature and reviewed a large number of papers from the published literature, data collected as part of the national, regional and international environmental research and monitoring programmes, and all PERSGA's published reports. This is in addition to the experiences of the scientific team and authors from working in the region over many years.

It is now widely accepted that there is a broad community of users who are eager to use and benefit from the state of the environment information (SOMER Australia 1994). The following are among the main user groups:

- the general public and specific community interest groups and sectors;
- government decision makers and policy analysts;
- secondary and university educational institutions;
- industry groups;
- natural resource planners and managers;
- the media (print and electronic);
- scientists; and
- international agencies.

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CHAPTER TWO

2 THE PHYSICAL ENVIRONMENT OF THE GULF OF AQABA

2.1 SUMMARY

The Red Sea topography generally consists of a more or less broad coastal plain, usually arid with little or no vegetation, with many wadis carrying occasional rainfall. The coasts of the Gulf of Aqaba are steep all along the gulf with very narrow or missing coastal plains. The bordering mountains rise up abrupt from the water edge. However, the head of the gulf is low lying; only rises 2 m above sea level**.**

The Gulf of Aqaba is located in the sub-tropical arid zone between 28–29◦30N and 34◦30–35◦E. It is a semi-enclosed basin that extends over a length of 180 km with a width between 5 and 25 km (average of 16 km).

The topography of the Gulf of Aqaba has been described as a regional north-south directed graben, bounded by two major flanks of higher elevations and cut with east-west directed wadis. The elevations start from values approaching zero nearby the sea zone, and start to increase gently to reach in the upper part of Wadi Al Yutum more than 350 meters above sea level and at the southern Wadi Araba more than 80 meters.

Along the Jordanian Gulf of Aqaba the following morphological features and land forms have been distinguished: the complex granite series, the active side wadis and their deposits, coastal wadis, alluvial fans, flood plains, and coastal zones.

The deepest point in the Gulf reaches 1825 m with an average depth of 800 m. The bathymetry of the Gulf is arranged in three deep elongated basins separated from each other by relatively low sills. The Gulf is connected to the Red Sea by the Strait of Tiran, which has a sill depth of about 265 m.

The Gulf exhibits a seasonal cycle of stratification in spring, maintenance of a shallow thermocline in summer, and subsequent deepening of the thermocline to produce deep mixed layers in winter. Much of the seasonal stratification variability is determined by exchanges with the rest of the Red Sea. Nonetheless, inter-annual variability in wintertime temperatures appears to set the depth of maximum mixing.

Because of being generally warm ($T>21$ ºC), and subject to dry winds much of the year, the Gulf is a site of high evaporation rates, estimated at 0.5-1.0 cm/day, with recent estimated values lower than earlier ones. Given a surface area of the Gulf of ca. 1.7 x 10^9 m^2, this implies a net inflow to the Gulf of ca. 54 m^3/s.

Because the densities of the Gulf are different from the rest of the Red Sea, there are strong density-driven flows. These exchange flows through the Straits of Tiran are substantially larger than the net flows through the Straits. About 3 x 10^4 m^3/s is entering near the surface, and leaving at depth the Gulf through the Straits. The exchange varies annually with an annual mean of 1.8 x 10^4 m^3/s.

Since the Gulf is a semi-enclosed concentration basin, the combined effects of exchange flow through the strait and evaporation produce a characteristic salinity profile with a noticeable subsurface salinity minimum in summer.

Surface water temperature may approach 28 ºC during summer months and fall to just above 20 ºC in winter. Temperatures within the water mass reflect a degree of stratification versus vertical and lateral mixing by water currents. Vertically, temperature falls with depth in summer although there appears to be an inversion at certain depths in winter months because the deep water mass has a temperature reportedly above 20 ºC.

The general weak currents (10 cm/s) in the northern Gulf are largely driven by the prevailing down-Gulf winds and by the semi-diurnal internal tides generated in the Straits of Tiran. Notably, surface (barotropic) tides are negligible. These internal tides vary annually and are stronger in deep water than nearshore.

The combination of winds and buoyancy forcing as modified by the earth's rotation produces a series of horizontal eddies throughout the Gulf, although in the narrower northern Gulf, they tend to be less organized and more variable than in the south. The associated velocities are relatively high, and can reach 100 cm s^{-1} near the edge of the eddies compared to the average velocities of 15 cm s^{-1} observed over most of all seasons. In addition, such horizontal eddies appear usually under calm condition, when the wind is relatively weak. Large velocities occur also during strong storms.

The annual meteorological measurements demonstratethat the wind speed fluctuates within a range of 0-12 ms^{-1} (mean: 4.5 ± 2.4 ms^{-1}). Occasionally, wind speed reaches more than 15 cms^{-1} but just for few hours. Moreover, a harmonic change of wind speed appears during summer causing a diurnal cycle that is represented by strong winds during daytime and relatively weaker winds during nighttime. Meanwhile, northerly winds (NNW-NNE) dominate over the study area and represent about 85% of total measurements.

A typical daily cycle of air temperature variations occur during the whole year. Mean air temperature values range between 32.2 ± 3.16 °C in summer and 17.6 ± 3.46 °C in winter. In general, winds and air temperature have obvious effect on humidity; therefore, relative humidity shows periodic variation following the daily cycle of air temperature and wind speed. Minimum humidity recorded in summer is 13% compared to a maximum of 83% in winter. The recorded wind speed and direction, air temperature and relative humidity for the years 2010-2013 in the northern Gulf of Aqaba show that most of the values for each year are comparable with year 2013 values.

The maximum sea level range, reference to Global means sea level (MSL), during the year 2013 was 154.3 cm. The highest value was 101.7 cm observed on December 12th, and the lowest value was -52.6 cm recorded in April 23rd.The seal level anomalies mostly depict a clear yearly cycle, where the lowest and highest monthly mean anomaly usually recorded in summer and winter, respectively.

The pH at coastal and offshore waters of the Jordan Gulf of Aqaba fluctuates around 8.3 with very minor temporal and spatial variations. This is typical for all coral reef waters because these waters are always saturated with calcium carbonate, which acts as a buffer and resists change in the pH.

Inorganic nutrients (ammonia, nitrate, nitrite, phosphate and silicate) are essential for marine phytoplankton productivity and growth. Higher concentrations of nutrients and chlorophyll *a* concentrations occur during winter. This may be attributed to deep water vertical mixing during winter in which deep water of high nutrients concentrations come up to the surface.

Cross-shore mixing (from shallow to offshore waters) due to density currents (gravity currents) has been recently documented. This process drives coastal water down slope offshore when it gets cooler at night. The increased nutrient concentrations in the euphotic zone enhances primary productivity resulting in higher phytoplankton abundance and increased chlorophyll *a* concentrations. Water column stratification and high irradiance during summer result in a depletion of the inorganic nutrients in the upper waters by enhanced primary productivity at the subsurface level (50-75m).

Ammonium concentration is fluctuated irregularly around 0.4µM with a tendency to higher concentrations during the winter months (January-March). Nitrate and nitrite concentrations during the last five years showed a regular shift from a summer low (0.10 and 0.01 µM) to relatively high early winter values (0.6 and 0.25 µM). Phosphate concentrations are generally low during summer (~ 0.10 µM at MSS) and high during winter (~ 0.10 µM at MSS). Silicate concentrations show the same trend with (1.0 µM at MSS) during summer and (~ 2.0 µM at MSS) during the winter.

The surface waters of the Red Sea and the Gulf of Aqaba are mostly oligotrophic (nutrient-poor), except in polluted areas (see Table 2.16). Nutrient distribution shows variations from north to south and with depth and season. The concentrations in the southern Red Sea are higher than those of the northern part, which can be attributed to the richer nutrient water inflow from the Gulf of Aden into the southern Red Sea during late summer.

Dissolved oxygen concentrations at the Gulf of Aqaba show regular pattern; inversely proportional to that of temperature, with a range of 6.4 to7.4 mgl^{-1}, indicating that the effects of the other ecosystem variables are masked by that of temperature. Waters of the Gulf of Aqaba are very well balanced in terms of respiration and photosynthesis and well ventilated due to the annual deep mixing. Most of the time a100% saturation is found.

2.2 THE RED SEA AND GULF OF ADEN–GENERAL DESCRIPTION

The Red Sea is (Fig. 2.1) a young (about 70 million years) body of water, created by the pulling apart of Africa and Arabia. It extends north-north-west and south-south-east between 12°N, 43°E and 30°N, 32°E and has a surface area of 44,000 km². It is a narrow elongated body of water, connected at its northern end with the Mediterranean Sea through the man-made Suez Canal and at its southern end with the Indian Ocean through the Strait of Bab el Mandab. Near the latitude 28°N, the Red Sea bifurcates into a Y-shape to form the Gulf of Suez and Gulf of Aqaba.

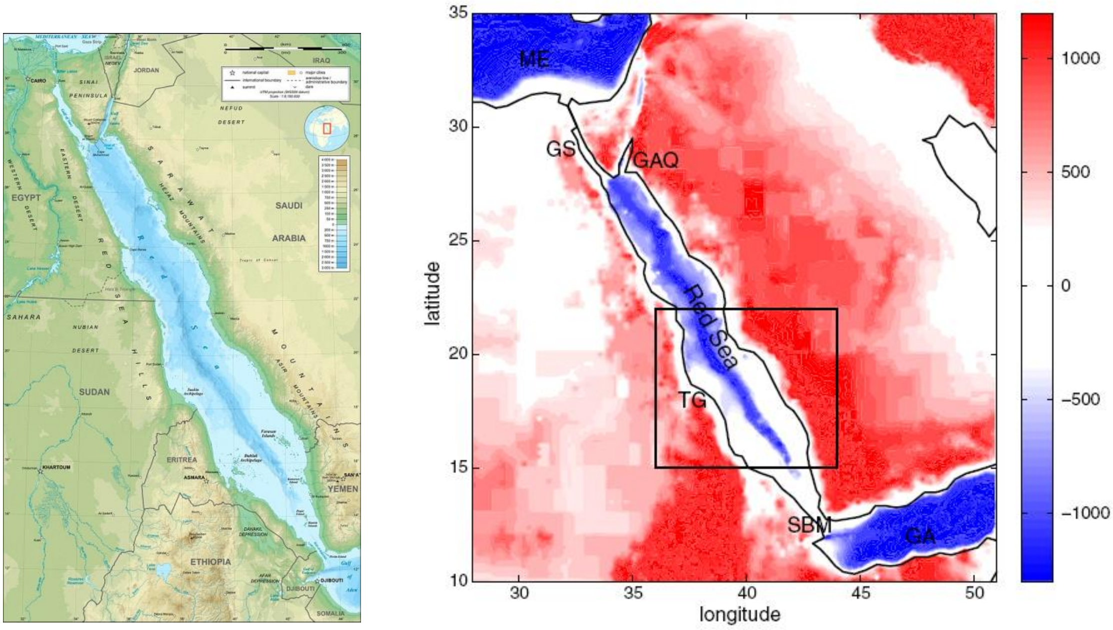

Figure 2.1: A Red Sea topographic map. The colours are the elevation of the topography (unit: m). The locations of Gulf of Aqaba (GAQ), Gulf of Suez (GS), Gulf of Aden (GA), Mediterranean Sea (ME), Tokar Gap (TG), Strait of Bab el Mandeb (SBM) are shown (After Zhai and Bower 2013).

The Red Sea proper (itself, excluding the Gulfs) extends for about 2000km. The shorelines of the sea are straight in the north but notably sinuous in its central and southern parts where they form vast bays. The distance between the eastern and western Red Sea coasts (width) is 180km at its narrowest part and about 360 km at the widest part at Massawa (Coleman, 1974); meanwhile its average width at Bab el Mandab is only 27km.It has a total surface area of 438,000 sq km and a maximum depth of 2,640 m. The northern limit of the Red Sea in the Gulf of Aqaba lies in latitude 29° 32’ 48” N, while the northern limit in the Gulf of Suez at Suez Bay is in latitude 29° 57’ 18” N (Fouda and Gerges 1994). The Red Sea is typically bounded on the landward side by a more or less narrow coastal strip (40 to 60 km wide), backed by high hills or mountains, which can rise to 3,000 m in some regions. The seabed consists of three main levels. A central trough in the Gulf of Aqaba reaches to depths of more than 1,800 m. In the northern and central Red Sea this central trough reaches to depths of more than 2,000 m, with the greatest depth, 2,640 m. From this trough, the seabed rises sharply to a terrace at depths of between 1,000 m and 600 m. This terrace rises again to a continental shelf with a maximum depth of 300–400 m, and is often much shallower at around 50 m deep (PERSGA 2006). The continental shelf of the Red Sea is 15-30 km wide in the north and about 120km wide in the south. However, in the most southern part of the sea, the Farasan and Dahlak banks are considered as parts of a shallow shelf extending to the centre of the sea. All these geomorphic features are framed by a strip of splendid coral reefs. Coral reefs fringe the entire Red Sea coast except for local break-ups at the mouths of ephemeral streams (Foudah and Gerges 1994; PERSGA 2006).

The Gulf of Suez extends for about 255 km with widths of 17-45 km and maximum depth of 83 m. The Gulf of Suez has always been a site of excessive sediment accumulation and therefore its bottom morphology is smooth, with gentle submarine coastal slopes. The excessive sedimentation has restrained the development of coral reefs (Fouda and Gerges 1994). By contrast, the Gulf of Aqaba is shorter, narrower, and much deeper. It extends for 180 km with widths varying from 25 km in its southern part to 16 km at the north. The Gulf proper is divided into three elongated deep basins striking North East. The northern deep is the shallowest (900 m deep) and is characterized by its flat bottom, while the other two deeps have irregular bottom topography and much greater depths. The maximum water depth in the Gulf reaches up to 1850 m in the central basin (Friedman, 1985). With the exception of the northernmost part of the Gulf, fringing coral reefs grow along the entire coastline varying in width between 10 and 100 m depending on the slope gradients at the shelf edge (Friedman 1985).

The Gulf of Aden trends West-Southwest - East-Northeast between 10°N, 43°E and 15°N, 52°E. It extends for 900 km from the western shore of the Gulf of Tadjura to a medial point between Ras Fartak and Ras Asir. The distance between the northern and southern shores of the Gulf is 125 km in the west, increasing gradually eastward to 375 km between Ras Fartak and Ras Asir (Geological-geophysical Atlas, Indian Ocean, 1975). Comparing to the younger Red Sea rift, the Gulf of Aden is much deeper and has markedly complicated bottom topography. It is characterized by a central rough zone occupied by the West Sehba Ridge with its rift valley running west through the Tadjura Trench. The Gulf of Aden is flanked by a narrow continental shelf in the south and relatively wider one in the north. Meanwhile, the seafloor slopes steeply in the south and more gentle in the north (Fouda and Gerges 1994).

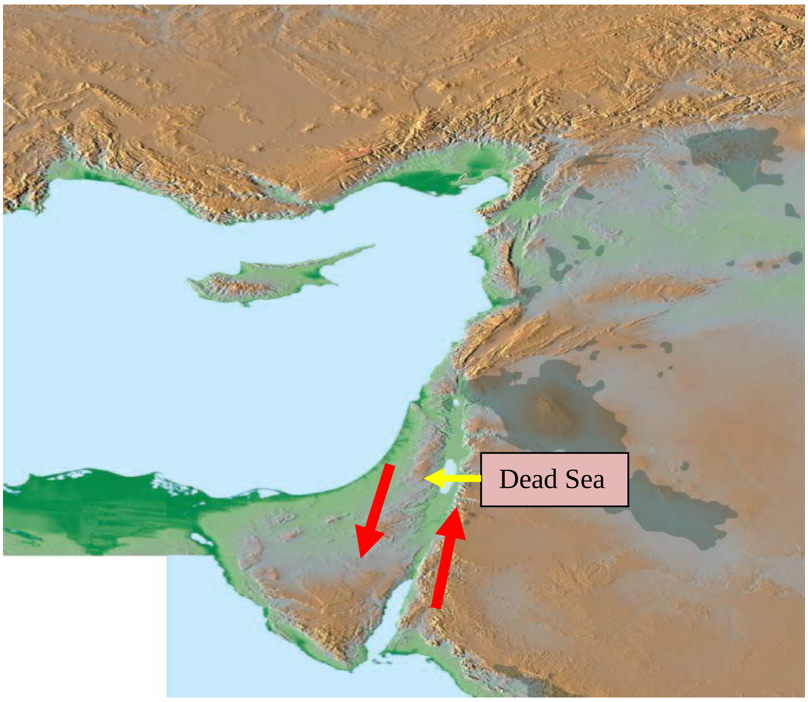

Figure 2.2: The Dead Sea transform system connects the Red Sea spreading ridge with the Alpine convergent belt. The movement along the transform zone has produced the long, deep, narrow pull-apart basins of the Gulf of Aqaba and the Dead Sea as well as the contractional folds of the northern Sinai and the Palmyra Mountains of Lebanon and Syria. Small eruptions of basalt occurred near the pull-apart basins (Opulithe 2014; Christiansen and Hamblin 2015).

The Dead Sea transform system extends from the spreading ridge of the Red Sea northward to a zone of continent-to- continent collision in the Alpine orogenic belt in southern Turkey (Fig. 2.2). The structure, topography, and history of the entire region are magnificent expressions of continental plates moving along a transform system. The transform zone is about 1000 km long and marks the boundary between the western edge of the Arabian plate and the northern part of the African plate. The main structure is the strike-slip fault zone, which involves several separate fault planes that slice through the entire lithosphere (Opulithe 2014; Christiansen and Hamblin 2015). These faults are not straight but have several angular bends. As a result, large, deep pull-apart basins have formed along the strike-slip fault zone (Fig .2.3). The Gulf of Aqaba (Elat) segment is the widest and deepest. The floor of one of these basins is more than 2000m below sea level. Farther north, the Dead Sea trough is another pull-apart basin; it is 400 m below sea level, with water depths exceeding 300 m in places. Sediment filling the Dead Sea trough is derived from erosion of the adjacent mountains. It is several kilometres thick and continues to pour into the graben, forming alluvial fans. In a more humid climate, the Dead Sea trough would be a freshwater lake extension of the Gulf of Aqaba. The structural features north and south of the Dead Sea are no less impressive. Note the direction of plate movement illustrated in Figure 2.2. The Arabian plate is moving northward and the African plate southward. Two major bends in the strike-slip fault system occur, one to the north in Lebanon and Syria and the other south of the Dead Sea. As the plates move near these bends, slippage along the fault is inhibited and broad zones of transpression result. This formed compressional folds that branch off the strike-slip fault zone in the Palmyra Mountains to the north (Fig. 2.2) (Opulithe 2014; Christiansen and Hamblin 2015).

The Dead Sea transform system began about 25 million years ago when Arabia was still part of the African continent. As rifting began to open the Red Sea, the Arabian plate split from Africa and began to move northward. The Dead Sea transform was initiated by this movement, and vigorous tectonic activity has continued ever since. Total offset along the southern extent is at least 100 km, but to the north displacement is less, suggesting that part of the plate movement has been taken up by folding in the Palmyra fold belt. Intermittent volcanism along the transform system has occurred since Mesozoic time, and Pleistocene basaltic lava flows and cinder cones are especially obvious (Fig. 2.2) (Opulithe 2014; Christiansen and Hamblin 2015).

Figure 2.3: Pull-apart basins in the Gulf of Aqaba and the Dead Sea dominate this photograph taken by astronauts aboard the Space Shuttle. Such basins are caused by movement on strike-slip faults that have sharp bends and offsets of the major faults (inset). These form three deep basins along the floor of the Gulf of Aqaba and the Dead Sea basin that lies below sea level (Opulithe 2014; Christiansen and Hamblin 2015).

2.3 GULF OF AQABA

The Gulf of Aqaba oriented NNE-SSW is the northernmost sea-flooded part of the Syrian-African rift system. The Gulf is a semi-closed basin, separated from the Red Sea by the Straits of Tiran, a narrow passage about 250m deep. A unique feature of the gulf is its great depth (> 1800 m) in proportion to its width (5-25). It has an average depth of 800m increasing to more than 1,800m as a maximum depth (Figs. 2.4 and 2.5).

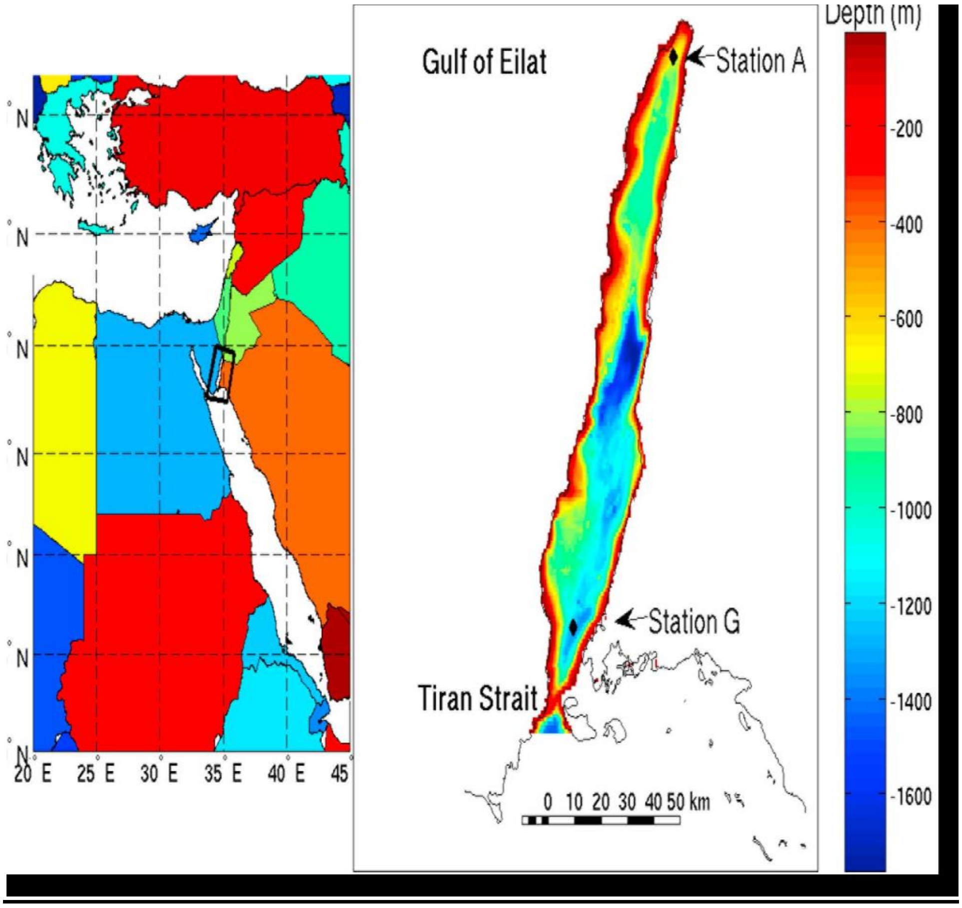

Figure 2.4: (left) The Gulf of Aqaba within the Red Sea region indicated by the inset, (right) with the Gulf bathymetry. From (Biton and Gildor 2011).

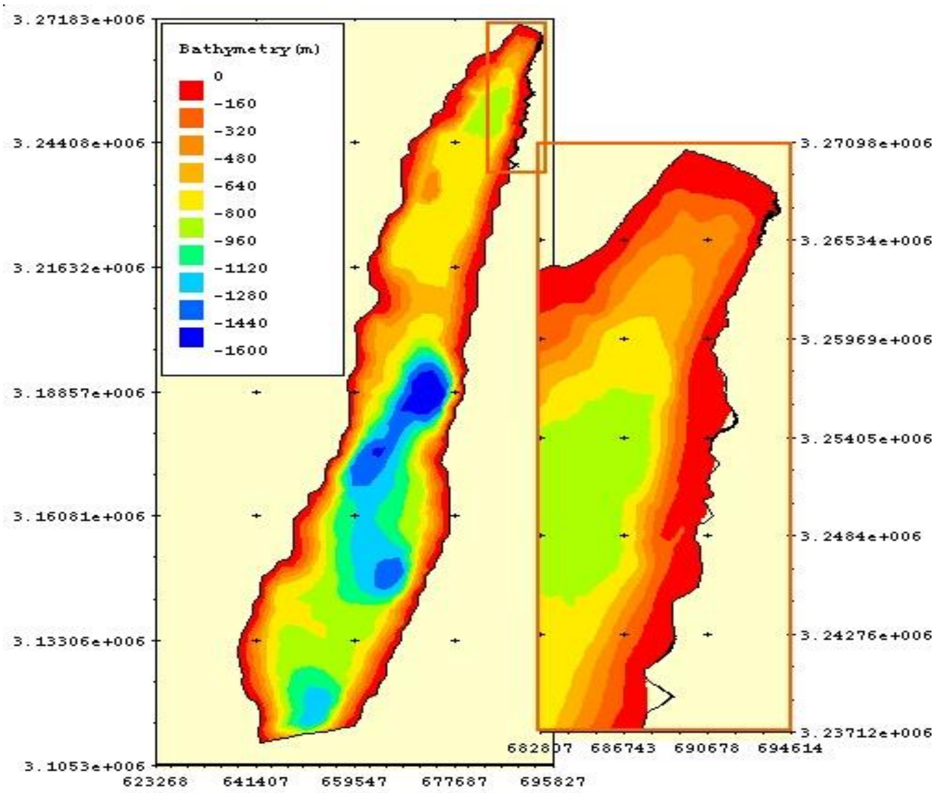

Figure 2.5: Map of the Gulf of Aqaba showing the Bathymetry (SMART 2005).

2.4 THE RED SEA AND GULF OF AQABA AS A TRADING ROUTE

The Red Sea was always considered a significant east-west maritime trading route. Aqaba at the northern tip of the Gulf of Aqaba and Suez at the head of the Gulf of Suez were historically considered trading sites and major naval stations under the Ottoman Empire. The importance of these ports had increased after the construction of Suez Canal in 1869 (PERSGA 2006). It is estimated that 7% of sea transported world trade passes through the Suez Canal, 35% of this trade is loaded from and to the Red Sea and Arabian Gulf ports, 20% from and to the Indian and South East Asian ports and 39% from and to the Far East area (Egypt, State Information Service 2014).

The annual capacity of the Canal is stated by the Suez Canal Authority (SCA) to be 76 ships/day. The numbers of ships using the Canal is changing with time due to many reasons among which the world`s economic and political conditions. The numbers of ships reached a maximum of 22,545 ships in 1982, and fell to reached 13,472 in 1998. These law numbers continued until 2003 when the number of ships increased gradually to reach 21,415 ships maximum in 2008. The number fell again by 2009, a trend that continued to reach 16,596 in 2013. However, the total tonnage of ships transits the Canal continued to increase, despite the increase or decrease in the number of ships passing the Canal. This is mainly due to the fact that larger ships are being used. The total tonnage of ships transiting the Canal increased from 378,226x10^3 tonnes in 1983 to 439,041x10^3 tonnes in 2000 and reached 928,472 x10^3 tonnes in 2012 and 928,467 x10^3 tonnes in 2013 (SCA 2013).

A second factor adding to the importance of the route is oil movement across Suez via the SUMED (Suez to the Mediterranean) pipeline which allows too large ships to transit the Canal to discharge their cargo at the oil terminal at Ain Sukhna, south of Suez. The pipeline runs from Ain Sukhna to Sidi Kerir on the Mediterranean coast of Egypt, west of Alexandria. It has a capacity of 120 million tonnes of oil/year. Loaded tankers call at the Ain Sukhna Oil Terminal to discharge their cargo to shore and return southwards in ballast to reload, generally in Red Sea or Arabian Gulf ports. The original depth of the Canal was less than 7 m and, as the size of ships in international trade has increased, the Canal has been deepened and widened to allow a growing proportion of world shipping to transit the Canal (PERSGA 2006).

2.5 MARITIME BOUNDARIES AND EXCLUSIVE ECONOMIC ZONES FOR THE COUNTRIES IN THE GULF OF AQABA

Maritime boundaries for countries in the Red Sea and Gulf of Aden are only partially defined (PERSGA 2006). The Gulf of Aqaba is the eastern extension of the northern part of the Red Sea. It is located along the Great Afro-Arabian Rift, as the southern continuation of the Wadi Araba Valley**.** From the head of the gulf to the Straits of Tiran, the length is approximately 180 Km; at the head of the gulf, the width is about 5km. It commences to widen near the undefined meeting point between the maritime boundaries of Israel, Jordan and Egypt, near Taba, where it is about 8 km wide (Fig. 2.6). From there it varies in width up to 27 km along its length, until near the exit of the Gulf, into the Red Sea, where it narrows again, towards the Straits of Tiran (Srebro 2009).

Aqaba at the head of the gulf is Jordan’s only connection with the sea and is therefore of considerable economic importance for Jordan, developing some major industries along its coast (Fig 2.7). Elat on the west-northern tip of the gulf is the main Israeli maritime connection with East Africa and South and East Asia, is through the gulf. Industry and industrial ports, maritime commerce, maritime agriculture and tourism all develop rapidly along its coasts. Rapid development, population growth and urbanization influence the social situation and present a threat to the gulf’s ecology through potential pollution of the environment both on land and at sea. Hence, the need for precise territorial and maritime boundary delimitation is a necessity, to enable the adjacent States to manage human activities in that respect (Srebro 2009).

2.5.1 MARITIME BOUNDARIES BETWEEN JORDAN AND ISRAEL IN THE GULF OF AQABA

The total length of the coasts along the gulf is over 400km, divided approximately as follows: Jordan-around 27.5km, Saudi-Arabia -around 190km, Egypt-over 200km and Israel about 12km. Saudi-Arabia claimed 12 nautical miles of territorial waters by A Royal Decree on 16 February 1958 , simultaneously establishing its base lines. However the four states along the coasts of the gulf-Jordan, Israel, Egypt and Saudi-Arabia, had had no agreed maritime boundaries between them in the gulf, until the Peace Agreement between Jordan and Israel was signed. Saudi-Arabia signed UN Convention on the Law of the Sea, 1982 (UNCLOS) on 7 December 1984.

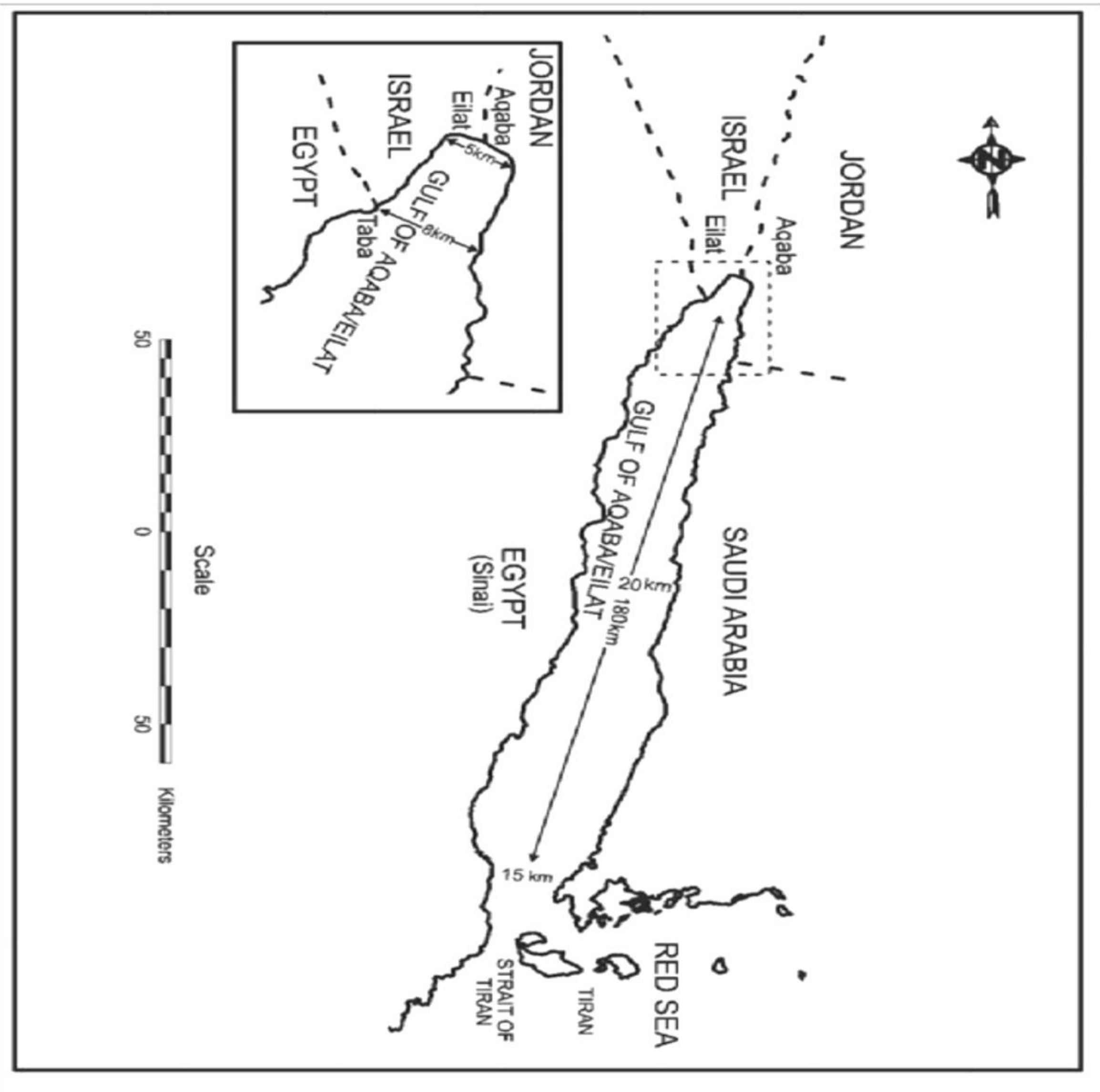

Figure 2.6: The Gulf of Aqaba (Srebro 2009)

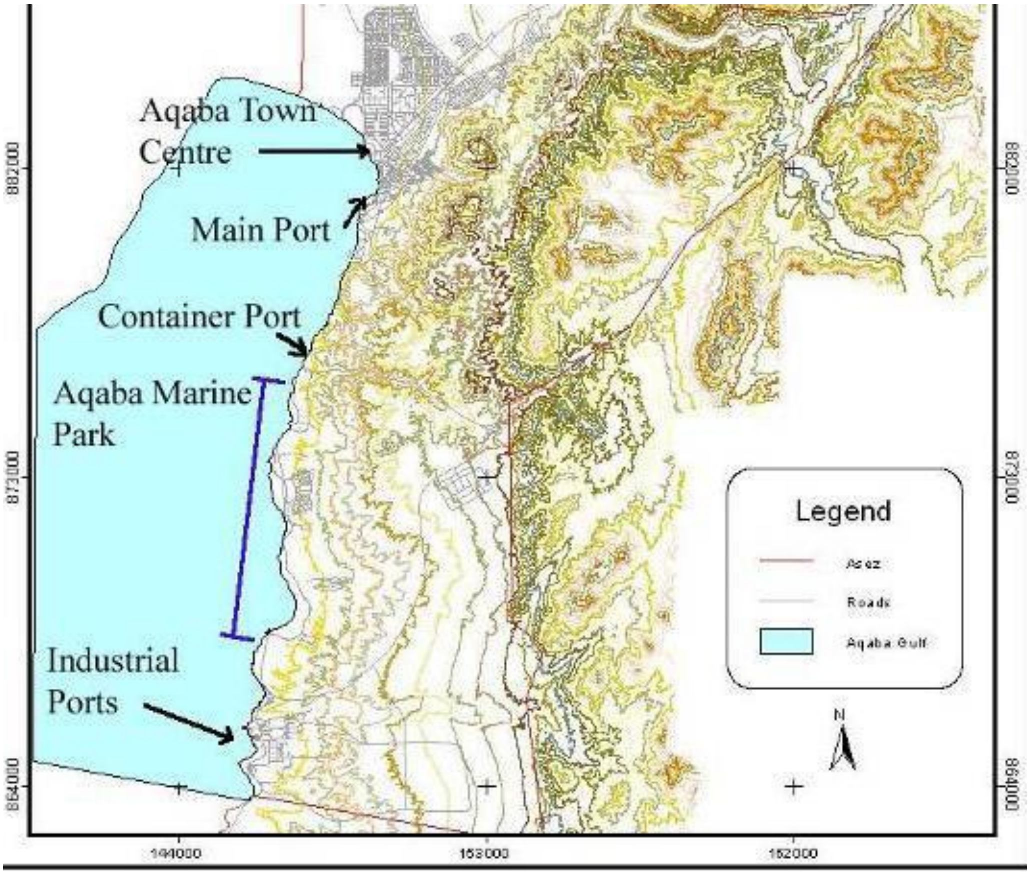

Figure 2.7: Aerial Photograph of Jordan's Gulf of Aqaba Coastline (ADC 2008)

Egypt claimed 12 nautical miles of territorial waters by Presidential Decree on 17 February 1958, which it reaffirmed, when ratifying the (UNCLOS**)**, on August 26th 1983. Later, Egypt declared its base lines along its coasts, including the Gulf of Aqaba, by Presidential Decree, on 9 January 1990. On 5 February 1990 Israel approved a law in which it claimed 12 nautical miles of Territorial Sea, replacing a preceding law from 23 October 1956, in which the Territorial Sea of Israel was already expanded from 3 nautical miles to 6 nautical miles. Jordan’s claim for three nautical miles of territorial sea followed the British Mandatory Act of 12 February 1943 (Srebro 2009).

According to Article 14 of the Peace Agreement between Israel and Jordan, and Article 5(2) of the Peace Treaty between Israel and Egypt, freedom of passage is assured along the mid of the gulf from the Straits of Tiran to the head of the gulf. Necessarily, this passage secants(a straight line that intersects a curve in two or more parts) through the territorial waters of all countries, since the sum of the Saudi Arabian and Egyptian claims alone (24 nautical miles) exceeds the width of the gulf. The sum of the Israeli and the Jordanian claims concerning territorial waters was 15 nautical miles, which exceeded the width of the head of the gulf. These overlapping claims, therefore, obliged Jordan and Israel to seek an agreed solution to the problem (Srebro 2009).

Israel and Jordan are adjacent coastal states at the head of the gulf and opposite coastal states along the gulf to the south of it (Fig. 2.8). The common southern point between Israel and Jordan along the maritime boundary in the gulf is common to Egypt as well; thus, a bilateral agreement on the subject was not suffice, and Egyptian involvement was required. The first boundary point on the coast is located slightly west of the middle of the head of the gulf, 2650m from the north-eastern corner of the gulf in Jordan and 2400m from the northwestern corner in Israel. The lengths of the coasts of the two states along the gulf are not identical, requiring attention to the issue of proportionality (Srebro 2009).

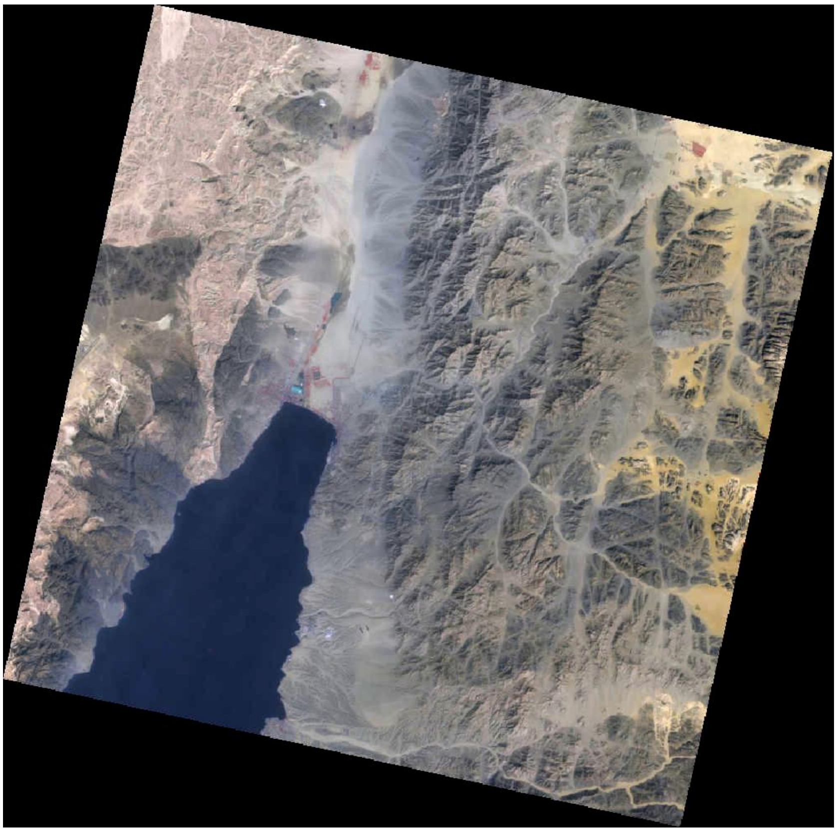

Figure 2.8: SPOT Satellite images of Aqaba for the year 2003 (SMART 2005).

2.5.2 THE DEFINITION OF THE MARITIME BOUNDARY

Following the 26 October 1994 Peace Agreement between Israel and Jordan the JTE (Joint Team of Experts) of the two states began negotiations to delimit the maritime boundary. Article 15 of UNCLOS says, that in the case of opposite or adjacent coasts between two states neither of the two states is entitled to extend its territorial sea beyond the median line between the two states. This became a directive and customary law since 1993. But in addition to the fact that neither Jordan nor Israel were parties to UNCLOS (Jordan ratified this convention on 24/6/1995), the configuration of the coast lines of Israel and Jordan at the head of the Gulf of Aqaba/Eilat is of both opposite and adjacent coasts. Thus, it is not fitting Article 15, which refers to the case of either opposite or adjacent coasts.

Within the context of over lapping claims, the thalweg of the lower points to serve as the navigation course, equal water areas to represent equitability and proportionality between relevant water areas and the relevant lengths of the coasts of the states. Even the natural line of geological structure had been checked. The other option was to check the Equidistance line, which corresponds to the guidelines set out in Article 15 of

UNCLOS and with ICJ (International Court of Justice) decisions. However, it was found that this method may not always be equitable in the case of adjacent coasts. Consequently, the two parties could not come to an agreement about one method, which will solve the problems and support one comprehensive solution (Srebro 2009). Therefore, the parties adopted a composite criteria method, which will implement one method for the adjacent zone and one for the opposite zone. Since the configuration of the coasts between the two states includes both adjacent and opposite coasts these conditions require a specific solution to define the transition of boundary between the zone of adjacent coasts and the zone of opposite coasts. The parties defined the transition line between the two zones based on the definition of a TRI-Equidistance point, which is equidistant from the three coasts at the head of the Gulf (Srebro 2005 in Srebro 2009).

In the adjacent coast area the parties decided to simplify the equidistance line and to connect by a straight line the beginning coastal point of the maritime boundary with the Tri-Equidistance point. The Tri-Equidistance point became the transition point from which and on the maritime boundary line was defined by the median line in the opposite coasts zone. This was achieved by connecting the centres of the circles tangenting the opposite coasts (Fig. 2.9). For the simplicity of the navigation this line was simplified to 3 straight legs compensated for the generalization (Fig. 2.10).

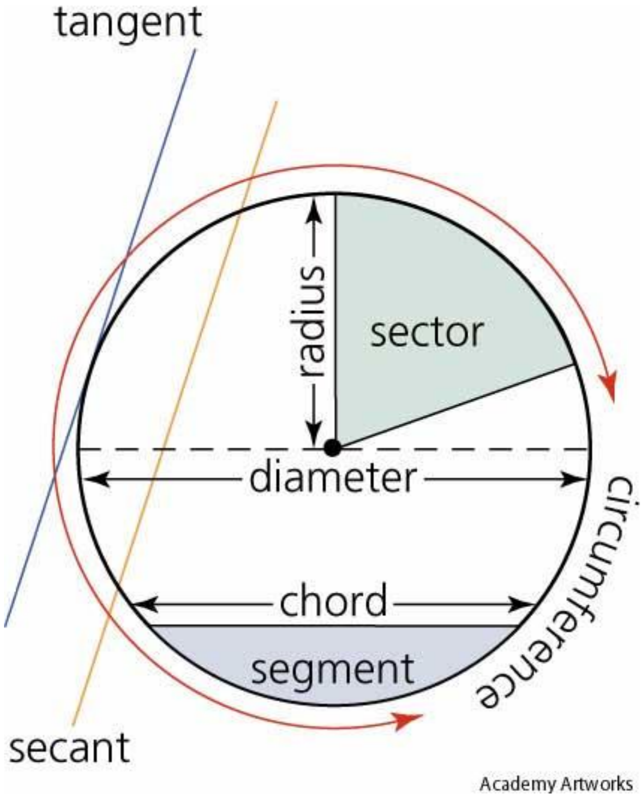

Figure 2.9: To explain the meaning of tangent.

The solution was incorporated in the maritime boundary agreement, which was signed by the two parties on 18 January 1996 (Maritime Agreement, 1996). The Joint Team of Experts (JTE) prepared a list of coordinates of the turning points and 1:25,000 chart of the maritime boundary line (Fig. 2.10).

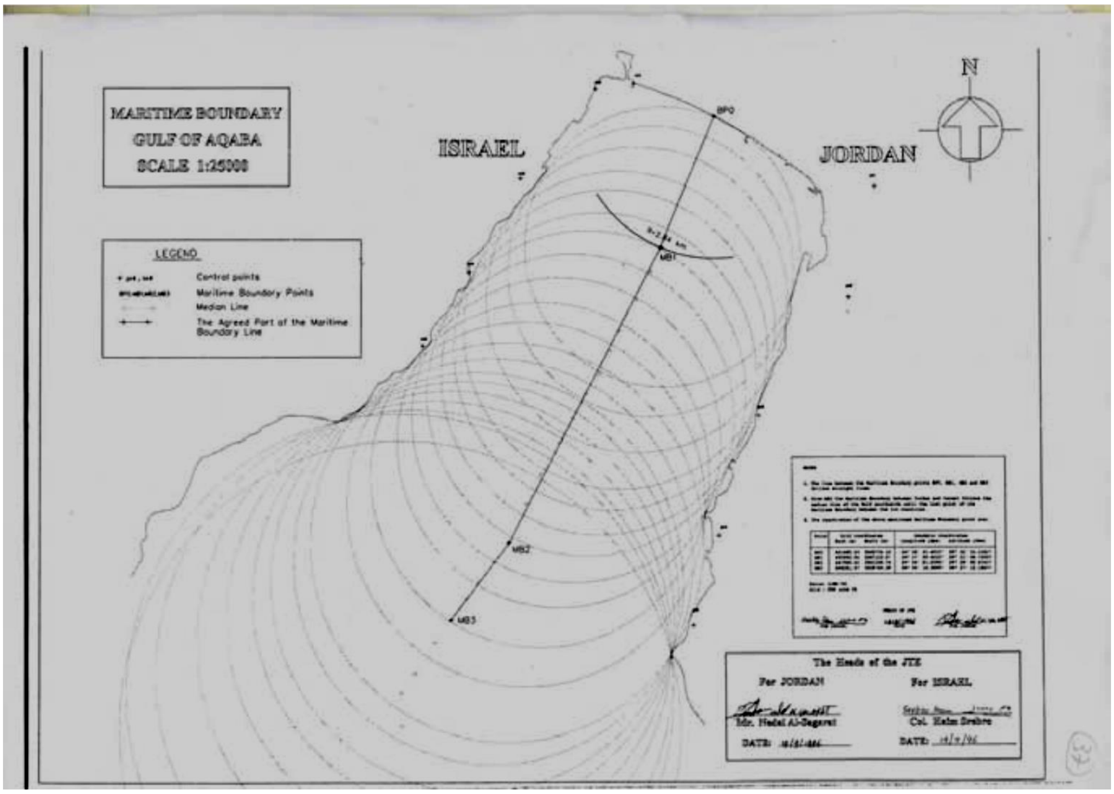

Figure 2.10: The Maritime boundary between Israel and Jordan (Srebro 2009).

Box 2.1: Maritime Boundary agreement between Israel and Jordan

"Maritime Boundary Agreement Between the Government of the State of Israel and the Government of the Hashemite Kingdom of Jordan, 18 January 1996"

In fulfilment of article 3.7 of the Treaty of Peace between Israel and Jordan of 26 October 1994 on the delimitation of their maritime boundary in the Gulf of Aqaba, the two parties signed what has been called the "Maritime Boundary Agreement Between the Government of the State of Israel and the Government of the Hashemite Kingdom of Jordan on 18th January 1996". According to this agreement the two parties have agreed on the following:

Article 1

1. The maritime boundary in the Gulf of Aqaba between the Hashemite Kingdom of Jordan and the State of Israel begins at Boundary Pillar 0 on the seashore and follows a straight line for 2.84 kilometres where it meets the median line of the Gulf.

Thence the maritime boundary follows the median line of the Gulf southwards until the last point of the maritime boundary between the two countries.

2. The Joint Team of Experts shall, as soon as possible after the date of the signature of this Agreement, jointly agree upon and document the methodology for defining the median line, and the procedure to fix the maritime boundary coordinates.

The list of maritime boundary coordinates shall be in geographic and UTM coordinates based on IJBD-94 and shall be measured by GPS.

3. This list of coordinates shall be binding and take precedence with regard to the location of the maritime boundary.

Article 2

Nothing in this Agreement shall affect, or be affected by, the position of either Party with regard to the location of either Party's maritime boundary in the Gulf of Aqaba with another State.

Article 3

This Agreement shall enter into force thirty days from the date of its signature.

This Agreement shall be transmitted to the Secretary-General of the United Nations for registration in accordance with the provisions of Article 102 of the Charter of the United Nations.

Table 2.1 shows the coordinates which were extracted from the agreement which was signed in September 1996 "September 1996 Agreement", establishing the coordinates of the maritime boundary between Jordan and Israel in the Gulf of Aqaba.

Table 2.1: Coordinates of the Israel - Jordan boundary on the Gulf of Aqaba.

Point	Latitude North	Longitude East
BP 0	29:32:33:316 N	34:58:41.4190 E (boundary line enters the coast)
MB 1	29:31:08.7253 N	34:47:59.4512 E
MB 2	29:28:00.6141 N	34:56:01.0296 E
MB 3	29:27:12.1667 N	34:55:16.3595 E

The maritime boundary was the first boundary in a territorial sea in this corner of the world. Three special boundaries were defined at the head of the Gulf of Eilat/Aqaba. Two of them are land boundaries – between Israel and Egypt and between Israel and Jordan. The third is the maritime boundary between Israel and Jordan. The two land boundaries are originated historically in the process of coming a part of the Ottoman Empire that reigned around 400 years between 1416 and World War I. This demarcation and documentation was the reference for the boundary delimitation in the 1994 Peace Agreement between Israel and Jordan. The new boundary was jointly demarcated and surveyed in 1995 using GPS, and was documented on the basis of a joint boundary datum.

Article 15 of the 1982 UN Convention on the Law of the Sea (UNCLOS), defines the delimitation of maritime boundaries in the territorial sea between two states that have adjacent or opposite coasts. Israel and Jordan have on the head of the Gulf of Eilat/Aqaba both adjacent and opposite coasts. The coastal point of the land boundary between Israel and Jordan is not on the middle of the northern shore of the gulf. In October 1995 Israel and Jordan agreed on a method of defining a maritime boundary in the head of a gulf. This is an international innovation (Srebro 2009). This method includes a definition of a point of transition between the zones of adjacent and opposite coasts. On the base of this agreement a Maritime Boundary Agreement was signed in January 1996 delimiting the boundary by coordinates and a map. Until today this is the only maritime boundary in territorial sea in this corner of the world.

As for the border between Egypt (Taba) and Israel (Elat) goes back to September 1986, when an agreed Arbitration Tribunal was established with regard to the definition of the location of the boundary pillar at Taba and additional 13 disputed locations. The Tribunal decided to accept the Egyptian claim, since this used to be the location of the pen-ultimate pillar, during the Mandate. Following the Arbitration, a new pillar was erected at the pen-ultimate location. Before the Israeli final withdrawal from Taba, the two states agreed to continue the line from the new pillar 91 to the sea, following the exact line of 1906 and during the Mandate, towards the location of the Parker pillar, which used to be the ultimate pillar during the Mandate. Two boundary markers A and B were erected on 27 February 1989 near the shore. These boundary markers were jointly surveyed and documented as part of the entire boundary documentation which was concluded on 26 March 1996.

2.6 METEOROLOGY- CLIMATE

2.6.1 GENERAL/RED SEA

2.6.1.1 Atmospheric Pressure

During the winter months there is high pressure in the north-western part of the region and a ridge of high pressure extends south-east across Arabia. A trough of low pressure extends north-north-west along the Red Sea and west-north-west into the Gulf of Aden. During the summer, wind patterns are shaped by low pressure over Iran and high pressure to the west over Ethiopia and Eritrea, and over Egypt.The whole of the Gulf of Aden and parts of the southern part of the Red Sea area affected by the monsoon winds that blow between the Horn of Africa region and the Indian subcontinent. From late September to early May each year, the dominant winds are north-east, and then winds blow strongly from the south-west during the summer months (After PERSGA 2006).

2.6.1.2 Wind Patterns

In January, winds in the northern half of Red Sea generally blow from the north north-west.This pattern extends from the northern end of the Gulf of Suez southwards to latitude 20°N. Winds in the Gulf of Aqaba during this period tend to be between north-west and north. This north-north-west wind pattern, generally blowing between Force 2 and Force 6, occasionally Force 7, is consistent in the Gulfs of Aqaba and in the main Red Sea south to latitude 20°N, from April and throughout the rest of the year.

However, during winter months, occasional southerly winds blow in this part of the Red Sea. During this season, very high winds have been known to affect the coast of the Gulf of Aqaba from time to time, and have caused damage to properties, small ships, boats and other equipment in the most-northern end of the Gulf. Occasionally very active cold fronts affect the north-west part of this area, giving rise to squalls and thunderstorms (PERSGA 2006). By comparison, in the southern part of the Red Sea, south of latitude 20°N, winds blow from the north-north-west during winter months. By April a low pressure area has formed between latitudes 15° and 20°N and the wind south of 15°N blows from the south-south-east towards this area at between Force 2 and Force 6, rarely Force 7. By July winds come from the north-north-west again, blowing towards the Strait of Bab el Mandeb. By October a low pressure area has formed and the wind becomes south-south-east again, Force 2 to 6 and occasionally Force 7 (PERSGA 2006).

2.6.1.3 Dust Emission and Visibility

Visibility in the region can be good to very good, particularly during the winter months; fog is rare throughout the year. However, occasional sand storms created by frontal systems, of short duration, can affect the Gulf of Aqaba and reduce visibility to a matter of 1–200 m (PERSGA 2006).

2.6.1.4 Exchange of Water with Gulf of Aqaba

The gulf is characterized by a low rate exchange of water with the Red Sea due to the narrow and shallow passage of Straits of Tiran. The gulf also acts like closed lake, with summer stratification and biannual turnover. The lower mass of water is colder and nutrient-rich, and has even less exchange with the Red Sea across the shallow Straits of Tiran, than surface water. This can lead to algal blooms on the reef following winter storms, which cause upwellings. The residence time of water can exceed two years in the upper depths of the Gulf and three years in the lower depths (ISPAN, 1992).

2.6.2 GULF OF AQABA

2.6.2.1 Ambient Air Temperature

Ambient temperature in Aqaba city ranged between daily average values of 12 ºC and 37 ºC and had a mean value of 25 ºC during the year 2012. However, hourly average values ranged between 6 ºC and 45 ºC (Alsawair and Solieman, 2013).

2.6.2.2 Wind Direction

Prevailing winds are from north, and thus the predominant wave direction is from the north. Wind measurements showed that the prevailing wind direction in Aqaba is of northern origin (north, northeast, and northwest), with a range between 69% (March) and 100 (September) and with total percentage of 87 %. Within this percentage the northeast wind prevailed during around 69 % of the time, north wind prevailed during around 16 % of the time, and northwest 2 % of the time. South wind (south, southeast, and southwest) prevailed during around 8 % of the year time. The remaining small percentage of the wind direction prevalence is shared between east and west directions. It is clear that north wind (north, northeast, and northwest) prevails throughout the year; however, south wind (south, southeast, and southwest) occurs relatively at higher frequency during March (16.5%), April (18.5%) and May (23%). Thus special attention should be paid to air emissions that may reach the city from phosphate terminal or industrial area during these mentioned months (Alsawair and Solieman, 2013).

2.6.2.3 Wind Speed

The prevailing wind speed was the 2.5-5 m/s speed ranges with a frequency of around 48 %, followed by wind speed of 0-2.5 m/s with a frequency of around 26 %, and the 5-7.5 m/s with a frequency of around 24 % (Alsawair and Solieman, 2013). Calm wind (0-2.5 m/s) prevailed during January (52%) and December (49%). Wind of moderate speed of (2.5-5 m/s) prevailed in October (61%), while wind of (5-7.5 m/s) prevailed in June (14%). The daily average wind speed values ranged between 0.83m/s and 7 m/s, and an overall average of 3.77 m/s. The highest wind speed observed was during day time between 14:00 Hr and 18:00 Hr (afternoon). Monthly variations of wind speed showed clear peaks of 4.97 m/s in September (Alsawair and Solieman, 2013).

2.6.2.4 Relative Humidity

The measured hourly average values of relative humidity in Aqaba ranged between 6 % and 84 %, the daily average ranged between 9 % and 68 %, whereas the average value for the year is 36 % (Alsawair and Solieman, 2013).

2.6.2.5 Atmospheric Pressure

Atmospheric pressure daily average value recorded at the city station reached a value of 1008 mbar and ranged between 990 mbar and 1020 mbar. It shows a gradual decrease from April until December (Alsawair and Solieman, 2013).

2.6.2.6 Incoming Solar Radiation

Incoming solar radiation is an important factor in the calculation of atmospheric stability and hence in air pollution dispersion modelling. The hourly average values had a mean of 337 W/m^2, with a maximum value of 1500 W/m^2. There are fluctuations in daily values of incoming solar radiation with a peak at (11:00 Hr) (Alsawair and Solieman, 2013).

2.6.2.7 Long Term Monitoring

The meteorological conditions (wind speed, wind direction, air temperature and relative humidity) in the northern Gulf of Aqaba during the year 2013 were measured continuously (10 min interval) by a local weather station (Delta-t Weather Station). These conditions were analyzed in order to understand and evaluate the effect of meteorological forcing in surface and subsurface physical characteristics at the northernmost Gulf of Aqaba (Fig 2.11). On the other hand, the results of the MSS weather station are comparable of those results mentioned in sec 2.5.2.1-2.5.2.6. The meteorological measurements demonstrate in general that the wind speed during the year 2013 in fluctuated within the range of 0-12 ms^{-1} (mean: 4.5 ± 2.4 ms^{-1}). Occasionally, wind speed reached more than15 cms^{-1} just for few hours, on January 7^{th}, 2013 (15.8 ms^{-1}). Moreover, a harmonic change of wind speed appeared during summer causing a diurnal cycle that was represented by the strong winds during daytime and relatively weaker winds during nighttimes. Meanwhile, northerly winds (NNW-NNE) dominated over the study area and represented about 85% of total measurements. A typical daily cycle of air temperature variation was noticed during all months of the year. Seasonal variations were also clear. The mean temperature values were 32.2 ± 3.16 °C, 23.7 ± 3.34 °C, 17.6 ± 3.46 °C and 24.3 ± 4.52 °C for summer, autumn, winter and spring, respectively (Fig. 2.11). In general, winds and air temperature had obvious effect on humidity. Therefore, relative humidity showed a periodic variation following the daily cycle of air temperature and wind speed. The minimum value reached 13% in summer (high temperature) and the maximum value reached 83% in winter (low temperature) (Fig. 2.11). Table 2.2 shows a statistical summary (mean + standard deviation) of wind speed, wind direction, air temperature and relative humidity in the northern Gulf of Aqaba for the years 2010-2013. The results revealed that most of the values for each year are comparable with those of year 2013.

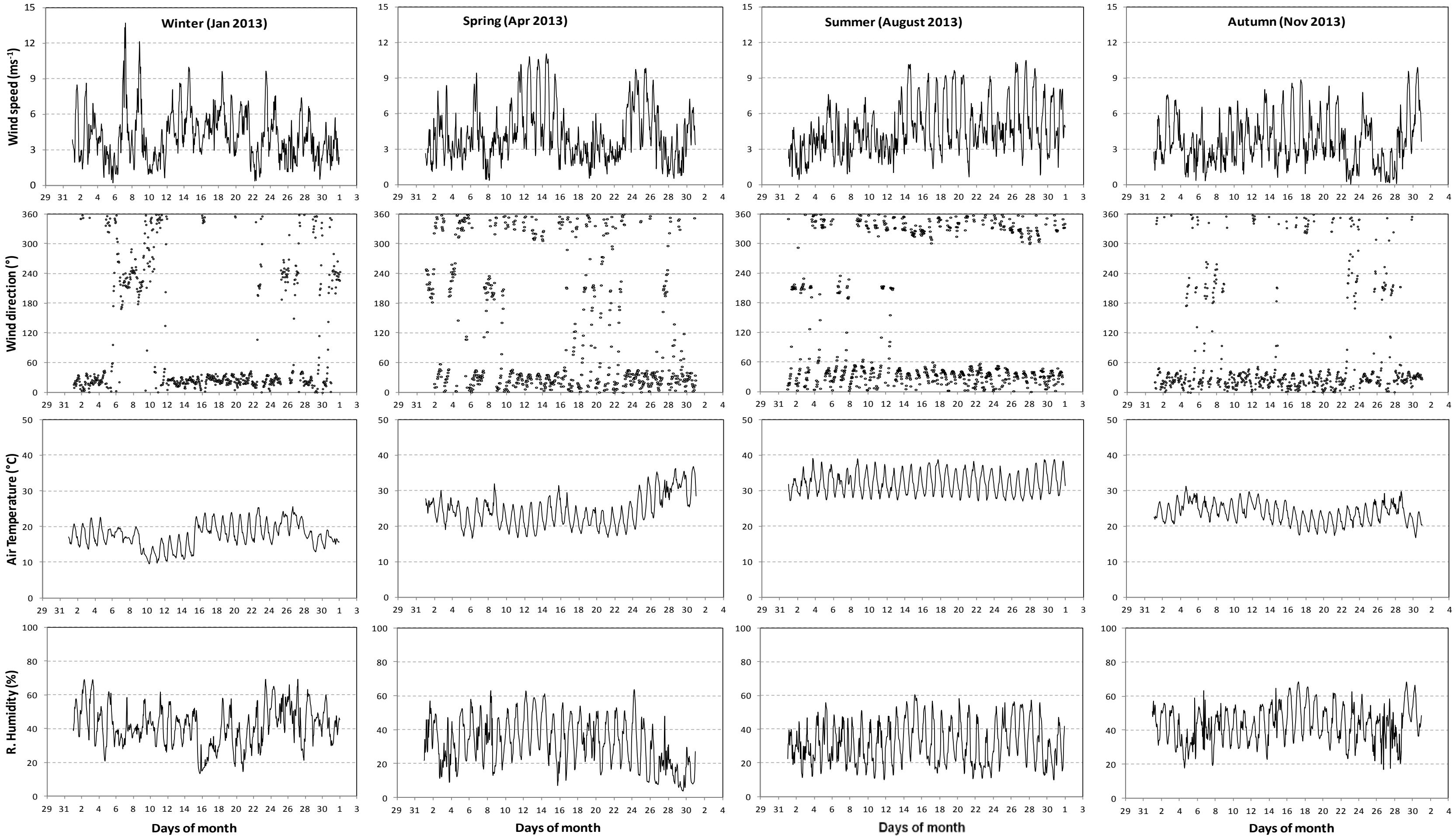

Figure 2.11: Meteorological conditions of hourly average of wind speed (ms^{-1}), wind direction (°), air temperature (°C) and relative humidity (%) in the northern Gulf of Aqaba during winter, spring, summer and autumn seasons of the year 2013.

Table 2.2: Statistical summary (mean and standard deviation) of wind speed, wind direction, air temperature and relative humidity of the years 2010-2014 in the northern Gulf of Aqaba.

Month	Wind speed (ms^{-1})		Wind dir. (°)		Air Temperature (°C)		R. Humidity (%)	
	mean	std	mean	std	mean	std	mean	std
Jan.	3.6	2.0	12.6	39.0	17.7	2.9	12.3	43.4
Feb.	4.0	2.4	13.3	37.7	19.1	3.4	13.1	40.3
Mar.	4.3	2.4	14.5	37.5	21.2	3.8	13.6	35.9
Apr.	4.5	2.3	17.8	39.6	24.6	4.1	13.7	32.5
May	4.7	2.3	18.6	39.6	28.4	4.0	12.7	30.0
Jun.	4.8	2.4	15.5	44.9	31.2	3.8	12.2	29.3
Jul.	5.1	2.5	12.5	46.6	32.4	3.4	12.5	33.0
Aug.	4.9	2.3	14.3	50.4	32.9	3.3	12.5	32.4
Sep.	5.2	2.5	16.5	51.4	30.6	3.1	12.5	39.7
Oct.	4.8	2.4	20.9	44.1	27.4	3.2	12.7	40.1
Nov.	4.3	2.0	21.0	43.6	23.1	3.2	12.7	40.1
Dec.	4.2	2.1	16.9	46.4	18.6	3.4	13.4	39.6

2.6.2.8 Dust Emission Sources

Three types of dust sources are found to affect dust levels in the ambient air of Aqaba City (Alsawair and Solieman, 2013). These are:

- Natural dust: wind-blown dust originating from Wadi Araba, transported by northern wind was found to increase dust levels in Aqaba. The highest monthly average concentration obtained for inhalable particulate matter 10 (PM10) was 141μg/m^3 in March, while the lowest was 30μg/m^3 in August. The background PM10 level in Aqaba is around 50 μg/m^3 based on hourly averages.
- Local dust emission sources such as traffic, construction activities and streets dust, which constitute the background dust levels in the city, and normally below limit in Jordanian Standards.
- Dust from Phosphate Terminal, transported by southern wind to the city. The prevalence of south wind (south, southeast, and southwest) occurs relatively at higher frequency during the months of May (23%), April (18.5%), March (16.5%), and November (14.5%). Recommended action: Controlling phosphate loading and unloading activities especially during March and April would be an effective tool to reduce phosphate levels in ambient air in the city.
- Meteorology: meteorology was found to affect levels and trends of pollutants concentrations during day time compared to night time and during winter time compared to summer time.

The prevailing wind direction in Aqaba was found to be of northern origin (north, northeast, and northwest), with a total percentage of 87 %. Pure north direction prevailed during around 16 % of the time, while northeast wind prevailed during around 69 % of the time, and northwest during 2 % of the time. South wind (south, southeast, and southwest) prevailed during around 8 % of the year time. The remaining small percentage of the wind direction prevalence is shared between east and west directions (Alsawair and Solieman, 2013).

2.6.2.9 Air Quality

A baseline air quality monitoring study was conducted by Ben Hayyan-Aqaba International Laboratories of ASEZA. The study covered the Phosphate Unloading Terminal within the area of Aqaba Main Port and three locations were selected at the South Port Site: Adderra Site to the south of the industrial zone; Al-Fajr Natural Gas Company site to the north of the Industrial Terminal; and Prince Rashed Marine Club to south of the Oil Terminal. The average values of inhalable particulates (PM10) exceeded the limit according to Jordanian Standards. In addition, the results showed that nitrogen oxides (NOx) values were significantly high. The Adderra Site and Prince Rashid Club sites showed elevated readings of NO2, and ammonia. The ammonia and PM10 levels were significantly higher than is allowed by the Jordanian Standard 1140. Levels at the coastline (Al-Fajr) site were mainly within the JS1140 limits (ADC 2008).

2.7 PHYSICAL OCEANOGRAPHY

2.7.1 SEA WATER TEMPERATURE

The relative isolation of this desert-enclosed sea, coupled with exposure to an arid, hot climate and high evaporation, cause temperature, evaporation and salinity to be unusually high as compared to the average range for oceans. Surface water temperature approaching 28 ºC may occur during the summer months and fall to just above 20 ºC in the winter. Temperatures within the water mass reflect a degree of stratification versus vertical and lateral mixing by water currents. Vertically, temperature falls within depth in the summer although there appears to be an inversion at certain depths in winter months because the deep water mass has a temperature reportedly above 20 ºC. The lack of regular fresh water input and the high evaporation rate contribute heavily to the particularly saline conditions within the gulf.

In winter time (February) sea surface temperatures reach their lowest point in the region. In the northern part of the Gulf of Aqaba these are as low as 18°C, while at the southern entrance of the Gulf of Aqaba they reach 21°C. In summer time (August) sea surface temperatures are at their maximum. The mean temperature in the Gulf of Aqaba is 27°C, rising to 31.5°C (ICRI, 1995).

The water of the gulf is exceptionally clear; the high transparency is related in part to the absence of major rivers or streams flowing into the sea

2.7.2 WAVE HEIGHTS AND DIRECTIONS

Wave heights and directions in the region are determined by the prevailing winds. The heights of sea waves depend on the distance from the land upwind, or the fetch, generally increasing in height the further the wind blows from the land. During the winter months, wind generated waves and swell in the northern Red Sea, as far south as 20°N, are normally less than 2 m in height from the north-north-west, but occasionally reach heights of over 2 m. During the south-west monsoon period in the summer months, the situation in the northern Red sea remains much the same, with wind and swell waves from the north-north- west, generally less than 2 m in height.

2.7.3 CURRENTS

Water currents in the Red Sea region are generally wind-driven and reflect the influence of the Indian Ocean monsoons as well as the daily and seasonal differential heating of the land and sea. Surface water currents tend to be anti-clockwise with low salinity water travelling north up the east coast of the Red Sea, becoming more saline as it crosses to the west, and then travelling south down the west coast of the Red Sea. The deflection caused by the shape of the coastline and the presence of offshore reef complexes can change this general pattern locally and the currents tend to be slow moving and ill-defined (UNEP 1985). During the winter months from November to April, the surface current generally sets from Bab el Mandeb to the north at a rate of 0.5 knots in the southern part of the Red Sea, decreases from 16°N to reach the southern end of the Gulf of Suez at about 0.25 knots. Along the east and west coasts of the Red Sea, in shallower waters, currents are variable, tending to set from north to south in eddies. During the summer, from June to September, the situation reverses, with currents setting south-south-east throughout the main body of the Red Sea at an average rate of around 0.25 knots in the northern section,

Due to evaporation in the Red Sea and an absence of inflow from any rivers, more surface water flows into the Red Sea from the Gulf of Aden than flows out. Currents through the Strait generally set north-west at an average rate of around 0.75 knots between October and May, but can reach 3.0 knots at times. Below the surface flow, there is a persistent outflow of highly saline water from the Red Sea into the Gulf of Aden. Between June and August the set is generally south-east at an average rate of 0.5 knots. In September currents are weak and variable. Currents are stronger in the Gulf of Aden than in the Red Sea and are associated with the direction and force of the north-east and south-west monsoons.

The currents in the Jordan Gulf of Aqaba are relatively weak (< 5 cms^{-1}) and the dominant direction is south-east parallel to the predominant wind direction in the northern Gulf. Currents are stronger at the surface (average of 10.3 ± 9.0 cms^{-1} at 2 m depth) than at depth (at 4-26 m depth, the average speeds are 2.1 ± 1.4 cms^{-1}). The average direction of the current recorded at 2 m and between 4-26 m depth is 246 ± 83°N and 153 ± 82°N, respectively. This indicates that the surface current is five times stronger than subsurface current and the current direction is generally parallel to the wind direction (ADC 2008).

The spatial structure of flows in the Gulf, at least as seen by current meters has been best revealed in observations made along the entire Gulf of Aqaba, during February-March 1999 using a 150 KHz ADCP mounted on the RV Meteor (Manasrah et al., 2004). These unique observations reveal a sequence of flow changes with time and space (Fig. 2.12). These changes do not match the basic tidal motion, and represent in some parts a phase difference in the horizontal current components of about 90°. These appear to be a chain of cyclonic and anti-cyclonic eddies positioned along the Gulf axis and occupying at least the upper 300m of the water column (Manasrah 2002; Manasrah et al 2004). The diameter of eddies ranged from 5 to 8 km with velocities ranging from 0 to 0.30 ms^{-1}. Some of this spatial variability is seen in Figure 2.13; a plot of spatial variability in the northern Gulf taken from Manasrah (2002). This spring-time data show that the current in the upper 200 m in the western and eastern parts of the northern Gulf of Aqaba was dominantly directed to the NE, while in the centre the current was mainly SE. Consequently, an anti-cyclonic circulation was observed in the upper 150 m between the western and central parts. Between 200 m to 300 m the NE current still dominated in the western part, while a transition from NE to SE can clearly be seen in the east. Obviously, the two opposite currents are parts of a larger anti-cyclonic circulation between eastern and western parts.

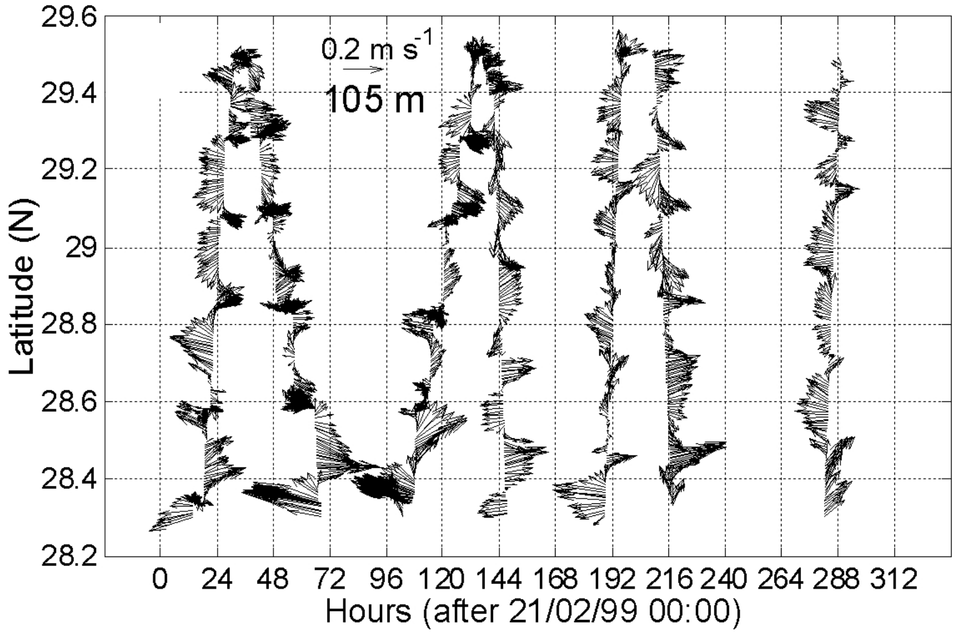

Figure 2.12: Time-latitude distribution of the current vectors along the axis of the Gulf of Aqaba at 105 m depth on repeated tracks during February 21st-March 6th 1999.

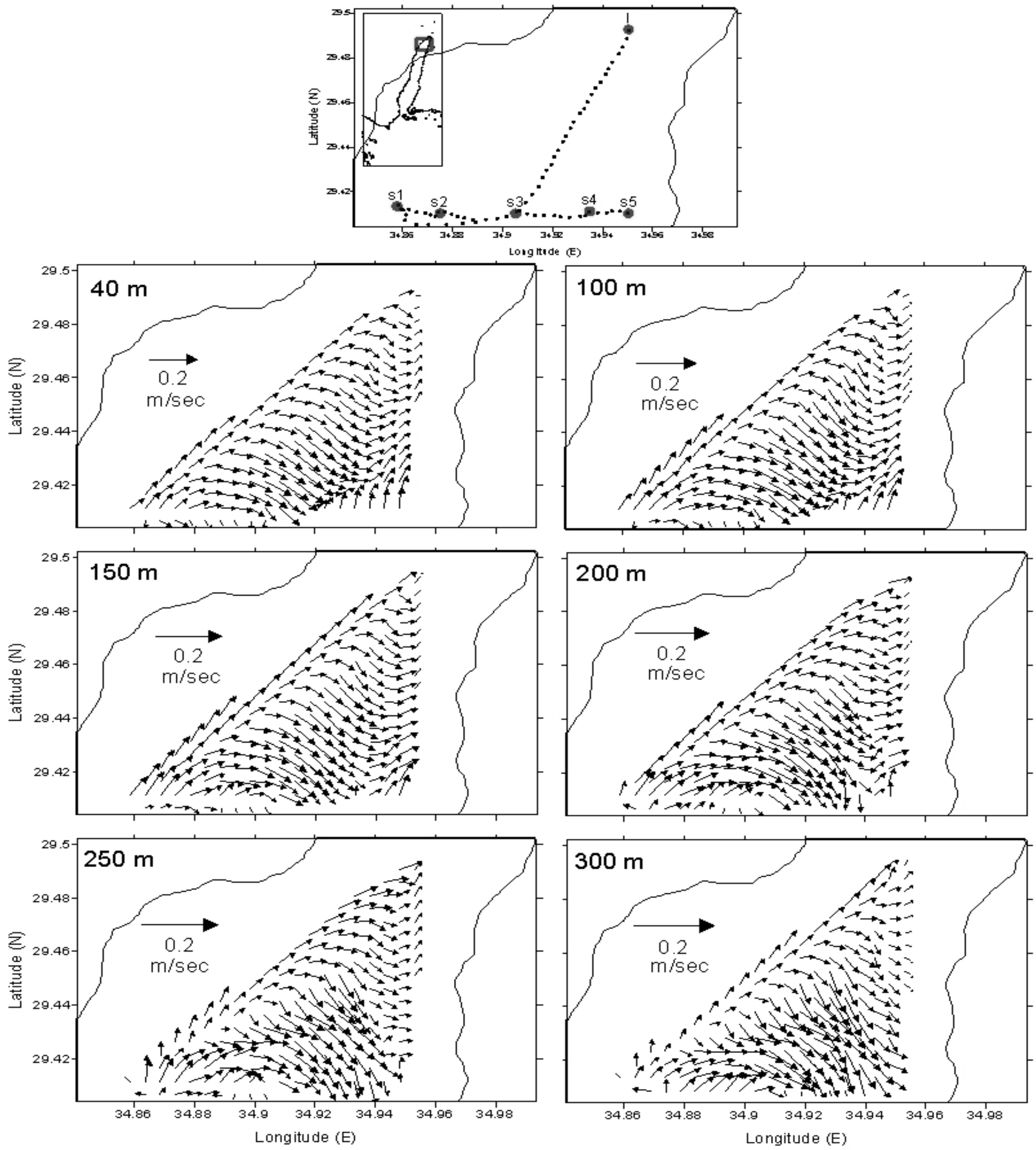

Figure 2.13: Distribution of the horizontal current vectors in the Northern Gulf of Aqaba at selected depth levels during March 5th 01:40-March 6th 16:00 1999.

Conversely to what observed at the whole gulf scale, in the northernmost part (10km) of the gulf, HF radar measurements of the surface currents reveal that coherent eddies are very rare, and appear only few times a year between November and April (Gildor et al., 2010). Therefore, it is not clear how much such eddies contribute to horizontal mixing in this region.

Since August 2005, Two 42 MHz SeaSonde HF radar systems have been operational in the northern gulf near the city of Eilat, and since July 2008 an additional station was installed on the Jordanian side near the MSS. This network is used to measure the complex surface circulation structure of the northern Gulf of Aqaba with very high spatial (300 m) and temporal resolution (30 min) (Gildor et al., 2009). Each of these stations measures the radial velocity of the surface currents. To reconstruct the velocity at a certain patch of water, at least two radar sites should measure the radial velocity there from two different angles (ideally with at least 15° difference). Strictly speaking, the radar measures the currents at the top few tens of cm of the water column. However, comparison to measurements by an Acoustic Doppler Current Profiler (ADCP) demonstrate that the shear in the top few meters is usually small, and most of the time the surface currents represent the upper 10-20 m.

The surface flow field can be quite complex and incoherent, as reported before. Often it is more structured, with the main component aligned with Gulf axis, and smaller east-west component (Fig. 2.14). However, due to the strong tidal signal, the direction of the flow changes twice a day.

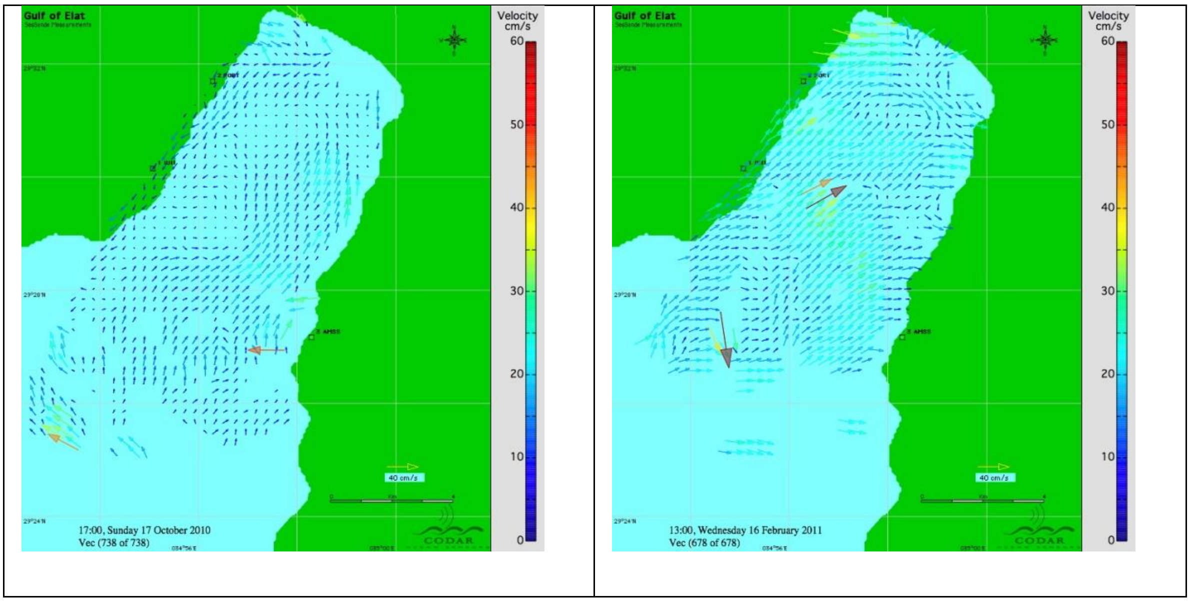

Figure 2.14: Two snapshots from the surface currents measured by the HF radar network during October 2010 and February 2011 (After: Red-Dead study 2011).

Occasionally (about 30% of the time, Gildor et al., 2009), temporary barriers to mixing exist at certain sub-regions and can "trap" water masses for 1-3 days. This may have important implications for the dispersion of pollutants, nutrients, larvae, etc., and therefore for a wide range of predictions. The mechanism behind the barriers is still unknown and further analysis is required to better understand their evolution and their effect on the ecological system.

Rarely, only few times a year between November and March, a coherent eddy occupying most of the region and lasting for a day or so was observed (Fig. 2.15 and Gildor et al., 2010). Although the shape and centre of eddies change in time, they are the dominant feature in the gulf when they are present. The associated velocities are relatively high, and can reach 100 cm s^{-1} near edge of the eddies, compared to the averaged velocities of 15 cm s^{-1} observed over most of the year. In addition, such eddies appear usually under calm condition, when the wind is relatively weak. The mechanism behind the formation of such coherent eddies is yet unclear. Large velocities appear also during strong storms, such as during February 15, 2011. An example can be seen in Figure 2.16.

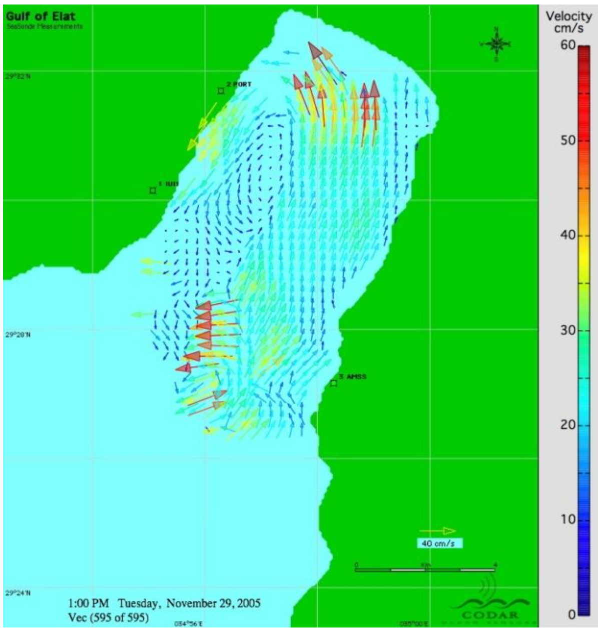

Figure 2.15: An example of coherent eddy from November 2005 (After: Red-Dead study 2011).

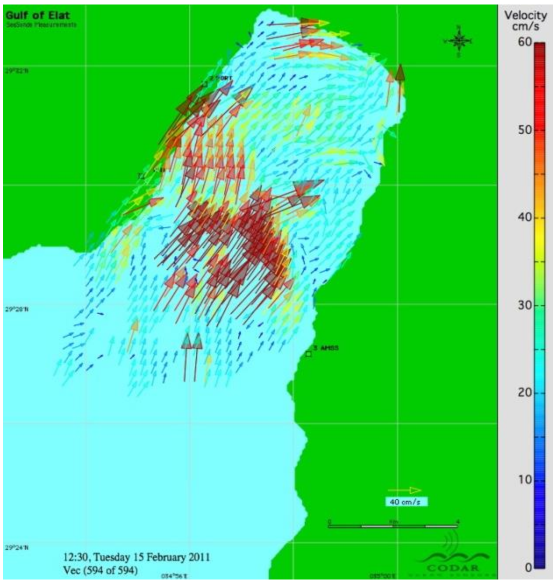

Figure 2.16: Surface currents during the southern storm of February 15, 2011 (After: Red-Dead study 2011).

The HF radar data can also be used to estimate the connectivity between the two sides of the gulf by advecting virtual passive particles. In order to do that, we need to fill spatial gaps and filter outliers. As the data collected during this year is still under processing, we demonstrate the idea using data from 2006 that was used in Carlson et al., 2010. The spatial gaps at each HF radar measurement time were filled using open-boundary modal analysis (OMA)[1], described by Lekien et al. (2004) for mapping total velocities and by Kaplan and Lekien (2007) for mapping radial velocities.

Within the context of this project we have developed a hierarchy of numerical circulation models to help assess the potential impacts of water abstraction from the gulf. The first set of simulations for this purpose consists of the control runs in which the models are used to reconstruct the present circulation. Since the models produce information at all locations and times, the control runs provide additional insight that the field measurements alone cannot. For example, Figure 2.17 shows the mean simulated temperature at a depth of 9.5 m (depth of the proposed northern intake) averaged over 60 M2 (principal lunar semi-diurnal) tidal cycles (~31 days) for the month of Aug 2010. In general the water in the gulf is cooler than the water of the northern Red Sea with a clear south to north temperature gradient. Two main features that clearly stand out are the inflow of the Red Sea water which forms a tongue that flows along the eastern shore, and the band of cooler temperatures along the eastern and northern shores which is indicative of the wind induced upwelling observed by Labiosa and Arrigo (2003) in satellite images.

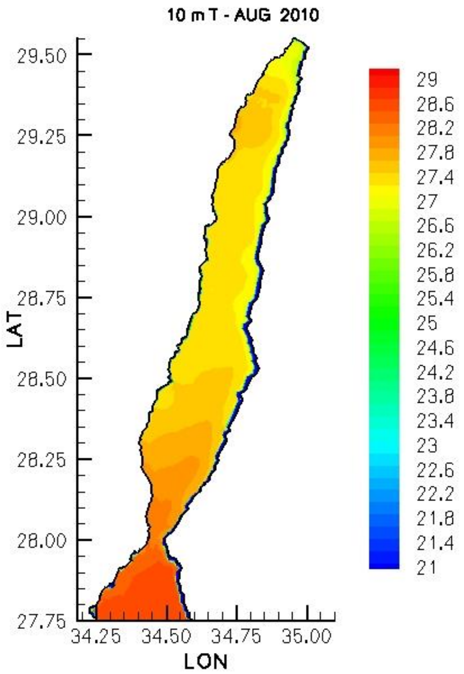

Figure 2.17: Simulated temperature at 9.5 m averaged over 60 tidal cycles for the month of August 2010 (After: Red-Dead study 2011).

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[1] The OMA procedure objectively maps the HF radar measurements using three sets of basis functions that are truncated at a specified spatial resolution. Dirichlet modes (with zero horizontal divergence) represent the flow's vorticity structure. Neumann modes (with zero relative vorticity) account for horizontal divergence. Boundary modes are used to represent the normal flow through the analysis domain open boundaries. Radial velocities were objectively mapped using the procedure of Lekien et al. (2004) as detailed in Lekien and Gildor (2009), with a spatial scale of approximately 350 m. This spatial resolution threshold resulted in a set of 100 Dirichlet modes, 130 Neumann modes, and 40 boundary modes (Lekien and Gildor 2009).

Figure 2.18 (Mar 2010) and Figure 2.19 (Aug 2010) show the residual currents at 25m averaged over 60 tidal cycles. As noted above, it is the mean currents, not the high frequency tidal fluctuations, which are of primary importance since they will control most of the transport of dissolved and suspended particles in the gulf.

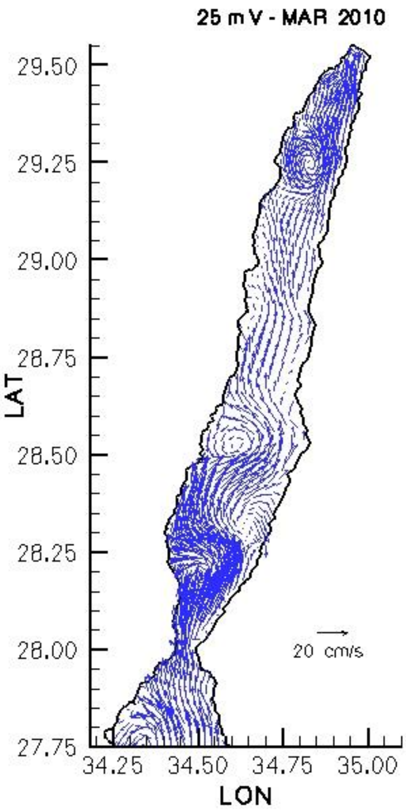

Figure 2.18: Simulated currents at 25 m averaged over 60 tidal cycles for the month of March 2010(After: Red-Dead study 2011).

The intense inflow of Red Sea water is quite apparent. The appearance of a chain of alternating cyclonic and anticyclonic eddies aligned along the gulf is also quite apparent as reported in previous modelling studies (e.g. Berman et al., 2000; 2003) as well as in the ADCP measurements reported by Manasrah et al. (2004) and Manasrah (2002) and as shown above in Figure 2.12. In the meandering jet that forms the boundaries of these eddies, the mean current speeds can often exceed 20 cm/s. It is also interesting to note that no coherent eddy appears in the northernmost part of the gulf which is consistent with the HF radar measurements of near surface currents reported above.

A similar map of the simulated, residual currents at 25 m for the month of Aug 2010 is shown in Figure2.19. Here too the chain of eddies is apparent as is the intense inflow of Red Sea water which flows along the eastern shore. Similarly no obvious coherent eddy appears in the northernmost region. It is quite possible that the constricted width of the northernmost section precludes the formation of such persistent eddies.

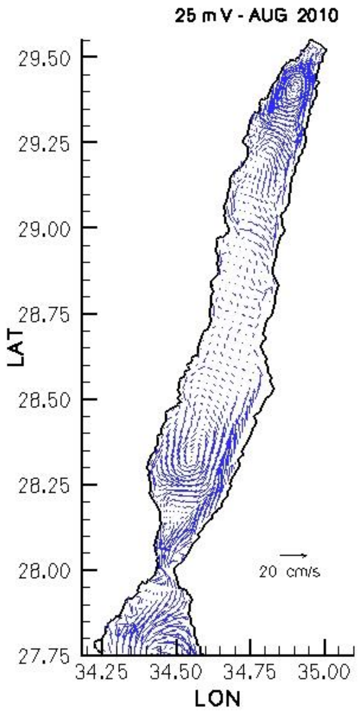

Figure 2.19: Simulated currents at 25 m averaged over 60 tidal cycles for the month of August 2010 (After: Red-Dead study 2011).

2.7.4 SEAL LEVEL AND TIDES

Over the last 100 years, the global sea level has risen at a rate close to 1-2 mm per year (Gornitz 1993; Tsimplis and Woodworth 1994; IPCC 2007). The most recent estimates of global average sea level rise over 10 years were 2.1 ± 1.2 mm/yr (Nerem et al. 1997), 1.4 ± 0.2 mm/yr (Cazenave et al. 1998) and 3.1 ± 1.3 mm/yr as measured by satellite data (TOPEX/POSEIDON) every 10 days over approximately five years (Nerem 1999). Sea level variations vary from region to region and could have serious consequences on coastal environments (e.g. Titus and Narayanan 1996). Therefore, a regional assessment of sea level increase is necessary. This can be estimated using statistical and numerical modelling approaches through field observations. Mean-sea-level data from coastal tide gauges in the north Indian Ocean were used to show that low-frequency variability is consistent among the stations in the basin. Statistically significant trends obtained from records longer than 40 years yielded sea level-rise estimates between 1.06-1.75 mm/yr, with a regional average of 1.29 mm/yr (Unnikrishnan and Shankar 2007). Tide gauges that measure the height of the sea relative to a nearby geodetic benchmark make the most straightforward measurements of sea level (Emery and Aubrey 1991). Beyond instrument platform effects, subsidence or emergence of the land at any specific location modifies the rate of relative sea level rise in that area. A long and continuous record of such measurements plays a crucial role as the available long-term records show common sea level fluctuations persisting over decades (e.g. Douglas 1992). Cui et al. (1995) identified three causes for regional sea level change: geological, regional dynamics and large-scale dynamics. The regional processes include the inverse barometric effect, the fresh water input, and the local atmospheric and oceanic circulation.

In the Red Sea, long-term sea level variations are mainly influenced by the effect of wind stress and the combined effect of evaporation and water exchange through the Strait of Bab al-Mandab (Edwards 1987; Sultan et al. 1995; Sultan et al. 1996). However, the main processes, wind stress and evaporation, compete with each other and their impact on sea level change is revealed over different time scales. Previous studies in the area, which investigated the seasonal sea level changes in the Red Sea, revealed high sea level values in winter and low values in summer (Morcos 1970; Osman 1984; Osman 1985; Edwards 1987; Sultan et al. 1995; Sultan et al. 1996). Sea level is a highly variable hydroclimate element, both spatially and temporally, at different time scales (inter-annual and intra-annual) (Manasrah et al. 2009).

In the Gulf of Aden tides are generally diurnal, or a mix of diurnal and semi-diurnal tide. The maximum spring range at Aden is 2.7 m. At the eastern end of the Gulf of Aden the tide becomes more semidiurnal, with a maximum range of about 2.7 m. The tidal range in the Red Sea is low (average spring range about 0.5 m) in the southern and northern parts, decreases from both ends of the Red Sea towards the centre and becomes negligible near Jeddah, where there is no appreciable semi-diurnal tide.

The tide of the Indian Ocean and Gulf of Aden does not affect that of the Red Sea, the tidal regime is a local oscillatory type with a semi-diurnal characteristic. The oscillation is not large, and when it is high water in the northern part of the Red Sea it is low water in the southern part, and vice versa. The Red Sea tidal oscillation enters the Gulf of Aqaba, giving a spring range in the Gulf of between 0.6 and 1.2 m. High tide occurs almost simultaneously over the whole of the Gulf of Aqaba (PERSGA 2006).

Tides in the Gulf of Aqaba are minimal, with a range on the order of one meter or less. They are semidiurnal (two high and two low tides every 24 hours).Tides in the northern Gulf of Aqaba have been measured continuously at 10 minute intervals at a fixed point at the Marine Science Station (MSS) and readjusted with reference to Mean Sea Level (MSL). The maximum recorded sea level range during 2004 was 1.42 m. The highest value was 0.94 m above MSL observed on 15 November 2004 whereas the lowest was -0.48 m below MSL recorded on 31 August 2004. Table 2.3 shows the average tidal characteristics recorded at the Aqaba Ports (ADC 2008).

Table 2.3: Tidal characteristics at the Aqaba Ports (ADC 2008) after National Imagery and Mapping Agency, 2002).

Datum	**Elevation (LAT, Meters)**
Highest Astronomical Tide (HAT)	+1.5
Mean high water springs	+1.10 (MHWS)
Mean low water springs	+0.30 (MLWS)
Mean high water neaps (MHWN)	+0.90
Mean low water neaps (MLWN)	+0.50
Mean sea level (MSL)	+0.70
Lowest astronomical level tide (LAT)	+0.00

Tides in the northern Gulf of Aqaba have been measured continuously with 10 minutes interval at a fixed point at the MSS and readjusted reference to the Global Mean Sea Level (MSL) and Multi-Annual Mean (MAM). The tide gauge measured sea level variation in the year 2013 till March 17th due to technical problems in the gauge. The annual mean of the sea level reference to the Global MSL and MAM for the years 2004-2013 are summarized in Table 2.4. Mean sea level of the Gulf of Aqaba reference to the Global

MSL during the year 2013 was about 16.0 ± 28 cm compared to 4.1 ± 24 cm during the year 2012. This implies that about 12 cm difference in mean sea level between the year 2013 and 2012. However, the Mean seal level records relative to two references (Global MSL and MAM) revealed relatively fixed annual difference of about 28.9 cm, i.e. the multi-annual mean sea level of the Gulf of Aqaba recorded herein is about 28.9 cm higher than the Global sea level average of world oceans (National Monitoring Programme 2013).

The maximum sea level range reference to Global MSL during the year 2013 was 154.3 cm. The highest value was 101.7 cm observed on December 12th, and the lowest value was -52.6 cm recorded on April 23rd (Figs. 2.20 and 2.21) (National Monitoring Program 2013). The seal level anomalies mostly depict a clear yearly cycle (Table 2.5), where the lowest monthly mean anomaly (5.0 cm) was in June. The highest monthly mean anomaly was 47.4 cm that occurred in November (National Monitoring Programme 2013).

Table 2.4: Annual mean of the sea level (cm) at the northern Gulf of Aqaba reference to Global Mean Sea Level (MSL) and to Mutli-Annual Mean (MAM) for the years 2004-2013. (National Monitoring Programme 2013).

Annual mean of the sea level (cm)			
Year	**Ref.: Global MSL[1]**	**Ref.: MAM[2*]**	**Difference[1-2]**
2004	16.4	-10.4	26.8
2005	16.8	-10.1	26.9
2006	15.6	-14.4	29.0
2007	0.5	-27.9	28.4
2008	8.9	-19.8	28.7
2009	5.2	-23.3	28.5
2010	7.2	-21.5	28.7
2011	-11.7	-39.7	28.0
2012	4.1	-24.4	28.5
2013	16.0	-12.9	28.9

: Multi-Annual Mean (MAM) was calculated for 10 years (2004-2013)

Table 2.5: Monthly statistical summary of the tidal records (cm) at the Northern Gulf of Aqaba reference to Global Mean Sea Level (MSL) during the year 2013 (National Monitoring Programme 2013).

Month	Readings	Mean	Min.	Max.	Range	Std. Dev.	Std. Err.
Jan	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Feb	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mar	2100	17.3	-28.64	63.8	92.5	21.4	0.47
Apr	4320	8.3	-52.60	68.3	120.9	25.1	0.38
May	4464	19.4	-43.13	66.2	109.3	24.4	0.37
Jun	4320	5.0	-41.78	54.6	96.4	23.3	0.35
Jul	4464	5.9	-44.97	56.3	101.3	22.3	0.33
Aug	4464	8.3	-43.91	66.5	110.4	23.3	0.35
Sep	4320	6.8	-43.62	61.9	105.5	24.3	0.37
Oct	4464	20.8	-42.55	73.8	116.4	25.1	0.38
Nov	4320	47.4	-0.71	88.8	89.5	23.4	0.36
Dec	3888	22.9	-52.31	101.7	154.0	32.9	0.53

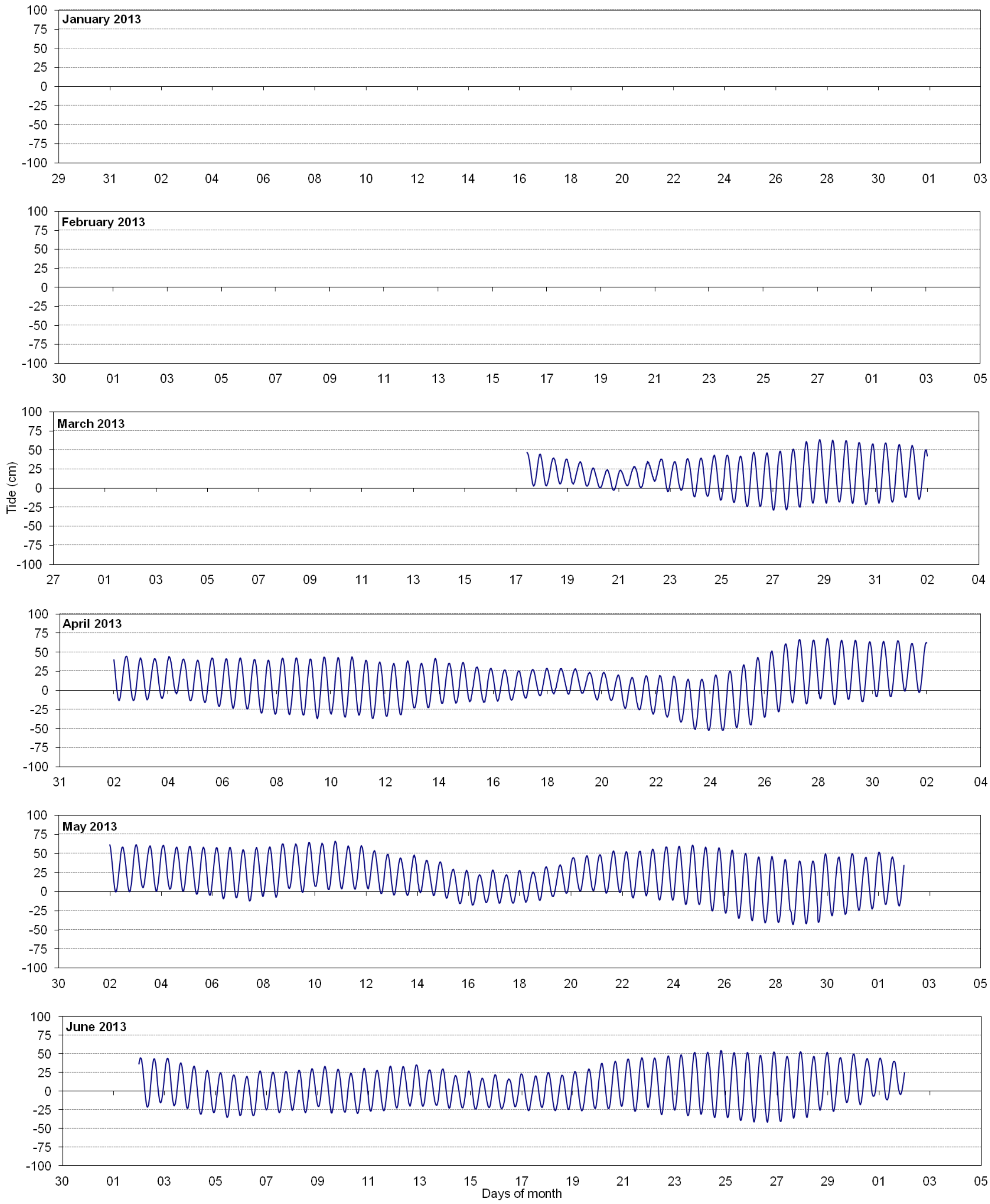

Figure 2.20: Tidal records (cm) at the Northern Gulf of Aqaba reference to Global Mean Sea Level (MSL) for the months January-June 2013 (National Monitoring Programme 2013).

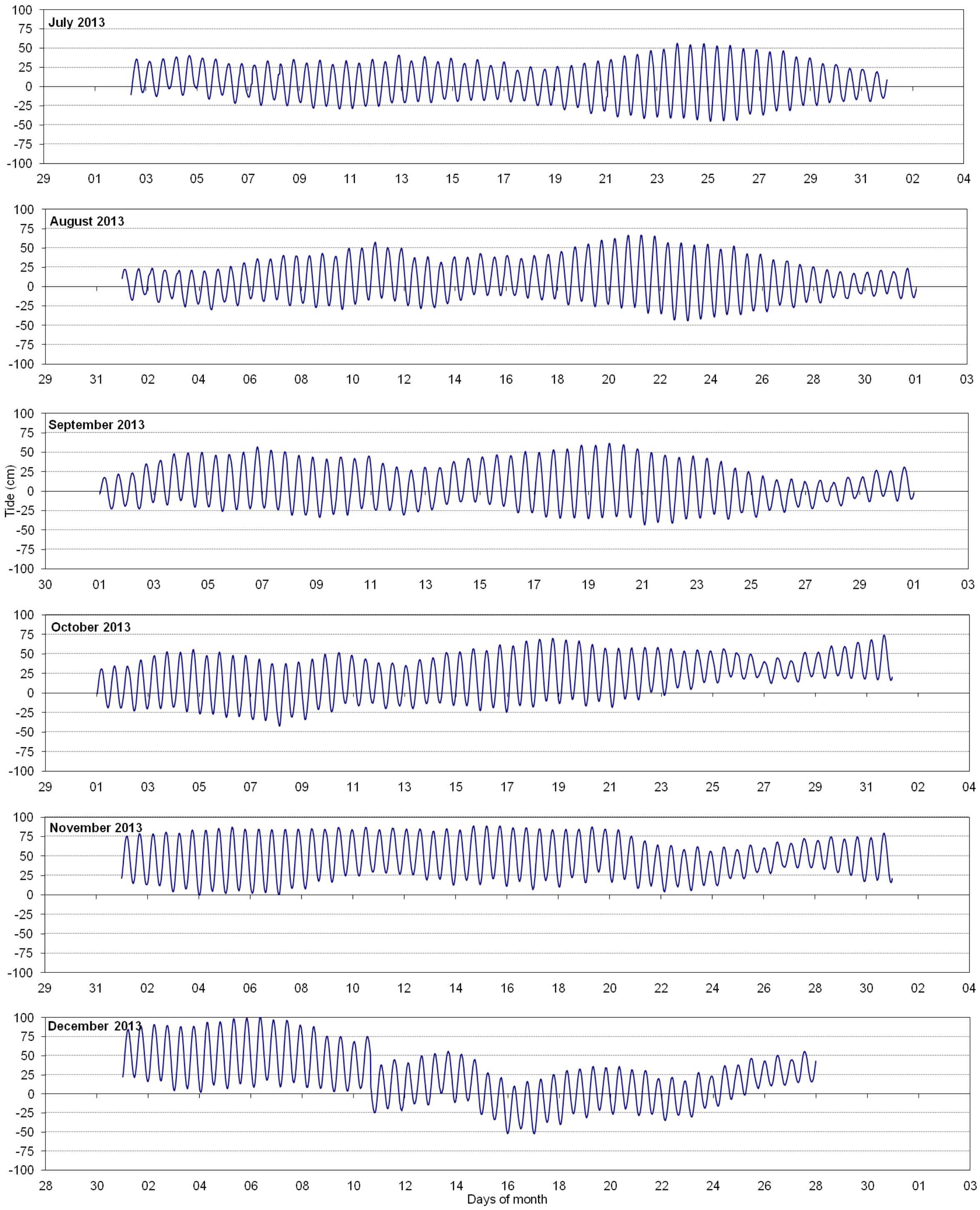

Figure 2.21: Tidal records (cm) at the Northern Gulf of Aqaba reference to Global Mean Sea Level (MSL) for the months July-December 2013 (National Monitoring Programme 2013)

The yearly cycle of the sea level anomalies at the northern Gulf of Aqaba follows the corresponding sea level variations in the Red Sea. The sea level changes of the Gulf of Aqaba are determined by the water balance of the Red Sea. Bogdanova (1974) reported that the level differences between the Red Sea and Gulf of Aden depends on the following factors: (i) real decrease of the water volume due to intensive evaporation from sea surface (ii) the variation of a positive component of water exchange through Bab el Mandeb and Suez Canal and (iii) the water redistribution in the sea due to the wind (Table 2.6). The average sea level in the northern Gulf of Aqaba during the year 2013 was almost the same in the Red Sea. This indicates that stable conditions in the northern Gulf of Aqaba dominated with respect to air pressure, winds evaporation rate.

In general, during the period December-May, wind induced water movement driven by the north-east monsoon, has a net flow from the Indian Ocean to the Red Sea, which results in elevating the water level in the Red Sea and the Gulf of Aqaba Table 2.6. During the period July-October, the wind induced water movement, due to the south-west monsoon, has a net flow from the Red Sea to the Indian Ocean, which results in a lower water level in the Red Sea and consequently in the Gulf of Aqaba, see Table 2.6 after Bogdanova (1974) (National Monitoring Programme 2013).

Table 2.6: Annual sea level (cm) variation in the Red Sea relative to the long term mean between central, northern, and southern parts.

Point of observations	Set of observations	Month												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Amp.
Suez[1]	12	10	9	9	12	6	0	-12	-21	-18	-12	3	12	33
Sudan[2]	37	13	9	6	7	5	-5	-16	-22	-14	4	11	11	35
Perim[3]	6	6	6	5	3	9	3	-6	-12	-15	9	-3	3	21
Aden[4]	25	5	7	7	10	10	4	-6	-14	-12	-10	-3	1	25
Level differ (cm)														
(2)-(1)		3	0	-3	-5	-1	-5	-4	-1	4	8	8	1	13
(2)-(4)		8	2	-1	-2	-5	-9	-10	-8	-2	6	14	10	24
(2)-(3)		7	3	1	4	-4	-8	-10	-10	1	5	14	8	24
(3)-(4)		-1	-1	-2	-7	-1	-1	0	2	-3	1	0	2	9

Bogdanova (1974)

2.7.5 RED SEA AND GULF OF ADEN WATER EXCHANGE VIA BAB EL MANDEB

Bab el Mandeb is a relatively narrow and shallow sill with a width of around 12 km, and a depth between 140 m on the east side (Yemeni side) to 290 m on the west side (Djiboutian side). This depth restriction limits the influence of the Indian Ocean on the

Red Sea. Evaporation in the Red Sea is high, estimated at around 2 m y^{-1}, while annual precipitation does not exceed 10 mm. Thus a net inflow of water from the Gulf of Aden to the Red Sea is required to maintain water levels in the Red Sea. It is estimated (Edwards 1987) that the water renewal time in the upper 200 m of water. The water above the thermocline is of the order of 6 years, while the time for turnover of water for the whole Red Sea is about 200 years. The flow through Bab el Mandeb is controlled in the surface layer by the monsoon winds. It is thought to consist of a wind-driven surface flow of water from south to north during the winter months when warmer water flows into the Red Sea from the Gulf of Aden. At the same, time cooler saltier water flows into the Gulf of Aden at the lowest level. During the summer months the high salinity outflow from the Red Sea is almost stopped, the flow in the surface layer is reversed, and intermediate water from the Gulf of Aden flows in to the Red Sea between the two out-flowing layers.

2.7.6 GULF OF AQABA HYDRODYNAMIC REGIMES AND WATER EXCHANGE VIA STRAIT OF TIRAN

The semi-enclosed nature of the Red Sea limits the opportunity for renewal of the water mass. The renewal times are around 200 years for the entire water body of the Red Sea (Sheppard et al. 1992), six years for the top 200 m (Sheppard et al. 1992), 30–45 years for deep waters of the Red Sea (Plähn et al. 2002), and one to two years for the Gulf of Aqaba (Hulings 1989). The Red Sea is permanently stratified by a strong thermocline so that the high nutrient concentrations in the deep waters are effectively isolated from the nutrient depleted shallow waters (Longhurst 1998). High evaporation drives a thermohaline circulation that advects nutrient-poor water from the northern Red Sea through the Straits of Tiran into the Gulf of Aqaba that is balanced by outflow of deeper dense water. The water body of the Gulf of Aqaba is more dynamic than the adjacent northern Red Sea. The Gulf of Aqaba is de-stratified during winter (December-April) to depths of at least 600 m following declining sea surface temperatures and wind mixing, resulting in elevated nutrient levels in the shallow waters (Manasarah et al. 2004).

The circulation in the Straits of Tiran, which controls the water exchange between the Gulf of Aqaba and Red Sea, has been studied by several authors (Murray 1984; Assaf, and Kessler 1976; Klinker et al. 1976; and Paldor and Anati 1979). All reports except the latest were based on calculations of heat flux and mass balance, rather than actual current measurements. The results must be considered as very preliminary so far. Nevertheless all studies agree on the general circulation pattern at the Straits of Tiran. However, they differ considerably in estimating the rate and magnitude of water exchange between the Gulf of Aqaba and the Red Sea.

Klinker (1976) described different schemes for summer and winter. In summer, they suggested a three layer water exchange system, where water from the Red Sea (q1) enters the gulf and travels northwards to about mid length of the Gulf. There, when the water has cooled and become more saline it loses buoyancy and starts to sink and travel southward (q2) beneath the in-flowing water. These two opposite water movements take place in the upper 150 m and have a stationary layer between them below 50 m. In deeper water below 150 m a third water parcel (q3) moves from the Red Sea into the Gulf of Aqaba. The extent of the northward travel of these waters has not been identified. However, in connection with the findings of the authors themselves and of Paldor and Anati (1979), that the deep-water below 150 m was uniform in temperature and salinity in the entire Gulf of Aqaba while the upper water differed significantly from south to north, it can be concluded that the deep-water inflow reported by Klinker et al. (1976), or a part of it at least, reaches the northern end of the Gulf.

The four quantities q0, q1, q2 and q3 reported by Klinker et al. (1976), were estimated by two basic assumptions; the conservation of mass and the critical Richardson condition across the Straits of Tiran. This resulted in similar values for q1 but quite different values for q3.

The conservation of mass calculation gave:

$q_0 = -280\ m^3\,s^{-1}$ evaporation from Assaf and Kessler (1976)

$q_1 = -2.38\times10^4\ m^3\,s^{-1}$ surface inflow

$q_2 = +4.55\times10^4\ m^3\,s^{-1}$ subsurface outflow

$q_3 = -2.20\times10^4\ m^3\,s^{-1}$ deep inflow

Calculations based on critical Richardson conditions across the Straits of Tiran gave:

$q_1 = -2.10\times10^4\ m^3\,s^{-1}$

$q_2 = +3.40\times10^4\ m^3\,s^{-1}$

$q_3 = -1.10\times10^4\ m^3\,s^{-1}$

In winter, the authors suggested a two layer water exchange system in the upper 150 m. Both methods for calculating the water exchange through the Strait gave similar estimates of quantities q1 (inflow) and q2 (outflow) of about $7\times10^4 m^3\,s^{-1}$.

Based on current measurements for one month duration (February) in the Straits of Tiran, Murray et al. (1984) suggested a two layer water exchange system between the Red Sea and the Gulf of Aqaba. According to these authors the water exchange in both directions was the same; $2.9\times10^4\ m^3\ s^{-1}$.

Different estimates have been reported regarding the average residence time of the water in the Gulf of Aqaba. The figure most commonly used by many authors is one year (Klinker et al. 1976; Paldor and Anati 1979; Hulings 1979).

In spring 1999, currents through the Strait of Tiran were recorded by R/V meteor cruise using a shipboard Acoustic Doppler Current Profiler 150 kHz (ADCP) covering a range of about 350 m at a bin length of 8 m and a pulse length of 16 m (Fig. 2.22). The number of bins was 60. The profiles were averaged over 2 minutes. A GLONASS/GPS-receiver was used for correction of the ship's motion and a three-dimensional GPS receiver (ADU) for highly accurate heading measurements in order to correct the Schuler oscillation of the gyro-compass (Manasrah et al. 2004).

ADCP measurements were used to study the water exchange through the Strait of Tiran; they exhibited a general view of the two-layer exchange between the northern Red Sea and Gulf of Aqaba through the Strait during February 21st–March 4th, 1999 (Fig. 2.23). Inflow (NNW) into the Gulf of Aqaba occurred in the 35–70 m of the water column over the sill. This inflow was also clear about 1.5 km to the north and south of the sill (Fig. 2.24), where the thickness was larger (35–150 m). The SSW outflow into the northern Red Sea observed below 70 m over the sill (Fig. 2.24) comprised a thick layer penetrating deeper (<200 m) about 1.5 km south and north of the sill (Fig. 2.24). The strength of the outflow to the northern Red Sea increased linearly with depth, reaching up to about 1 m s^{-1} at 200 m depth (Fig. 2.24d) (Manasrah et al. 2004).

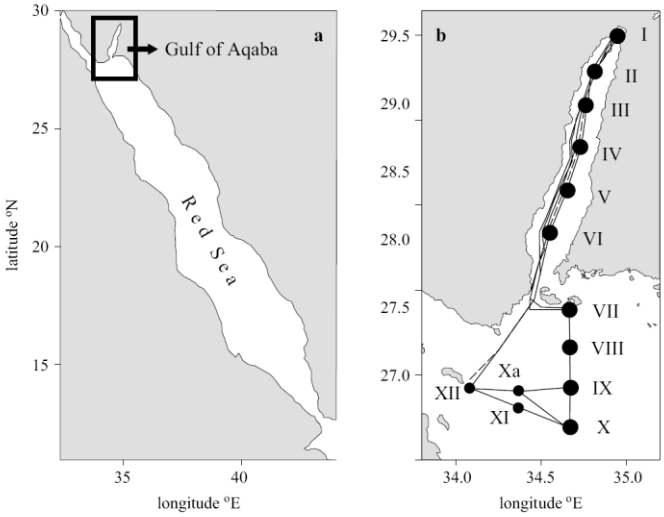

Figure 2.22: Study area map (a) and station locations (positions I–XII) and route of current measurements in the Gulf of Aqaba and northern Red Sea, r/v 'Meteor' cruise 44/2 (b).

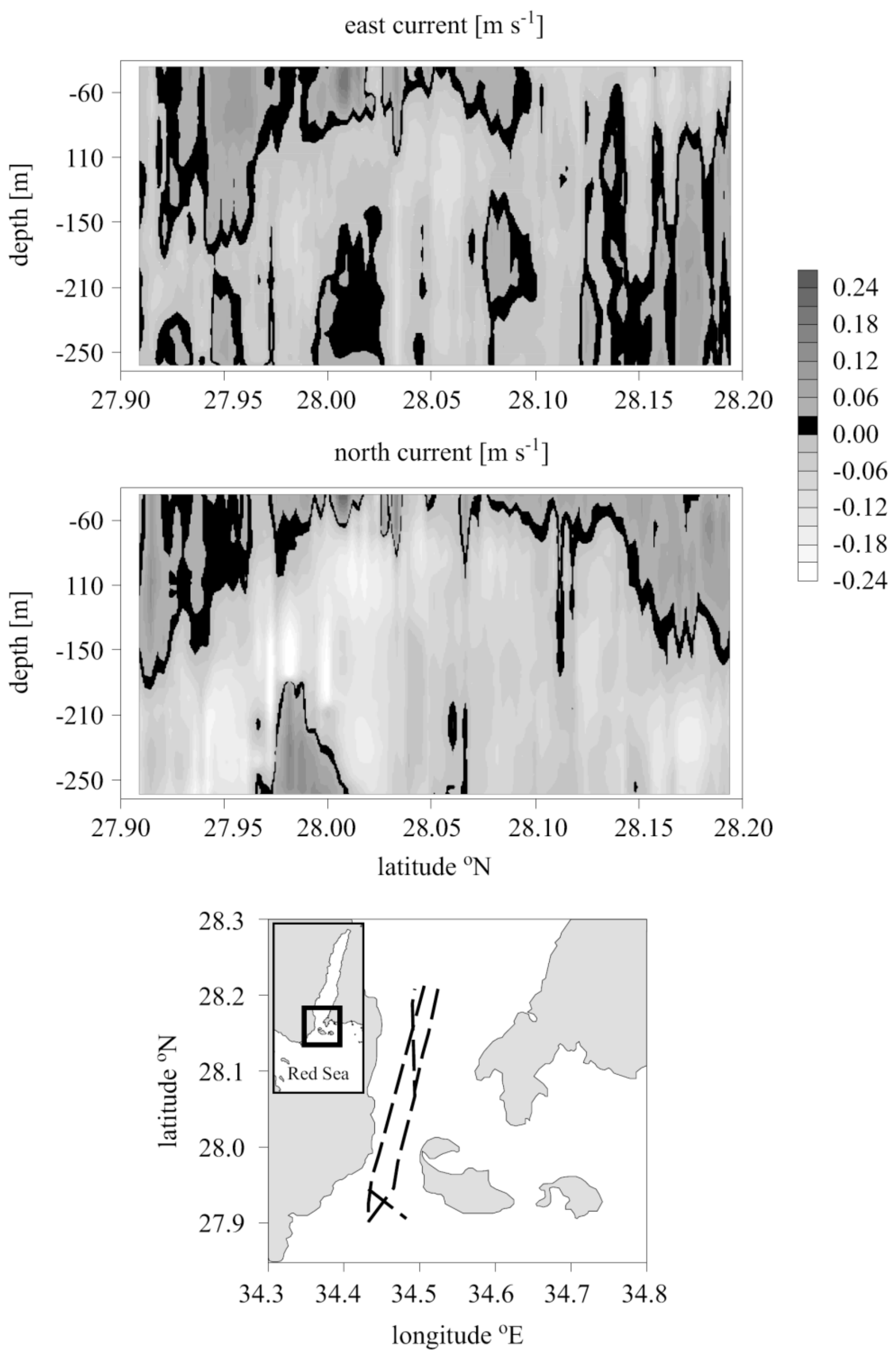

Figure 2.23: Vertical section distribution of the east and north current components [m s−1] through the Strait of Tiran during February 21st–March 4th 1999, ‘Meteor’ cruise 44/2.

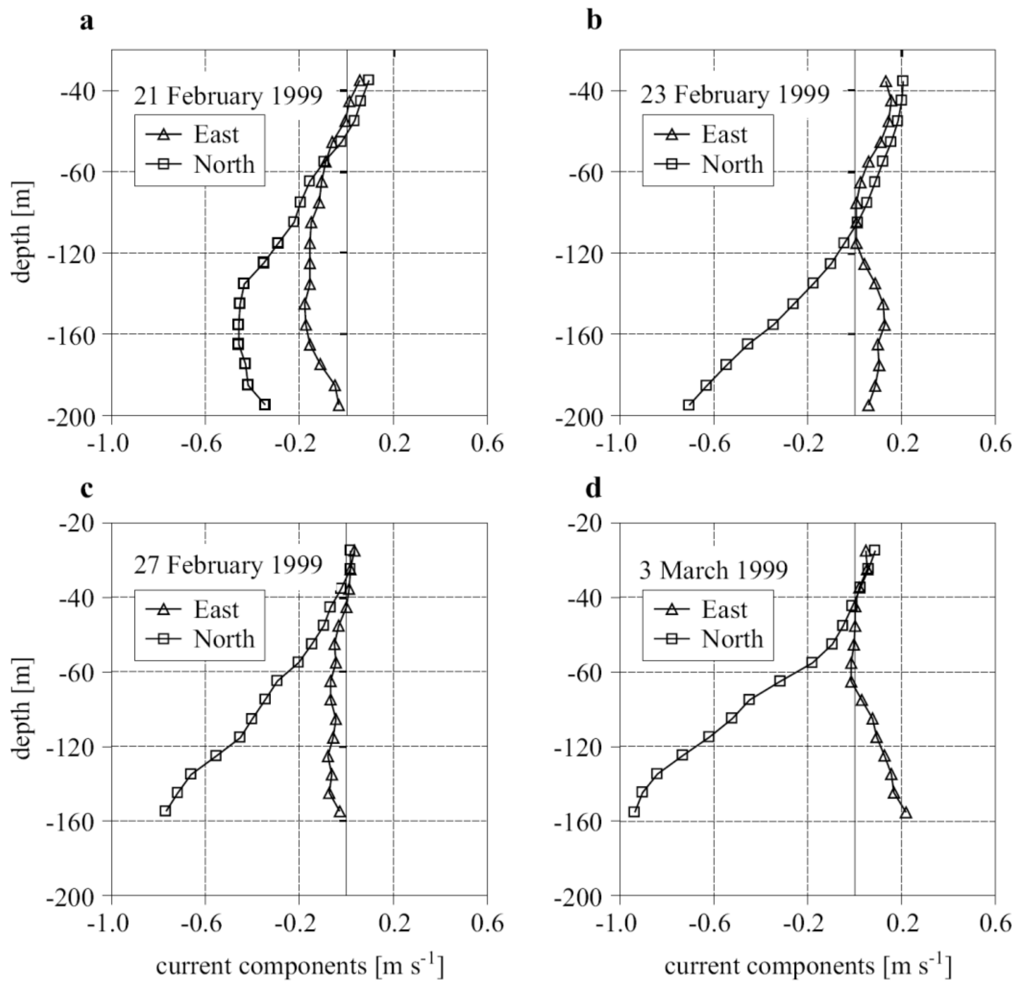

Figure 2.24: The east and north current components (all in [m s−1]) profiles at the sill of the Strait of Tiran measured on different dates during r/v 'Meteor' cruise 44/2

2.8 CHEMICAL OCEANOGRAPHY

2.8.1 GENERAL/RED SEA

2.8.1.1 Salinity

The Red Sea is warm and highly saline. Evaporation in the Red Sea is also high and averages 1–2 m yr^{-1} in both summer and winter. Similarly, very high evaporation rates occur in the Gulf of Aqaba (2 m yr^{-1}) and in the southern Red Sea (2.35 m yr^{-1}). The result of this very high evaporation is a gradual increase in salinity towards the north. Salinity at Bab el Mandeb averages 37 ‰ and in the northern Red Sea at the entrance to the Gulfs of Aqaba and Suez salinity averages 41 ‰. Salinity throughout the Red Sea is higher in summer than winter. In the northern Red Sea the seasonal variation is 1 ‰ and in the southern Red Sea the seasonal variation is 0.5 ‰. The ambient salinity levels may be very close to the physiological limits of many species, which highlights the potential sensitivity of the Red Sea biota to localised anthropogenic increases. There is an increase in salinity with depth in the Red Sea. The depth gradient is greater in the southern Red Sea due to the influence (to a depth of 200 m) of low salinity water from the Gulf of Aden.

At depths greater than 200 m in the deep basins of the Red Sea the salinity is remarkably homogeneous at 40.6‰ (with the exception of the hot brines) (Morcos 1970).Hot brines emerge from the sea floor in areas with an active seafloor rift and are characterised by very high salinity and high temperatures (Degens & Ross 1969). It occurs at depths of more than 2,000 m where water temperatures can reach up to 60°C and salinity exceeds 300‰.Vertical salinity differences are very small between 50-150m. In general, the eastern side of the Gulf is less saline, most likely due to the influx of Red Sea (ICRI, 1995).

2.8.1.2 Primary Productivity

The high transparency of the waters means that the euphotic zone is deep, extending to 77–105 m in the Gulf of Aqaba and to 74–94 m in the northern Red Sea (Stambler 2005). However, primary productivity throughout most of the Red Sea is low, relative to other oceans, due to the thermocline preventing the recycling of nutrients from deeper water to the euphotic zone. Terrestrial runoff is also very low and unpredictable and therefore nutrient supplies from rivers are very limited to non-existent. The input of terrigenous nutrients is limited to sporadic dust events (Sheppard et al. 1992).Pelagic primary productivity varies seasonally and spatially throughout the RSGA (Table 2.7). Pelagic primary productivity is high along the Gulf of Aden coastline during summer months of May to September. During this time (summer months) surface water chlorophyll can attain peaks of 3.5 to 5.5 mg chlorophyll *a* m^{-3}. The high pelagic primary productivity follows the enrichment of the shallow waters with cool, nutrient-rich water upwelling from the depths of the Gulf of Aden during the south-west monsoon.

Table 2.7: Annual average primary productivity (g carbon m^{-2} d^{-1}) in the Red Sea and Gulf of Aden (Sheppard et al. 1992).

Location	**Primary productivity** g carbon m^{-2} d^{-1}
Gulf of Aqaba	0.2 – 0.9
Gulf of Suez	0.22
Northern Red Sea	0.21 – 0.50
Central Red Sea	0.39
Southern Red Sea	1.60
Gulf of Aden	1.60

Movement of Gulf of Aden surface water into the southern Red Sea extends high pelagic primary productivity to 19°N.By this point the water body is nutrient-depleted because the dissolved nutrients in the northward flowing water body have been reduced by phytoplankton uptake. This transition between the northern and southern Red Sea according to productivity and nutrient status is also matched by transitions in many floral and faunal groups. Seasonal peaks of chlorophyll in the northern Red Sea occur in spring (February–May) when surface water concentrations reach 0.4 mg chlorophyll *a* m^{-3}. Significant primary production occurs at 200 m in the Gulf of Aqaba due to high water transparency (Sheppard et al. 1992).

The Gulf of Aqaba water is characterized as oligotrophic; with average inorganic nutrient concentrations for phosphate, nitrate and nitrite in surface offshore waters rarely exceed 0.2, 0.7, and 0.2 µM, respectively. And shallow and stable thermocline present for most of the year, except during the winter season when the water column become mixed due to the convective mixing of the deep; nutrient-rich waters flowing to the surface. This leads to higher productivity during winter season and low productivity during summer. With Chlorophyll *a* concentration reaching their lowest concentration during summer and highest concentration during winter ranges from 0.08-0.52 ug/L and 0.09-0.53 µg/L, for waters in front of MSS and offshore, respectively.

Figure (2.25) shows Chlorophyll *a* concentrations measured in water samples collected from 13 stations (green circles) in the Jordanian Gulf of Aqaba during the period (2009-2013). Diameter of the green circles corresponds to the Chlorophyll *a* concentration, illustrating the difference in productivity between stations.

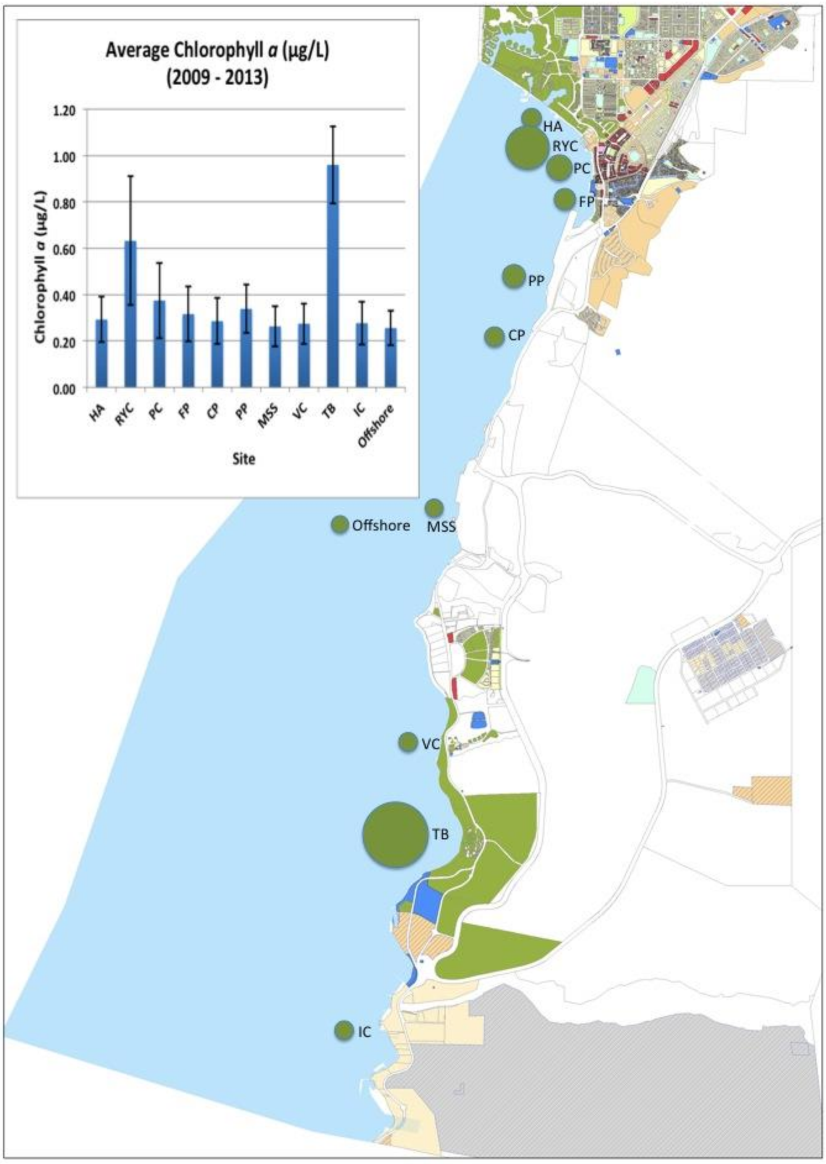

Figure 2.25: The average Chlorophyll *a* concentration (µg/L) over the years (2009-2013). It shows the range of Chlorophyll *a* between years. HA: Hotels area, RYC: Royal Yacht Centre, PC: Public Beach, FP: Fishers Port, CP: Clinker Port, PP: Passengers Port, MSS: Marine Science Station, VC: Visitor Centre, TB: Tala Bay, IC: Industrial Complex, Offshore: Offshore station (control station).

The strong seasonal fluctuations in the waters of the Gulf of Aqaba associated with destratification cause a seasonal succession in the phytoplankton community that is more like temperate waters than tropical waters (Lindell & Post 1995; Post et al. 2002).

2.8.1.3 Nutrients

Nutrients (nitrogen, phosphorous, and silica) are utilised by phytoplankton for growth and reproduction. The Red Sea is regarded as oligotrophic except for small areas off the Sinai Peninsula, the transition zone between the Red Sea and Indian Ocean, and local areas of anthropogenic enrichment. There are no known upwellings in the Red Sea due to stratification and limited mixing (Weikert 1987). In late winter-early summer the surface waters near Jeddah experience nutrient enrichment resulting from the regeneration of nutrients from winter plankton blooms (Shaikh et al. 1986). The Gulfs of Aqaba and Suez are nutrient-poor compared with the Indian Ocean (Sheppard et al. 1992). Nutrient concentrations in the northern and central Red Sea are lower than the southern Red Sea. This is attributed to the inflow of nutrient-rich waters from the Gulf of Aden in late summer that leads to a 25% increase in nutrient concentrations in the southern Red Sea relative to the central Red Sea (Thiel 1990).Maximum concentrations of phosphate in the southern Red Sea in October follow upwellings in the Arabian Sea in August and September.

Phosphate (PO4) levels are below 1.5 mg m^{-3} in the northern Red Sea with a sudden drop in surface water nutrients north of 19°N (Sheppard et al. 1992). Surface water phosphate levels vary seasonally in the Gulf of Aqaba, ranging between 0–0.25 µM in summer (May- November) and 0.75–1.0 µM in winter (December-April) (Badran 2001). Nitrate concentrations decrease northwards so that levels are very low in the waters of the northern Red Sea and Gulf of Suez. Surface water nitrate levels vary seasonally in the Gulf of Aqaba, ranging between 0–0.05 µM in summer (May-November) and 0.05–0.1 µM in winter (December-April) (Badran 2001).

Average silicate concentrations throughout the Red Sea are low, averaging between 0.1 and 0.8 µg kg^{-1}. Maximum silicate concentrations (25 µg kg^{-1}) occur in the southern Red Sea at depths between 80 and 200 m. Seasonal variations in silicate concentrations follow the variations in phosphate concentrations (Rushdi 1996).Surface water silicate levels in the Gulf of Aqaba range from0–1.1 µM in summer (May-November) to 1.1–1.4 µM in winter (December-April) (Badran 2001).

2.8.1.4 Dissolved Oxygen

Concentrations of dissolved oxygen in the Red Sea are determined by horizontal and vertical water circulation, water temperature, and salinity. Dissolved oxygen is lowest in warm waters of high salinity. Dissolved oxygen levels are near saturation (i.e. 4.8–6.5 ml O_2 L^{-1}) in surface waters in most of the Red Sea and Gulf of Aden (Sheppard et al. 1992; Quadfasel and Baudner 1993). Dissolved oxygen is typically high in the northern and southern Red Sea, and lower in the central Red Sea. This spatial variation is associated with lower water temperatures in the north and high primary productivity in the south. Dissolved oxygen concentrations in surface waters are lower in summer than winter due to higher temperatures and salinity (Poisson et al. 1984). The saturated layer in the Red Sea extends to a depth of about 100 m, after which values drop to 10–25% saturation in the oxygen minimum layer and then rise to double this in the deep water layer. In the Gulf of Aqaba there is a gradual decline with depth but never below 50% saturation. In other parts of the Red Sea dissolved oxygen reaches minimum concentration at 400–600 m depth. In this layer dissolved oxygen concentrations vary between 0.5 and 1.75 ml L^{-1}.

Dissolved oxygen in deep waters is higher than the intermediate depths. The physical and chemical seawater data results collected in front of the Industrial Complex of the Jordanian Phosphate Mining Company (JPMC) during the year 2006 are shown on Table 2.8.

Table 2.8: Monthly averages of measured physical and chemical offshore water parameters for the year 2006 in front of the MSS (ADC, 2008).

Month	Year	Temp. (ºC)	Oxygen (mg/l)	NH4+ (µM)	NO3- (µM)	NO2- (µM)	PO4-3 (µM)
January	2006	21.60	7.21	0.28	0.33	0.20	0.04
February	2006	21.44	7.35	0.39	0.29	0.12	0.05
March	2006	21.52	7.29	0.29	0.46	0.05	0.04
April	2006	22.27	7.22	0.31	0.36	0.05	0.05
May	2006	22.58	7.11	0.25	0.30	0.03	0.05
June	2006	24.94	6.93	0.28	0.16	0.03	0.04
July	2006	25.66	6.80	0.27	0.12	0.02	0.05
August	2006	25.39	6.65	0.30	0.17	0.02	0.03
September	2006	24.80	6.74	0.20	0.12	0.02	0.03
October	2006	25.08	6.69	0.20	0.17	0.03	0.05
November	2006	24.81	6.94	0.26	0.27	0.04	0.04
December	2006	23.06	6.86	0.96	0.41	0.07	0.03

2.8.2 THE GULF OF AQABA

2.8.2.1 pH

The acidity of seawater measured usually by the pH which is an important parameter in assessing water quality. It is used for calculating carbonate, bicarbonate, and CO_2 concentration and stability index. It offers a direct measure of the acidity or alkalinity of certain waters. It governs the water solvent properties and determines the extent and type of physical, biological and chemical processes likely to occur within a water body or between water and surrounding soils or rocks. Productivity and community structure of aquatic species are liable to be adversely affected by a decrease of about 0.5 to 1.0 pH units in natural surface waters with pH normally within the range of 6.5 to 8.5 units. Thus, it is obvious that monitoring the pH of the aquatic environment is valuable for water pollution control, particularly in the case of wastewater discharge. Figure (2.27) shows pH record at a reference site at the Marine Science Station (Fig. 2.26) water for the last five years. Records of pH fluctuated around 8.3 with very minor variations. This is typical not only for the waters of the Gulf of Aqaba, but for all coral reef waters (Sorkin, 1995). This is because these waters are always saturated with calcium carbonate, which acts as a buffer and resists any change in the pH.

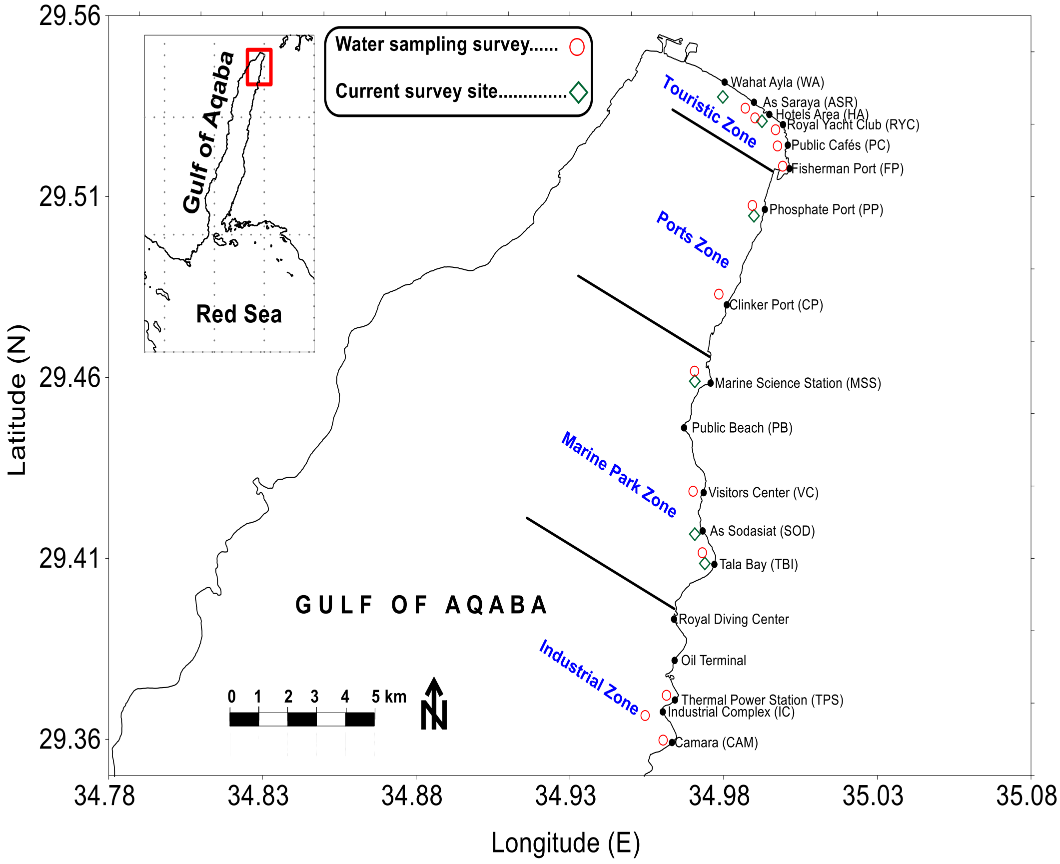

Figure 2.26: Location of some sites of different anthropogenic activities at the Jordanian coast of the Gulf of Aqaba.

Figure 2.26 shows pH record at a reference site at the Marine Science Station water for the last five years 2009-2013.

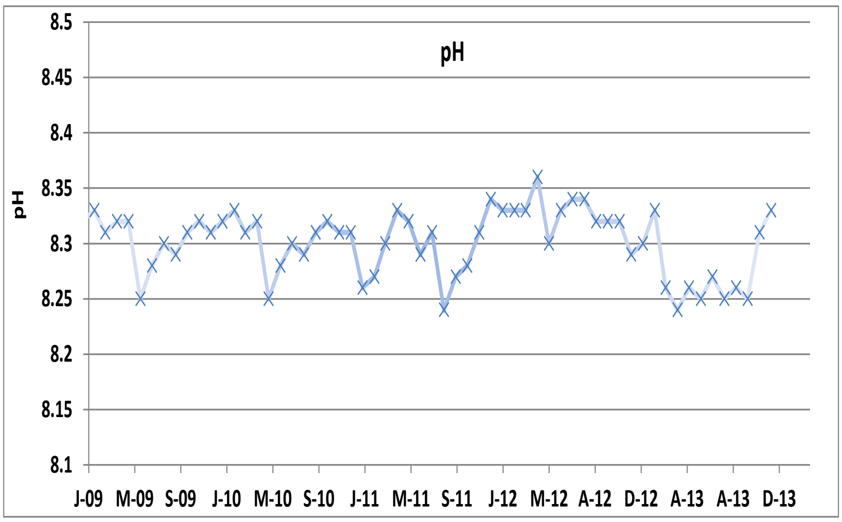

Figure 2.27: Time series of pH records from the coastal water in front of the Marine Science Station for the period January 2009- December 2013.

Table 2.9 shows the pH spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Records of pH, at coastal and offshore sites fluctuated around 8.3 with very minor temporal and spatial variations showing no difference between the different sites in summer and winter. This is according to Sorkin (1995) typical for all coral reef waters and is attributed to that these waters are always saturated with calcium carbonate, which acts as a buffer and resists any change in the pH.

2.8.2.2 Nutrients

Inorganic nutrients (ammonia, nitrate, nitrite, phosphate and silicate) are minor constituents of seawater that are essential for marine phytoplankton productivity and growth. However, the presence of excessive amounts of the nutrients may lead to 'Eutrophication'. In this process the high fertility of the water allow for a rapid and excessive blooming of phytoplankton with initial over production of oxygen but at the end of the bloom the decomposition of the dead plants strips the oxygen from the water. Eutrophication occurs in areas where a restricted water circulation pattern allows high nutrient (and other pollutants) to build up due to the minimum dilution of the pollutants. The nutrient species, normally involved in eutrophication, are ammonia, nitrite, nitrate, and orthophosphate.

Table 2.9: pH average records of five years (2009-2013) at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	RYC	PC	FP	CP	PP	MSS	VC	TB	IC	Offshore
Jan	8.30	8.30	8.31	8.30	8.30	8.30	8.31	8.30	8.30	8.30	8.31
Feb	8.32	8.31	8.32	8.32	8.31	8.31	8.32	8.31	8.31	8.32	8.30
Mar	8.31	8.31	8.31	8.32	8.30	8.31	8.30	8.31	8.31	8.31	8.31
Apr	8.31	8.32	8.32	8.31	8.31	8.31	8.31	8.31	8.32	8.31	8.32
May	8.29	8.28	8.28	8.28	8.29	8.29	8.29	8.28	8.28	8.29	8.30
Jun	8.27	8.28	8.28	8.28	8.29	8.28	8.28	8.28	8.27	8.28	8.27
Jul	8.30	8.29	8.29	8.29	8.30	8.30	8.30	8.30	8.30	8.29	8.28
Aug	8.28	8.28	8.28	8.28	8.28	8.29	8.28	8.29	8.28	8.29	8.29
Sep	8.28	8.28	8.28	8.28	8.29	8.29	8.29	8.29	8.28	8.29	8.28
Oct	8.29	8.27	8.29	8.28	8.28	8.28	8.30	8.29	8.29	8.29	8.29
Nov	8.29	8.29	8.29	8.29	8.30	8.30	8.31	8.30	8.31	8.31	8.29
Dec	8.32	8.31	8.31	8.31	8.32	8.32	8.32	8.31	8.31	8.32	8.32

According to the monitoring programme of the Marine Science Station and some research conducted at the Gulf Of Aqaba (e.g. Badran et al. 2005; Rasheed et al. 2012), higher concentrations of nutrients and chlorophyll *a* concentrations were recorded during winter. This may be attributed to 1) deep water vertical mixing during winter in which deep water concentrations of different parameters in the offshore water come up to the surface. Cross shore mixing due to density currents have been recently documented (Manasrah et al, 2004; Niemann et al., 2004). This is an all year process that drives coastal water as it gets cooler at night down slope offshore. Increased nutrient concentrations in the euphotic zone enhance primary productivity resulting in higher phytoplankton abundance and increased chlorophyll *a* concentrations 2) water column stratification and high irradiance during summer result in a depletion of the inorganic nutrients in the upper waters by enhanced primary productivity at the subsurface level (50-75 m).

Ammonium

Ammonium concentration is an important ecosystem variable in water monitoring because of its high reactivity in the biogeochemical processes and the relatively high uncertainty in its analysis when compared with other environmental variables (Badran & Foster, 1998). Figure 2.28 shows ammonium concentrations at a reference site at the Marine Science Station water for the last five years. Ammonium concentration is fluctuated irregularly around 0.4µM (Fig. 2.28) with a tendency to higher concentrations during the winter months (January-March), which can be attributed to the mixing conditions, in the water column (Badran et al. 2005).

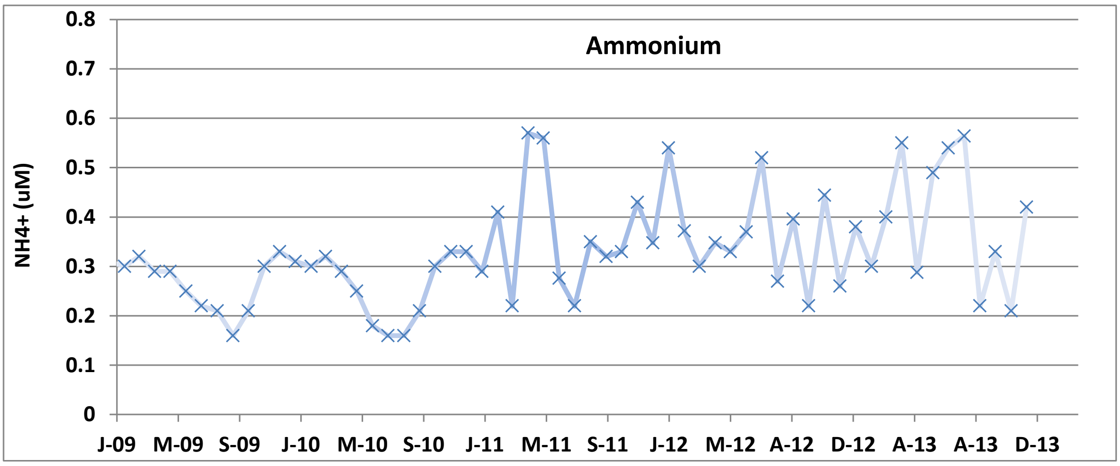

Figure 2.28: Time series of ammonium concentrations (µM) in coastal water in front of the Marine Science Station for the period January 2009- December 2013.

Table 2.10 shows ammonium spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Ammonium concentrations (µM) at coastal and offshore sites fluctuated around 0.4 µM with minor temporal and spatial variations showing no difference between the different sites in summer and winter. Some higher concentrations were found at the northern tourist zone in some months which were attributed to the extensive tourist and or fishermen port activities.

Nitrate and Nitrite

Both nitrate and nitrite concentrations during the last five years (Fig. 2.29) showed a regular shift from a summer low (approximately 0.10 and 0.01 µM, respectively) to relatively high early winter values (approximately 0.6 and 0.25 µM, respectively). Winter mixing in the Gulf of Aqaba dominates during the period between January and April (Klinker *et al.*, 1978; Rasheed *et al.*, 2002; Manasrah *et al.*, 2006). Deep winter mixing introduces new nutrients into the surface water. Nitrate concentrations in deep water were recorded to be more than 2 µM (Badran *et al.*, 2005; Manasrah *et al.*, 2006). This could have a higher impact on the nitrate and nitrite concentrations during winter months.

Table 2.10: Ammonium average concentrations for five years (2009-2013) at some coastal sites of different anthropogenic activities at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	RYC	PC	FP	CP	PP	MSS	VC	TB	IC	Offshore
Jan	0.36	0.56	0.38	0.55	0.42	0.55	0.27	0.40	0.70	0.49	0.34
Feb	0.50	0.42	0.62	0.45	0.49	0.44	0.34	0.35	0.37	0.50	0.32
Mar	0.54	0.65	0.41	0.59	0.73	0.52	0.31	0.33	0.40	0.37	0.38
Apr	0.48	0.49	0.59	0.66	0.59	0.70	0.41	0.49	0.54	0.42	0.36
May	0.53	0.45	0.62	0.41	0.43	0.48	0.36	0.43	0.70	0.43	0.39
Jun	0.39	0.50	0.48	0.53	1.05	0.43	0.31	0.37	0.86	0.33	0.27
Jul	0.40	0.53	0.39	0.46	0.38	0.53	0.30	0.29	0.39	0.30	0.29
Aug	0.25	0.56	0.34	0.52	0.47	0.39	0.35	0.25	0.56	0.25	0.25
Sep	0.30	0.43	0.32	0.45	0.27	1.04	0.35	0.28	0.51	0.33	0.24
Oct	0.43	0.51	0.46	0.75	0.39	0.52	0.40	0.40	0.51	0.34	0.26
Nov	0.45	0.97	0.64	0.95	0.42	0.44	0.38	0.36	0.45	0.32	0.34
Dec	0.44	0.75	0.48	0.40	0.38	0.50	0.34	0.29	0.36	0.45	0.36

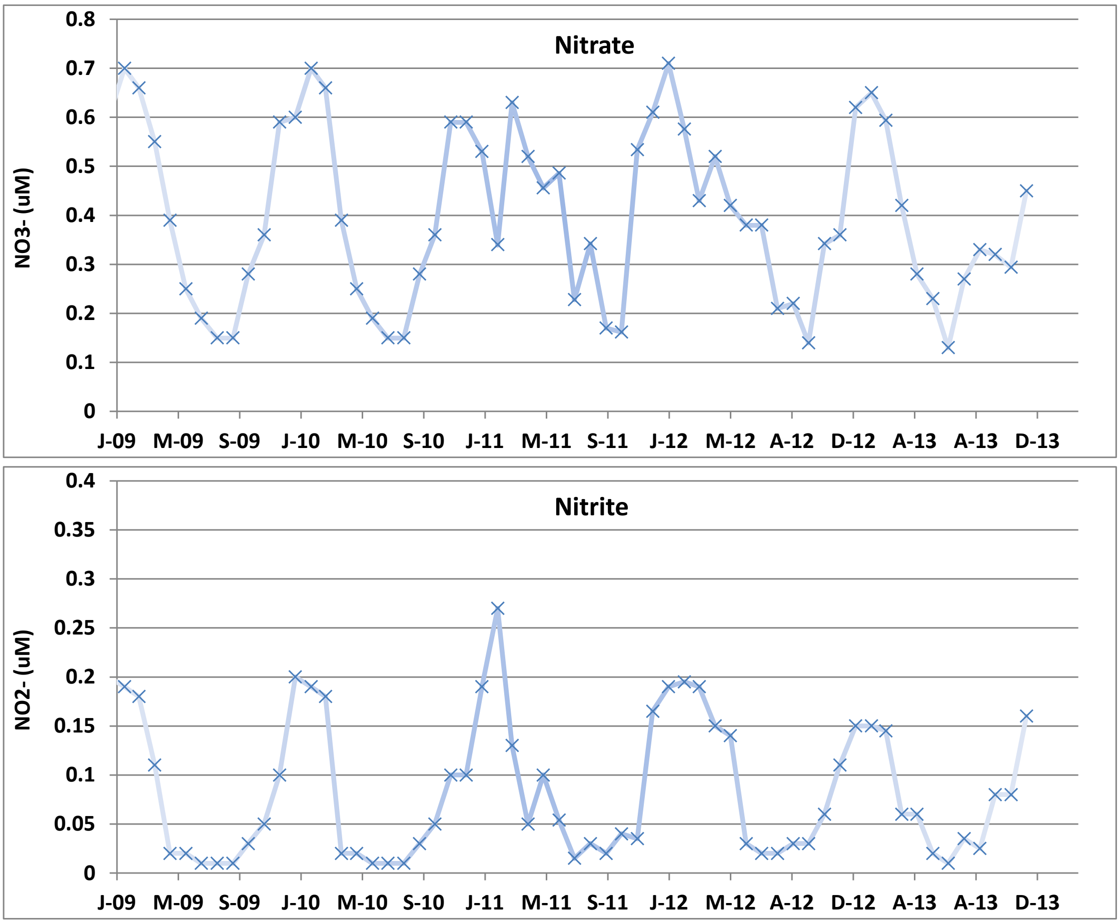

Figure 2.29: Time series of nitrate and nitrite concentrations (µM) from the coastal water in front of the Marine Science Station for the period January 2009- December 2013.

Table 2.11 shows nitrate spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Nitrate concentrations at all coastal and offshore sites showed also a regular shift from a summer low to a relatively high winter values as a result of the mixing and stratification conditions. However, nitrate in addition to silicate and chlorophyll a (see following sections) in northern stations in Tourist Zone especially in RYC, FP and PC sites were generally high in some months. The reasons for these modifications can be some of these factors (i) the northern part of the Gulf of Aqaba is the most protected from the northern winds, which reduces the movement of the water and increases the residence time and consequently reduce the horizontal mixing between the coastal and offshore waters (ii) in spite of the official "Zero Discharge Policy" in Jordan, uncontrolled discharge of nutrient rich water especially at the public cafés and fisherman port sites mostly may contribute significantly to the increase of some parameters, such as ammonium and nitrate (iii) although the termination of fish aquaculture in Elat in the northern part of the Gulf before approximately five years, organic matter that accumulated during the operation of the aquaculture activities may increase nutrient concentrations through the degradation of these matter iv) in RYC, washing of boats and the limited water exchange between the lagoon and outside may increase silicate and nitrate concentrations and subsequently chlorophyll *a*. Tala Bay also had higher concentrations of nitrate, silicate and chlorophyll *a*. This might be due to not enough water exchange between the water inside and outside the lagoon. However, this modification is still not high to be considered as eutrophication state as chlorophyll a concentrations were mostly less than 1 µg l^{-1} (Bell 1992).

Table 2.11: Nitrate average concentrations for five years (2009-2013) at some coastal sites of different anthropogenic activities at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	RYC	PC	FP	CP	PP	MSS	VC	TB	IC	Offshore
Jan	0.67	1.03	1.13	1.29	0.77	1.07	0.64	0.67	1.45	0.60	0.58
Feb	0.83	1.36	1.89	1.37	0.68	1.02	0.59	0.63	0.82	0.71	0.70
Mar	0.66	1.05	1.73	2.23	0.53	0.87	0.59	0.64	1.95	0.91	0.62
Apr	0.55	0.74	1.39	2.20	0.59	1.14	0.48	0.56	2.59	0.54	0.61
May	0.53	0.56	0.76	1.32	0.57	1.20	0.50	0.46	1.71	0.50	0.38
Jun	0.37	0.97	3.14	2.97	0.42	0.66	0.32	0.32	3.07	0.25	0.28
Jul	0.34	0.73	1.19	1.67	0.36	0.69	0.22	0.19	1.03	0.34	0.19
Aug	0.20	0.50	0.56	0.79	0.24	0.33	0.22	0.22	1.42	0.27	0.19
Sep	0.23	0.55	0.81	1.25	0.26	1.12	0.61	0.22	3.08	0.21	0.19
Oct	0.29	0.85	0.72	0.88	0.27	0.40	0.27	0.33	2.78	0.33	0.26
Nov	0.45	1.66	1.54	1.08	0.42	0.86	0.42	0.40	1.32	0.65	0.36
Dec	0.50	2.49	2.80	1.52	0.66	0.77	0.59	0.57	1.46	1.16	0.51

Table 2.12 shows nitrite spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Nitrite concentrations at all coastal and offshore sites showed also a regular shift from a summer low to a relatively high winter values as a result of the mixing and stratification conditions. Spatial nitrite variations showed no differences between the different sites in summer and winter.

Table 2.12: Nitrite average concentrations for five years (2009-2013) at some coastal sites of different anthropogenic activities at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	RYC	PC	FP	CP	PP	MSS	VC	TB	IC	Offshore
Jan	0.20	0.19	0.21	0.23	0.20	0.21	0.19	0.22	0.24	0.21	0.20
Feb	0.22	0.22	0.24	0.21	0.22	0.23	0.20	0.20	0.22	0.23	0.24
Mar	0.16	0.14	0.19	0.22	0.18	0.17	0.17	0.20	0.18	0.20	0.20
Apr	0.08	0.09	0.10	0.09	0.08	0.11	0.08	0.08	0.08	0.08	0.13
May	0.06	0.05	0.07	0.07	0.06	0.06	0.07	0.07	0.09	0.05	0.04
Jun	0.04	0.03	0.05	0.03	0.04	0.03	0.03	0.03	0.07	0.04	0.03
Jul	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.04	0.02	0.01
Aug	0.02	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.03	0.02	0.02
Sep	0.02	0.06	0.04	0.03	0.04	0.02	0.02	0.03	0.07	0.03	0.02
Oct	0.04	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.08	0.05	0.03
Nov	0.08	0.10	0.09	0.09	0.07	0.10	0.07	0.07	0.10	0.09	0.07
Dec	0.12	0.13	0.14	0.10	0.12	0.12	0.13	0.09	0.11	0.10	0.09

Phosphate

Phosphate rock is insoluble in seawater (Abu-Hilal, 1985; Rasheed *et al.*, 2005). Besides, localized small amounts of soluble phosphate can be of minor significance, because it has been almost established that nitrogen rather than phosphorus is the primary productivity limiting nutrient (Badran, 2001; Rasheed *et al.*, 2005). This implies that anthropogenic phosphorus can be assimilated only if surplus nitrogen is available (Rasheed *et al.*, 2005). Typical of the oligotrophic waters, phosphate concentrations were generally low during summer and high during winter (Fig. 2.30). Records of phosphate at MSS showed a high concentration during winter (~ 0.10 µM) and low values during summer (0.03 µM).

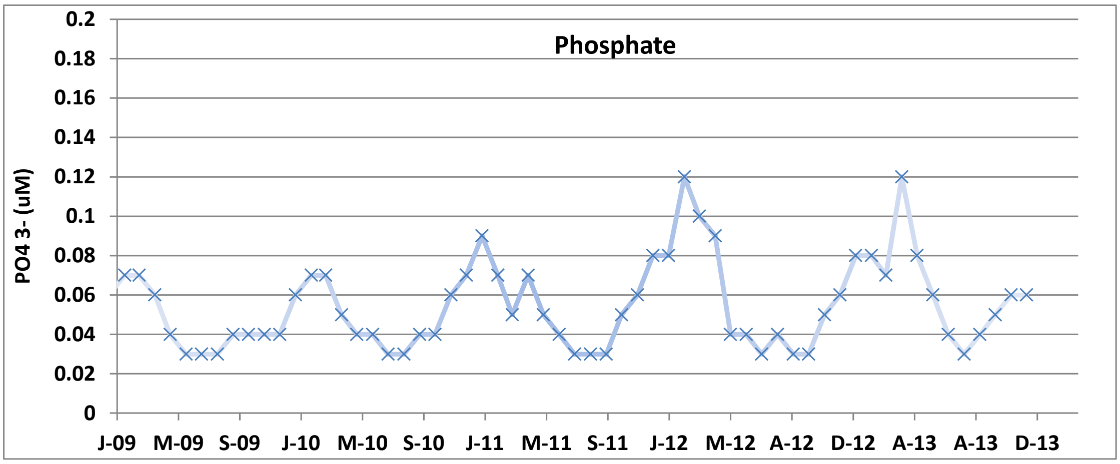

Figure 2.30: Time series of phosphate concentrations (µM) from the coastal water in front of the Marine Science Station for the period January 2009- December 2013.

Table 2.13 shows phosphate spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Phosphate concentrations at all coastal and offshore sites showed also a regular shift from a summer low to a relatively high winter values as a result of the mixing and stratification conditions. Phosphate concentrations showed no clear differences between the different sites in summer and winter.

Table 2.13: Phosphate average concentrations for five years (2009-2013) at some coastal sites of different anthropogenic activities at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	RYC	PC	FP	CP	PP	MSS	VC	TB	IC	Offshore
Jan	0.20	0.19	0.21	0.23	0.20	0.21	0.19	0.22	0.24	0.21	0.20
Feb	0.22	0.22	0.24	0.21	0.22	0.23	0.20	0.20	0.22	0.23	0.24
Mar	0.16	0.14	0.19	0.22	0.18	0.17	0.17	0.20	0.18	0.20	0.20
Apr	0.08	0.09	0.10	0.09	0.08	0.11	0.08	0.08	0.08	0.08	0.13
May	0.06	0.05	0.07	0.07	0.06	0.06	0.07	0.07	0.09	0.05	0.04
Jun	0.04	0.03	0.05	0.03	0.04	0.03	0.03	0.03	0.07	0.04	0.03
Jul	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.04	0.02	0.01
Aug	0.02	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.03	0.02	0.02
Sep	0.02	0.06	0.04	0.03	0.04	0.02	0.02	0.03	0.07	0.03	0.02
Oct	0.04	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.08	0.05	0.03
Nov	0.08	0.10	0.09	0.09	0.07	0.10	0.07	0.07	0.10	0.09	0.07
Dec	0.12	0.13	0.14	0.10	0.12	0.12	0.13	0.09	0.11	0.10	0.09

Silicate

Silicate source in the Gulf of Aqaba as the other nutrients is mainly deep water reservoir which introduces silicate into surface and coastal waters during mixing conditions. However, according to Badran (2001), atmospheric deposits of silicate carried by the desert winds may be another source of silicate in the Gulf of Aqaba.

Silicate concentrations were generally low during summer and high during the winter (Fig. 2.31). Concentrations of silicate at MSS showed a high concentration during winter (~ 2.0 µM) and low values during summer (1.0 µM).

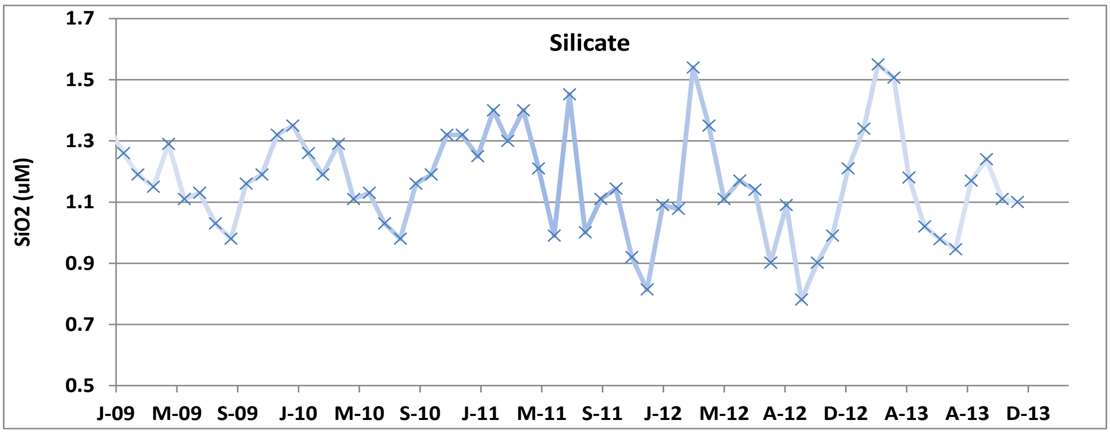

Figure 2.31: Time series of silicate concentrations (µM) from the coastal water in front of the Marine Science Station for the period January 2009- December 2013.

Table 2.14 shows silicate spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Silicate concentrations at all coastal and offshore sites showed also a regular shift from a summer low to a relatively high winter values as a result of the mixing and stratification conditions. Silicate concentrations showed no clear differences between the different sites in summer and winter. However, as for nitrate, silicate in northern stations in Tourist Zone especially in RYC, FP and PC sites were generally high in some months (See nitrate and nitrite section for details). Tala Bay also had higher concentrations of silicate which might be due to not enough water exchange between the water inside and outside the lagoon.

Table 2.14: Silicate average concentrations for five years (2009-2013) at some coastal sites of different anthropogenic activities at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	RYC	PC	FP	CP	PP	MSS	VC	TB	IC	Offshore
Jan	1.27	1.80	1.78	1.70	1.44	1.68	1.30	1.32	1.83	1.47	1.23
Feb	1.35	2.20	2.77	1.33	1.38	1.63	1.18	1.23	2.04	1.63	1.53
Mar	1.40	1.95	1.96	1.70	1.28	1.51	1.44	1.47	3.70	1.75	1.36
Apr	1.38	1.82	1.78	1.80	1.57	1.91	1.28	1.27	2.63	1.32	1.24
May	1.25	1.46	1.41	1.37	1.27	1.52	1.30	1.41	1.76	1.38	1.29
Jun	1.26	1.88	2.56	1.67	1.33	1.42	1.16	1.25	2.17	1.19	1.14
Jul	1.00	1.42	1.47	1.54	1.04	2.17	1.15	1.17	2.35	1.55	1.05
Aug	0.99	1.33	1.21	1.01	0.95	1.09	0.97	0.98	1.39	1.11	1.05
Sep	1.12	1.89	1.52	1.63	1.19	2.26	1.22	1.12	2.53	1.24	1.03
Oct	1.14	2.29	1.40	1.18	1.06	1.20	1.10	1.49	2.07	1.24	1.11
Nov	1.27	2.82	2.26	1.46	1.12	2.08	1.29	1.24	1.74	1.36	1.39
Dec	1.15	2.80	2.67	1.61	1.33	1.56	1.11	1.19	1.71	1.44	1.25

2.8.2.3 Dissolved Oxygen

Dissolved oxygen, nutrients and chlorophyll *a* are together the most direct measure of the trophic characteristics of the system. The higher the nutrient and chlorophyll *a* concentrations are, the more euotrophic the system is. Dissolved oxygen concentrations in eutrophicated systems vary rapidly and significantly. It shoots up high during the day time when light is available and drops down sharply during night when there is no photosynthesis. Oxygen is essential in most biological processes in aquatic environment. The levels of the dissolved oxygen can be indicative of the type of physical, chemical and biological activities in a particular water body. Oxygen is consumed by organisms and it is used for organic matter degradation. If a large amount of an effluent of oxidizable organic matter enters a water body or if the production of organic matter becomes very high, it is very likely that the water gets anoxic and its ability to support life decreases considerably.

The dissolved oxygen concentration at the MSS site showed a regular pattern inversely proportional to that of temperature with a range of 6.4 to7.4 mgl^{-1} (Fig. 2.32) indicating that the effect of the other ecosystem variables was masked by that of the temperature. The concentrations recorded most of the time were in fact 100% saturation concentrations. Waters of the Gulf of Aqaba are very well balanced in terms of respiration and photosynthesis and well ventilated due to the annual deep mixing (Badran 2001; Rasheed *et al.*, 2005; Manasrah *et al.*, 2006). This highlights temperature and salinity as the two main factors controlling the dissolved oxygen concentration, because of the strong dependence of the oxygen solubility on these two variables.

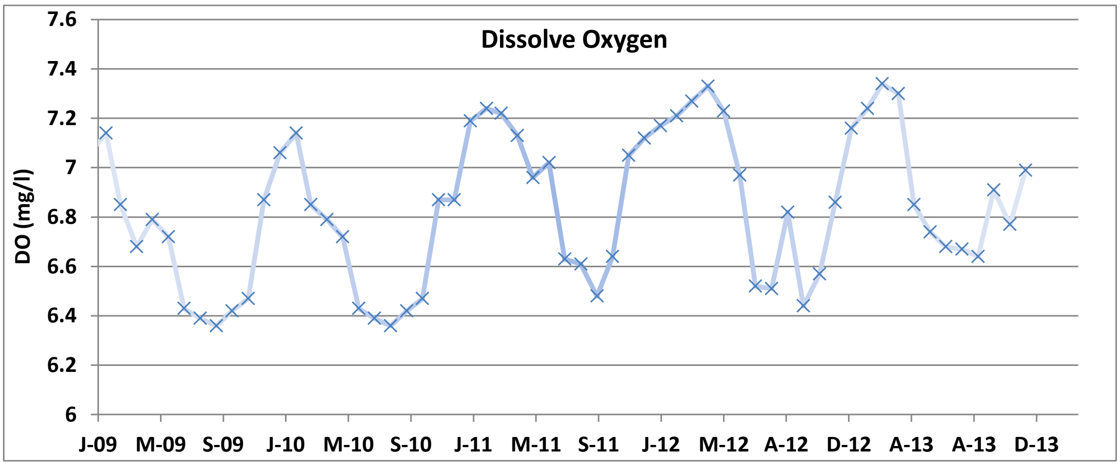

Figure 2.32: Time series of oxygen (mg/l) from the coastal water in front of the Marine Science Station for the period January 2009- December 2013.

Table 2.15 shows oxygen spatial variation along the Jordanian Coast of the Gulf of Aqaba (see Fig. 2.26). Dissolve oxygen at all coastal and offshore sites showed also a regular pattern inversely proportional to that of temperature with a range of 6.4 to7.4 mgl^{-1}. Spatial nitrite variations show no differences between the different sites in summer and winter.

Table 2.15: Oxygen records for five years (2009-2013) at some coastal sites of different anthropogenic activities at the Jordanian Coast of the Gulf of Aqaba (for site locations see Fig.2.26) and at offshore site 3 km off the coast.

	HA	**RYC**	**PC**	**FP**	**CP**	**PP**	**MSS**	**VC**	**TB**	**IC**	**Offshore**
Jan	7.11	7.16	7.11	7.12	7.16	7.16	7.13	7.15	7.13	7.12	7.10
Feb	7.21	7.17	7.19	7.23	7.20	7.20	7.19	7.20	7.20	7.23	7.20
Mar	7.15	7.05	7.09	7.12	7.10	7.09	7.11	7.11	7.08	7.10	7.23
Apr	7.11	7.00	7.06	7.07	7.02	7.06	7.05	7.03	7.01	7.02	7.08
May	6.90	6.84	6.84	6.80	6.90	6.90	6.91	6.90	6.86	6.85	6.95
Jun	6.74	6.69	6.73	6.70	6.77	6.75	6.78	6.77	6.59	6.71	6.82
Jul	6.56	6.57	6.56	6.54	6.55	6.51	6.53	6.57	6.44	6.61	6.61
Aug	6.49	6.37	6.46	6.49	6.47	6.51	6.51	6.47	6.39	6.60	6.48
Sep	6.50	6.50	6.47	6.49	6.45	6.43	6.54	6.49	6.40	6.46	6.48
Oct	6.58	6.62	6.62	6.61	6.57	6.61	6.58	6.62	6.67	6.59	6.55
Nov	6.84	6.79	6.76	6.80	6.78	6.79	6.75	6.79	6.75	6.82	6.71
Dec	6.94	6.95	6.99	7.01	6.98	6.94	6.94	6.96	6.93	6.94	6.83

2.8.3 *NUTRIENTS AND CHLOROPHYLL-A DYNAMICS IN THE GULF OF AQABA COMPARED TO THE RED SEA*

The surface waters of the Red Sea as the Gulf of Aqaba are mostly oligotrophic (nutrient-poor), except in polluted areas (Table 2.16). Nutrient distribution shows variations from north to south and with depth and season. The concentrations in the southern Red Sea are higher than those of the northern part which can be attributed to the richer nutrient water inflow from the Gulf of Aden into the southern Red Sea during late summer (Weikert, 1987).

Table 2.16: Summary of nutrients and primary productivity in the Red Sea.

Year & Ref.	Nutrients	Phosphate mg-P/L	Nitrate mg-N/L	Primary productivity
Theil and Karbe (1986)	Oligotrophic (poor in nutrients)			Low
Badran (2001)	Oligotrophic	0.004 (Northern RS)	0.02 (Northern RS)	Low (chl*a* less than 1 µg/l)
Rasheed*et al*. (2003)	Oligotrophic	0.003 (Northern RS)	0.015 (Northern RS)	Low (chl*a* less than 1 µg/l)
Manasrah*et al.* (2006)	Oligotrophic	0.001-0.003	0.003-0.004	Low (chl*a* less than 1 µg/l)
Richter and Abu Hilal (2006)	Oligotrophic	Below detection limit	5.0	Low
Mohorjy and Khan (2006)	Oligotrophic	Below detection limit (Jeddah coast)	5.0 (Jeddah coast)	
Monitoring Program for Yanbu (2010)	Oligotrophic	0.004	0.02	Low (chl*a* less than 1 µg/l)

The concentrations of inorganic nutrients, particularly nitrogen and phosphate in the Gulf of Aqaba are found to be low especially during summer (1.0 and 0.1 µM respectively (Rasheed et al. 2002). During winter, deep water from the Gulf of Aqaba is mixed with surface water, resulting in nutrient enhancement in the coastal surface waters (Rasheed et al., 2002). Overall, biological productivity in the Red Sea is poor, and oligotrophic conditions become more persistent towards the north.

The lack of anthropogenic nutrient load as well as restricted inflow of nutrients from the Arabian Sea across the narrow and shallow strait of Bab-el-Mandeb, as well as strong vertical stratification limits the supply of new nutrients from deeper waters. As a result of these conditions, except for reefs along margins and shelves in the southern part of the Red Sea (Richter and Abu- Hilal, 2006), oligotrophic conditions exist almost throughout the Red Sea. Furthermore, lack of regular fresh water inflow and high evaporation rates contribute significantly to the oligotrophic nature of the system (Reiss and Hottinger, 1984; Badran, 2001).

In the middle of the Red Sea, near the Jeddah coast, Mohorjy and Khan (2006) found phosphate and ammonium concentrations below detection limits and nitrate concentration of 26.6 mg/l (as NO_3^-). The deposition of dust transported from nearby sources and subsequent biological fixation of nitrogen acts as source of nutrient in the region (Richter and Abu- Hilal, 2006). In summer, prevailing winds flow down the Red Sea through its entire length, reinforcing the clockwise airflow in the Arabian Sea. This generates strong south-westerly winds, leading to cooler conditions, and nutrient-rich water upwelling. Upwellings result in higher nutrient water conditions and the development of *Eckloniakelp* beds in certain areas, inhibiting the development of coral reefs (Chiffings, 2003). However, on the whole, the Red Sea is considered an oligotrophic water body.

In a detailed study in the Gulf of Aqaba which can serve as a gauge for the Red Sea, Mansrah et al. (2006) described nutrient and temperature distributions in relation to depth and seasons. They found a clear thermocline in the upper 200 m which became significantly weaker with depth. During summer (June) when the stratification started to build up, the difference between the surface and 200 m waters was about 2.6 °C (sea surface temperature ~23.8 °C), whereas the temperature between 200-400 m depth was almost homogenous with values ranging between 21.1-21.2 °C. The thermocline during August and September had maximum temperature differences of about 5.1 °C between 0-200 m depths. Average sea surface temperature was 26.8 °C, while the average temperature in the 200-400 m water was 21.4 °C. Subsequently, deterioration of the stratification began during October in the upper 75 m with an average temperature of about 25.5°C, while the stratification weakened between 75-300 m of the water column with temperature values ranging between 25.4 - 21.1 °C.

Temperature stratification was mirrored by nutrient and dissolved oxygen distributions in the entire water column. Nitrate, phosphate, and silicate increased from the surface to deep water while dissolved oxygen decreased. Low nitrate concentrations with values of 0.2 - 0.4 μM, persisted in the upper water column (surface to 100 m), while the values reached up to 2 μM in the lower water column (300-400m). Phosphate and silicate also exhibited a similar trend to that of nitrate. Low concentrations in the upper water column were around 0.05 and 1.0 μM for phosphate and silicate respectively. While higher values in the lower water column were recorded (0.15 and 2 μM for phosphate and silicate respectively).

Oxygen concentrations decreased gradually with increasing depth in the water column ranging from approximately 7.0 mg l^{-1}at the surface to approximately 5 mg l^{-1} in the 400 m deep water.

Nitrite concentrations during summer have a characteristic subsurface nitrite concentration maximum of about 0.5 μM which is found to a depth of approximately 100m. During mixing winter condition, however, homogenize nitrite concentrations of 0.5 μM are found in the entire water column down to 300m depth. Chlorophyll *a* follows the same pattern of nitrite concentrations where subsurface maxima of 0.4 μg $l^{-1}$are found in summer to approximately 75 m depth, and homogeneous concentrations of approximately 0.3 μg l^{-1} are found in winter down to 300 m.

2.9 TERRESTRIAL TOPOGRAPHY, DEFINITION OF COASTLINES

2.9.1 THE RED SEA/GENERAL

The description of the terrestrial topography across the region arbitrarily uses the 500 m contour line and the distance of this line from the coastlines of the Red Sea and Gulf of Aden as an indicator of the terrain and width of the coastal plain. It contains additional notes on the heights of the main hills or mountains further back from the coast, the nature of the coast itself and comments on wadis extending to the coast. The topography generally consists of a more or less broad coastal plain, usually arid with little or no vegetation, with many wadis carrying occasional rainfall. The Gulf of Suez is bounded on both sides by arid hills and mountains rising to over 1,700 m. The 500 m contour line is an average distance of 30 km from the coastline on the western side of the Gulf, and within 25 km along the eastern coast. At some points where isolated hills rise more steeply the 500 m contour is within 4–5 km of the coast. Mount Sinai (2,285 m) and Gebel Katherina (2,642 m) lie roughly in the middle of the Sinai Peninsula, 55 km from the Gulf of Suez and the same distance from the Gulf of Aqaba. The hills on either side of the Gulf of Aqaba also rise steeply from the coastline. The 500 m contour on the west side of the Gulf is generally within 5 km of the coast, and the east side within 7 km. On the coast in the two gulfs are some areas of relatively narrow beach, but in many parts the coastlines are rocky. Following the coast of Egypt from the Strait of Gubal to the border with Sudan the 500 m contour is set back around 40 km from the coast, giving a wider coastal plain. From Aqaba town to the Saudi border the coastline has areas of sandy beaches, with fewer areas of rocky coastline. Small wadis at various points along this coast carry runoff to the sea when occasional local rains fall (PERSGA 2006).

2.9.2 GULF OF AQABA/GEOLOGICAL SETTING

The Gulf of Aqaba is situated at the southern extent of the Dead Sea Transform. It occupies the southern part of the segment of the great valley that extends from the Zagros-Taurus Mountains in Turkey through the Red Sea and into East Africa. The Gulf of Aqaba oriented NNE-SSW is described as the northernmost sea-flooded part of the Syrian-African rift system. The gulf is a semi-closed basin, separated from the Red Sea by the Straits of Tiran, a narrow passage about 250m deep. A unique feature of the gulf is its great depth in proportion to its width. It extends over a length of 180 km and a width of 5 to 26 km, and reaches almost 1850m depth. It has an average depth of 800m.

In its greater depth and narrower width, the Gulf of Aqaba graben differs from the Gulf of Suez graben. The Gulf of Suez has experienced at least since Early or Late Eocene time, and since that time has been filled with sediments. By contrast, the Gulf of Aqaba did not originate until Late Pliocene or Early Pleistocene time and it lacks Neogene sediments. When rifting began, the Gulf of Aqaba was not connected to the Red Sea but extended as an isolated trough from the Araba Valley to the submerged ridge at the Straits of Tiran (Fig.2.2). The graben could have resulted from either movement in several stages along a left-lateral wrench fault, or from gravitational and tensional effects with dip-slip movements, the last major being of Middle Pleistocene age (Friedman, 1985 in Hulings, 1989) (Fig.2.3).

According to Garfunkel and Ben-Avraham (1996) the evolution of the Gulf started with the initiation of the Red Sea Rift in the late Oligocene to early Miocene The ongoing separation of the Arabian and African Plates was accommodated in the north by the Suez Rift and, after about 15 Ma, by the initiation of the Sinai triple junction and the formation of the DST between the Arabian and the Sinai Sub-Plate (Courtillot et al., 1987). The left-lateral slip along the rift has since Miocene increased to an amount of 105 km. It separates the Sinai sub-plate in the west from the Arabian plate in the east. Boarding areas of the rift are elevated nearly 4 km. This elevation decreases northwards. The volcanic activities are all the same very minor. The rift connects the area of seafloor spreading beneath the Red Sea with the area of Zagros-Taurus of continental collision. The Gulf proper is divided into three elongated deep basins striking North East. The northern deep is the shallowest (900 m deep) and is characterized by its flat bottom, while the other two deeps have irregular bottom topography and much greater depths (Friedman, 1985). With the exception of the northernmost part of the Gulf, fringing coral reefs grow luxuriously along the entire coastline varying in width between 10 and 100m depending on the slope gradients at the shelf edge (Friedman, 1985).

The long sub-parallel faults of the gulf which enclose the big, deep and enlarged enechelon sediment basins are called pull apart basins, fault bound depressions. The lateral submarine slopes of Gulf of Aqaba are fault planes and are virtual precipices; for the most part the shores are equally precipitous. Alluvial fans extend from the mountains to the shore and into the gulf. The sediments infill is as much as 5 km thick (Heiss *et al.*, 1999).

The coasts of the Gulf of Aqaba are steep all along the gulf with very narrow or missing coastal plains. The bordering mountains rise up abrupt from the water edge. However, the head of the gulf is low lying; only rises 2 m above sea level (The Red Sea and Gulf of Aden Pilot, 1980). According to Ben-Avraham and Garfunkel (1986) and Ben-Avraham and Tibor (1993) the Gulf of Aqaba comprises four main sedimentary basins, the Dakar, Tiran, Aragonese and Aqaba (Elat) Deeps, and slightly beyond the limits of the Gulf of Aqaba, the Hume Deep. These basins, distributed in an en-echelon pattern, have been considered to represent pull-apart basins. The Aqaba (Elat) Deep is the northernmost basin in the marine part of the DST. It is approximately 50 km long, up to 25 km wide and is bounded by faults at its longitudinal margins and shows faulting at its northern and southern extensions (Reches et al., 1987; Ben-Avraham and Tibor, 1993). The transition from the (Aqaba) Elat Deep to the Arava Valley, the adjacent on land sedimentary basin (Ben-Avraham et al., 1979), takes place at the top end of the Gulf, the Gulf's Head, where the Gulf narrows considerably

The morphology of the Aqaba (Elat) Deep is characterized by an almost at-sea floor of approximately 900 m water depth and steep scarps, bounding the Deep along the western and eastern flanks. The boundary faults separate the coarsely stratified sediments on the slopes from regularly bedded infill of the deep basins (Ben-Avraham, 1985). The sedimentation rate in the northern part of the Gulf is fast enough to level out large scale tectonically induced irregularities (after Reches et al., 1987; Ben-Avraham and Tibor, 1993), resulting in a flat-like sea floor.

The northern Gulf of Aqaba is surrounded by metamorphic–plutonic rocks, which are elevated to levels of more than 1000 m close to the Gulf. In general, the areas bordering the DST to the east and to the west were uplifted up to 4 km in the area of the Gulf of Aqaba (Ben-Avraham et al., 1979), whereas the Arabian Plate experienced an explicit larger amount of uplift (Barjous and Mikbel, 1990; Khalek et al., 1993; Wdowinski and Zilberman, 1996).

The region east of the northern Gulf is characterized by a platform area covered with alluvial sediments in front of a mountain range pediment composed of Precambrian basement. The western side of the northern Gulf is dominated by the presence of a N–S trending Graben, a Miocene structure that was probably formed during the early phase of displacement along the DST. Ben-Avraham and Tibor (1993) suggested that this Graben lineament continues into the Gulf of Aqaba and controls the location of transverse faults in the Gulf. On both sides of the Gulf, outcropping basement is transected by a variety of faults (e.g., Eyal et al., 1981). The strike of these faults roughly corresponds to the trend of the DST.

2.10 GULF OF AQABA/GEOPHYSICAL DATA/BATHYMETRIC DATA

The Gulf of Aqaba is separated from the Red Sea by a sill which has been reported to be 340 m deep. The walls of the Gulf of Aqaba are very steep. The normal gradient ranges from 60 to 70 percent, (ISPAN 1992). It is practically non continental shelves boarding the gulf. The coastal plains are missing or particular tight. The continental slopes are among the steepest in the world (Hulings 1989; Al Oran 2005).During the Meteor Cruise M44/3 in 1999, a dense multichannel seismic data set was simultaneously acquired with swath sounder data which were continuously recorded by means of an ATLAS HYDROSWEEP system. The resulting bathymetric chart (Fig. 2.33) reveals a complete coverage of the sea floor of the northern Gulf of Aqaba **(**Ehrhardta et al. 2005).

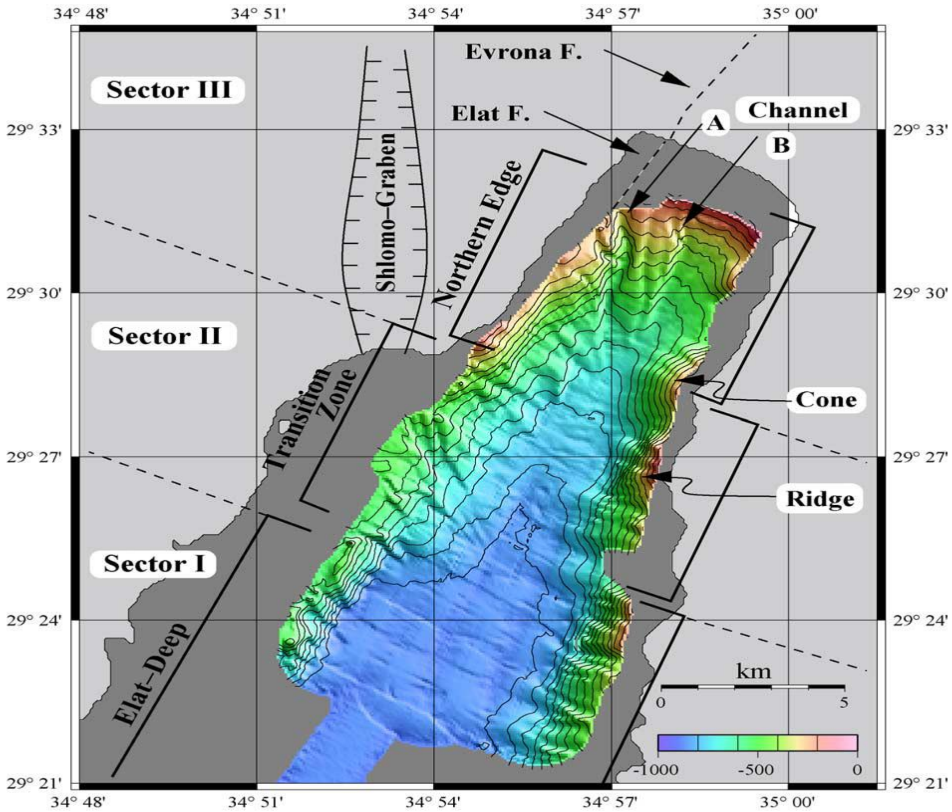

Figure 2.33: Bathymetric map of the Northern Gulf of Aqaba from the multibeam data of Cruise M44/3 (illuminated and color coded; isobath interval: 100 m). The area is subdivided into three sectors: the Northern Edge, the Transition Zone and the Aqaba (Elat) Deep sectors. Bathymetric features are explained in the text (Ehrhardta et al. 2005).

The observed features split the survey area into three sectors. The southern sector (Aqaba/Elat) Deep, (Sector I) is characterized by steep slopes. These scarp-like features bound the almost at basin floor. The western slope has a slope angle of 17.5º and is steeper than the eastern slope, with a slope angle of 14.0º. In the central sector (Transition Zone, (Sector II), the western slope changes its slope angle abruptly and is inclined much more gently (5.7– 6.4º). The eastern slope is dominated by two obvious features: A linear ridge-like structure trends subparallel to the strike of the Gulf, and, further north, a cone is well expressed by the bathymetric data. The limits of the central sector (Transition Zone, Sector II) can be correlated with the continuation of the Shlomo Graben. The northern sector (Northern Edge, (Sector III) shows a steepening of the slope on its western side to about 16º. This is not observed on the eastern side of this sector, but a considerable water depth of 500 m close to the coastline points to a steep scarp-like slope a short distance east of the survey area. The Gulf's Head exhibits two northward trending channels (ChannelsA and B in (Fig. 2.34). Channel A seems to connect to the Elat Fault, whereas Channel B is not continuous to the northern limit of the survey area **(**Ehrhardta et al. 2005)

The Reflection seismic data show that as observed in the bathymetry, the almost at-like sea floor in the (Aqaba (Elat) Deep) is bounded by a steep slope in the west and a less steep slope in the east. The results of the Meteor Cruise M44/3 (Abu-Ouf et al., 2000) show a strong variation in time and space, as the average sedimentation rate for the northernmost Gulf of Aqaba is about 33 cm/1000 and, for the central part of the (Aqaba (Elat) Deep), it is about 5 cm/1000 a for the last 8000 years. The sedimentation rate is affected by the climatic conditions, as Arz et al. (2003) calculated higher values for cold/wet periods and lower values for hot/dry periods.

The recently active transpressional deformation indicates that strike-slip motion is partly accommodated along the eastern slope of the northern Gulf. The previously proposed stepover of the main branch of the DST along the western side of the Gulf's Head has been mapped for the first time in detail. The stepover is much smoother than previously suggested and does not follow the steepest slope gradient of the (Aqaba (Elat) Deep). Close to the stepover, the strike-slip fault bifurcates, and a newly discovered right-bending branch runs northeastward toward the Jordan coast, where thrust faulting is shown in the seismic data (Ehrhardta et al. 2005).

2.11 GENERAL FEATURES OF THE JORDANIAN COASTLINE

The 26.5 kilometre-long Jordanian shoreline of the Gulf of Aqaba provides the only access to the sea for Jordan for ship transport, fishing, and industrial development that requires large amount of cooling water. The coast has been divided generally into zones for development purposes, the city of Aqaba, port area, south tourist area including the marine park and the public beach and the industrial zone area.

The northern Gulf of Aqaba is surrounded by metamorphic–plutonic rocks, which are elevated to levels of more than 1000 m close to the Gulf. In general, the areas bordering the DST to the east and to the west were uplifted up to 4 km in the area of the Gulf of Aqaba (Ben-Avraham et al., 1979).

Using aerial photos (Stereoscopic study –3D visibility of 1:30,000 scale black-white aerial photos/1992), Al-Farajat (2001) distinguished the following morphological features and land forms along the Jordanian Gulf of Aqaba (Fig. 2.34):

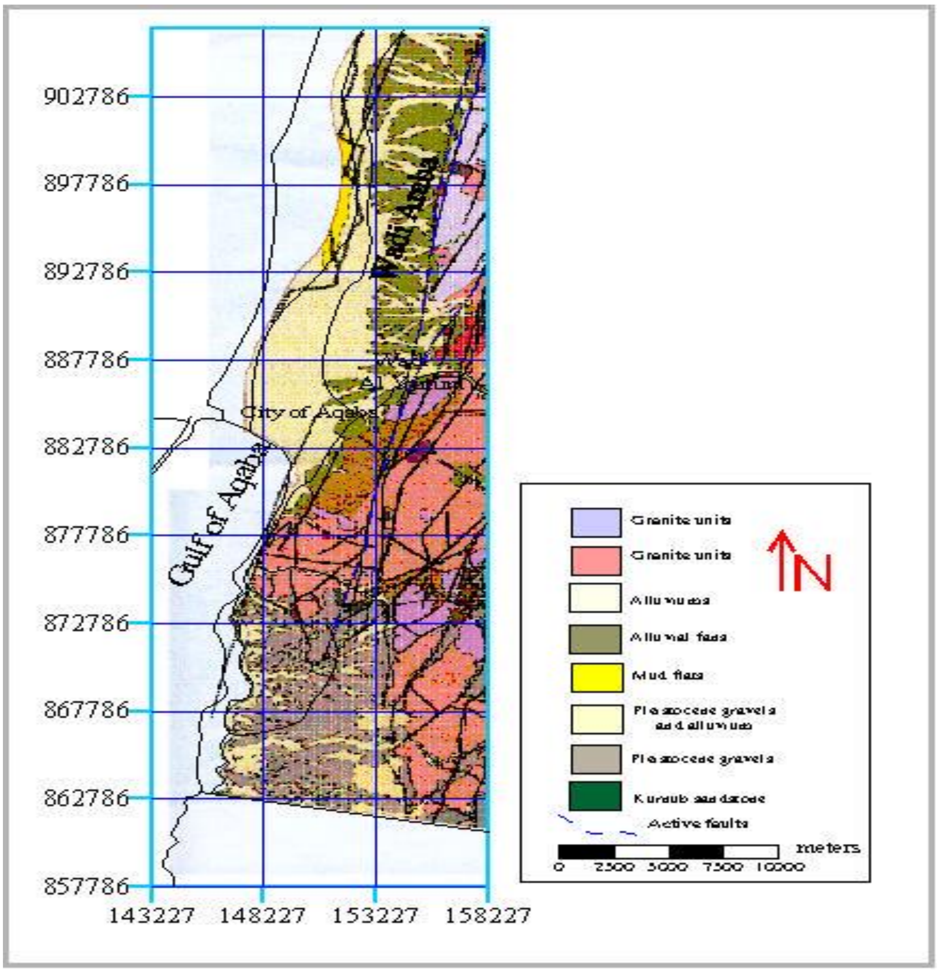

Figure 2.34: Rock units in the study area (After Al-Farajat 2001)

1. The complex granite series relief configuration: The granite series prevail with the major direction of their contact with the overburden trending at about 40° from the north. To the east of Aqaba port, the contact approaches the periphery of the sea. In the southern part they disappear to allow the overburden to exist. This area is nearly free of urbanization except some industries. According to their natural relief configuration, they divide the rain products in two parts; one to the eastern side of them mainly to the early start of Wadi Al Yutum, and the second is towards the eastern part of the study area.
2. The active side wadis and their deposits: these wadis intersect the granite series from east to west and follow as major E-W faults. From N to S eight wadis exist within the granite series and their overburden.. These wadis deposit their flood sediments on land.
3. Coastal wadis: The followings wadis end into the sea, and are classified as coastal wadis; Wadi Ash Shallala, Wadi Jeishieh, Wadi Mabruk, and Several Wadis cutting the existed Pleistocene gravels in the southern part. They deposit their sediment loads as alluvial fans. The major direction of their mouths is towards the west. These wadis seem to be active and are of a length ranges between 8000-3000 meters, and width of 500-250 meters. Exception is Wadi Al Yutum which is the biggest in terms of its length and catchment area, and its capacity to transport clastics deposits. It extends from the north eastern parts through the Rum Basin towards the Southern Wadi Araba Basin. Its width ranges from 500-300 meters.

Wadi Mabruk forms a small delta in the sea. Wadi Ash Shallala is the only wadi on which land use exists.

Al-Rifaiy (1988) considered the coastal wadis as vulnerable zones. The nature of the deposits in the wadis are of two types in terms of the deposition environment; in the normal situations they receive the mountain's weathering products with the action of gravity as mountain debris. The debris appears as small hills nearer to many mouth forms in the granite series. Floods produced from heavy rainfall drive this debris away. The second possibility occurs with rain effect; local extended depositional layers of different grain sizes in the wadis within the last criteria may exist.

4. Alluvial fans: alluvial fans are the most abundant feature. Heavy rain some times, flushes large amounts of rock debris down slopes. The transported alluviums made up the alluvial fans. On alluvial fans, coarser rocks and gravel are deposited near the mouth of the canyon, near the apex of the fan. Coarser material is also found in and along the main channel beds further down the fan from the apex. These materials can be carried further down the channel because the carrying capacity of the stream flow does not decrease as rapidly in the channel as it would elsewhere on the fan. As the distance from the head of the fan increases, the size of the materials continues to decrease, from rocks and gravel, to small gravel and sand, and finally to fine sands and silts.

   The active wadi deposits are found in the lowest part of the wadi profiles They slope to the west with an angle at the apexes of about 3.82°, 1.85° at the middle parts and the slope is still decreasing until it approach zero at the end of every fan. In the southern Wadi Araba, alluvial fans follow the mouths of side wadis that have been formed due to the E-W faulting process in the granite complex.

   About 18 alluvial fans exist clearly, their extent range from 30 sq. km to less than 1 sq. Km. The length of the vertical axes range from 0.6 to 5 km, while the widths range from less than 1 km to 7 km. They start in northern Aqaba between. In this part they are mostly rounded to semi-rounded shape. Their sediments are mainly derived from the granite weathering products.

   In the southern part where Pleistocene gravels prevail, they are mostly elongated alluvial fans. Their deposits are a mixture of granite weathering products, and Pleistocene gravel weathering products.

   Alluvial fans are divided into two zones; active and inactive. The active zones are those where recent floods flow. They are less elevated than the inactive zones, which are about one meter higher in elevation. Coastal wadis deposit a part of their loads on land forming alluvial fans, the rest flows to the sea to form small deltas. Wadi Mabruk is an example on that.
5. Flood plains: Flood plains extend to the ends of the alluvial fans. The flood water that flows and seeps along the alluvial fans become slower in the flat lands where the slope decreases. This allows the rest flood water to collect in areas called flood plains and palays. The resulted deposits are mainly the smallest sizes such as clay and silt. The mud flat zones are formed as a result of flood water in such areas.
6. Coastal zones: coastal zones are the land zones directly surrounding the sea. The width of the coastal zone is governed by the city urbanization and hotels. It is wide in the northern area (3-4 km) narrowing in the middle part to a few tens of meters and broadening in the south to 4-5 km. The Granite Mountains approach the periphery of the shoreline south of Aqaba Port.

After analysing aerial photos Al-Farajat (2001) came up with the following conclusions: The structural evolution of the Dead Sea Transform Fault led to the present land forms of

Aqaba; the elevations of the area range between zero and about 1600 meters above sea level. The granite mountains form the highest elevations with slopes more than 45°; the dominant area is a series of parallel ridges and wadis running east-west from the backdrop of high granite mountains to the gently sloping coastal strip; the width of the coastal strip varies considerably in the different parts of the south coast; north of the Marine Science Station (MSS) the mountains are high and rugged, close to the coast the wadis are narrow and steep sided; further south, and especially east of the bay, the land form is more open, with wider and less defined wadis but some dramatic outlying hills (Fig. 2.35).

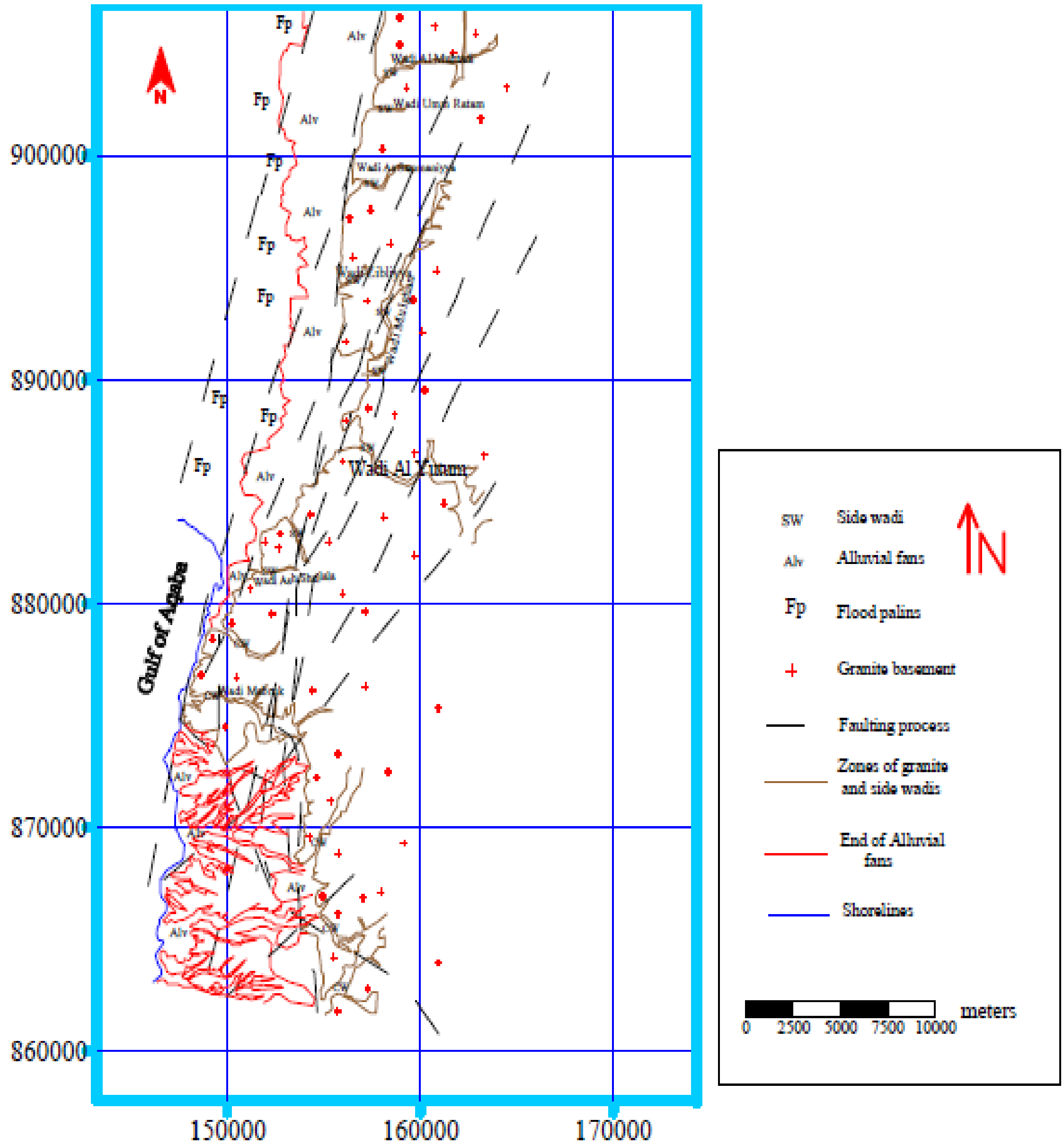

Figure 2.35: End type of map of the aerial photographical analyses in Aqaba (After Al-Farajat 2001).

In the northern part the alluvial fans are forming the distinguishable features; their depositional nature indicates active uplifting processes of the nearby Granite Mountains where the deposition is still take place. Wadi Al-Yutum to the north east of the Aqaba city meets the end of southern Wadi, and their sediments form the flood plains where the Aqaba city is located. The major slope direction of these flood plains is towards the Gulf of Aqaba. The low lying Gulf of Aqaba –Wadi Araba alluviate depressions in the west is bordered by an abrupt straight granitic fault scarp, along the foot of which alluvial fans have developed. Mountain peaks east of the escarpment retain an even altitude not rising markedly above a median altitude of about 1300 meters, and falling gradually eastwards. All wadis, drain ultimately south and west. Wadis are narrow and deeply incised near the western mountain front but widen towards the marine base level as the drainage incision becomes less.

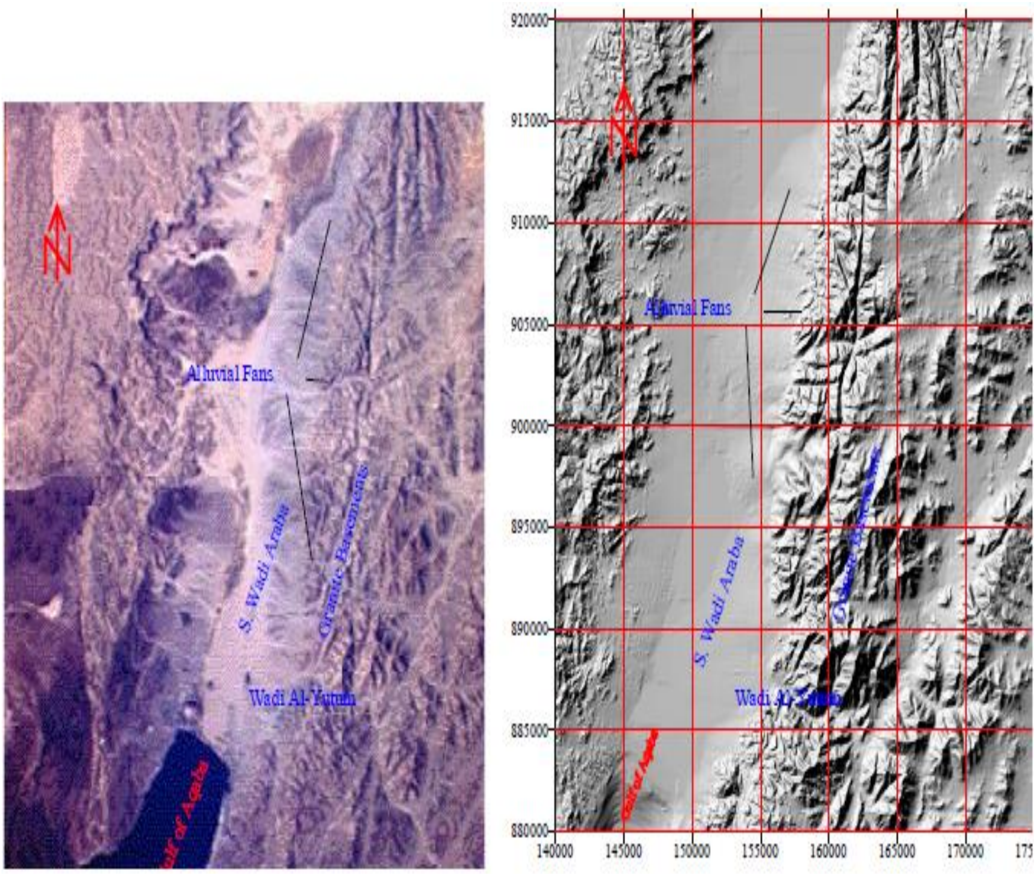

Figure 2.36: shows view correlation between the shaded reliefs of the units of the area north of the Gulf of Aqaba together with a space photo of the same location

The fan complex from Wadi Yutum has displaced the main axial drainage of the Wadi Araba to the west, caused bonding and mud flat development, and has contributed to the gentle shelving of the submarine slope at the head of the Aqaba Gulf and the Gulf's termination at this point. Alluvial fans and alluvium slope seawards compose the foundations of the city of Aqaba.

Using the Digital Elevation Models (DEM), Al-Farajat (2001) described the topography of the Gulf of Aqaba, as a regional north-south directed graben, bounded by two major flanks of higher elevations and cut with east-west directed wadis. The elevations start from values approaching zero nearby the sea zone, and start to increase gently to reach in the upper part of Wadi Al Yutum more than 350 meters above sea level and at the southern

Wadi Araba more than 80 meters. In the southern part, the elevations start from values of zero, and rise very gently east wards until the highway. From the highway to the east they start to strongly rise to reach more than 500 meters nearby the granite zone. The granite series have tops reaching about more than 1000 meters above sea level. Figure (2.37) shows the regional (DEM) model of the Gulf of Aqaba and its surrounding. Figure (2.38) shows the local DEM model of the Gulf of Aqaba.

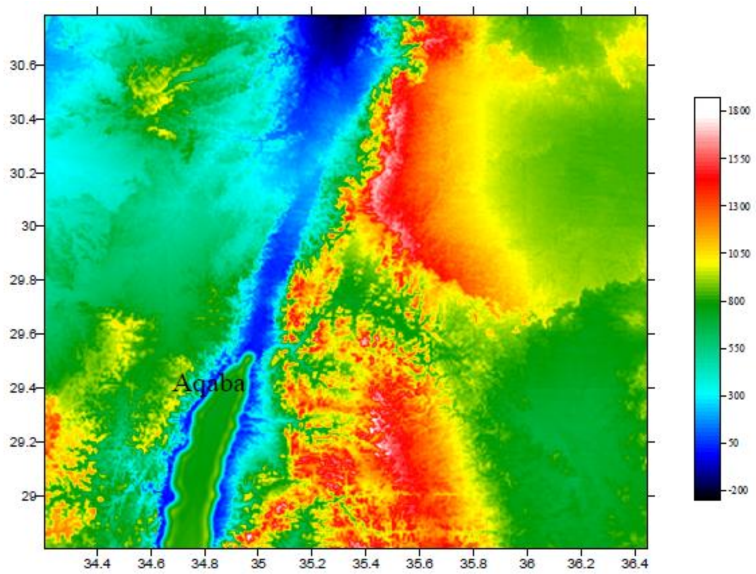

Figure 2.37: Regional DEM model of the Gulf of Aqaba and its surroundings (Al-Farajat 2001).

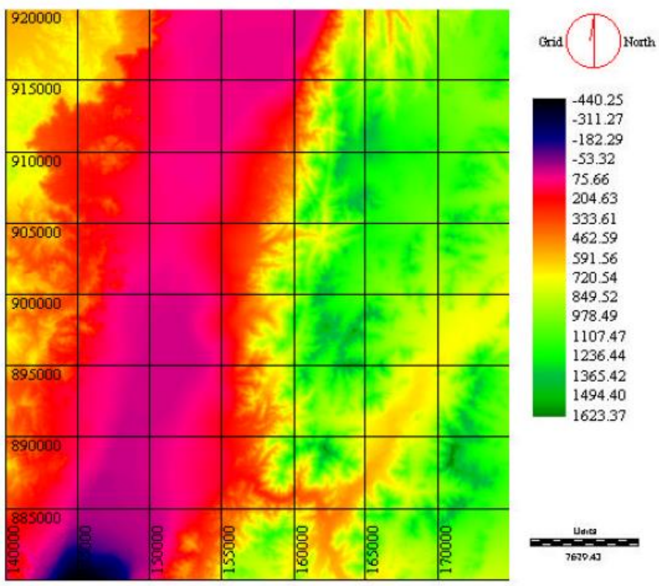

Figure 2.38: Local DEM model of the Gulf of Aqaba (Al-Farajat 2001).

2.11.1 BEACHES AND REEFS

The north beach of Aqaba consists primarily of sand and gravel beaches. In the nearshore, seabed is sandy with few corals. The slope of the nearshore seabed increases southward, leading to very deep water relatively close to shore. The beaches of the Gulf of Aqaba are narrow and the sand is immature. These beaches are of low relief with a gentle (5-15º, foreshore slope (Abu Jaber, 1991). Further south along the coast, more coral reef areas are evident. These reefs are found scattered nearshore, while that of offshore is extending in a more continuous way, although such continuity is interrupted by several bays. Morphologically, the reef of Aqaba fringes the shoreline, with the area offshore of the reef zone dropping abruptly into deeper water. In most areas, a shallow lagoon separates the shoreline from a shallow, fringing reef flat.

The Jordanian coast displays a belt of discontinuous fringing reefs that are developed preferentially on small capes and are separated by wide embayment. The positions of these bays correspond to wadi mouths and they are characterized by a sandy sea bed colonized by scattered coral heads and sea grass beds. The fringing reef lining the coast varies in their distribution. In exposed zones, an extensive 2 to 10 m wide reef flat is formed, while in less exposed areas, patch reefs may coalesce to constitute an irregular reef flat (Hulings,1989).The fringing reef along the Jordanian coast is of extreme environmental importance. It is part of the northernmost reef in the northern Hemisphere. This reef system is considered the most diverse within the Northern Hemisphere with many endemic species (IUCN, 1993).According to Abu Jaber (1991), the 26.5 kilometre-long Jordanian shoreline of the Gulf of Aqaba can be classified on the basis of its morphology into three distinct zones which differ considerably in their morphology, sand budget and their surrounding topography; the northern sandy coast, the northern eastern cliffed coast, and the southern crenulated coast.

2.11.2 THE NORTHERN SHORELINE

The northern shoreline has a cusped/bayed morphology and is lined offshore by an arcuate bar system, where the offshore bar and the cusped/bayed shoreline are out of phase. The longshore currents along the northern coast is an oscillatory motion in which the wave set up erodes an embayment on the coast and accretes an offshore cusp and the wave set down accretes a cusp on the shore. The beach material is composed entirely of fine sand.

2.11.3 THE NORTHEASTERN SHORELINE

Unlike the northern beach, this stretch of shoreline is utilized for port facilities. It is narrow and built by angular, coarse, immature rock fragments ranging in size from pebbles to boulders and by the finer fraction, which is derived from adjacent mountains. The shoreline is paralleled by a system of discontinuous reefs that can either act to buffer the high wave energy resulting in an accretionary beach, or else the channels between reef patches can funnel the wave energy in the form of strong directed rip currents and deplete the beaches of their sediment. The lack of sand along these four kilometres may be attributed to many factors including the absence of alluvial fans, the funnel injection of waves in between natural channels of the reefs, and the various man-made development structures.

2.11.4 THE SOUTHERN SHORELINE

The southern beaches comprise the largest portion of the Jordanian coastline. It extends 14 km, from the Marine Science station in the north to the Saudi border at the far south. The southern beaches are lined offshore by a buffer of live coral reefs, alternating between patchy corals and fringing corals. The sandy stretches along the southern coast are patchy, the major sources of sand for these beaches are; the sediments carried from adjacent beaches by long shore currents, the sediments produced as a result of the scouring of waves at the base of the alluvial fans, and the sediments carried by flash floods during the rainy season. The southern shoreline is made up of a series of capes and embayment. The wide bays are generally located at the mouth of a wadi outlet separated by narrow capes. Similar to the northern coast, the offshore corals serve along this shoreline as a protection to the beaches by acting as a buffer to the incoming wave energy. The resultant waves approaching the beach are weak and incapable of moving sediments into their system. Sandy beaches are commonly protected offshore by a wide reef flat while beaches lined offshore by patch reefs are made up of pebble to cobble size lag sediments.

Beachrocks are exposed along many of the shores, forming 1–3m wide strips at the shoreline. They are cemented by calcium carbonate and the clasts are similar to the present-day loose beach sediments varying in size from millimetre scale to a few centimetres. Beachrocks have also been found buried by loose sediments at many construction sites along the shore of the northern Gulf of Aqaba (Shaked et al. 2002). Numerous uplifted fossil reefs are exposed near the shores of the gulf at the southern end of Sinai, and the northeastern corner south of the town of Aqaba. These are Pleistocene reefs that formed during sea level high stands and reached their present position as a result of sea level fluctuations and tectonic uplift (Al-Rifaiy and Cherif, 1988). Uplifted Pleistocene reefs are not found on the northwestern shores of the gulf, but a fossil reef slightly above the sea level near Elat was dated by Friedman (1965) at 4.7 ka. Reefs of similar age are found at similar elevations along

2.12 STORMWATER, FLOODING AND DRAINAGE

Floods are the main agents transporting eroded material from the surrounding exposed crystalline basement into the gulf in this arid region. At the mouths of catchment basins alluvial fans develop, and offshore from large Wadi mouths submarine fans shape the slope.

Many developments in ASEZ are taking place on alluvial fans of wadis, which do not always have water, so the area will inevitably be hit by disasters when flood happen (Figure 8). In fact, a container company's yard at the mouth of Wadi Mabrak was struck by a disaster in February 2, 2006, causing a casualty. On the same day, the disaster hit the alluvial fan of Wadi Yutum and caused large scale sediment-related damage which included five deaths, the destruction of 18.5 km of water pipes and water production wells, and damage to the airport. Wadi Yutum is within the main development area in the Aqaba Special Economic Zone (Al-Weshah and El-Khoury 1999).

The northern parts of Aqaba are the most vulnerable regions for flash flood hazards. These areas contain all the town residential expansion area, the Aqaba International Industrial Estate, the King Hussein International Airport, and all the northern light industries and logistics areas. The total development potential of that part of Aqaba required the construction of a rain water diversion flood channel along the new northern Aqaba airport parallel highway which connects with Dead Sea-Aqaba road. The total expected cost is JD 30 millions. The flood channel is near completion (96% of the work). Figure 10 shows an example of flood diversion channels in northern Aqaba (DRMP-ASEZP 2010).

Along the shoreline sediments are transported by beach-drift driven by the dominant (95% of the time) north-wind driven waves oblique to the shores, and by heavy southern storms that occur several times a year (ADC 2008).

The Jordanian sector of the Gulf of Aqaba receives storm water from paved urban and resort areas and floodwater from catchments to the north and east. Flooding is a significant problem in some areas of Aqaba despite low annual average rainfall. Forty six (46) catchment areas have been identified which input into the Aqaba basin from the Jordanian side. There are 7 main catchments draining to the coastline. Wadi Yutum runoff flows down towards the north of Aqaba and the Gulf. The runoff of Wadi T and Shallalah pass through Aqaba's urban centre. Wadi Jeishieh runoff drains towards the Main Port and that of Wadi Mabruk (Shmaisy) passes through the Container Port. Further south, runoff from Wadi 9 (Al-Mamlah) passes through the tourist area of "Coral Coast" and Tala Bay (ADC 2008).

A significant sediment load is carried by runoff from these catchments, which pass through urban areas of Aqaba. The Wadi Yutum drainage system delivers sediments into an extensive alluvial fan area located to the north of Aqaba. This drainage system passes through urban Aqaba via outfalls into shallow areas of the upper end of the Gulf, while coastal wadis either flow through short drainage channel or closed drainage systems or directly into deep water of the Gulf (ADC 2008). Wadi 2 (Derreh) runoff passes the northern end of the industrial area. The remaining 39 catchments vary in size from 0.1 to about 7.4 km^2 (ADC 2008).

2.13 DEFINITION OF COASTLINES

The definition of coastlines in the region is affected by the lack of modern hydrographic surveys carried out in the Red Sea and Gulf of Aden. In many parts of the region the coastline and coastal features may be inaccurately shown on the latest charts. Coastlines have been adjusted to reflect their positions as defined by the World Geodetic System 1984 (WGS84), but the positions of many of the coastlines is based on old and sometimes inaccurate data. Positions obtained from satellite navigation systems, such as the Global Positioning System (GPS), are referred to the World Geodetic System 1984 Datum. These positions can be plotted directly on chart. However, due to the age and quality of some of the source but old information, positions obtained from satellite navigation systems may be more accurate than the charted detail. Therefore, a considerable amount of re-surveying of the coastline itself in most of the region, and several of the ports, is required in order to produce accurate paper and electronic charts that show the coastlines, and other features, in their correct positions (PERSG 2006).

2.14 STATUS OF HYDROGRAPHIC SURVEYING IN THE REGION

2.14.1 CURRENT NAVIGATION CHARTS

Chapter V of the IMO Safety of Life at Sea (SOLAS) Convention requires all ships to carry navigation charts. Nowadays, Electronic Navigation Charts (ENCs) are now used on many ships as a mean of improving navigation safety. SOLAS Chapter V recognises that an Electronic Chart Display and Information System (ECDIS), supported by appropriate backup arrangements, can meet its requirements. Charts must be kept up to date in order to meet SOLAS requirements. ENCs charts conform to the

International Hydrographic Organization (IHO) specifications contained in the IHO Special Report S-57. They are compiled from a standardised database of individual items containing all the chart information necessary for safe navigation and may contain supplementary information such as sailing directions and environmental requirements to be followed by ships. The region is well covered by the current folio of nautical charts, of the UKHO. The region, falls within the area designated by UKHO as Area 6 which covers the Red Sea and Gulf of Aden (PERSG 2006).

2.14.2 THE IHO REGIONAL HYDROGRAPHIC SURVEYING

In order to produce the accurate charts of the region needed by modern shipping, high quality hydrographic survey data is essential. The International Hydrographic Organization (IHO) Special Report 55 (or S-55) on the Status of Hydrographic Surveying and Nautical Charting worldwide dated July 2004 covers the bathymetry for the waters of the Red Sea region. The Gulf of Aden and the Red Sea are included also within the North Indian Ocean Hydrographic Commission (NIOHC). The (IHO) report shows that in Jordan, none of the water area with depths less or greater than 200 m has been adequately surveyed, and 90% of the shallower area requires to be resurveyed to modern standards. However, no such survey of deeper waters is required, because the 27 km long Jordanian coastline is steep, reaching depths of over 200 m within 1–3 km of the coast, with no significant dangers to navigation lying offshore (PERSG 2006).

Table 2.17: The status of survey coverage in Jordan for water depths below and above 200 m. A = percentage which is adequately surveyed. B = percentage which requires re-survey at larger scale or to modern standards. C = percentage which has never been systematically surveyed. Bracketed dates indicate most recent update (Extracted from PERSGA 2006).

Country	Water dept	Survey Coverage Status (%)		
Jordan (Jan 2004)		A	B	C
	<200	0	90	10
	>200	0	0	100

2.14.3 CLIMATE CHANGE AND SEA-LEVEL RISE, POTENTIAL IMPACTS ON REGIONAL COASTLINES

Rising sea levels pose a huge threat to ports, islands, and coastal cities and its infrastructure. Global warming is blamed for the rising atmospheric and marine temperatures around the globe. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), air temperatures will rise between 1.4 and 5.8°C between 1990 and 2100. Rising CO_2 levels in the atmosphere, due to the emissions from industrial plants, desalination plants, power plants, and vehicles, are considered responsible for temperature rises. At present, the rise in sea level due to melting ice over Greenland and Antarctica is believed to be of the order of 2 mm/year. According to (IPCC), sea levels could be between 9 cm to 88 cm higher than that recorded in 1990. For the Red Sea and Gulf of Aden, rising sea levels may pose a threat in a number of low-lying areas. These include large areas of sabkha close to the coast, ports, sewage, desalination, power, and industrial plants built at sea level. It includes also any working areas elevated less than a metre above the spring high tide levels, new free zone areas built on reclaimed land at the edge of the sea, such as those at Jeddah.

For the Red Sea and Gulf of Aden, rising sea levels may pose a threat in a number of low-lying areas. These include large areas of sabkha close to the coast, ports, sewage, desalination, power, and industrial plants built at sea level. It includes also any working areas elevated less than a metre above the spring high tide levels, new free zone areas built on reclaimed land at the edge of the sea, such as those at Jeddah (SOMER 2006). The impacts of sea level rise on coastal areas covers many aspects including impacts on water resources, agricultural and health resources in the coastal areas. Usually, impacts are exacerbated by other phenomena such as subsidence, presence of ground water and aquifers (El Raey 2010).

Direct inundation may occur on low land areas and will have serious implications on the coastal shape, resources and tourism. Salt water intrusion will have direct impact on groundwater resources. Impacts of salt water intrusion include increase of soil salinity, deterioration of land and agricultural productivity in the coastal zone, and socioeconomic and health implications. The severity and frequency of extreme events such as droughts, storm surges heat waves, dust storms and flash floods are expected to be exacerbated by climate changes. This phenomenon is not limited to coastal zones; however, due to the high sensitivity of the coastal zone, these changes are expected to hit the coastal zone the most. The rise of sea level will limit the light that reaches deep lying coral reefs which will no longer be capable of sustaining growth. Again the direct interrelationship of global warming, increase of ocean salinity and biodiversity of coral reef and marine life are well recognized in the coastal zone. Its implication on tourism and national income may be severe. The loss of biodiversity of medicinal plants, marine life and on land fauna and flora in coastal zone is also an important factor. Direct and indirect implications on the socioeconomic systems are important factors that have to be taken into consideration (El Raey 2010).

The impact of climate change on world famous coral communities in the Red Sea will include coral bleaching due to increasing temperatures, loss of habitats and loss of biodiversity hence deterioration of tourism. A study on the potential impacts of sea level rise on Saudi Arabia (Saudi, 2005) indicates that an increase in sea level rise could impact many cities along the Red Sea. It will increase intrusion of saline water from the Red Sea into coastal aquifers, which will potentially affect the freshwater supply in coastal zones. In cases of flooding in coastal areas, salt water will further intrude into aquifers which will increase the demand for freshwater from desalination plants. Groundwater levels in these areas might also be affected by the intrusion of saline water. Recently increase of soil salinity has been observed in Gizan and some other coastal cities. This increment has impacted the agricultural activities and the production of cultivated products (Saudi, 2005).

Results indicate that a sizable proportion of the Red Sea will be affected to a combination of inundation and erosion, with consequent loss of developed properties including industrial, recreational and residential areas. As the sandy beach is lost due to erosion, fixed structures nearby are increasingly exposed to the direct impact of storm waves, and will ultimately be damaged or destroyed unless expensive protective measures are taken It has long been anticipated that the rate of long term sandy beach erosion is two orders of magnitude greater than the rate of rise of sea level. Therefore, any significant increase of sea level has direct consequences for coastal inhabitants. About 401, 984 and 1726 hectares of sandy beaches are estimated to be lost by the year 2100, for the Low Sea Level

Rise Scenario (LSLRS) of 0.2m rise, the Medium Sea Level Rise Scenario (MSLRS) of 0.49m rise and the High Sea Level Rise Scenario (HSLRS) of 0.86m rise, respectively (El Raey 2010).

One of the most significant impacts of sea-level rise is acceleration of inundation of coral reefs, wetlands, and mangroves. The rich biodiversity of the wetlands in Saudi Arabia coasts is seriously threatened by loss of wetlands due to sea level rise. Large scale changes in species composition and zoning in mangrove forests are also expected due to changes in sedimentation and organic accumulation, nature of coastal profile and species interaction due to sea-level rise (Saudi, 2005).

2.14.4 SEA LEVEL MONITORING

In order to monitor sea level changes, tide gauges at key locations through the Red sea region are important, particularly at sites for which long-term records are already available. In recent years the stations in the Red Sea have not been reporting tide gauge data to PSMSL. Therefore, there are gaps for many years in the records provided by the stations in this region. Permanent Service for Mean Sea Level (PSMSL) Country Codes have been allocated for countries in the Red Sea region such as Djibouti (475), Egypt (330), Sudan (477) and Yemen (485), but unfortunately not for Jordan. The region should also be aware of, and involved in as appropriate, the Global Sea Level Observing System (GLOSS). IOC is coordinating a programme for the establishment of global and regional sea level networks for oceanographic, climate change and coastal research purposes in which Jordan and other Red Sea countries are not involved (PERSGA2006).

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CHAPTER THREE

3 SOCIO-ECONOMIC DEVELOPMENT AND LAND-BASED SOURCES OF POLLUTION

3.1 SUMMARY

All countries in the Red Sea region are experiencing a rapid increase in population; around 3% annually in countries such as Egypt, Saudi Arabia and Yemen and 2.2% in Jordan.

According to the population census of 2004 the population of Aqaba was 80,059. By the end of 2010, the population of Aqaba was 103,000 compared to 98,750 in 2007 (Department of Statistics/Jordan, DoS). The estimated population of Aqaba by the end of 2012 was about 139,200. The population of Aqaba is growing at a rate of 2.2%. This fast growing coastal town is considered the heart of the Aqaba Special Economic Zone (ASEZ).The increase in the population growth puts a lot of pressure on the coastal environment resources and coastal cities infrastructure.

Throughout history, Aqaba has played an active role in international transit due to its strategic position along East-West and North- South trade routes and the presence of its seaport. Recently and since 1981 Jordan had become the main supply route for goods destined to Iraq. Aqaba had become a key transit point for Egyptian workers going to and from Jordan and Iraq.

The economy of Aqaba has increased after the establishment of the Aqaba Special economic zone and more than US$20 billion have been invested in Aqaba since 2001.The main economical activities in Aqaba are associated with the port, some industries, and tourism and re-export activities. New resorts and tourism projects are being constructed. Along with tourism projects, Aqaba has also attracted global logistic companies such as APM Terminals and Agility (APM named after Arnold Peter Møller (1876-1965 Copenhagen) to invest in logistics, which boosted the city's status as a transport and logistics hub.

Many industrial activities are located in the South Coast Industrial Zone adjacent to Saudi Border. The main activities are: the Jordan Phosphate Mines Co. Industrial Complex, the Thermal Power Plant, the Arab Potash Company and the Arab Gas Pipeline, and the Aqaba International Industrial Estate (AIIE) that will serve as a hub for fully serviced light manufacturing and logistics.

The ports of Aqaba are the largest employer in the region with over 3100 employees, workers and labours in the main Aqaba port in 2013. The total number of employees, workers and labours ranged between 5761 in 1992 to 5032 in 2002 (see Table 3.7), as compared to 1700 workers in industry and about 800 workers in the tourism sector. The port revenue is exceeding JD200 million. Along with that, tourism is a key force in Aqaba that generates and estimated revenue of JD 40 million.

The capacity of the port has been increased significantly over the years. Since 1979 the traffic through Aqaba port has grown at high rates (see Table 3.8). Aqaba port has received 32,026 vessels during the last eleven years (2003-2013) with an annual average of 2,912 vessels.

The number of passengers between 2004 and 2013 ranged between a maximum of 1,375,411 in 2006 and a minimum of 726,920 in 2013 (annual mean 986,650 passenger) (see Table 3.8).

Exports during the period 2003-2013 ranged between a minimum of 6 million tonnes (MT) in 2009 and about 9 MT in 2011. By comparison, imports in the same period ranged between a minimum of 8.3 MT in 2009 and about 12 MT in 2012 (see Table 3.8).

The total cargo handlings (imports and exports) via the port varied from 6,600 tonnes (T) in 1952 to 20 MT in 1988 with revenue of JD 40.5 million. In 2005 it was 20.4 MT with revenue of JD 62 million. The revenue reached maximum of JD 83 million in 2012 (see Table 3.11).

The main exported items include fertilizers, raw phosphate, potash and cement. The main imported industrial items are ammonia, sulphur and gasin addition to crude oil and oil products. The imported oil is mainly crude oil (3.7- 4.0 MT). The official figures of the 2012 annual report showed a general trend of increase in the imports of the liquefied gas, diesel and Gasoline.

According to Aqaba Development Corporation (ADC), the new Port of Aqaba project costs will cost 5 billion dollars, and includes Liquefied Petroleum Gas Terminal (LPG) Jetty, and Liquefied Natural Gas Terminal **(**LNG) Jetty and the rehabilitation of the Oil Terminal, New Phosphate Terminal, Industrial Port, Miscellaneous Liquids Jetty, General Cargo and Ro-Ro Terminal, the Grain Terminal, and the New Ferry (Passenger) Terminal.

The mineral resources production, sales, revenues, and social and environmental impacts constitute very important issues to Aqaba and Jordan. Official reports of the Arab Potash Company (APC) show that the production increased after 2009. The company produced 1.8 MT of potash and sold 1.6 MT in 2012, and sold 1.8 MT in 2013. The revenues increased from JD 373,700 in 2009 to JD 521,209 in 2013. The number of employees of the APC and other related subsidiaries companies is 2427.

The company and other related subsidiaries companies are employing 2427 workers and provided Jordan with JD175 million in 2011, JD100 million in 2012, and JD 75 in 2013 as percentage of the net profit of each of these years. In addition, APC provided more than JD 10 million to support development projects with a focus on vital sectors that include water, education, health and infrastructure.

The Jordan Phosphate Mines Company Production of the Rock Phosphate in the last five years exceeded the 5 MT per year. The production in 2013 was (5,398,584) tones. The revenues had increased from JD 373,700,000 in 2009 to JD 521,200,000 in 2012 .The profits had increased in parallel to sales revenues. Profits had increased from JD131,800,000 in 2009 to JD198,822,000 in 2012 to JD130,661,000 in 2013.

The annual exports ranged between 3.5-4.0 MT during the past five years. In average 3.5 MT are exported through Aqaba port. In 2013 a total of (960,755) tonnes were transported by railroad and a total of (4,328,561) tonnes were transported by trucks. During this year, the quantity of Rock Phosphate exported reached to (3,245) MT. In addition, the company sold 483,000 thousand tonnes of diammonium phosphate (DAP) fertilizer.

The net sales revenues reached JD 574.4 million. This is compared to JD 759.4 million in 2012. The net profits after deducting income tax and distributions reached JD 131.7 million in 2012, compared to 92.88 million in 2009.

From this income, the company which is employing 4056 with 1194 of them in Aqaba is contributing to the development of the local society and support of various activities. The financial donations, given by the company, during 2013, exceeded JD 4.3 millions.

However, the activities of the company are not without environmental effects in Aqaba. During transportation, storage, and loading some phosphate is lost to the atmosphere, to the land around the storage areas, under the ship loader, near the berth, and to the sea. The estimated lost quantities range between 0.05, 0.1% and 1%.

The lost phosphate particles are causing important environmental problem in Aqaba, because substantial quantities of it is lost to the water of the Gulf and settled on the bottom of the sea. The environmental effects of the dust include increasing of suspended solids and water turbidity, reduction of water clarity and light penetration, siltation on the coral reef and depression of coral growth, and increasing the levels of dissolved phosphate nutrients and other toxic heavy metals.

It is anticipated however, that the problem of phosphate dust and its impacts on the environment will be overcome in the new Aqaba Ports Relocation and Development Project. This can be achieved by the development of adequate mitigation measures to reduce or eliminate emissions. Such measures should include specifications for equipment (filters, pumps, curtains, etc) and procedures.

Water consumption and increasing demand in Aqaba region is a foreseen future problem. Economical growth over the past four decades has been accompanied by a parallel growth in population which is expected to reach approximately 250,000 by the year 2020. The high growth rate of economical development which include expansion in the tourism and resort hotels, maritime and land transportation, and industrial and commercial activities will increase the demand for water with time.

At present, the water consumption in the region is estimated at 14.5 million cubic metres (MCM) plus 2 MCM of treated wastewater which is used for irrigating some 200 Hectares (ha) of palm farms and the green areas project. In the future, demand for water will increase to reach about 33.5 MCM on the average, by the year 2020. The demand will be 43MCM (about three times than the demand of 14.94 MCM in 2005) if the high growth model (7.3 % population increase) is considered. The effluent from the tertiary treatment plants is expected to increase and reach 7 MCM by the year 2020.

These conditions will create water and environmental problems in Aqaba. For example, Aqaba will suffer in the near future shortages of water supply that has to be overcome by supply and demand management options. Since current supplies from Disi aquifers (east of Aqaba city) are limited, new supplies would depend on the desalinated sea water.

The other problem associated with increasing demand and consumption of water, is the increased domestic wastewater treatment, use and loss. The maximum estimated wastewater effluent from Aqaba wastewater treatment plant ranges from 750 m^3 to 1500 m^3 in summer and winter respectively. These amounts are used for irrigation of plant trees, forage crops, landscape, palm orchards and the potential golf courses. It is expected that wastewater losses from these activities can reach 20 to 25% of these amounts. These lost quantities will percolate to shallow groundwater and eventually reach the Gulf of Aqaba. A simulation study revealed that the semi-enclosed nature of the Gulf of Aqaba makes it more susceptible to pollution with nitrates.

A recent report indicated that the most anticipated change in the percentage land-use between 2004 and 2018 will be in urban areas (1.94 to 4.45%), industrial or commercial areas (1.35 to 3.52%), port areas (0.39 to 0.90%), and airport area (1.52 to 2.27%).

The land-use changes for Aqaba Special Economic Zone (ASEZ) area of about 375km^2 between 1990 and 2004 **(**see Table 3.33**)** showed that continuous urban fabric was expanding and about 46% of discontinuous urban fabric has changed to urbanized areas. Assuming that similar trend of land-use changes will take place in the future. The predicted land-use by 2018 shows that most change will be in the urbanization and the industrial and commercial areas.

Tourism is very important to the economy and social development of Jordan who experienced a steady increase in tourism during the first decade of the 21st century. Jordan first National Tourism Strategy 2004-2010, had led to great economic advantages. During 2010 Jordan recorded over 8 million tourism arrivals of them about 4.6 million were overnight visitors; tourism expenditure reached more than JD 2.4 billion which contributed 12.4% to the national gross domestic production (GDP); direct employment reached 41,900; and hundred thousand full time-equivalent jobs. The 2011-2015 National Tourism Strategy (NTS) targets an increase of total arrivals to 9.4 million; grow tourism receipts to JD4.2 billion; and grow domestic tourism receipts by 30% over the period.

Aqaba Special Economic Zone Authority (ASEZA) reported that the number of tourists visited the ASEZ in 2006 rose to about 432,000, an increase of 5% over previous year. Approximately 65% (293,000) were Jordanians. In 2010 number of tourists was 503,551 including 294,592 (59%) incoming tourism.

More than $20 billion has been invested in developing Aqaba's massive mega projects in tourism infrastructure and logistics. ASEZA targeted occupancy of 67% in 2014 and 70% in 2015 compared to 45% in 2009 (see Table 3.35).

According to one report, the rapid increase process of hotel-rooms development resulted in Aqaba moved from a "RESPONSE" strategy experienced until 2004, into a "LEVERAGE" strategy until 2011, followed by a possible "GROWTH" strategy towards 2015–2017.

In Eilat at the north-western side of the Gulf of Aqaba, the 'Eilat 2030' strategic plan, tourist development will cause an increase in number of visitors to 7 million visitors, hotel-rooms to 35,000, and a local population of approximately 150,000 inhabitants.

In Egypt tourism is considered one important factor of economic growth where Tourism generates estimated revenue of US$ 10.8 billion annually. This is equivalent to approximately 6% of national GDP if the direct and indirect activities related to tourism are considered.

The Red Sea Governorate represents about 33%, and South Governorate (North Sinaï) at about 32% of the total hotel capacity in Egypt. Together they represent 65% of the total capacity.Tourists are attracted to these governorates because of the coral reefs. Tourists ranked coral reefs at the first place (73%), before climate, beauty of landscape and beaches. Coral reefs are an important component of nature-based tourism and sustainable tourism is a crucial component of tourism strategy in Egypt, Aqaba in Jordan and Eilat for Israel. Almost 75% of tourism activity in Egypt is concentrated on the Sinai and Red Sea

Unfortunately, the relationship between tourism and the environment is unbalanced; tourism is environmentaly dependent and the environment is vulnerable to the impact of tourism (Wong 1993). Therefore ecotourism along the coral reefs of the Red Sea represents a challenge to sustainability.

The construction and operation of tourist facilities and tourist activities have significant impacts on the marine environment but particularly on coral reefs. It has been estimated that 73% of the coral along the Egyptian coast has suffered damaged as a result of coastal constructions. Overfishing is also a major local threat affecting 55% of reefs, particularly in the Gulf of Aqaba.

Marine protected areas (MPAs) are also affected by the continued development of the tourism industry, which was considered as major and most threatening pressure on MPAs in Egypt. Accordingly, the conservation and management of coral reefs is a priority issue in Egypt, since it is the most important source of income to MPAs through tourism.

The other common causes of environmental threats in all MPAs in Egypt is pollution caused directly by tourists (littering caused by divers, snorkelers and anchor chains in coral reef areas).

Marine litter is traditionally classified into land- or ocean-based, depending on its source. According to GESAMP, land-based sources account for up to 80% of the world's marine pollution and much of the litter reaches the ocean from beach-based activities.

Marine litter of diverse types were reported from the coastal and marine environment of the RSGA region. Marine litter has been reported in the waters and beaches of Jordan, Egypt, Saudi Arabia, Yemen, Djibouti, northern coast of Somalia and Sudan. It has been reported from MPAs in Egypt, Sudan and Djibouti.

Among the types of marine litter reported in Aqaba and RSGA are plastics (fragments, sheets, bags, containers); polystyrene (cups, packaging, buoys); rubber (gloves, boots, tyres); wood (construction timbers, pallets, fragments of both); metals (drink cans, oil drums, aerosol containers, scrap); paper and cardboard; cloth (clothing, furnishings, shoes); glass (bottles, light bulbs); fishing gear (nets, abandoned/lost fishing gear); and plastic pellets. In almost all reports plastics were by far the most abundant.

Most of the litter on the Jordanian beaches and in coastal waters of the Gulf of Aqaba results from recreational and shipping activities. The cargo and passengers' ships are a major source of debris. About 19 million items are reaching the marine environment in front of the Marie Science Station (MSS) from the ferry boat at Aqaba passengers' port each year. Other sources of debris are fishing activities and input from several wadis and small valleys during the occasional but very strong floods caused by rain storms common to the region.

The origin of the debris is mainly local (Aqaba), but some debris from Egypt, Eilat, and Saudi Arabia was found on beaches along the Jordanian coasts and beaches.

Management activities in Jordan includevisual monitoring; daily beach clean-up activities; monthly clean-up dive campaigns in the Aqaba Marine Park and other site; participation in the International Coastal Cleanup Campaigns; "Clean-up the World" campaign**;** and public awareness activities and programmes for management of marine litter.

In addition, ASEZA is implementing and enforcing legislations and coastal management policies such as the Aqaba Marine Park Regulation No. 22 year 2001and the Environmental Protection Regulation No. 21 year 2002.

The following actions are suggested to limit, reduce, and enhance the appreciation of the litter problem along the Gulf of Aqaba.

- initiate local and regional research and long-term marine litter monitoring The scientific information would provide input for conservation;
- assist passengers and merchant shipping lines to comply with MARPOL 73/78 and its annexes;
- develop a strategy that integrates land-based solid wastes management issues with those associated with ship and boat generated marine litter;
- increase of existing co-operation among scientists, decision makers, general public on local, national, regional and international scales ;
- implement a solid waste management plan and enforce a Marine Park management plan that will help to control the transboundary solid waste impacts on the marine and coastal water resources of the area;
- promote sound solid waste management practices in Aqaba town, Aqaba ports and in the whole region of the Gulf of Aqaba and the Red Sea;
- Develop a long term strategy for conducting a marine litter cleanup and outreach campaign and establish a public education programmes that target local and international tourists, Aqaba town citizens, students, ports corporation employees and all workers involved in shipping, industry and transport activities;
- Review, develop, implement and enforce a legislative and regulatory framework for the management protection and control of pollution including monitoring with a regional focus; and
- Take measures by the Jordan Ports Corporation and similar port authorities along the Red Sea and Gulf of Aqaba and make available adequate port facilities in all ports of the region to ensure the compliance of vessels, ships and boats with MARPOL 73/78.

Protection of the marine environment of the Jordanian Gulf of Aqaba has been the subject of many articles in many national laws, by-law, and regulations since 1961. All of them contain articles on prohibiting dumping of litter in the marine environment.

In addition, the Gulf of Aqaba as part of the Red Sea, has been designated under the terms of regulation 10 of MARPOL and its annexes as a ‘‘Special Area’’. Annex V, in particular prohibits and restricts the disposal of all garbage, ropes, fishing gear and plastics from ships in any special area. Consequently, Jordan became a party to many regional and international environmental conventions, protocols, treaties, and agreements pertaining to marine litter issues.

According to PERSGA however, the implementation of the national regulations and other regional and international conventions by member states is grossly inadequate, mainly due to lack of sufficient capacities and coordination between different authorities, in addition to a lack of sufficient updating of the laws.

3.2 POPULATION AND POPULATION GROWTH

3.2.1 INTRODUCTION

Utilisation of the coast increased dramatically during the 20th century, a trend that seems certain to continue through the 21st century. Coastal population growth has led to widespread conversion of natural coastal landscapes to agriculture, aquaculture, silviculture, as well as industrial and residential uses (Valiela, 2006). It has been estimated that population densities in coastal regions are about three times higher than the global average (Small and Nicholls, 2003). The attractiveness of the coast has resulted in disproportionately rapid expansion of economic activity, settlements, urban centres and tourist resorts. Migration of people to coastal regions is common in both developed and developing nations. Rapid urbanisation has many consequences: for example, dredging of waterways for navigation, port facilities, and pipelines exacerbate saltwater intrusion into surface and ground waters. Increasing shoreline retreat and risk of flooding of coastal cities in many countries have been attributed to degradation of coastal ecosystems by human activities.

The direct impacts of human activities on the coastal zone have been more significant over the past century than impacts that can be directly attributed to observed climate change (Lotze et al., 2006). The major direct impacts include drainage of coastal wetlands, reclamation, and discharge of sewage, fertilisers and contaminants into coastal waters. Extractive activities include sand mining and oil production, harvests of fisheries and other living resources, introductions of invasive species and construction of structures. Engineering structures change circulation patterns and alter sediment and nutrient delivery. Natural systems are often directly or indirectly altered, even by soft engineering solutions, such as beach nourishment and fore dune construction (Nordstrom, 2000; Hamm and Stive, 2002). Ecosystem services on the coast are often disrupted by human activities. For example, tropical and subtropical mangrove forests and temperate salt marshes provide goods and services (they accumulate and transform nutrients, attenuate waves and storms, bind sediments and support rich ecological communities), which are reduced by large-scale ecosystem conversion for industrial and urban development, and aquaculture

All countries in the Red Sea region are experiencing a rapid increase in population; around 3 % annually in countries such as Egypt, Saudi Arabia and Yemen and 2.2% in Jordan. Within these countries, people move to coastal cities with the hope of finding employment opportunities in ports, customs operations, fishing, tourism and related activities. The increase in the population growth put a lot of pressure on the coastal environment resources and coastal cities infrastructure. The short term economic developments take priority over the concepts of sustainable use and long-term benefit.

Construction of ports, marinas, hotels, roads, residential, and other infrastructure is being extended along the northern, western and eastern coasts of the Gulf of Aqaba. Diving in the coastal waters of the Gulf of Aqaba, has adversely impacted and deteriorated coral reefs, coral species, fish diversity and abundance has deteriorated over more than four decades around Aqaba and Eilat (Zakai and Chadwick-Furman 2002; Epstein 2001) and even in many Egyptian marine protected areas and cities (Sami et al. 2011; Baha El Din, 2003; Smith and McMellor, 2005; Mabrouk, 2007). The other common causes of environmental threats in all MPAs in Egypt is pollution caused directly by local population and tourists (littering caused by divers, snorkelers and anchor chains in coral reef areas (Baha El Din, 2003; Smith and McMellor. 2005; Mabrouk, 2007). The population growth, in addition to increasing industrial, tourism, maritime and other investment activities necessitate a continuous watch, monitoring, and evaluation. Efficient management of solid wastes and marine litter such as the glass bottles, metal cans, plastic bags, plastic containers present along the coast, is urgently required (PERSGA 2006).

3.3 POPULATION OF JORDAN AND ASEZA (AQABA)

The population of Jordan is growing at a rate of 2.2%, with life expectancy of 73.4 years. Still this population growth is creating poverty and affecting ecologically fragile environments. According to the population census of 2004 the population of Jordan was

5,350,000. It increased to 6,388,000 in 2012. The population growth rate however showed a trend of significant decrease from 4.4% in the period 1979-1994 to 2.6% in the period 1994-2004 and recorded 2.2% in the period 2004-2012 (Table 3.1). The life expectancy of this population is increasing with time and recorded 73.4 in 2012 compared to 71.5 in 2009. The population density in 2012 was 71.9 distributed over an area of 88,794 Km^2. Males constitute 51.5% (3,293,000) of the young population of Jordan (Table 3.2) Basic Indicators for (2012) showed that the Crude Birth Rate is 28.1 (per 1000) while Crude Death Rate: 7.0 (per 1000).The total fertility rate for females in ages 15 – 49 years is still high and recorded 3.5 children in 2012. The percentage of urban population is 82.6% (5,276,400) whereas the percentage of the population in the rural areas is only 17.4% (DoS 2012; DRMP-ASEZA 2010**).**

Table 3.1: Population growth rate in Jordan

Period	Population Growth Rate
1952-1961	4.8%
1961-1979:	4.8%
1979-1994	4.4%
1994-2004	2.6%
2004-2012	2.2%

Table 3.2: Population of Jordan by sex according to the 2004 census, and estimated population for years 2005-2012 (DoS 2012)

Year	Male	Female	Total
2004	2,757,700	2,592,300	5,350,000
2005	2,821,100	2,651,900	5,473,000
2006	2,886,600	2,713,400	5,600,000
2007	2,950,000	2,773,000	5,723,000
2008	3,015,000	2,835,000	5,850,000
2009	3,082,000	2,898,000	5,980,000
2010	3,151,000	2,962,000	6,113,000
2011	3,221,100	3,027,900	6,249,000
2012	3,293,000	3,095,000	6,388,000

Statistics Yearbook 2012, Department of Statistics (DoS), Jordan)

Aqaba probably dates back to Iron Age. It has been inhabited since 4000 BC. Its strategic location at the junction of trading routes between Asia, Africa, and Europe made the city a centre of the early settlement Edomites, and then of the Arab Nabataeans. During Roman times, the great long distance road (The King's Highway) led from Damascus through Amman, ending in Aqaba (Aila and Aelana), where it connected with a west road leading to Philistines and Egypt. After spread of Islam, it came under the rule of the Islamic Caliphate, Umayyads, Abbasids, Fatimids and Mamluks. The early days of the Islamic era saw the construction of the city of Ayla, the ruins of which are found at the northernmost tip of the Gulf of Aqaba to the east of the Movenpic Hotel.

At the beginning of the 16th century Ottoman (Turkish) Empire ruled the Arab Region for four centuries. During World War I, the Ottoman forces were forced to withdraw from the town in 1917 and Aqaba was ceded to the British protectorate of Transjordan in 1925. However, the strategic position of Aqaba became very clear in 1980 when Aqaba port grew to be a major site for imports of Iraqi goods during the 1980s until the 1991 Gulf War.

Development planning efforts continued during the seventies, until the creation of the Aqaba Regional Authority (ARA) in 1984. In 1990, Aqaba was designated as a Governorate with a population of 74,399 persons. The population of the Aqaba city itself was 63,157. In August 2000, the Aqaba Special Economic Zone Authority (ASEZA) was established as the statutory institution empowered with regulatory, administrative, fiscal and economic responsibilities within the Aqaba Special Economic Zone (ASEZ). ASEZA was mandated for the management and the development of the ASEZ **(**Fig. 3.1)

Nowadays, Aqaba is still a strategically important city to Jordan, as it is the country's only seaport. The port is Jordan's most important import/export hub at the Gulf of Aqaba/Red Sea. It plays an important role in the economic life of Jordan. Many industrial enterprises are found at the south coast of Aqaba near the border with Saudi Arabia. Millions of tonnes of phosphate and potash are exported via Aqaba ports. In addition, the town's sea and land environments have many attractions to offer the visitors; since the late seventies it became a famous tourist attraction centre for diving, swimming and snorkelling in its warm clean water and fantastic coral reefs and clean sandy beaches.

According to the population census of 2004 the population of Aqaba was 80,059. By the end of 2010, the population of Aqaba was 103,000 (DoS 2013). The estimated population of Aqaba by the end of 2012 was about 139,200. This fast growing coastal town is considered the heart of the Aqaba Special Economic Zone (ASEZ).The population of Aqaba is growing at a rate of 2.2%, with life expectancy of 73.4 years. The population growth rate however showed a trend of significant decrease from 4.4% in the period 1979-1994 to 2.6% in the period 1994-2004 and recorded 2.2% in the period 2004-2012. The life expectancy of this population is increasing with time and recorded 73.4 in 2012 compared to 71.5 in 2009. The population density in 2012 was 20.2 (71.9 for Jordan) distributed over an area of 6905 Km^2 (7.8% of total area of Jordan (88,794 Km^2**)** (Table 3.3). Males constitute 51.5% (3,293,000) of the young population of Jordan (Table 3.4). Basic Indicators for (2012) showed that the Crude Birth Rate is 28.1 (per 1000) while Crude Death Rate: 7.0 (per 1000). The total fertility rate for females in ages 15 – 49 years is still high and recorded 3.5 children in 2012. The percentage of Aqaba urban population is 86% (119,700) compared to 82.6% (5,276,400) for Jordan, whereas the percentage of the population in the rural areas (Table 3.5) is only 14% (17.4% for Jordan) (DoS 2012; DRMP-ASEZA 2010). The unemployment percentage among males and females is a little higher in Aqaba that those in Jordan (Table 3.6).

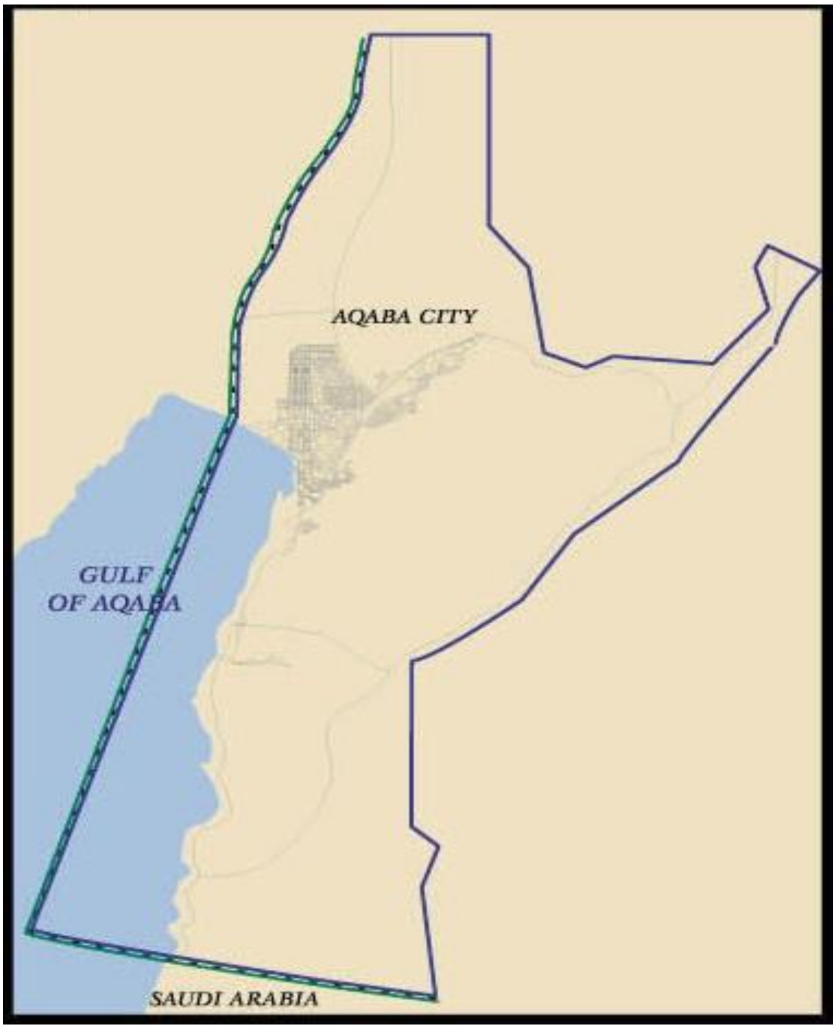

Figure 3.1: Map showing the boundary of Aqaba Special Economic Zone (ASEZ) (SMART 2005).

Table 3.3: Estimated population of Jordan and Aqaba, area (Km^2) and population density by governorate at the end of 2012 (DoS 2012).

District	Population	Area Km^2	Population Density	%
Aqaba	**139,200**	**6,905**	**20.2**	**7.78**
Jordan	**6,388,000**	**88,794**	**71.9**	**100**

Table 3.4: Estimated population of female and males in Jordan and Aqaba Governorate at the end of 2012 (DoS 2012)

District	%	Total	Female	Males
Aqaba	2.2	139,200	61,700	77,500

Jordan/Total	100	6,388,000	3,095,000	3,293,000

Table 3.5: Estimated total, urban and rural population of Jordan and Aqaba Governorate, at the end of 2012

District	**Population**	**Rural**	**Urban**
Aqaba	**139,200**	**19,500**	**119,700**
Aqaba Qasabah District	115,840		
- Aqaba Sub-District	110,150		
- Wadi Araba Sub-District	5,690		
- Quairah District	23,360		
- Quairah Sub-District	18,070		
- Diesah Sub-District	5,290		
Jordan/Total	**6,388,000**	**1,111,600**	**5,276,400**
%	**100.0**	**17.4**	**82.6**

Table 3.6: Unemployment rates by sex and governorate at 2012 (DoS 2012)

	Females	**Males**	**Total**
Aqaba	21.0	14.7	15.7
Jordan	19.9	10.4	12.2

3.4 ECONOMIC AND SOCIAL DEVELOPMENT

The Southern Region of Jordan has great significance for the socio-economic development in the region and in the whole of Jordan. The Region has very important mineral resources, huge reservoirs of fossil underground water resources, and touristic places with international and national significance. In the Southern Region of Jordan, the city of Aqaba has always been an important Sea Port, all through historical ages. Throughout history, Aqaba has played an active role in international transit due to its strategic position along East-West and North- South trade routes and the presence of its seaport. Recently and during the Iran-Iraq War, Aqaba became the most important supply line for Iraq. Since 1980 Jordan had become the main supply route for goods destined to Iraq. In addition, Aqaba had also become a key transit point for Egyptian workers going to and from Jordan and Iraq. The Second Gulf War and the imposition of United Nation sanctions against Iraq, curtailed the utility of Aqaba as a regional seaport. During the 1990s however, Aqaba faced strong competition from Latakia and Beirut. Consequently, by the late 1990s, the port, was handling only 12.5 MT of goods each year, compared to 21 MT per year in the late 1980s. However, the economy of Aqaba has increased after the establishment of the Aqaba Special economic zone. More than US$20 billion have been invested in Aqaba since the establishment of the Special Economic Zone in 2001. Nowadays, new resorts such as Ayla Oasis, Saraya Al-Aqaba, and Marsa Zayed are being constructed, and Tala Bay is already completed. Along with tourism projects, Aqaba has also attracted global logistic companies such as APM Terminals and Agility (APM named after Arnold Peter Møller, commonly known as A. P. Møller, (1876-1965 Copenhagen) is a Danish businessman who was the founder of the A.P. Møller-Maersk Group in 1904) to invest in logistics, which boosted the city’s status as a transport and logistics hub.

Many industrial activities are located in the South Coast Industrial Zone adjacent to Saudi Border. The main activities are: the Jordan Phosphate Mines Co. Industrial Complex, the Thermal Power Plant, the Arab Potash Corporation and the Arab Gas Pipeline. To the north, Aqaba International Industrial Estate (AIIE) covers an area of 530,000 m^2 east of the Aqaba International Airport and 12 km north of the port was established in 2001.The Jordan Industrial Estates Corporation (JIEC) aims to create, manage and expand this Industrial Estate that will serve as a hub for fully serviced light manufacturing and logistics. AIIE enjoys both the status of a special economic zone and a qualified industrial zone (QIZ). The latter gives access of the products from AIIE to the markets of the USA with custom and tax exemptions.

3.4.1 REAL ESTATE & TOURISM DEVELOPMENT

There are many hotels in Aqaba and new hotels are also under construction. Over twenty billion dollars worth of investment is pouring into Aqaba by Gulf. Tala Bay, a US$500 million resort is already completed, while some projects are currently under construction (ADC 2014): Examples of these projects are:

3.4.1.1 Marsa Zayed

Marsa Zayed is a 3.2 Km^2 development including 2 Km of waterfront and is the biggest real estate and tourism project to take place in the history of Jordan. It is a mega mixed-use waterfront project, including high-rise residential towers, recreational, entertainment, business and financial districts and several branded hotels. Several marinas, in addition to a state-of-the-art cruise ship terminal, which will become one of Jordan's touristic landmarks. The total cost of this project is more than US$ 10 billion and will be completed by 2017 (ADC 2014).

3.4.1.2 Ayla Oasis

Ayla is an ambitious waterfront development that created (17 km) of new seafront from a (250 m) strip on the Gulf of Aqaba by creating a new bay (Plate 3.1). The development scheme includes a variety of about 3000 residential units, in addition to 1700 rooms in 4- and 5-star hotels to be constructed over a period of 9 years, a golf course and a town centre that encompasses a marina, and recreational facilities. The total cost of this project is about (US$ 1.4 Billion) with a total area of (430 hectare) on the northern shore. The project will be completed by 2017 (ADC 2014).

Plate 3.1: Ayla oasis project at the northern Gulf of Aqaba (Courtesy of Levon Hagop/Hagop Photo Studio).

3.4.1.3 Saraya Aqaba

Saraya Aqaba is one of the region's major tourist and real estate development projects. The project comprises approximately (63.4 hectare) of a master planned development combining shopping, entertainment and cultural activities within the context of an authentically styled ancient city. Saraya Aqaba features six and five star hotels with more than 1200 rooms and a water park as well as residential developments. The total project cost is estimated at over (US$ 1 billion), the works for the project will be completed by the end of 2016 (ADC 2014; Personal Communications Saraya Management 2015).

3.4.1.4 Mada'en Aqaba Real Estate Development Company

Mada'en Aqaba Real Estate Development Company took over two land plots with a total area of (19 hectare) which will be used to develop residential compounds. The total Investment value is US$ 102 million (ADC 2014).

3.4.1.5 Jordanian Engineering Association Residential Compound:

The Jordanian Engineering association took over the development of a (4.4 hectare) plot of land. The Expected total investment of the project is (US$ 50 million) (ADC 2014).

3.4.1.6 Tala Hills (Al-Hidba)

The project cover a total land area 75,000m^2 with total build up area 37,250m^2 divided to 24,360 m^2 residential units (588 units), 11,117 m^2 hotel and 1,772.9m^2 services and facilities, at a total cost of $35 million. The resort includes 588 residential units (ADC 2014).

3.5 TRANSPORTATION ANDSEA PORTS

3.5.1 AQABA PORTS: MARITIME AND LAND TRANSPORT

The main economical activities in Aqaba are associated with the port, some industries, tourism and re-export activities. The port is the largest employer in the region with over 3100 employees, workers and labours by 2013. The total number of employees, workers and labours has decreased since 1992 from 5761 to 5032 in 2002 and reached 3576 in 2009 (Table 3.7) (Aqaba Port Annual Report 2013) as compared to 1700 workers in industry and about 800 workers in the tourism sector (SMART 2005).. The revenue is exceeding JD200 million. Along with that, tourism is a key force in Aqaba growing that generates and estimated revenue of JD40 million.

Table 3.7: Changes in Aqaba Port manpower (1992 - 2013) (Aqaba Port Annual Report 2013).

Year	Employees	Total no. of employees, workers and labours
2013	**1257**	**3112**
2012	1259	3210
2011	985	3288
2010	1022	3386
2009	1159	3576
2008	1241	3713
2007	1331	3964
2006	1565	4420
2005	1744	5125
2004	1834	5060
2003	1922	4706
2002	2177	5035
2001	2190	5133
2000	2204	5234
1999	2210	5117
1998	2273	5398
1997	2341	5644
1996	2469	5544
1995	2383	5060
1994	2413	5106
1993	2491	5265
1992	2416	5761

The capacity of the port has increased significantly over the years. Since 1979 the traffic through Aqaba port has grown at high rates (Table 3.8). For example, Aqaba port has received 32,026 during the last eleven years (2003-2013) with an annual average of 2,912 vessels. The number of passengers between 2004 and 2013 ranged between maxima of 1,375,411 in 2006 and 1,204,562 in 2007, and a minimum of 726,920 in 2013(annual mean 986,650 passenger) (Table 3.8). The highest numbers of ships (type of ships) are passenger ships, followed by containers, dry bulk, and liquefied gas (Table 3.9). The number of trucks that visited the port during the period 2003-2013 reached 3,326,375 with an annual average of 302,400 trucks (Table 3.10). Exports in the same period ranged between a minimum of 6 MT in 2009 and about 9 MT in 2011.By comparison, imports in the same period ranged between a minimum of 8.3 MT in 2009 and about 12 MT in

2012 (Table 3.8). The total cargo handlings (imports and exports) via the port varied from 6600 tonnes (T) in 1952 to 5 MT in 1979 and revenue of JD 9 million. It increased during the 1980s to reach 20 MT in1988 with revenue of JD 40.5 million. It decreased after then from 15 MT in 1990 to about 12 MT, and changed within a narrow range (12-14 MT) between 1996 and 2001 (Table 3.11). In 2002 it was 14.1 MT (revenue JD 51 million) compared to 20.4 MT in 2005 (revenue JD 62 million). The revenue reached maximum of JD 83 million in 2004 and 2012 (Table 3.11).

Table 3.8: Traffic of ships, goods and passengers via Aqaba Port during years 2003 - 2013

Year	**No of Vessels**	**Traffic Of Cargo Handling**			**No. of Passengers**				
		Import (000) Tonnes	**Export (000) Tonnes**	**Total (000) Tonnes**	**Nuwaibi/Aqaba**		**Tourist**		**Total**
					Arrival	**Departure**	**Arrival**	**Departure**	
2013	2885	11785	4531	16316	231186	266961	114452	114321	726920
2012	3083	11944	7411	19355	335769	389665	99883	100037	925354
2011	2892	10209	8975	19184	314956	354628	71276	69894	810754
2010	2902	8795	8056	16851	353003	413375	74438	74121	914937
2009	2900	8302	5899	14201	393353	435252	47478	47531	923614
2008	3024	9165	7787	16952	564535	551845	41270	40191	1197841
2007	2941	10297	7495	17792	527519	569584	53744	53715	1204562
2006	2884	10145	7020	17165	630092	657027	44208	44084	1375411
2005	2933	12432	7998	20430	427278	453520	20494	20430	921722
2004	2888	12265	8771	21036	423514	434479	10781	10760	879534
2003	2694	9607	8240	17847	315701	356067	2948	2900	677616

Table 3.9: Ships traffic (Type and number of ships) via Aqaba Port during the years 2004-2013.

Ships Traffic (Number of Ships)										Number of Passenger
Year	**General Cargo**	**Containers**	**RO-RO**	**Passenger**	**Cruise**	**Dry Bulk**	**Liquid Bulk**	**Miscellaneous**	**Total Ships**	
2013	130	444	421	1222	112	262	217	77	2885	726920
2012	116	451	357	1455	107	268	253	76	3083	925354
2011	72	497	315	1318	113	333	187	57	2892	810754
2010	97	533	318	1259	151	313	190	41	2902	914937
2009	80	569	296	1312	132	238	220	53	2900	923614
2008	93	362	195	1688	103	347	202	34	3024	1197841
2007	121	354	193	1589	86	341	209	48	2941	1204562
2006	85	378	183	1557	63	347	185	86	2884	1375411
2005	112	443	204	1308	39	361	252	214	2933	921722
2004	109	422	221	1202	20	385	229	300	2888	879534

Table 3.10: Land transport via Aqaba Port / imports and exports from 2003 – 2013

Year	No. of trucks	Loaded from port (weight tonnes)	Phosphate discharged in Port (tonnes)	
			by rail	by trucks
2013	294546	6677516	960755	511635
2012	272206	6792939	1524280	2791783
2011	248430	6107573	1917800	3446489
2010	234440	5640226	2103424	2099640
2009	285112	5963298	2062346	1146148
2008	290496	6952087	2572820	1772638
2007	302623	7410812	2333096	1249995
2006	304943	7520973	2311091	948558
2005	269371	7708269	2624133	1446804
2004	407188	9604124	2777306	1739581
2003	417022	8901543	2388731	1217191

Table 3.11: Development of Aqaba port traffic, imports, export, total handling and revenue during selected years 1952-2013

Year	Number of ships	Imports (tones)	Exports (tones)	Total (tones)	Revenue 1000 (JD)
2013	2885	11784359	4531249	16315608	78398
2012	3083	11943770	7411012	19354782	83701
2011	2892	10208427	8975169	19183596	73000
2010	2902	8795570	8055688	16851258	68001
2009	2900	8302396	5898943	14201339	51446
2008	3024	9165077	7787184	16952261	45715
2007	2941	10297422	7495028	17792450	50235*
2006	2884	10144463	7020391	17164854	59214**
2005	2933	12431848	7998340	20430188	61941
2004	2888	12264692	8770887	21035579	83014
2003	2694	9607267	8239880	17847147	66128
2002	2789	5286178	8872683	14158861	50800
2001	2673	5251616	7791443	13043059	46600
2000	2505	5359612	7192948	12552560	44506
1999	2351	5373740	7480047	12853787	45265
1998	2608	5333727	7310256	12643983	43318
1997	2997	4778310	7534814	12313124	43464
1996	2735	4612453	7396376	12008829	45428
1995	2382	5077045	6679115	11756160	43944
1994	2485	3923903	6648377	10572280	38532
1993	2491	5252689	6381181	11633870	41873
1992	2430	6021703	7361798	13383501	37896
1991	2075	5547998	7677470	13225468	29374
1990	2222	6164599	8871857	15036456	32712
1989	2446	8694675	9985974	18680649	35013
1988	2583	9143165	10952973	20096138	40574

1987	2555	8743749	11271622	20015371	36868
1986	2677	7153240	9697388	16850628	37880
1985	2671	6370104	8177607	14547711	32663
1984	2329	6448343	7158108	13606451	29483
1983	2454	6098755	5059108	11157863	29432
1979	1238	2301369	2708731	5010100	9916
1978	1197	1550781	2108273	3659054	2773
1977	944	1389390	1722283	3111673	3126
1976	1064	1368661	1631842	3000503	2705
1970	220	195567	186328	381895	311
1969	269	205007	538542	743549	245
1968	275	161415	694749	856164	248
1967	452	353793	650929	1004722	451
1966	666	590281	657218	1247499	454
1965	570	408201	521634	929835	526
1964	542	340333	493127	833460	478
1963	500	451695	275189	726884	364
1962	435	368642	286493	655135	354
1958	305	272405	137812	410217	119
1957	95	47604	99172	146776	55
1956	138	76795	67336	144131	23
1955	219	134625	66251	200876	43
1954	173	80142	12339	92481	14
1953	117	56178	4010	60188	10
1952	12	6588	84	6672	0

The main exported items include fertilizers, raw phosphate, potash and cement (Table 3.12). The main imported industrial items used in the industries in Aqaba are ammonia, sulphur and gas (Table 3.13) in addition to crude oil and oil products (Table 3.14). The imported oil is mainly crude oil (3.7- 4.0 MT). However, the figures of the 2012 annual report of the Ministry of Energy and Mineral Resources (Table 3.14) show a general trend of increase in the imports of the liquefied gas, diesel and gasoline.

Table 3.12: Exported cargoes via Aqaba Port during years 2004-2013 in tonnes

Dry Bulk							General Cargo	Total exports
Year	**Fertilizer**	**Potash**	**Phosphate**	**Cement**	**Other**	**Total Bulk**	**Total general cargo**	
2013	851145	1240340	1462298	0	0	3553783	977466	4531249
2012	739458	1208847	4282617	0	0	6230922	1180090	7411012
2011	900447	1725573	5402910	0	4958	8033888	941281	8975169
2010	1074113	1721230	4296845	0	10808	7102996	952692	8055688
2009	971713	825551	3248075	0	5062	5050401	848542	5898943
2008	968637	1565329	3975840	0	248050	6757856	1029328	7787184
2007	1055250	1573560	3604329		186025	6419164	1075864	7495028
2006	1157822	1372415	3254305	0	293082	6077624	942767	7020391
2005	1060636	1570580	4006311	0	17124	6654651	454367	7998340
2004	1159243	1760970	4665955	0	5700	7591868	382947	8770887

Table 3.13: Imports via Aqaba Port during years 2004-2013 in tonnes

Year	Ammonia	Gas	Sulphur	Total Imports
2013	163665	279178	553691	11784359
2012	180908	292809	409047	11943770
2011	197254	284369	508530	10208427
2010	200334	220644	628618	8795570
2009	197038	235825	486357	8302396
2008	206279	191310	338271	9165077
2007	227071	233295	415588	10297422
2006	239939	173781	669178	10144463
2005	206175	226479	596395	12431848
2004	259864	179034	560084	12264692

Table 3.14: Quantities of Imported crude oil and oil products, 2000 - 2012 (000 metric tonnes)

Year	Crude	Fuel	Liquefied Gas	Diesel	Gasoline	Jet Fuel	Total
1997	3444	611	105	213	-	-	3117
1998	3559	796	103	246	7	-	4711
1999	3501	773	138	191	-	-	4603
2000	3763	626	133	239	-	-	4761
2001	3875	647	138	182	-	-	4842
2002	3926	758	155	230	25	-	5094
2003	4023	570	171	292	40	-	5096
2004	4244	100	179	543	135	1	5202
2005	4602	19	178	785	93	1	5678
2006	4258	-	182	509	65	1	5015
2007	4040	0.0	233	429	166	1	4869
2008	3769	91	196	320	141	1	4544
2009	3633	0.0	234	414	231	1	4510
2010	3485	307	219	670	400	1	5078
2011	3189	674	288	1361	540	1	6137
2012	3623	703	288	2089	426	1	7130

Source: Ministry of Energy and Mineral Resources/Jordan-Annual Report 2013.

The figures show also a substantial increase in the amounts of all types of oil products (LPG, Gasoline, Jet Fuel, Diesel, and Fuel Oil) except Kerosene. Consequently the total consumption of oil products increased from 4,580 MT in 2000 to 6665 MT in 2012 **(**Table 3.15).

Table 3.15: Petroleum products consumption2000-2012(000 metric tonnes)

Product	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
LPG	292	298	290	299	313	335	319	339	312	378	377
Gasoline	544	668	670	697	741	840	873	1022	1065	1083	1147
Jet Fuel	178	215	228	314	300	297	216	318	351	354	379
Kerosene	174	214	215	181	150	131	100	111	69	75	81
Diesel	1417	1439	1769	2005	1837	1794	1493	1614	1577	2407	3103
Fuel Oil	2133	1976	1509	1395	1333	1193	1100	823	1273	1670	1578
Total	4849	4810	4681	4891	4674	4590	4101	4227	4647	5967	6665

Source: Ministry of Energy and Mineral Resources/Jordan-Annual Report 2013.

The Aqaba Container Terminal (ACT) is one of the active ports in Aqaba. It has a total area of 500,000 m² and is can accommodate vessels up to1000 meters long after the terminal expansion project which was accomplished at the end of 2013 and increased the capacity of the terminal to 1.2 million twenty foot equivalent units **(**TEUs) with a cost of USD $140 million. The terminal has four berths (Table 3.16) with a maximum depth of 24m in the channels and a maximum depth of 14.5-20m at the berth itself.

Table 3.16: Aqaba Container Terminal Berths (DRMP-ASEZA 2010).

Berth name	**Length (m)**	**Max depth**
Berth 1	333	14.5
Berth 2	333	14.5
Berth 3	333	20
RORO Berth	40	10.3

The operational efficiency of the terminal has developed and increased in the period 2000-2013. The number of vessels was 529 in 2001. After then the number had decreased to reach a minimum of 356 vessels in 2007, but a trend of increase prevailed (Table 3.17). The total throughput (TTL) has also increased rapidly and constantly with time from 215, 257 to 405,660 in 2006 and more than doubled (872,810) in 2013 (Table 3.18). In 2013 the total exports (TEUs) increased by 20%.

Table 3.17: Development of total throughput (TTL) and number of vessels arrived at Aqaba Container Terminal (ACT) between 2000 and 2012 (ACT 2013).

Year	**TTL Volume TEU***	**Number of vessels**	**Average TEUS per VSL**
2000	215,257	506	425
2001	241,037	529	456
2002	277,307	509	545
2003	301,373	470	641
2004	359,719	421	854
2005	392,177	463	847
2006	405,660	378	1,073
2007	414,662	356	1,165
2008	587,530	367	1,601
2009	674,525	569	1,185
2010	605,659	532	1,138
2011	705,648	491	1,437
2012	817,434	445	1,837
2013 YTD**	872,810	401	1,988

***Shipping cargo is measured in twenty foot equivalent units (TEU). The most prevalent TEU containers are 20 feet long and 1,300 cubic feet in volume.**
**** YTD: yet to be determined.**

The revenues of the terminal have increased over the last five years from 49 million JD in 2010 to more than JD 74 million in 2012. In 2013, ACT increased its revenues by 16% to JD 86 million. ACT provided the country with 20 million JD in taxes and shareholder remittances. The number of employees has increased continuously over the same period from 727 in 2010 to 886 in 2013. During the same year ACT increased community investment to 175,000 JD (Table 3.18).

Table 3.18: Development of revenues of the Aqaba Container Terminal (ACT) over the last four years (2010-2013) (ACT 2013).

Year	2010	2011	2012	2013
Total Throughput (TEU)	605,659	705,648	817,434	872,810
Employees	727	704	802	886
Revenues	49,084,571	60,696,029	74,262,738	86,005,044

Usually, the operations and expansion of ports cause adverse environmental impacts, but the management authorities of the ACT put emphasis on minimising these impacts on the on the environmental and local community. The ACT conducted training on the Environmental Management System to increase understanding of compliance and audit requirements within the ISO 14001 system and to comply with PERS requirements. The ACT engaged hundreds of employees in trainings related to environmental management for their job functions. In addition, as safety and environmental protection measures vessels carrying IMO 1.1 explosives, ammonium nitrate, radioactive materials and potassium chloride are prohibited berthing alongside The total volume and type of solid waste produced in the terminal as presented in (Table 3.19). The high volume of waste in produced during 2012 was attributed to the berth expansion project. However, in 2013 ACT reduced waste disposed by 96% relative to 2012 figures. To improve waste management in the future, ACT added waste segregation into their environmental management system for regular monitoring and evaluation of performance. Small volume of oil spills occurred in the terminal during 2010 (total volume 3,474 litres), 2012 (3,772 litres) and 2013 (404 litres). The terminal preventative approach to avoid oil spills contributed to 89% reduction in spill volume from 2012-2013 (ACT 2013).

Table 3.19: Annual volume and type of solid waste produced in the Aqaba Container Terminal during 2009-2013 (ACT 2013).

Year	2009	2010	2011	2012	2013
Total waste segregated (kg)	460	466	246,861	4,357,795	155,288
Waste recycled (%)	-	0%	5%	76 %	56%
Waste by type					
Solid waste (wood, plastic, container seals, tires) (kg)	-	-	53,429	87,058	32,065
Paper and cardboard (kg)	-	-	13,432	3,321,000	87,673
Organic waste (kg)	-	-	159,000	940,000	35,000
Medical Waste (kg)	-	-	21	38	55

Accordingly, Aqaba Special Economic Zone Authority's granted a letter of compliance to ACT. The letter states that ACT is in compliance with local environmental laws and regulations, and that no violations were recorded by ACT during 2013.

3.5.2 AQABA NEW PORT PROJECT/ PORT RELOCATIONPROJECTS

Aqaba's current port will be relocated to the southernmost part of the province near the Saudi border. Its capacity will surpass that of the current port. The project costs 5 billion dollars and it will be completed by 2016 (ADC 2014) (Fig. 3.2). The Aqaba Special Economic Zone (ASEZ) Port community is undergoing major development and upgrading. The Port community master plan calls for introducing new port facilities such as Aqaba New Port, Liquefied Petroleum Gas Terminal (LPG) Jetty, and Liquefied Natural Gas Terminal **(**LNG) Jetty and developing existing facilities such as the rehabilitation of the Oil Terminal, New Phosphate Terminal, Industrial Port, Miscellaneous liquids jetty, as well as the Passenger Terminal (Fig. 3.2) (ADC 2014).

The New Port of Aqaba includes 3 new terminals that are located in a large basin created by dredging the foreshore, and they include the General Cargo and Ro-Ro Terminal, the grain Terminal and the New Ferry Terminal. The General Cargo & Ro-Ro Terminal will consist of a new multi-purpose General Cargo Terminal. It will replace the existing General Cargo berths in the Aqaba Main Port and will accommodate other Cargo displayed by other port developments. The New Grain Terminal will replace the existing grain facilities at the Main Port; the terminal will consist of a new grain berth, storage terminal with truck loading facilities and a bagging plant (ADC 2014).

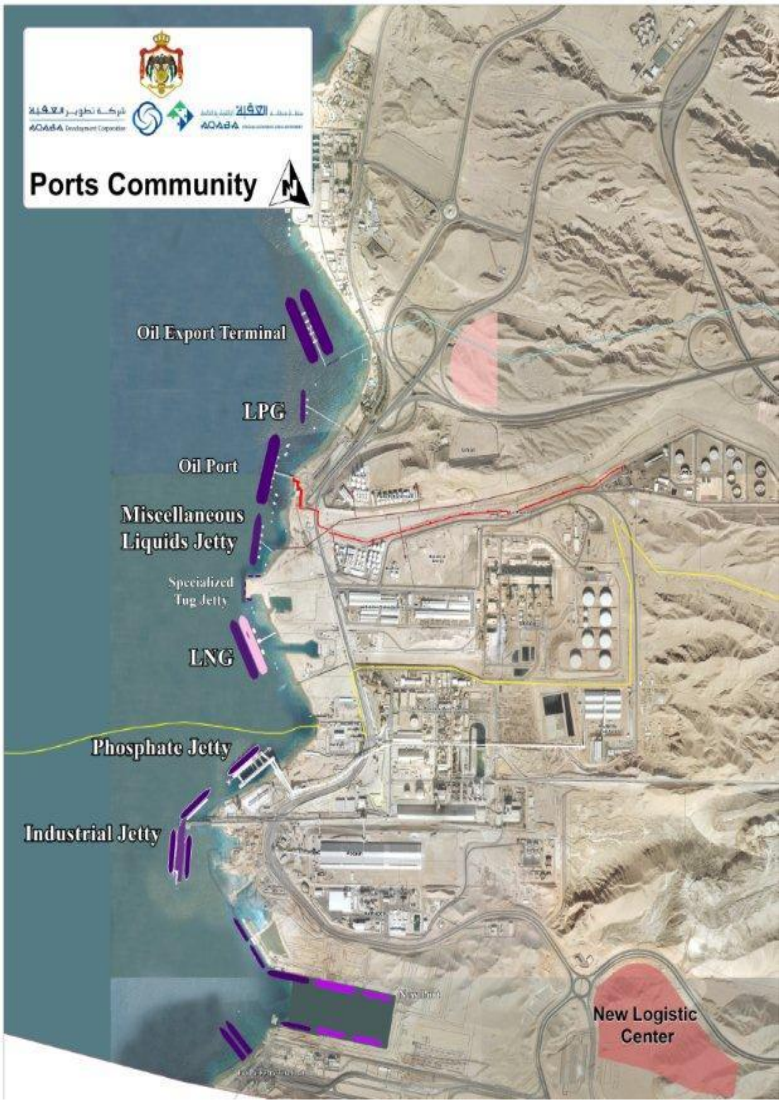

Figure 3.2: The new Aqaba Port at the south coast of Aqaba at Al-Derreh (ADC 2014).

3.5.2.1 Liquefied Natural Gas (LNG) Terminal

The estimated cost of the project is US$ 65 million in addition to lease and operational costs for the Floating Storage Regasification Unit (FSRU). The time frame is 2012 – 2014. The terminal is consisted of (1) Berth (2 berthing Dolphins and 4 mooring Dolphins), unloading and gas processing equipment and connections to current gas pipeline (ADC 2014).

3.5.2.2 Liquefied Petroleum Gas (LPG) Terminal

The estimated cost of the project is US$ 28 million. The time frame is 2013 –2014. The project aims toward constructing a permanent terminal to import LPG in sufficient quantities meeting kingdom's needs. The terminal is consisted of (1) berth, unloading equipment and transport lines (ADC 2014).

3.5.2.3 Oil Terminal

The estimated cost of the project is US$ 28 million. The time frame is 2013 –2014. The project has been established to maximize the Aqaba Oil Terminal handling capacity for crude oil and refined products. In addition it includes upgrading the Oil Jetty and berth facilities to allow safe berthing and de-berthing operations on a 24/7 basis for the full range of tanker sizes for unloading of crude oil, refined product, LPG and Miscellaneous chemical liquids. The associated transfer pumps and pipelines will be upgraded to enable the terminal to handle approximately 14 million tons annually of crude oil, refined products and miscellaneous chemical liquids (ADC 2014).

3.5.2.4 Miscellaneous Liquids Jetty

The estimated cost of the project is US$ 40 Million. The time frame is 2013 –2014. The terminal consists of (1) berth that will be used to import, loading and unloading and store miscellaneous liquids, miscellaneous chemical liquids, crude oil light products and vegetables and mineral oils (ADC 2014).

3.5.2.5 New Phosphate Terminal

The estimated cost of the project is US$ 240 Million. The project includes the construction, expansion, installation, testing, commissioning, and operation of the phosphate Terminal. The new Dry Bulk Jetty will be used for export and will be provided with Dust and Spillage Controls facilities (ADC 2014).

3.5.2.6 Industrial Port

Time frame is 30 years on BOT basis. The estimated cost of the project is US$ 141 Million. The project aims to increase the handling capacity of dry bulk potash and expansion of current terminal by adding a new industrial jetty and rehabilitation of the existing industrial terminal and increase maritime safety and marine environment protection (ADC 2014).

3.5.2.7 Aqaba new Passenger Terminal

The estimated cost of the project is US$ 56 Million. The location of the terminal is to the South of Aqaba New Port. The project aims to construct a new ferry terminal for transporting passengers, vehicles and commodities (ADC 2014).

3.6 MINERAL RESOURCES PRODUCTION, SALES, REVENUES AND EMPLOYMENT

3.6.1 POTASH/ARAB POTASH COMPANY (APC)

APC is one of the important pillars of the national economy of Jordan. APC's contributions to the Treasury of Jordan in 2012 were approximately JD 115 million. The company is one of the leading enterprises in the Amman financial market, one of the private sector's leading exporters and earners of foreign currency, and one of the private sector's leading creators of work opportunities.

Official Reports of the company show that APC production increased after 2009. It reached 3.3 million tonnes in 2011. The company produced 1.8 million tonnes of potash in 2012, of which it sold 1.6 million tonnes. In 2013 APC sold 1.8 million tonnes. The revenues increased also during the same period from JD 373,700 in 2009 to JD 720,200 in 2011 and JD 521,209 in 2013 (Table 3.20) (APC 2013).

Table 3.20: Arab Potash Company (APC) production, sales (million tonnes) and sales revenue (1000 JD) during the years 2009-2013 (APC 2013).

Year	**2013**	**2012**	**2011**	**2010**	**2009**
Potash Production-million tons	**1.7**	**1.8**	**2.3**	**1.9**	**1.1**
Potash Sales - million tons	**1.8**	1.6	2.2	2.1	0.9
Consolidated Sales Revenue*	521,209	586,268	720,200	559,000	373,700
Net Profit after Tax	130,661	198,822	299,700	162,700	131,800

*** Consolidated sales revenue in thousands of Jordan Dinars.**

Of the 1,736,000 tonnes produced during 2013, about 1,210,000 tonnes (70%) were transported to Aqaba warehouse, 372,000 tonnes (21%) to the local markets, 94,000 tonnes to KEMAPCO (5%), 50,000 tonnes to JBC (3%), and 10,000 tonnes to NJFC (1%). The local and regional sales constitute 19%. The products which are transported via Aqaba Ports are sold mainly to India, China and other Asian countries (72%)**.** The rest (9%) is sold to Europe and Africa

The revenues had increased from JD 373,700,000 in 2009 to JD 720,200,000 in 3011 and decreased during 2012 and 2013 when it reached JD 521,209,000.The profits had increased in parallel to sales revenues. After profits had increased from JD131,800,000 in 2009 to JD299,700,000 in 2011 then decrease to JD 198,822,000 and to JD130,661,000 in 2013 (APC 2013).

The number of employees of the APC and other related subsidiaries companies (Jordan Magnesia Company (JORMAG0, Arab Fertilizers and Chemicals Industries (KEMAPCO), Numeira Mixed Salts and Mud Company, and Dead Sea Industries Company (JODICO) is 2427, out of which 2004 are in Ghore Al Safi and 298 are in Aqaba (220 in KEMAPCO and 78 in the (APC) (APC 2013).

The company provided Jordan with JD175 million in 2011, JD100 million in 2012, and JD 75 in 2012 as percentage of the net profit of each of these years. In addition, APC provided more than JD 10 million to support development projects with a focus on vital sectors that include water, education, health and infrastructure. In 2013 APC spent around JD 10 million on projects adopted in consultation with local authorities and civil society organizations, in the areas of water, sanitation, environmental protection, construction of public facilities, health services, support for professional and workers' associations, maintenance of mosques and churches, support for media students, and support to schools and universities. More than 2,000 organizations and 100,000 citizens benefitted from these grants (APC Annual Report 2013).

3.6.2 JORDAN PHOSPHATE MINES COMPANY (JPMC)

Phosphate Mines Company was established in 1953 as a public shareholding Company. The Company is considered as important enterprise that is contributing to the national economy, and to upholding the interest of the nation, citizens and institutions. According to the 2013 annual report of the company is employing 4056. The Total number of employees in Aqaba is 1194 including 47 in the export department, 1072 (45 female) in the industrial fertilizers complex and 75 in the new rock phosphate terminal.

Production of the Rock Phosphate in the last five years exceeded the 5 million tonnes per year. The production in 2013 was (5,398,584) tonnes, with a reduction of (15.4%) compared to the year 2012. Production during the period 2009-2013 is broken down as shown in Table 3.21.

Table 3.21: Mine production (quantities) of phosphate during 2009 – 2013: (thousands tonnes)

Mine	**2013**	**2012**	**2011**	**2010**	**2009**
Al-Hessa	724	771	882	634	492
Al-Abiad	1,057	1,159	1,864	1,666	1,372
Eshidiya	3,618	4,453	4,848	4,229	3,417
Russeifa	-	-	-	-	-
Total	5,399	6,383	7,594	6,529	5,281

In 2013 a total of (960,755) tonnes were transported by railroad and a total of (4,328,561) tonnes were transported by trucks. During 2013, the quantity of Rock Phosphate exported reached to (3,245) million tonnes, out of which 1,852 million tonnes were consumed locally. In addition, the company sold (483) thousand tonnes of DAP fertilizer. The following table shows the phosphate sales and exports during the period 2009-2013 (Table3.22).

Table 3.22: Phosphate sales during the period 2009 – 2013

Year	**2013**	**2012**	**2011**	**2010**	**2009**
Exports	3,245	4,336	5,403	4,297	3,248
Local Consumption	1,852	1,852	2,038	2,209	1,943
Total	5,097	6,188	7,441	6,506	5,191
Aluminium Fluoride	**8**	**9**	**11**	**9**	**9**

Production and sales of Dap fertilizers, Phosphoric Acid, Aluminium Fluoride, and Sulphuric Acid are presented in Table 3.23.

Table 3.23: Production and sales of the chemicals fertilizers at Industrial Complex during 2009-2013 (thousands tonnes)

Product/ Production	**2013**	**2012**	**2011**	**2010**	**2009**
DAP Fertilizer	494	551	706	732	623
Phosphoric Acid	251	272	309	344	306
Sulphuric Acid	822	843	929	1049	918
Product/Sales					
Product	**2013**	**2012**	**2011**	**2010**	**2009**
DAP Fertilizer	483	532	663	760	641
Phosphoric Acid	24	18	41	19	30
Sulphuric Acid	48	20	13	19	30
Aluminium Fluoride	8	13	14	5	8

The net sales revenues reached JD 574.4 million, which include rock phosphate sales, fertilizers sales, subsidiary companies sales and trading in raw material sales. This is compared to JD 759.4 million in 2012. Other non-operational revenues reached JD 14.9 million, compared to JD 9,2 million in 2012.The net profits after deducting income tax and distributions reached JD 2.6 million in 2013 compared to JD 131.7 million in 2012, JD 145.26 in 2011, JD 80.232 in 2010 and JD 92.88 million 1n 2009.

In 2010 the company signed an agreement with ADC / ASEZA on a (BOT) basis for 30 years to develop and operate the new Rock phosphate terminal which is located in the new industrial area on the southern coast of Aqaba. The port is capable of handling (6) million tonnes per year. It is designed for receiving ships with tonnages varying from 5,000 to 100,000 tonnes. It includes a loading station with a capacity of 240,000 tonnes, and a tubular belt linking the loading area at the port with storage facilities with a capacity of 36,000 tonnes per day. Equipment were designed according to the latest technology in order to reduce dust as part of the company's environmental, health and safety commitments, as well as stipulations of the latest international standards and legislation applied at the ASEZ.

In 2013 the company and the Arab Potash Company (both equal partners in the Jordan Industrial Port Company) signed an agreement with Jordan Industrial Port Company and ADC to develop, operate and manage the Industrial Port. The project includes the, construction, operation and management of the industrial port on a BOT basis for 30 years. Construction is expected to be completed and operation to begin in 2016. The Jordan Industrial Ports Company will become able to export DAP fertilizers, Muriate of Potash (Potash MOP): Potassium Chloride, compound fertilizers NPKs (Nitrogen, Phosphorus, Potassium) and phosphoric acid, as well as to import required raw materials.

The Company is contributing to the Development of the local society and support of various activities. The financial donations, given by the company, during 2013, reached JD 4,315,485. The allocated amounts have increased during the last four years (JD1,031,733, 1,039,543, 3,993,703 and 2,282,786) in 2009, 2010, 2011, 2012 respectively. These amounts were donated to develop the local society and support of various activities such as community rehabilitation program for southern governorates; vocational training corporation; scholarships, cultural, tourism, social activities; environmental and health care; Hashemite fund for human development; public institutes and unions; sports activities; municipalities in Jordan; pockets of poverty; schools; science institutes; Jordanian universities, and educational centres.

The 2013 annual report of the Jordan Phosphate Mines Company indicated that the company gives utmost importance for the ideal use of resources and preserves the unique marine environment in the Gulf of Aqaba particularly Corals. Therefore, the Environment Management Regulations Certificate was renewed for the Industrial Complex and it was applied pursuant to international standards (OHSAS18001:2007). The Company rehabilitate some units at the sulphuric acid plant, which entails the replacement of the absorption towers, the final drying tower and some heat exchangers to control SO_2 and SO_3 emissions to lowest possible levels.

The Fertilizer Industrial Complex in Aqaba obtained the ISO 14001 Environmental Management System, OHSAS 18001 (Occupational Health & Safety Management System) and the ISO 9001 Quality Management System approved by (Lloyd's Register Quality Assurance). Moreover The Export Department in Aqaba obtained the ISO 9001 by (SGS).

The company has many subsidiary companies that contribute to the economy of Jordan and employ hundreds of employees. The companies include:

A- Jordan-India Fertilizer Company L.L.C (JIFCO): The Jordan Indian Fertilizers Company (JIFCO) was established in Jordan in 2008 to produce phosphoric acid in the Eshidiya area and the cost for the project is estimated at USD 830.5 million.

B- Jordan Abyad Fertilizer & Chemicals Company (JAFCCO): The Jordan Abyad Fertilizer & Chemicals Company (JAFCCO) was established in 2007 to produce fertilizers and chemicals at Al-Wadi Al-Abiad mine,

C- Jordan Industrial Ports Company:

Jordan Industrial Ports Company was established in 2009 for the purpose of managing and operating the Aqaba Industrial Port. It belongs to both Jordan Phosphate Mines Company and Arab Potash Company equally. The project expected cost is JD (100) million.

D -Manajim for Mining Development Company (MMDCo.): Manajim Mining Development Company was established in 2007.

E- PT Petro Jordan Abadi Company: The PT Petro Jordan Abadi Company was established in Indonesia in partnership with the Indonesian Petrokimia Gresik Company to produce phosphoric acid using phosphate from the Jordan Phosphate Mines Company, and is expected to begin actual production in July 2014.

F- Arkan for Contracting & Construction Company: The Company is responsible for mining activities at Wadi Al-Abiad Mine.

J- Indo-Jordan Chemicals Company (IJC): The Indo-Jordan Chemicals Company (IJC) was established in 1992 with a capital of USD (63.4) million. The annual production capacity is (224) thousand tonnes of phosphoric acid, and it is fully owned by Jordan Phosphate Mines Company. Phosphoric Acid production during 2013 was (193.4) thousand tonnes compared (175.6) thousand tonnes in 2012. Phosphoric Acid sales during 2013 was (195.2) thousand tonnes compared (165.4) thousand tonnes in 2012. The total number of employees in the Indo-Jordan Chemicals Company (IJC) was (387) by the end of 2013.

H. Roy'a Transportation Company limited: The Roy'a Transportation Company was established in 2010 with a capital of JD (100) thousand. It is fully owned by Jordan Phoshpate Mines Company. The total number of employees in the Roy'a Transportation Corporation reached (30) by the end of 2013.

I. Nippon-Jordan Fertilizer Company (NJFC): The Nippon - Jordan Fertilizer Company (NJFC) was established in 1992 with a capital of USD (24) million and produces compound fertilizers and Ammonium Phosphate fertilizer with an annual production capacity of (300) thousand tonnes. Jordan Phosphate. Mines Company contribution is 70% of NJFC's capital. Production of chemical fertilizers (NPK&DAP) during 2013 was 184 thousand tonnes compared with 96 thousand tonnes in 2012. Chemical fertilizers (NPK & DAP) sales quantities during 2013 were 193 thousand tonnes compared with 54 thousand tonnes in 2012. The total number of employees in the Nippon-Jordan Fertilizer Company (NJFC) was (108) by the end of 2013.

3.7 RAW PHOSPHATE DUST (PHOSPHORITE) PARTICLES IN COASTAL ENVIRONMENT OF THE GULF OF AQABA

3.7.1 PHOSPHORITE (RAW PHOSPHATE) PRODUCTION IN JORDAN

Phosphatic strata in Jordan underlie approximately 60% of the country (Abed, 1988), but economically exploitable deposits contain 5.5 billion tons of mineable phosphate (Abed and Amireh, 1999). The phosphorite-bearing strata in Jordan belong to Al-Hisa Phosphorite Formation (AHP) (Powell, 1989). The thickness is about 70 m in central Jordan (Abed et al., 2005). The deposits in Jordan have high phosphorous pentoxide (P_2O_5) content (32%) capable of producing high grade concentrate phosphate rock (JPMC 2005); Abu-Hilal et al., 2008).

Jordan Phosphate Mines Company (JPMC) currently mines and produces various grades of phosphate rock at its mines in Al-Hisa, Al-Abiad and Eshidiya. The production is directly linked with the size of phosphate exports, in addition to the amount used in diammonium phosphate (DAP) fertilizer and phosphoric acid production in local plants. In 2002, phosphate rock production rose to nearly 7.18 MT from 5.84 MT in 2001. In 2009 it was 5.281 MT and increased to reach maximum levels 7.594 MT in 2011 but decreased again to 5.399 MT in 2013. National exports of phosphate rock amounted to $136.2 million compared with $127.6 million in 2001 (Central Bank of Jordan, 2003; Jordan Phosphate Mines Company, 2005 Phosphate rock from the mines is transported to Aqaba by trucks or by train. Phosphate to be exported is stored in warehouses at Aqaba port, which are served by conveyor belts. The annual exports ranged between 3.5-4.0 million tons during the past five years (Phosphate Mine Company 2005; Abu-Hilal et al., 2008). In average 3.5 million tons are exported through Aqaba port. There are two berths available for shipments which can handle up to 8 million tons of phosphate rock per year.

3.7.2 IMPACTS OF PHOSPHATE DUST PARTICLES FROM PHOSPHATE TRANSPORTATION AND LOADING ACTIVITIES ON THE ENVIRONMENT OF THE JORDAN GULF OF AQABA: A REVIEW.

3.7.2.1 *Particulate, Dissolved, Organic, Inorganic, Reactive Soluble and Insoluble Phosphorus*

During transportation, storage, and loading some phosphate is lost to the atmosphere, to the land around the storage areas, under the ship loader, near the berth, and to the sea. The Jordan Phosphate Mines Company has estimated the lost quantities between 0.05 and 0.1%. Schuhmacher et al. (1982) and Freemantle et al. (1978) have made higher estimates of 0.1 and 1%, respectively. In all cases, however, phosphate dust generated during storage and loading is considered an important environmental problem in Aqaba because of the substantial quantities of the phosphate that is lost and settled to the water of the Gulf of Aqaba during the loading process (Abu-Hilal, 1985; Abu-Hilal, 1999; Fishleson, 1973).

Phosphorus exists in marine environment in several forms which include particulate and dissolved; organic (OP) and inorganic (IP); reactive soluble and insoluble (Jenkins and Ives, 1973). Particulate phosphate is more abundant than soluble reactive, since the latter is the forms utilized by living organisms (Chase and Sayles, 1980). The sum of all phosphorus components is termed total phosphorus (TP) (Carlson and Simpson, 1996). Phosphorus is available in seawater as dissolved inorganic phosphate; mainly in the form of orthophosphate ions, such as HPO_4^{-2} (87%), PO_4^{-3} (12%) and $H_2PO_4^{-1}$ (1%). In contrast, particulate organic phosphorus is associated with living or dead organisms (Elmsley and Hall, 1976).

In coastal waters of the Gulf of Aqaba the concentration dissolved inorganic phosphate range was between 0.02 to 0.2µM (Rasheed et al., 2002; Abu-Hilal et al., 2008). In offshore waters dissolved inorganic phosphate concentration had homogeneous values throughout the water column in winter and spring due to mixing. Rasheed et al. (2003) indicated that phosphate-phosphorous and other nutrients are generally higher in winter than in summer. According to Manasrah et al. (2006) deep winter mixing and high nutrient concentration dominates during winter. Shortly after the water stratifies in spring, the nutrients are drawn down by phytoplankton during the spring bloom and remain low throughout the rest of the year. Minimum values were recorded in the upper 50m waters during summer (Badran, 1996; Rasheed, 1998). The thermohaline structure of the Gulf of Aqaba is a major controlling factor of the nutrient, chlorophyll *a* and primary productivity seasonal cycles (Badran et al., 2005).

Sediment acts a sink as well as a source of nutrients (including phosphate) for the overlying water (Bates and Neafus, 1980; Holdern and Armstrong, 1980). 19-65% of inorganic phosphorus in sediment is exchangeable with the overlying water (Li et al., 1973). The maximum release of these nutrients is under anaerobic conditions (Bates and Neafus, 1980; Rasheed et al., 2003). Phosphate-phosphorous and other nutrients concentration in the sediment pore water is higher than those in the waters overlying these sediment, which, under very calm condition resulted in fluxes of 0.1 and 0.01 $\mu mol\ m^{-2}\ d^{-1}$ for dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP), respectively (Rasheed et al., 2002). Estimate by MSS for the total phosphorous concentration in bottom sediments is in the range between 87 to 460 $\mu g\ g^{-1}$ (MSS records, 1999). According to Al-Rousan (1998) the bottom sediments of the Jordanian coast waters contain 0.07% total phosphorous, 0.05% total nitrogen, and 0.35% organic matter as organic. The phosphate concentration in the interstitial is about 50 times higher than those of the overlying waters.

The environmental effects of the dust include increasing of suspended solids and water turbidity, reduction of water clarity and light penetration, and siltation on the coral reef and depression of coral growth. Other potential impact includes increasing the levels of dissolved phosphate nutrients and other toxic heavy metal such as Cd, As, and Zn (Abu-Hilal, 1999), in addition to relatively high contents (44-165 ppm) of uranium, (Abed, 1985; Abu-Hilal, 1994), all of which are considered to be environmentally hazardous. The deposition on the sea bottom and siltation on the coral reef around the loading berth is a clear physical effect (Hawkins et al., 1991). In addition, phosphate particles decrease the space available for new larval settlement, and enhance mucus production by coral which is an energy consuming process (Te, 1992). Furthermore tolerant and opportunistic coral species such as *Stylophora pistillata*, may dominate or replace other coral, thus modifying the biodiversity and the community structure of the reef (Loya, 1976; Walker and Ormond, 1982; Richmond, 1993). It has been found that phosphate in very high concentration decreases coral calcification (acts as a crystal poison of calcification) and causes coral death (Simkiss, 1964; Walker and Ormond, 1982; Stambler et al., 1991). Studies showed that some of the raw phosphate (flouroapatite) does dissolve in the seawater and therefore it may contribute to the level of the inorganic phosphate nutrient in the ecosystem (Abu-Hilal et al., 2008). The phosphate level in the Phosphate Loading Berth area was in nearly three to four times higher than that of the waters in the adjacent areas (Abu-Hilal, 1985).

Phosphate rock in the form of fluorapatite is the main natural resource of Jordan contains variable concentrations of heavy metals (cadmium, lead, mercury, arsenic and zinc) (Jordan Phosphate Mines Company, 2005), in addition to relatively high contents (44-165 ppm) of uranium, (Abed, 1985; Abu-Hilal, 1994), all of which are considered to be environmentally hazardous.

The lost raw phosphate may at least partially dissolve under specific conditions and form dissolved inorganic phosphorus (DIP) to increase the natural concentration of DIP in the water of the Gulf of Aqaba, or may settle and deposit onto the sea bottom as particulate phosphate. However, the dissolution depends on many factors which include but not restricted to pH, temperature of sea water, redox potential (Eh) and grain size of sediments. Solubility increases with decrease in the pH of water and interstitial water. It increases with increase water temperature (Guidry and Mackenzie, 2003). By comparison, the solubility decreases with increase in the grain size of the powdered phosphate rock (Abu-Hilal et al., 2008). In all cases however, the redox potential of the sediment plays an important role in the dissolution rate and adsorption and desorption of heavy metal by organic matter in such environment (Abu-Hilal, 1993).

Many studies have been conducted to estimate the levels and magnitude of phosphate and related pollutants in the Gulf of Aqaba. For example, Mulqi (1978) found that the maximum solubility rate of phosphate rock in the water of the Gulf of Aqaba, is about 56.3 μg-at/l and inversely proportional to particle size. He concluded that the phosphate resulted from the dissolution of the phosphate rock particles is rapidly diluted and dissipated in the waters of the Gulf of Aqaba. Freemantle et al. (1978) reported that the average solubility of the phosphate dust was 20 μg at/l. Abu-Hilal (1985) studied the magnitude and distribution trends of total phosphate-phosphorus in the same study area. He found abnormally high values of total phosphate near the phosphate loading berth which decreases with increasing distance from the loading phosphate berth. However, he indicated that these high phosphates remained localized within the vicinity of the loading berth area. In addition, Abu-Hilal (1987) conducted another study to investigate the concentration and distribution of different species of phosphorus in the same area. He found that the concentrations of apatite, non-apatite inorganic phosphorus, inorganic and organic phosphate were higher in sediments of the area which is in immediate vicinity of the phosphate loading berth. He also found that the concentrations of all phosphorus forms tend to decrease with increasing depth and distance from the loading berth. Fishelson (1973,1977) conducted a study to investigate the biological effect of phosphate dust and concluded that dust along with oil pollution are major factors for nutrients enrichment in the coral reef area in northwestern tip of the Gulf of Aqaba (Eilat).

The effect of phosphate dust particles on the marine organisms has been studied by few researchers. Hashwa (1980) found that the phosphate dust, in *vitro*, is slowly solubilised by microorganisms. He also reported that phosphate dust falling into the sea causes water turbidity and reduces underwater visibility which creates unfavourable conditions for the proliferation of microorganism. Natour and Nienhuis (1980) reported higher chlorophyll *a* values in areas of phosphate dust and sewage pollution. Mergner (1981) considered gross change in a coral reef is attributable to algal growth resulting from phosphate dust. He suggested that increased levels of phosphate do not directly kill the tissue of coral but rather enhances the injury of the coral leading to their death. Walker and Ormond (1982) found that the localized pollution of coral reef along the Jordanian Gulf of Aqaba, due to sewage discharge and to phosphate dust spillage during loading of phosphate mineral into ships, caused increasing death rate of colonies of coral *Stylophora pistillata*. They reported a death rate of 4-5 times as great in the polluted area as in the control area. Madi (1982) found that crude phosphate dust falling into the water increase the concentration of the dissolved inorganic phosphorus at the phosphate loading berth. She also found that the terrigenous sediment samples from the phosphate loading berth area exhibited higher bacterial number and activities than samples from two control sites (Yamaniyah and North coast). Hawkins et al. (1991) attributed the damage of coral reef to the release and impact of several hundred tons of phosphate from a cargo ship. They suggested that the large amount of phosphate powder remained as sediment is inhibiting coral settlement and possibly reduce its growth. Al-Moghrabi and Horani (1998) indicated that there was significant improvement ($P<0.05$) in the water quality of the Gulf of Aqaba between the year 1978 and 1995 due to closing of water sewage plant in 1985 and the suppression of phosphate dust emission.

The mechanism of sedimentation of phosphate particles and the role of physical and biochemical factors in its sedimentation have been also investigated by other workers. Rasheed et al. (2005) indicated that phosphate fluxes were about two fold higher in the uncontaminated sediment which has significantly lower organic carbon and total phosphate concentrations than in the phosphate-contaminated sediment. They also found that the adsorption rate of phosphate onto carbonate sediment was about twice that onto silicate sediments, which indicates that carbonate sediment acts as a buffering system keeping soluble phosphate concentrations at certain steady-state levels.

Rawajfh (2009) in 2007-2008 carried a study to investigate the accumulation pattern, magnitude and distribution of the phosphate rock dust particles that reach the coastal seawater of the Jordanian Gulf of Aqaba during ship loading at the Phosphate Loading Berth (PLB). He measured the concentration of phosphate-phosphorus was measured in water, sediment and trap-sediment and the speed and direction of currents in the area of the study (Fig. 3.3).

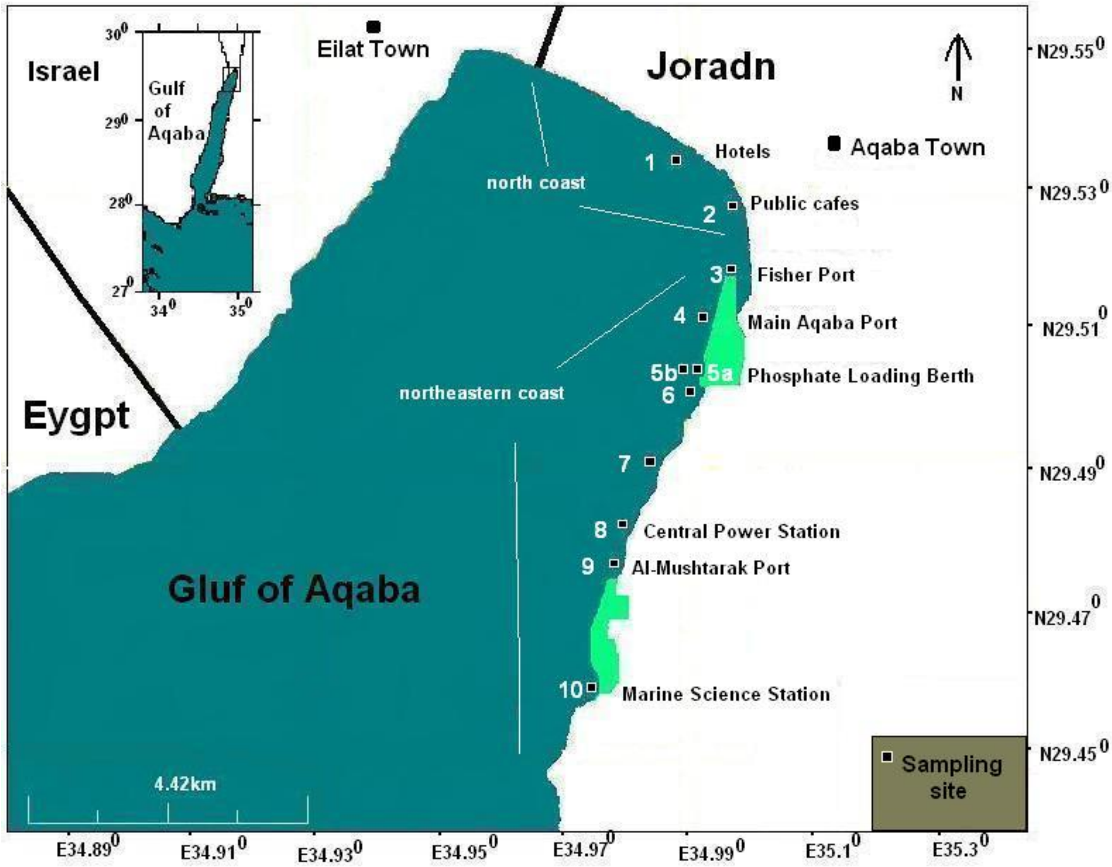

Figure 3.3: Locations of sampling sites (Rawajfh 2009).

He reported that the phosphate pollution is located mainly near the phosphate loading berth, the concentrations of the measured species of phosphorus (total phosphorus (TP), inorganic phosphorus (IP), and organic phosphorus (OP) in trap-sediments were higher than their concentrations in sediments, and IP was the major species of phosphorus in the study area (Tables 3.24 and 3.25).

He found higher concentrations of TP and IP and OP in trap-sediments and sediments around PLB compared to other sites (Table 3.25); the concentrations decrease with distance from the PLB area, and the concentrations of phosphorus are higher in the stations located to the south of the PLB area than those located to the north of it, despite the fact that the distances between the PLB and the north sites are less than the distances between the PLB and the south sites (Table 3.26). This suggests that the prevailing southeastward current is reflected on the distribution of phosphate-phosphorus. These findings are in agreement with similar trends reported previously by Abu-Hilal (1987a).

Table 3.24: Percentage of TP and IP in trap-sediments where calculated as P_2O_5 and TCP (Rawajfh 2009).

Site	Mean concentration mg g $^{-1}$			TP and IP as % P_2O_5	
	(TP)	**(IP)**	**(OP)**	**TP as %P_2O_5**	**IP as % P_2O_5**
HA (Hotels Area)	1.39	1.15	0.24	0.32	0.26
PC (Public Cafees)	3.29	3.05	0.24	0.75	0.70
FP (Fisher Port)	2.61	2.15	0.46	0.60	0.49
AP (Aqaba Port)	10.32	9.34	0.81	2.37	2.14
Phosphate Loading Berth (**PLBC**)	98.43	91.73	6.70	22.56	21.02
Phosphate Loading Berth Offshore (PLBO)	63.33	57.50	5.83	14.51	13.18
PLBS (Phosphate Loading Berth) South	102.33	96.99	5.34	23.45	22.23
PSN (Central Power Station North)	22.21	21.02	1.18	5.09	4.82
PS (Central Power Station)	15.22	13.80	1.42	3.49	3.16
MP (Al-Mushtarak Port)	5.69	5.01	0.73	1.30	1.15
MSS (Marine Science Station)	2.77	2.70	0.07	0.64	0.62

Similarly, Rawajfh (2009) reported a slight increase in dissolved inorganic phosphorus (DIP) concentration in the close vicinity of PLB area which has been attributed to the dissolution of lost raw phosphate particles in the waters of this site (Hulings and Abu-Hilal, 1984; Al-Moghrabi and Horani, 1998). He found also that the DIP concentration in surface waters and near-bottom waters was highest at PLB area and tend to decrease with increasing distance from this site. Furthermore, He found that DIP concentrations generally increase in winter. However, the available evidences indicate that the increase of DIP due to the partial dissolution of the raw phosphate reaching the water of the Gulf of Aqaba would not cause a substantial or significant increase in the prevailing levels of DIP in the water of the Gulf of Aqaba to abnormal or hazardous levels (Abu-Hilal et al., 2008; Rasheed et al., 2005).

In an investigation by Abu Hilal et al (2008) on the impact of quantity, grain size, and source (type) of raw phosphate on dissolution rate of three types of raw phosphate (apatite) from the three main sources of exported phosphate (Al-Hasa, Al-Abyad and Esh-Shydiya) in sea water of the Gulf of Aqaba. It was found that as the weight of apatite from any of the three mining sites increased, dissolved inorganic phosphate-phosphorus (DIP) and fluoride in sea water solution increased, and the dissolution rates were inversely related to particle size. Using a worst-case scenario, a conservative estimate of the maximum increase in DIP in seawater of the Gulf of Aqaba due to the apatite particles lost to the sea during ship loading resulted in DIP concentrations of 0.03µM per year. They concluded that under the effect of the one year residence time of the water in the Gulf of Aqaba, the DIP concentration will not increase by more than 0.03µM under the estimated annual quantity of exported phosphate. Fluoride will not increase by more than 0.03 mg/l under the same conditions. Accordingly, the increase in DIP due to the partial dissolution of the raw phosphate reaching the water of the Gulf would not cause substantial or significant increase in the prevailing levels of DIP and fluoride in the water (Abu Hilal et al. 2008).

Table 3.25: Percentage of TP and IP in sediments when calculated as P_2O_5 and TCP (Rawajfh 2009)

Site	**Mean concentration mg g $^{-1}$**			**TP and IP as % P_2O_5**	
	(TP)	**(IP)**	**(OP)**	**TP as %P_2O_5**	**IP as % P_2O_5**
HA (Hotels Area)	0.81	0.62	0.19	0.19	0.14
PC (Public Cafees)	1.18	1.02	0.16	0.27	0.23
FP (Fisher Port)	1.26	1.06	0.20	0.29	0.24
AP (Aqaba Port)	1.79	1.57	0.22	0.41	0.36
Phosphate Loading Berth (**PLBC**)	94.86	89.67	5.19	21.74	20.55
Phosphate Loading Berth Offshore (PLBO)	45.74	40.53	5.21	10.48	9.29
PLBS (Phosphate Loading Berth) South	86.78	78.31	8.48	19.89	17.94
PSN (Central Power Station North)	5.40	3.74	1.66	1.24	0.86
PS (Central Power Station)	3.04	1.77	1.26	0.70	0.41
MP (Al-Mushtarak Port)	2.03	1.79	0.24	0.47	0.41
MSS (Marine Science Station)	0.69	0.64	0.05	0.15	0.32

Table 3.26: Effect of location and distance between the sampling sites and the phosphate loading berth/ central (PLBC) on the mean concentration values (mg g $^{-1}$) of the measure parameters (Rawajfh 2009).

Site	Location relative to **PLBC**	Distance from **PLBC** (m)	TP mean	IP mean
HA (Hotels Area)	north	2974	0.81	0.62
PC (Public Cafees)	north	2515	1.18	1.02
FP (Fisher Port)	north	1407	1.26	1.06
AP (Aqaba Port)	north	710	1.79	1.57
(PLBC (Phosphate Loading Berth/Central)	------	0	94.86	89.67
PLBS (Phosphate Loading Berth/ South)	south	235	86.78	78.31
PLBO (Phosphate Loading Berth/Offshore)	west	50	45.74	40.53
PSN (Central Power Station/ North)	south	1516	5.40	3.74
PS (Central Power Station)	south	2904	3.04	1.77
MP (Al-Mushtarak Port)	south	3537	2.03	1.79
MSS (Marine Science Station)	south	5390	0.69	0.64

3.7.2.2 Heavy Metals in the Jordan Gulf of Aqaba: Association with Phosphate and Phosphate Dust

One of the significant environmental and competitive aspects of Jordanian phosphate rock is its relatively low concentration of heavy metals (Jordan Phosphate Mines Company, 2005) when compared with other phosphate rocks produced from other sources worldwide. However, this economically important mineral still contains appreciable amount of cadmium, lead, mercury, arsenic and zinc (Jordan Phosphate Mines Company, 2005; Abu-Hilal, 1999).

Heavy metal concentrations in sediment cores and surficial sediment from different sites and depths of the Gulf of Aqaba have been studied by many people during the past two decades (Abu-Hilal, 1987, 1993; Whabeh, 1990; Abu-Hilal et al., 1988; Abu-Hilal and Badran, 1990; Abu-Kharma, 2006; Al-Tawaha, 2007). Abu-Hilal and Badran (1990) studied the distribution and concentration levels of some heavy metal at different depths of coastal sites along the Aqaba coastline. They reported that the sediments of some sites contain high Cd, Co, Cu, Fe, Mn, Pb and Zn concentrations. The heavily polluted sites were the phosphate loading berth site with the main Aqaba port area and near the sewage outlets which was in use at that time. The surface and vertical distribution of these metals were similar to the distribution of total phosphate-phosphorous and fluoride which were derived over the past years from the deposited phosphate rock particle and raw sewage. Within his course of study on the distribution and magnitude of phosphate dust particles in the coastal environment of the Gulf of Aqaba, Rawajfh (2009) measured the concentration of some heavy metals in the sediments and trap-sediments from locations along the coast. The following is a brief extract of his findings.

Cadmium

He found that the concentration of (Cadmium) Cd in trap-sediments was highest (13.14 $\mu g\ g^{-1}$) at sites around the PLB area. It was also high sites (10.29 $\mu g\ g^{-1}$) in sediments of these sites. The spatial distribution of Cd in trap-sediments and sediments is almost the same with relatively higher Cd levels in trap-sediments (Table 3.27), a fact that can be attributed to the effect that occurs when the Cd rich phosphate particles become mixed with other calcareous and terreginous particles in the sediments. In general, the concentrations decrease with increasing distance from PLB. These results are close to the range of values reported by Abu-Hilal (1993) and Abu-Kharma (2006).

Lead

Lead (Pb) in traps-sediment from all sites was highest (73.82±21.10µg.g^{-1}) at the Fisher Port (FP) site and the lowest (28.06 µg.g^{-1}) at the HA. The high concentration of Pb in sediments (51.67µg g^{-1}) was recorded at sites closer to the phosphate loading berth with general trend of decrease with increasing distance from this area. The high Pb around this area is mainly due to the substantial amount of lost raw phosphate (apatite) which contains relatively high concentration of Pb (Table 3.27) (Abu-Hilal, 1987). The lowest (9.81 µg g^{-1}) was found at the HA. The concentration of Pb in the sediment of the Fisher Port area was also high and was attributed to the intensive boat activities that include glass boats, in addition to skiing, patrolling, sport and private boats (Al-Shloul, 2006). The results were within the range of Pb reported by Abu-Kharma (2006) and Al - Tawaha (2007).

Table 3.27: Concentration of heavy metals (µg g^{-1}) in phosphate rock (Rawajfh 2009)

Site	TCP%	Cd	Pb	Zn	Cu
Al-biad	70-72	4.58	33.03	120.15	14.17
Al-Hisa	73-75	2.37	34.00	75.38	6.77
Al-shedeh	73-75	2.46	29.33	45.48	6.44
Mean	-------	3.13	32.12	80.33	9.12

Zinc

The concentrations of Zn in the trap-sediments were higher than the concentrations in the sediments. The highest Zn concentration in sediments (97.84µg.g^{-1}) was recorded at the PLB area. The trend of spatial distribution of Zn is more or less similar to that of Cd and Pb; the concentrations tend to decrease with increasing distance from the PLB. The elevated Zn concentration around PLB was attributed raw phosphate powder (apatite) which contains high Zn levels (190-490 ppm) (Table 3.27) (Abu-Hilal, 1987).

Copper

The highest mean concentration of Cu in trap-sediments (39.87 µg g^{-1}) and sediments PLBC (15.99 µg g^{-1}) were recorded around the PLB area. The Cu levels in trap-sediments were higher than its level in sediments. As in the other heavy metals measured, Cu in trap-sediments and sediments tend to decrease with increasing distance from PLB which consent with previous studies (Abu-Hilal, 1993; Abu-Kharma, 2005; Al-Tawaha, 2007). The results show that the measured Cd, Pb, Zn and Cu concentrations in the sediments of the Gulf of Aqaba are in the range or close to its concentration in phosphate rock (Table 3.27) except in the sediments of the PLB area where Cd level was (2-3) times higher than its concentration in the phosphate rock. However, the concentrations in the sites that are relatively far from the PLB are much less than its concentration in the phosphate rock (Table 3.27).

3.7.3 FUTURE MANAGEMENT AND MITIGATION MEASURES OF PHOSPHATE DUST PARTICLES EMISSIONS IN THE NEW PHOSPHATE TERMINAL

Within the new Aqaba Ports Relocation and Development Project, it is anticipated that the problem of phosphate dust and its impacts on the environment will be overcome. In the EIS of Aqaba Ports Relocation and Development Project (ADC/Aqaba Development Corporation 2008), it was suggested that the construction of a road is preferable over the construction of a railway or conveyer belts despite the fact that emissions from the trucks will be greater, and the risk of dust emissions from the loading, unloading and transportation processes are greatest. Therefore, the study called for careful mitigation and management of dust and emissions. Spillage risk from the trucks, risk from the truck unloading facility at the port, the conveying to the berth, and the ship loading should be studied and assessed by the designers.The design should develop adequate mitigation measures to be taken to reduce or eliminate emissions and ensure compliance with Jordanian Standards. Measures should include specifications for equipment (filters, pumps, curtains, etc) and procedures. Documentary evidence on the performance of the various equipments should be provided.

3.8 WATER RESOURCES, CONSUMPTION AND DEMAND IN AQABA

Aqaba economical growth over the past four decades has been accompanied by a parallel growth in population. Since 1972, Aqaba has been expanded from a small town of 19,000 to a city of 89,000 inhabitants at the end of 2004 (Table 3.28). By the end of 2012, the city reached a population of 139,200. The anticipated coastal population is expected to reach approximately 250,000 by the year 2020. If growth goes at high level this figure can be reached taking into account current plans for resort hotels and vacation communities development as well as expansion in the industrial and commercial activities.

The high growth rate of economical development, which include expansion in the tourism and resort hotels, maritime and land transportation, and industrial and commercial activities will increase demand for water. At present, water supply to Aqaba is derived from the aquifers of the Red Sea basin and from the adjacent non-renewable Disi Aquifer system. The Government has allocated 17.5 million cubic metres (MCM) of water from Disi and about 2.5 MCM from other aquifers. The water consumption in the region is estimated at 14.5 MCM plus 2 MCM of treated wastewater which is used for irrigating some 200 ha of palm farms, the green belt and the airport afforestation project. The effluent from tertiary treatment plants is expected to reach 7 MCM by the year 2020 and will be used for irrigating landscape areas, palm farms and newly developed forest areas. In the future, demand for water will increase to reach about 33.5 MCM on the average by the year 2020 (SMART 2005).

Table 3.28: Indicator of water demand (MCM) under status low growth model (LG 3.3%), medium growth model (MG 5.3%) and high growth model (HG 7.3 %) with current responses (SMART 2005).

Indicator	Unit	Baseline	BAU	OPT	PES
Regional Population	Urban	94400			

	Rural	15750			
	Total	**110150**			
Population Growth Rate	%/year	2.8	2.8	2.2	3.0
Migratory Rate	%o/year	15	15	10	15
Population Density	Peoplekm^2	294	294	320	500
Crude Death Rate	%o /year	5	5	3.5	4.5
Crude Birth Date	%o/year	29	29	24	35
Life Expectancy at Birth	years	71.5	71.5	73	70
Urban Growth Rate	%o/year	24	32	24	32
Growth of G.D.P.	%	4.5	4.5	5.5	2
Domestic Water Consumption (daily average)	m^3/sec	0.11	0.11	0.17	0.2
Commercial Water Consumption (daily average)	m^3/sec	0.02	0.02	0.05	0.07
Agricultural Water Consumption (daily average)	m^3/sec			0.01	0.1
Industrial Water Consumption (daily average)	m^3/sec	0.13	0.13	0.25	0.35
Environmental Water Demand (daily average)	m^3/sec	0	0		0.05
Water Consumption by Tourism (daily average)	m^3/sec	0.07	0.07	0.21	0.3
Total Water Consumption (daily average)	m^3	29326	29326	65000	90000

***Scenario* 1: baseline scenario for 2003**
Scenario 2: status quo (BAU) scenario
Scenario 3: medium growth (OPT) scenario
Scenario 4: high growth (PESS) scenario

In (SMART 2005) Shatanawi and Al-Houri predicted the future water demands under different growth models based on projected population growth for Aqaba. They evaluated the water demand for the years 2005, 2010, 2015 and 2020 under low growth model (3.3 % population increase), medium growth model (5.3 % population increase) and high growth model (7.3 % population increase). In 2020 the estimated demand based on high growth model (7.3 % population increase) will be 43.00 MCM, about three times the demand of 14.94 MCM in 2005 (Table 3.29).

Table 3.29: Population growth and future water demand (MCM) under status low growth model (LG 3.3%), medium growth model (MG 5.3%) and high growth model (HG 7.3 %) (SMART (2005).

LG	**Year**	**2005**		**2010**		**2015**		**2020**	
	Population	91,200		107,275		126,183		148,422	
		lpcd	Demand	lpcd	Demand	lpcd	Demand	lpcd	Demand

	Total		**14.942**		**17.578**		**20.675**		**24.312**
MG	Population	91,200		118,069		152,854		197,888	
	Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand	lpcd	Demand
	Total		**14.942**		**19.345**		**25.045**		**32.423**
HG	Population	91,200		129,716		184,498		262,416	
	Sector	lpcd	Demand	lpcd	Demand	lpcd	Demand	lpcd	Demand
	Total		**14.942**		**21.253**		**30.230**		**43.00**

Table 3.30: Water supply for household & municipal purposes in Aqaba Governorate 2007-2011 (million cubic meters) (SMART 2005).

Year	**2011**	**2010**	**2009**	**2008**	**2007**
Aqaba	15.3	14.6	12.4	14.3	15.4

After showing the water supply for household & municipal purposes in Aqaba Governorate 2007-2011 (Table 3.30), the report showed the different management option for three growth models (Table 3.31) and indicated that Aqaba will suffer in the near future shortages of water supply that has to be overcome by supply and demand management options. The demand management responses would include reducing the unaccounted for water from a current figure of 36% to 30% by 2020 and further reduction to 25% by the year 2020. Since current supplies from Disi aquifers are limited to 17.5 MCM at the maximum, new supplies would depend on the desalinated seawater. This trend will create environmental problems in ASEZ (in Aqaba region).

Table 3.31: Results of different management option for the three growth models (SMART 2005).

Indicators	**Scenarios**												
	Baseline	**Current response**			**Water demand Management response**			**Water supply management response**			**Water supply and demand management response**		
	2003	BAU	OPT	PESS	BAU	OPT	PESS	BAU	OPT	PESS	BAU	OPT	PESS
Supply (MCM)	**14.85**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**22.5**	**27.5**	**37.5**	**22.5**	**27.5**	**37.5**
Population growth (%)	**3.3**	**3.3**	**5.3**	**7.3**	**3.3**	**5.3**	**7.3**	**3.3**	**5.3**	**7.3**	**3.3**	**5.3**	**7.3**

Scenario 1: baseline scenario for 2003 with current responses
Scenario 2: status quo (BAU) scenario with current responses
Scenario 3: medium growth (OPT) scenario with current responses
Scenario 4: high growth (PESS) scenario with current responses

This amount of wastewater effluent flow rate has been estimated based on the fact that the effluent from Aqaba wastewater treatment plant ranges from 750 m^3 to 1500 m^3 in summer and winter respectively. These amounts are used for irrigation of plant trees, forage crops, landscape, palm orchards and the potential golf courses. It is expected with the best irrigation management and systems, the losses can reach 20 to 25% of this wastewater. These amounts will percolate to shallow groundwater and eventually will reach the Gulf of Aqaba. Nitrate as a main pollutant was studied at different discharge rates, and generated by return flow and seepage. The polluted plumes were simulated at different concentration. The simulation revealed that the semi-enclosed nature of the Gulf of Aqaba makes it more susceptible to pollution.

SMART (2005) report indicated that the most anticipated change in the percentage land-use between 2004 and 2018 will be in urbanized areas from 1.94 to 4.45%, industrial or commercial areas from 1.35 to 3.52%, port areas from 0.39 to 0.90% and airport area from 1.52 to 2.27%.The land-use changes for ASEZ area of about 375 km^2 between 1990 and 2004 (Table 3.32) showed that continuous urban fabric was expanding, and about 46% of the discontinuous urban fabric has changed to urbanized areas. The areas have witnessed more urbanized facilities especially around the eastern shoreline. Assuming that similar trend of land-use changes will take place in the future, the predicted land-use in 2018 shows that the most changes will be in the urbanization and the industrial and commercial areas.

Table 3.32: Percentage land use of Aqaba in 1990 and 2004 and expected land use of 2018 (SMART 2005).

Land Use	**1990**	**2004**	**2018**
Continuous and Discontinuous urban fabric	**1.94**	**3.24**	**4.45**
Industrial or commercial	**1.35**	**2.60**	**3.52**
Airport	0.70	1.52	2.27
Port areas	0.39	0.61	0.90
Mineral extraction sites/Quarries	0.25	0.25	0.23
Green urban areas	0.11	0.13	0.15
Sport and leisure facilities/Parks and recreations	0.85	1.10	1.37
Permanently irrigated land	0.19	0.54	0.85
Bare rock	39.13	37.78	32.08
Open spaces with little or no vegetation / Bare soil	37.42	34.54	36.41
Water bodies/treatments	0.07	0.09	0.12
Red Sea/Gulf of Aqaba	17.58	17.60	17.59

3.9 TOURISM IN THE AQABA SPECIAL ECONOMIC ZONE AND ALONG THE JORDAN GULF OF AQABA

3.9.1 INTRODUCTION/THE SIGNIFICANCE OF TOURISM

Tourism is one of the fastest-growing industries of the 21st century in terms of global GDP contribution, foreign exchange earnings and job creation. According to the UN World Tourism Organization (UNWTO), in spite of occasional shocks, international tourist arrivals have shown virtually uninterrupted growth from 438 million in 1990, to 681 million in 2000 and to 935 million in 2010. The tourism industry represents 5% of global economic activity (Buckley, 2011). With an annual growth rate of 6.2%, the annual economic value of tourism surpassed US$1 trillion in 2011 (UNWTO 2012a; Gladstone et al. 2013).

In 2012 receipts from international tourism in destinations around the world grew by 4% reaching US$ 1075 billion. This growth is equal to the 4% increase in international tourist arrivals which reached 1035 million. (UNWTO 2013, PR No.: PR13033 Madrid 15 May 2013).

In 2013, despite global economic challenges, international tourism results were well above expectations, with an additional 52 million international tourists travelling the world. During this year the international tourism generates US$ 1.4 trillion in export earnings and the international tourist arrivals grew by 5% in 2013, reaching a record 1,087 million arrivals ((UNWTO 2014a; UNWTO 2014b).

For 2014, UNWTO forecasts 4% to 4.5% growth, above the long term projections (UNWTO 2014b). UNWTO retains confidence in its long-term forecasts for international growth in tourism, which projects that international arrivals will reach nearly 1.6 billion by the year 2020 and 1.8 billion by 2030 (UNWTO 2014b; UNWTO 2014b). As a worldwide export category, tourism ranks fifth after fuels, chemicals, food and automotive products, while ranking first in many developing countries (UNWTO 2014a).

Tourism in the Middle East (including the countries bordering the Gulf and Red Sea) is expected to grow by at least 5% per year up to 2020, with growth projections for other regions of 4.1%. The top three receiving regions will be Europe (717 million tourists), East Asia (397 million) and the Americas (282 million), followed by Africa, the Middle East and South Asia (UNWTO, 2010).

With a longer history of commercial tourism, some countries around the Red Sea have established coastal and marine tourism industries, and their continued development is a goal of the national development plans of Egypt Sixth Five-Year Plan (2007–2012) and Jordan National Tourism Strategy (NTS 2011–2015).

3.9.2 TOURISM IN JORDANAND ASEZA

Tourism is and will continue to be a long-term driver of economic growth in Jordan, accounting for the largest slice of GDP in Jordan's productive economy. Jordan tourism strategy builds on improving Jordan's overall competitiveness as a tourism destination and positioning the country as a distinctive and culturally enriching experience for visitors. This involves coordinating the efforts of stakeholders across the government and private sectors in order to optimize performance within all key components of tourism such as marketing, pricing and packaging, product development, hospitality and service quality and general business performance.

The importance of tourism to the economy and social development of Jordan experienced a steady increase in tourism during the first decade of the 21st century. Jordan has developed the first National Tourism Strategy through a public-private partnership to cover the period 2004-2010. As a result, marketing and promotion efforts have been strengthened, the quality and variety of tourism products and services have improved, professional human resource practices have been more widely adopted across the industry, and important steps have been taken in creating a regulatory environment that is more conducive to tourism development. Collectively this led to great economic advantages, and today tourism accounted for over 12.4% of Jordan's GDP in 2010.

Over eight million tourism arrivals in 2010 of which 4.55 million were overnight visitors, a 20.3% increase in overnight visitors of 2009. Tourism expenditure reached more than JD 2.423 billion which contributed 12.4% to the national GDP. Direct employment reached 41,900 in 2010 and is estimated to support several hundred thousand full time-equivalent jobs. Key achievements of the 2004-2010 strategy were the opening of three new overseas Jordan Tourism Board (JTB) offices and improvements in marketing and promotion (Table 3.33) which led to:

- Visitor numbers grew by 48%, from just over 5.5 million visitors in 2004 to more than 8.2 million by 2010. As a result, overall receipts increased from JD943 million in 2004 to more than JD2.4 billion in 2010 - a growth of 257%.
- Receipts from domestic tourists increased substantially since 2007 (by 34%), as did receipts generated from Gulf (43%), Arab (38.2%) and foreign visitors (57.5%).

Table 3.33: Number of arrivals and tourism receipts 2004-2010

	2004	2005	2006	2007	2008	2009	2010
Arrivals	5,586,659	5,817,370	6,712,804	6,528,625	7,100,483	7,084,552	8,247,135
Receipts	943	1021.6	1460.8	1638.3	2088.9	2066.9	2423

In addition, the NTS 2004-2010 supported an increase of almost 85% in direct and indirect employment through tourism. It increased the direct employment from 22817 in 2003 to 68451 in 2010. The Indirect employment increased from 41900 in 2003 to126000 in 2010. In addition, over two million Jordanians were impacted by awareness campaigns which sought to highlight the benefits of tourism to the economy.

The tourism strategic priorities for the 2011-2015 strategy were built on achievements realized during the 2004-2010 strategy period. The industry, working with the Ministry of Tourism and Antiquities (MoTA) and other public sector stakeholders have created strategic objectives for the 2011-2015 strategy period along with key activities under four pillars: marketing, product development, human resource development and improving sector competitiveness via a more enabling environment.

To build on these results, over the next period 2011-2015 marketing and promotion efforts will focus on growing international and domestic tourism numbers and revenue and extending visitor length of stay through improved international and domestic marketing. The targets of this pillar include increase total arrivals to 9.4 million; grow tourism receipts to JD4.2 billion; and grow domestic tourism receipts by 30% over the period.

In 2007 Petra was designated as a New 7 Wonder. Consequently, the number of hotel rooms in Jordan increased by 32.7 %, from 18,127 in 2004 to 24,009 in 2010 with the addition of 24 new hotels during that period. New tourism services and infrastructure were added in other areas as well; for example, the number of tourist restaurants almost doubled, the number of tour guides increased by nearly 60%. The Targets for the 2011-2015 NTS include: increase air capacity by 20%**;** complete 20 new tourism infrastructure projects**;** and classification of 100% hotels and 80% restaurants.

Product developments are anticipated to continue over the 2011-2015 period, and a number of large scale projects have been announced. They include hotels, resorts and mixed use properties on the shores of the Dead Sea and Aqaba. Also, a new modern airport was opened during the first half of the strategy period, enabling Jordan to capitalize on growing global air traffic.

Between 2011 and 2015, the plan is to achieve the following targets in the area of product development and competitiveness. Labour Market has markedly developed**;** by 2010 direct employment in tourism had increased by almost 85%, accredited university-level hospitality programmes have been developed. In addition, other Jordanian higher education institutions that offer specialized tourism and hospitality programmes have increased enrolment, female participation in the workforce has grown to 10%, upgraded vocational training centres were launched, and over two million Jordanians were reached by awareness campaigns that sought to highlight the benefits of tourism to the economy.

To add to the important product development that has been achieved as a result of the 2004-2010 NTS, the Targets for the 2011-2015 NTS include: increase air capacity by 20%**;** complete 20 new tourism infrastructure projects**;** and classification of 100% hotels and 80% restaurants. Between 2011 and 2015 the focus of all marketing and promotion activities is to grow international and domestic tourism numbers and revenue by expanding the range, and improving the effectiveness, of marketing activities. The 12 market segments that present significant opportunities for Jordan are:

1. Cultural heritage (archaeology);
2. Religious tourism;
3. Eco-tourism;
4. Health and wellness;
5. Cruises;
6. Meetings, incentives, conference and events (MICE);
7. Adventure and activity tourism;
8. Scientific, academic, volunteer and educational (SAVE);
9. Filming and photography;
10. Festivals and cultural events;
11. Summer and family holidays; and
12. Sports and recreation

3.9.3 TOURISM IN "THE AQABA SPECIAL ECONOMIC ZONE" (ASEZ)/ GULF OF AQABA/RED SEA

Aqaba is well known for its beach resorts, which service visitors who come for fun in the sand as well as water sports. It also offers activities, which take advantage of its desert location. Aqaba Town and The Aqaba Special Economic Zone (ASEZ) in addition to Petra are qualified destinations for international and national tourism.

Aqaba is located in place of the ancient town of Ayla. The city covers an area of approximately 375 km^2 and its population in 2013 is estimated at 139,200 people. In the 1970s, it became a tourist destination, and during the 1980s it started to be a tourist destination for northern Europe tourism. Aqaba ‘Oasis Golden Triangle’ vision combines heritage sites (Petra), culture and desert (Wadi Rum), sea and sun leisure and diving activities. In early 2000, Aqaba was declared as economic free zone, and the Aqaba Special Economic Zone Authority (ASEZA) was established with full autonomy and responsibility. According to ASEZA tourism directorate, in 2006, the authority reported 432,000 tourist visits, of which 293,000 Jordanians (68%) and the rest incoming tourists. Of foreign tourists, Europeans visited the Zone in the largest numbers, with about 98,000 visiting during the year. Results in 2010 indicate 503,551 tourists including 208,959 Jordanians (41%) and 294,592 (59%) incoming tourism. Aqaba airport serves about 230,000 passengers, of which approximately 150,000 tourists. Today, there are 40 hotels in Aqaba, including 6 international brand hotels, 20 diving clubs and 18 tourist agencies. More than $20 billion has been invested in developing Aqaba’s massive Mega Projects in tourism infrastructure and logistics. Among the leading projects are Saraya Al-Aqaba, Ayla Oasis, Tala Bay, Marsa Zayed and other development such as Port Relocation, Aqaba Container Terminal (ACT) and the expansion of King Hussein International Airport (KHIA) (Tirosh 2013).

Aqaba's 2002 strategy tourism strategy development has followed the roadmap outlined in the Strategic Plan for Aqaba Tourism (Price Waterhouse Coopers) prepared with USAID assistance in 2002, building on the Aqaba General Plan. The five year Aqaba marketing strategy which was launched in 2004 had three overall objectives:

- To re-position Aqaba as an international destination as more high quality, high yield products;
- To broaden awareness of Aqaba as a holiday base, a quality diving centre, a cruise liner port, and a potential gateway to Jordan and the region; and
- To increase the length of stay of visitors.

Figures indicate that Aqaba had increased its share of Jordan's bed nights which indicates success in marketing. However, Aqaba's performance in terms of hotel occupancy, upon which the viability of future hotel development largely depends, was not high. Although bed nights have grown slightly, room occupancy was around 52% in 2005 to 47.5% in 2008. This is because expanding room supply is exceeding the growth in demand (MoTA (2005-7); ASEZA Tourism Directorate 2008). ASEZA is expecting more rooms will be added, more rooms will be available and the new marketing strategy is targeting occupancy of 67% in 2014 and 70% in 2015 compared to 45% in 2009 (Table 3.34) (Aqaba Tourism Marketing Strategy 2009).

Table 3.34: Aqaba forecast rooms available

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Net additional rooms		1,489 0	0	470	0	300	1,940
Forecast rooms available	4,044	5,533	5,533	6,003	6,003	6,303	8,243
Target room occupancy (%)	45	50	55	60	65	67	70

Source: Projections supplied by ASEZA Tourism Directorate.

ASEZA has achieved a huge progress over the period of 2000–2011, Aqaba accelerated development processes of tourist infrastructure and Mega Projects.The Targets of the 2011-2015 NTS include: creation of 25,000 additional new jobs; increase the female participation in the workforce by 15%; and provide hospitality skills training for 40,000 employees.

Adler et al. (2009) indicated Aqaba as a "New player in the Red Sea". Gal (2010) indicated that new developments and massive changes in the region and Aqaba create an opportunity with enormous potential for rapid development. Therefore, he recommended removing borders barriers for tourists and maintaining a regional cooperation of synergy in the Red Sea region.

Jordan Ministry of Tourism and Antiquities (MoTA) (2004) focused on achieving three main objectives: Positioning international destination with quality products, increasing awareness of the city as a base for holidays and dive centre and increasing Length of Stay (LOS). Because of a difficult economic situation in 2008 and tough competition in the Red Sea region, it was an urgent need to increase the existing room occupancy mainly because of new hotels and the creation of appropriate differentiation with Egypt and Eilat. The Aqaba Tourism Marketing Strategy (2009) identified weaknesses in Aqaba, particularly in Human Resources (HRs), tourist attractions and activities, quality service, quality of beaches, nightlife and markets. The plan stated that it is necessary to develop Aqaba as a tourist destination, but this cannot be materialised because of relatively small number of suitable hotels and other facilities. Khoury and Bartlett (2010) examined the previous strategic plans, focusing on factors including extending length of stay (LOS), which remained unchanged (1.9 bed-nights/visitor). Consequently, recommendations emphasis on creating high-quality tourism products, meetings, incentives, conferences and exhibitions (MICE) centre, golf course, water park and aquarium, highlighting the urgent need to develop the city centre, fort, heritage sites, shopping street, nightlife activities and efficient transportation. It has been recommended to attract tourism market segments of the North and West Europe, Russia and Middle Eastern countries and the traditional domestic market. The main concern is that Aqaba city will continue to remain only a ‘gateway’ for tourists on their way to Petra and Wadi Rum. King Hussein International Airport (KHIA) is currently utilised only approximately 25% of its capacity of one million passenger movements annually, and therefore it is has been proposed to run low-cost flights to attract more incoming tourists. Aqaba diving activity is considered the tourism core product, affecting length of stay (LOS) to increase. Unfortunately, this industry suffers from a small number of divers, and diving clubs need to improve infrastructure and safety standards. It has been also recommended to emphasis on the development of tourism products in the city itself and develops human capital and jobs creation.

According to the Israel Central Bureau of Statistics, 3.5 million visitors entered Israel in 2013 and had 22.5 million nights; 3% increase. Tourism's contribution to the economy in 2013 was NIS 40 billion (nearly 10 milliard USD) and number of direct employees in tourism was 100,000 and double with indirect employees**.** Eilat on the Gulf of Aqaba, with a population of approximately 60,000 people, has an area of approximately 11,000 acres. Tourism industry is the main and important source of city’s economy. Tourism development started in the 1960s and in the 1970s the development was dramatic with incoming tourism of approximately 250,000 tourists per year. Nowadays, Eilat is considered a popular (about 2.5 million tourists per year) destination for domestic and international tourism. An increase in the number of hotel-rooms to 2550 and charter flights reached 13 flights per week. Eilat in 2011 runs 9500 registered rooms in 49 hotels, serving as 6.7 million bed-nights a year of domestic and incoming tourism at a proportion of 6:1 consecutively.

A report by UNWTO (2009) noted that the incoming tourism from Eilat to Aqaba, counted about 16,727 bed-nights of Israelis in 2009, and significantly increased in 2010. For the Eilat market, Aqaba operates as a tourist destination that is competitive with Egypt and Turkey. According to Sheinin (2009) ‘Eilat 2030’ strategic plan, tourist development will cause an increase in number of visitors to 7 million visitors, hotel-rooms to 35,000 and a local population of approximately 150,000 inhabitants.

In 2011 Israeli approved the construction of a second international airport in Timna 18 km north of Eilat's which will become operational on 2017. The old airport in Eilat and the new airport in Timna will together serve about 1.5 million passengers per year. 2,080 hotel rooms and 1,000 apartments will be built on the site of the Eilat Airport, after it is vacated. The hotel, recreation, and residential plan will include 275-dunam (63.75-acres) of open public space. In 2012 a high-speed railway project was approved to link Eilat with Beersheba and Tel Aviv, and will run through the Wadi Araba. All these projects are part of a plan to turn Eilat into a metropolitan area of 150,000 people (now some 50 000) and 35,000 hotel rooms (Rusila (2014); GPO/Tourism Ministry/Israel 2013).

Despite these plans, Tirosh (2013) commented that Eilat is not meeting all the practical processes of tourism development. By comparison, Aqaba is experiencing a strategic process of "LEVERAGE", which, over some several years, is expected to be changed into a "GROWTH" strategy. He noted that since early 2000, Eilat hotel-rooms were in a steady state. He noted that hoteliers in Eilat do not initiate new hotels if there is no feasible Return on Investment (ROI) in a reasonable time. Domestic tourism market share is approximately 85% of the total hotel occupancy rate of about 70%. Without significant increase in incoming tourism, Eilat will be stuck in a steady state of stagnation. In contrast, Aqaba is characterized by a significant exponential fit ($r2$ = 0.9112), under a rapid increase process of hotel-rooms development. This behaviour explains a sequential move from a "RESPONSE" strategy experienced until 2004, into a "LEVERAGE" strategy until 2011, followed by a possible "GROWTH" strategy towards 2015–2017. Tirosh (2013) concluded that if the development trend of hotel-rooms in Eilat and Aqaba will continue to exist without substantial external and internal interferences, number of hotel-rooms in Eilat and Aqaba towards the period of 2017–2020 is expected to even. Aqaba tourism development LEVERAGE ‘Leading Strategy’ relies on a clear policy of Jordan through ASEZA. Aqaba is in a process of development of hotels, particularly of international brands, which is expected to reach approximately 8000 rooms in the years 2015–2017, and even equal to Eilat in 2020. Unlike domestic tourism in Eilat reaching a level of 85% of all tourists, domestic tourism in Aqaba contributes about 40% occupancy in hotels. Therefore, the development of tourism hotel infrastructure and the ratio of 1:2.5 between domestic and incoming tourism creates a challenge, which requires effort in developing new markets and continued growth of incoming tourism (Tirosh 2013).

Tourism in Egypt is considered one important factor of economic growth as it represents about 40% of the Egyptian non-commodity exports in 2007/2008. The tourism sector represents the main source of foreign currency. Also, it is one of the main labour-intensive activities as the total employment provided by this sector is estimated at about 4.5 millions jobs which is equivalent to about 13% of the total labour force. Moreover, the contribution of the tourism sector in GDP in 2008/2009 reached about 3.6% (Egypt Yearbook 2009).The Red Sea Governorate represents about 33% of the total capacity, followed by south governorate (North Sinaï) at about 32% of the total hotel capacity in Egypt. Together they represent 65% of the total capacity. Egypt‘s tourism investment in coastal resorts is very high. For example, in 1999, 90% of Egypt‘s tourism investment was concentrated in coastal resorts or Southern Sinai, with a large concentration on dive tourism and beach holidays around the Red Sea Gulf of Aqaba which was considered one of the world‘s fastest-growing resort areas (Shackley 1999). Tourism in Egypt generates an estimated US$ 10.8 billion annually. This is equivalent to approximately 6% of national GDP if the direct and indirect activities related to tourism are considered. It provides employment for 12% of the national work force (AFP, 2007). Much of the revenue from tourism in Egypt is derived from the Red Sea region (IUCN-USAID, 2007).

3.9.4 IMPACT OF TOURISM ON THE COASTAL ENVIRONMENT AND RESOURCES OF THE GULF OF AQABA/RED SEA

Seen as an expanding source of economic growth, developing nations have invested in their tourism industries and in 2010 these destinations represented 47% of global tourism activity (UNWTO, 2012b). An attractive marine life and favourable climate have encouraged the rapid development of a major tourist industry along the coasts of the Red Sea (PERSGA/ GEF 2004c). The coastal zone attracts the greatest number of tourists (Davenport and Davenport, 2006) and the greatest growth in tourism is occurring in the sub-sector of coastal and marine tourism (UNEP, 2009). Coastal and marine tourism activities are diverse, and include activities on the shore (e.g. walking, curio collecting, animal observation, off-road vehicle tours), in coastal waters (e.g. swimming, surfing, boating), in offshore waters (cruising, marine mammal observation, fishing), under the water (e.g. diving, shark feeding), and specialist niche activities (e.g. marine research tourism, adventure tourism) (Hall, 2001; Wood, 2010). Starting from the early 1990s, the Red Sea region has been targeted for massive tourism development in Egypt. In 2000, the existing number of rooms was 10,549 representing 22.2 percent of the total hotel accommodation capacity in Egypt. The target for 2012 was to achieve 140,000 rooms (JICA (1999). The northern part of the Red Sea has the highest coral diversity and number of islands (GEF 1998). The marine realm exhibits a wide spectrum of ecosystem, habitat and species diversity due to the variation and interplay of the substrate types. The special combination of warm, clear water and limited freshwater runoff from adjacent arid lands has contributed to extensive coral-reef development throughout the entire Red Sea region.

In addition, the coral reefs cover a distance of about 1500 km along the Red Sea coastline including islands, the Gulf of Suez and the Gulf of Aqaba. Over 300 species of corals have been recorded in the entire Red Sea, A fairly high percentage of some fish groups associated with coral reefs in the Red Sea are endemic (GEF 1998). The Red Sea is home to four species of marine turtles— the hawksbill, the green, leatherback and loggerhead— all of which are globally threatened. Dugongs are also found in the Red Sea and classified as vulnerable. Hundreds of coastal birds and migratory species are frequent visitors to the Red Sea shores to find food and resting places during the long-haul flight from Siberia to South Africa (IUCN 2000).

3.9.5 TOURISM THREATS TO THE CORAL REEFS OF THE GULF OF AQABA/RED SEA

The unique marine habitats as coral reefs, mangroves and sea grass beds provide key resources for coastal populations: food, shoreline protection and stabilization, and economic benefits from tourism (Barrania 2010). They are found in countries that are highly dependent on tourism as a source of foreign income (Ibrahim and Ibrahim 2003). The Red Sea including the (Gulf of Aqaba tourism) is one of the most important tourists' magnets for the ecologically-valued landmarks (the coral of the Gulf of Aqaba). The coral reefs and their biodiversity in the Gulf of Aqaba (Nuweiba, Taba), South Sinai (Sharm el-Sheik within the Ras Mohammed National Park), the North (Hurghada, Safaga and Quseir) and South (Marsa Alam) Red Sea coast have made these two areas a world-privileged destination for diving tourists (Shaalan 2005). Coral reefs are an important component of nature-based tourism and sustainable tourism is a crucial component of tourism strategy in Egypt, Aqaba in Jordan and Eilat for Israel. Almost 75% of tourism activity in Egypt is concentrated on the Sinai and Red Sea (Smiths et al. 1998). Red Sea is considered to be one of the best scuba diving locations (Ibrahim and Ibrahim 2003). Jobbins (2006) reported that a survey made in 2004 to determine the top motivations for foreigners to travel to South Sinai, showed that tourists ranked coral reefs at the first place (73%), before climate, beauty of landscape and beaches. Accordingly, Egypt has been promoted many destinations for tourism in the Red Sea coast and Gulf of Aqaba in hope that it will increase in tourism revenue, economic growth and employment opportunities. The number of hotels in the Gulf of Aqaba/Egypt has increased from 5 in 1989 to 141 in 2006 while the number of hotel rooms increased from 565 to more than 48,000 (Kotb et al. 2008). The number of tourism boats has increased sharply over the last 20 years. In Sharm El Sheik dive boat number rose from 23 in 1989 to 350 in 2006 (Hilmi 2012).

Unfortunately, the relationship between tourism and the environment is unbalanced; tourism is environmentally dependent and the environment is vulnerable to the impact of tourism (Wong 1993). Therefore ecotourism along the coral reefs of the Red Sea represents a challenge to sustainability. The various environmental stresses associated with tourism can be grouped in four types (Pearce 1985): permanent facilities directly related to tourism (such as hotels, golf courses, marinas, access roads, water and sewage treatment plants, power generation plants, etc); generation of wastes and transportation; tourist activities; and effect on population dynamics or induced impact of tourism.

The tendency to develop facilities very close to the coast threatens the coral reefs, mangroves, beaches and aquatic species. The construction and operation of individual marinas for each resort is usually accompanied by destruction of coral reefs, sedimentation and changes in shorelines. The construction activities of hotels and supporting infrastructure generate considerable quantities of wastes, which in most cases are improperly disposed of. Also, the air borne particulates during construction, oil spills and uncontrolled workers activities may disturb the surrounding ecosystem. The operation of resorts has significant environmental impacts on the environment. Air pollution results mainly from power generation and transportation of tourists, workers, and goods. Improper solid waste disposal and lack of management may result in health problems and negative aesthetic impact. Chemicals for different hotel activities can result in damages to the ecosystem if they reach the natural sensitive environment (Shaalan 2005). Tourist activities may damage the reefs intentionally to keep samples as souvenirs; others may throw garbage in the sea (Shaalan 2005).

Tourism constitutes a major threat for coral reefs in two ways: directly, damage caused by tourist use of the reefs and indirectly, by anthropogenic impacts. Among the direct impacts, there are trampling, coral breaking by divers or snorkelers (Zakai and Chadwick-Furman 2002; Epstein 2001), damages from recreational boat anchoring and boat grounding. Riegl and Velimerov (1991) found that coral breakage was the most common damage, especially on highly frequented reefs. Also, all observed damage was most frequent within the first ten meters depth, suggesting that rather than by experienced divers who practice a more eco-friendly tourism (Jobbins 2006). Because there are few natural beaches, some coastal resorts have created artificial beaches on rocky shores. This concerns not only reef habitats, but also the sand transported down current causing sedimentation and increasing water turbidity. Indirect impacts include sewage run-off, sedimentation caused by urban construction, dredging, coastal alteration, over-fishing and destructive fishing (dynamite fishing), pollution, and discharge of chemicals (chlorine, copper…) from desalination plants. Coastal modification and land reclamation has been the prime cause of reef degradation through the discharge of increasing quantities of fine sediment (El-Gamily et al. 2001). Holden (2000) estimated that 73% of the coral along the Egyptian coast has been damaged as a result of construction. Burke et al. (2011) classified overfishing as the major local threat affecting 55% of reefs, particularly in the Gulf of Aqaba (Kotb et al. 2008). A study on a shallow fringing reef at 55 km south of the Suez Canal showed that between 2004 and 2007, dead coral cover increased by 50%, sea urchin counts increased by 58% (Moustafa et al. 2008). Jameson et al. (2007) compared four coral sites exposed to extensive tourism with a site that is fairly unexposed. They found that all of the tourism-exposed sites suffered from physical damage reflected in consistently having a lower frequency of hard coral (especially *Acropora* coral), higher percent of soft coral, and a higher percentage of algae. According to Jameson et al. (2007) and El Gamily et al. (2001) this coral reef damage was primarily a result of anchor and diver damage and dynamite.

According to (Sami et al. 2011) and others (Baha El Din, 2003; Smith and McMellor, 2005; Mabrouk, 2007), the continued development of the tourism industry is the major and most threatening pressure on MPAs in Egypt (Baha El Din, 2003; Smith and McMellor, 2005; Mabrouk, 2007). The other common causes of environmental threats in all MPAs in Egypt is pollution caused directly by tourists (littering caused by divers, snorkelers and anchor chains in coral reef areas (Baha El Din, 2003; Smith and McMellor. 2005; Mabrouk, 2007) or indirectly from landfills, dredging and sedimentation, sewage discharge and effluent from desalination plants (Baha El Din, 2003; 2004; Mabrouk, 2007); and coral reef deterioration by physical impacts on the reefs. Therefore, to mitigate the problem it is necessary to establish a tourism capacity for each area, and limit the number of tourists, although this will affect the income of the MPAs since it comes mainly from tourism. The conservation and management of coral reefs is a priority issue in Egypt, since it is the most important source of income to MPAs through tourism and diving activities. A certain number of diving activities per day according to the carrying capacities of each area and coral reef cover should be implemented. Direct anchoring should be prohibited on coral reefs (Sami et al. 2011).

According to global estimates (World Bank, 2002), counting only the economic value of coral reef fisheries, tourism, and shoreline protection, the costs of destroying 1 km of coral reefs ranges between US$137,000 and 1,200,000 over a 25-year period and the properly managed coral reefs can yield an average of 15 tons of fish and other seafood per square kilometre each year. This means that the total economic value of Egypt's Red Sea reefs is estimated at US$ 205.5 million to 1800 million, and can yield about 1400 tonnes of seafood. Assessment of the cost of coral reefs and fisheries degradation in the Egyptian Red Sea area caused by unregulated tourism activities was estimated between US$ 2626 to 2673 million per year. These include:

1- The physical loss of natural capital: available estimates (Jameson and al, 1999) indicate that the replacement value of one square meter of coral reefs is US$ 3000. Based on an estimate of 4 million square meters (Institute of National planning, 2003) of coral reef damaged as a result of tourism projects within the studied area, the total value of the loss of the natural capital is about 12 billion US dollars.
2- The loss of income from marine recreational activities: According to available estimations of World Bank (World Bank, 2002), the losses of income from marine recreational activities in Hurghada Area alone ranged between US$ 110 to 157 million.
3- The cost of shoreline protection: the cost to build an artificial barrier replacing a damaged reefs along the coast is estimated at 12.5 million US$ per km.
4- The cost of loss of fisheries resources: Based on the above mentioned estimates (one square kilometre yields 15 tonnes of sea food products and 4 million square meter of reefs were damaged), the losses of fish production was estimated at 60 tons with a value of US$ 0.556 million at 2007 market prices.

Fortunately, until now, there had been little evidence of climate change impacts on Red Sea coral reefs. However, thermal stress and ocean acidification are anticipated to increase threat levels in the Middle East region to nearly 90% of the reefs by 2030 while by 2050, these climate change impacts combined with current local impacts will push all these reefs to threatened status (Burke et al. 2011).

As part of the NTS 2004-2010 eco tourism was highlighted as a segment with ready product and it was indicated that protected areas around Jordan and The AMP in Aqaba are central to the destination's appeal (NTS 2004-2010; UNDP/ASEZA 2014). The NTS 2011- 1015 acknowledged that Jordan's strategic challenges facing tourism development are complex, involving multiple supply and demand factors (NTS 2011-2015; UNDP/ASEZA 2014). The Tourism Marketing Strategy for Aqaba 2005-2010, the Aqaba tourism branding was based among others on sea, sun, sand and the golden triangle (Petra, Wadi Rum, and Aqaba).

3.10 MARINE LITTER IN THE COASTAL ENVIRONMENT OF THE JORDAN GULF OF AQABA WITHIN THE AQABA SPECIAL ECONOMIC ZONE (ASEZ)

3.10.1 INTRODUCTION

Marine litter is traditionally classified into land- or ocean-based, depending on its source. According to GESAMP (1991), land-based sources account for up to 80% of the world’s marine pollution. Much of the litter reaches the ocean from beach-based activities, being blown into the water or picked up by tides. Significantly large quantities of small plastic pellets and granules have been observed on beaches of many parts of the world as early as 1972 (e.g. Carpenter, 1972; Carpenter and Smith, 1972; Gregory, 1978; Shiber, 1979; McDermid and McMullen, 2004). The apparent threats of plastic pellets on marine life are primarily due to ingestion by marine birds and fishes (Carpenter et al., 1972; Azzarello and Van-Vleet, 1987; Rayan et al., 1988; Zitko and Hanlon, 1991; Moser and Lee, 1992). Pellets may adsorb, accumulate and transfer toxic chemicals to other marine organisms (Derraik, 2002; Endo et al., 2005; Rios et al., 2007).

PERSGA prepared a document that provides a Regional Action Plan (RAP) for combating the marine litter problem and achieving its sustainable management within the Red Sea and Gulf of Aden. The RAP defines a set of priority actions pertaining to a number of objectives, and organized around three components that include public awareness and education; legal and institutional frameworks; and research and monitoring. A national action plans (NAPs) to be developed for each member country in accordance with this RAP (PERSGA/UNEP 2008).

Marine litter has been identified by the Global Program of Action for the Protection of the Marine Environment from Land-Based Activities (GPA)/UNEP 1995) as one of nine pollutant ‘source categories’. It was recognized as a priority issue in UNEP’s Governmental Council/ Global Ministerial Environment Meeting in March 2004 (UNEP 2005). Inadequate regulations or poor enforcement of regulations, combined with weak public awareness allow marine litter problems to keep escalating. This has prompted PERSGA to consider marine litter as one of the main components of the Regional Programme of Action for the Protection of the Marine Environment from Land-Based Activities (RPA). Management of solid wastes including marine litter is highlighted in Article 7 of the Protocol Concerning the Protection of the Marine Environment from Land-Based Activities in the Red Sea and Gulf of Aden, signed by the PERSGA member countries in September 2005. The protocol includes a clear commitment to taking appropriate actions to eliminate solid waste dumping in the sea (PERSGA/UNEP. 2008).

The Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-Based Activities adopted in 1995 was developed for the protection of the marine environment from land-based activities. Management of marine litter in the PERSGA region is one of the proposed projects. This Regional Action Plan (RAP) for the sustainable management of marine litter has been prepared within the above mentioned framework. The RAP strategies, objectives and actions are based on an assessment of coastal and marine litter in the PERSGA region.

3.10.2 MARINE LITTER IN THE RED SEA REGION

In the PERSGA region diverse types of marine litter were reported from the coastal and marine environment.

- Plastics (fragments, sheets, bags, containers)
- Polystyrene (cups, packaging, buoys)
- Rubber (gloves, boots, tyres)
- Wood (construction timbers, pallets, fragments of both)
- Metals (drink cans, oil drums, aerosol containers, scrap)
- Sanitary or sewage related litter
- Paper and cardboard
- Cloth (clothing, furnishings, shoes)
- Glass (bottles, light bulbs)
- Pottery/ceramics
- Munitions (phosphorus flares)
- Fishing nets
- Abandoned/lost fishing gear

In Jeddah, Saudi Arabia, litter is often observed floating on inshore surface water in the vicinity of coastal resorts. Along the South of Jeddah coast which extends up to 50 kilometres from the city centre and considered a public recreational area, many types of litter are dumped, mainly plastic items on the beach. It is the local inhabitants that cause litter to accumulate on the beaches in the (PERSGA/GEF 2001; PERSGA 2006). Unfortunately some wadis are used as landfills and dump areas by both municipalities and people living in the area. This garbage and its associated litter may then be carried to the sea after rainstorms. A recent survey was conducted along the Obhur coastline of Jeddah, Saudi Arabia showed that most of the litter was from local land-based sources, with some regional influences. More than 75% of the litter was plastic. The type of litter components (cans, beverages, cosmetics, hand bags, cloths, rubber mattresses and toys) indicate that these were left by beach goers (Basaham et al. 2006; Kitto and Sambhu 2012. Remnants of fishing crafts and gear were comparatively low. Abundance of litter was 1.72-12.54 items. Litter quantity on the coast is inversely proportional to its geographical distance to a population and directly proportional to visitor frequency (Kitto and Sambhu 2012).

In Egypt, the major marine litter discharges were reported to be from urban and recreational areas. In Sudan, solid wastes are dumped on the shore near human settlements, in Port Sudan, forming large garbage sites from which marine litter washes into the sea through run-off or due to winds PERSGA/GEF 2001; PERSGA 2006).

In Yemen villages, the beaches have accumulated litter dumped by local inhabitants in the absence of effective collection services (PERSGA/GEF 2001; PERSGA 2006). Qualitative estimates of the quantities of marine litter suggest that plastics and metals are also the dominant types. In Al Salif city on the Red Sea coast, litter accumulates with piles of plastic bags. Along the inshore Hadramout (Gulf of Aden), over 25 types of litter, including rubbish and discarded fishing gear, were reported (MWE/EPA 2003). Al Shawafi and Ahmad (2011) studied the distribution of litter on Red Sea beaches of Yemen. They found ropes, netting, lamb bulbs, foot wear, plastic bags, bottles, aluminium cans, cardboard, wood loges, rubber, polystyrene blocks and plastic sheets. The pollutants varied from region to region but most of the litter was plastics including food bags, oil and water bottles and bait bags. Most of these pollutants originate from the sea, due to the heavy maritime traffic and to the fishing vessels. In Fishing industry, urban run-off, shipping, oil rigs, agricultural and municipal wastes are major sources (PERSGA/GEF 2001; PERSGA 2006).

In Djibouti and northern coast of Somalia, solid wastes are dumped on the shore. The household-waste dumping sites represent major sources of coastal and marine litter that reaches the sea via run-off. In Djibouti, litter and refuse consists mostly of plastics, glass bottles and discarded fishing nets occur especially in areas frequently visited by people.

The distribution of coastal and marine litter in some marine protected areas (MPAs) in the region was reported by PERSGA prior to their declaration; Iles des Sept Frères and Ras Siyyan MPA in Djibouti, and Mukawwar Island and Dungonab Bay MPA in Sudan (PERSGA/GEF 2001; PERSGA 2006). However, only broad estimates of the total and relative amounts of the different marine litter types are available for some PERSGA member countries. The lack of quantitative data on marine litter types and sources in the region is attributed to the lack of marine litter monitoring and research (PERSGA 2006).

3.10.3 TYPES, SOURCES AND STATUS OF MARINE LITTER POLLUTION IN THE COASTAL ENVIRONMENT OF THE JORDAN GULF OF AQABA WITHIN THE AQABA SPECIAL ECONOMIC ZONE (ASEZ)

Many human activities are taking place along the Gulf and many development projects exist or planned, particularly at the northern tip of the Gulf and along the Egyptian coasts at the west. The principal categories of activities that are of environmental concern in the area and along the Gulf include industrial development, oil and hazardous material spills, mariculture, wastewater disposal, shipping, commercial and sport fishing, tourism and dumping of litter. There are signs that many of these activities are causing many related environmental problems in the area, among which is the accumulation of marine litter along the shores of the Gulf (Abu Hilal and Al Najjar 2004). A two years period (1994-1996) monitoring programme was carried out to investigate the magnitude of this environmental problem in the most urbanized, industrialized and populated parts of the northeastern portion of the Gulf of Aqaba along the Jordanian coastline. The programme yielded an unprecedented data on the accumulation rates, types, sources and spatial and temporal distribution of these pollutants (Abu Hilal and Al Najjar 2004).

Plastics were by far the most abundant (49.5 % in 1994 and 51.1% in 1995) followed by wood (16.0 % in 1994 and 12.6 % in 1995). The third most abundant group was glass (9.9 %) in 1994 and cardboard (11.2 %) in 1995. It was concluded that most of the litter on the Jordanian coastline of the Gulf of Aqaba results from two sources; recreational and shipping activities. The trends in composition and distribution of the litter indicate that the cargo ships and passengers' ships are a major source of debris. This is particularly true in the case of the Marine Science Station -Marine Nature Reserve (MSS-MNR) beach. The problem of litter on this zone appears to be mainly due to the un-controlled dumping of large quantities of plastic materials and in part the result of dropping other items such as soft drinks cans, match boxes, plastic straws, sanitary napkins, disposable diapers and garment pieces such as shoes, boots, sandals shirts and small blankets which were found on the beach and on the bottom of the sea in the passengers port area. Thousands of cigarette butts and filters, cigarette boxes and spent disposable lighters were observed on this beach. All these items come from the Aqaba passengers' port just north of the MSS beach. It was estimated that 19 million items are reaching the marine environment from ferry boat each year (Abu Hilal and Al Najjar 2004).

It was observed that the marine environment in the study area receives inland input from several wadis and small valleys. Debris from several wadis and small valleys is transported to sea by occasional but very strong floods caused by rain storms common to the region. At that time many wadis and valleys have been used as open dump and incineration sites for all types of solid wastes originating from the Aqaba town and ports. The estimated solid waste from these two origins was more than 60 tons/day from the city and about 30 tons/day from the port (Abu Hilal and Al Najjar 2004). However, debris of foreign origin as indicated by inscription or imprinting were also found. Many of these were from Eilat on the west side of the Gulf as indicated from the imprinting language (Hebrew). They include cardboards, canned food in tins, non-carbonated natural water plastic bottles, plastic oil containers and plastic cover and caps. Many other debris items were originated from Egypt and Saudi Arabia (Abu Hilal and Al Najjar 2004). The seasonal distribution of the litter clearly indicates a relationship between passengers’ port activities during the late spring and the whole summer. These periods coincided with high peaks of passengers' movement from the Arabian Gulf States and Saudi Arabia to Egypt via Aqaba port in Jordan and Nuwaibi port in Egypt. A report by PERSGA (2006) indicated that major source for marine litter along the Jordanian coast of the Gulf of Aqaba is recreational and leisure activities, which is contributing to approximately 67% of the total quantity of marine litter discharged over three years (2003-2007), while shipping and port activities contributed 30% and the fishing industry only 3% (PERSGA 2006).

Clean up campaigns have been conducted in 2003 and 2004, for collecting submerged debris from underwater sites within coral reef areas along the Jordanian coast of the Gulf of Aqaba. Counts per m^2 ranged between 0.90 items/m^2 in the Aqaba Marine Park Centre reef and (5.9 items/m^2) in the most polluted reef with an overall mean of 2.8 items/ m^2 for the whole study area. Plastic accounted for 42% of the items counted, while fishing gear was the second most common item and constituted 31%. Metal items were also abundant (17%) (Abu Hilal and Al Najjar 2009a) indicated that the waste discarded from the Aqaba (Jordan) – Nuweiba (Egypt) ferry boat is a major source of litter found on the beach of the protected area within the Marine Science Station beach at the southern edge of the passengers' port. They noted also that the presence and distribution of various debris items on the beaches reflects the effect of the north–

northeast and northwest prevailing wind and the incoming onshore current movements. The relatively high counts (3250) of fishing gear items (90% of the total debris) in one of the coral reef areas was attributed to the relatively high fishing activities in the tidal flat and reef off this site compared to other sites (Abu Hilal and Al Najjar 2009). Other surveys showed that from about 1.2 tonnes of marine litter collected in Jordan during 2003-2005, plastic and rubber together represented 59%, metals 18%, glass 15%, and the rest (fishing equipment, paper and others) 8% (PERSGA 2006). Lost gillnet entangled by corals and gillnet setup used by local fishers in a method called ‘‘Hakoorah’’ (Plural: Hawakir) as permanent rectangular-like shape array can catches target and non-target fishes and continues to do so when it is in use or even when it is collapsed or neglected and thus act as a ‘‘ghost fishing’’ apparatus. The types of benthic marine debris indicate that the sources of debris include passenger ships, beach goers, recreational fishing and boating activities, and commercial fishing activities (Abu Hilal and Al Najjar 2009).

The occurrence of plastic pellets on the Jordanian beaches of the Gulf of Aqaba has been also reported (Abu-Hilal, and Al-Najjar 2009b). Pellets with a variety of colours, shapes and sizes were found. The presence of these pellets was attributed to accidental spillages, cargo loss during sea transport and sweeping of spills of raw plastic materials imported as feedstock for local plastic factories in Jordan. Unfortunately, the Jordanian beaches on the Gulf of Aqaba were found to be heavily polluted with these pellets (Abu-Hilal, and Al-Najjar 2009b).

3.10.4 MANAGEMENT, PUBLIC AWARENESS AND MONITORING OF MARINE LITTER

In many coastal areas of the Red Sea and Gulf of Aqaba, solid waste management is either inadequate or lacking altogether (PERSGA/GEF 2001). Upgrading solid waste and wastewater managements have previously been identified by the PERSGA member countries as important priorities for controlling land-based pollution (PERSGA/GEF 2001; PERSGA 2006). One of the major problems affecting marine pollution in the PERSGA region is the lack of public awareness and limited understanding of the environmental impacts of solid waste. Accordingly, several initiatives have been undertaken at both regional and national levels. In 2005, PERSGA member countries signed the “Protocol Concerning the Protection of the Marine Environment from Land-Based Activities” which is an important step towards a coordinated regional approach to deal with the subject of marine litter (PERSGA 2006). Article 7 of the Protocol titled “Management of Solid Waste” says: the contracting parties commit themselves to:

1. Taking all appropriate action to ensure elimination of the solid wastes and litter reaching the marine and coastal environment by prevention or reduction of solid waste generation and by introduction of enhancements to waste treatment, including methods of collection and recycling and final disposal thereof.

2. Cooperating with each other, and with international organizations, on exchange of information relevant to the practices and experiences relating to solid waste management, recycling, reuse, and cleaner production processes.

At the regional level, PERSGA has started some capacity building programmes and developed many training workshops in many subjects including coastal zone management; environmental impacts of development projects; management of solid wastes in industrial areas, improvement of wastewater management; and environmental inspection

A Regional Programme of Action for the Protection of the Marine Environment from Land-Based Activities in the Red Sea and Gulf of Aden (PERSGA's RPA) has been established by the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA). The Regional Protocol was adopted in 2005. The Programme has been initiated in close coordination and support with the UNEP/GPA (Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities). It deals with several relevant issues such as wastewater treatment, solid wastes management and inspection. The Protocol would enhance the legal framework for the development and implementation of the PERSGA's RPA. Many other management responses and initiatives carried out by PERSGA that principally, or in part, take the problem of marine litter into account. These include development of Coastal Zone Plans, Regional Action Plans for key habitats and key species, Master Plans for Marine Protected Areas, hydrographical surveys and navigation aids to reduce risks of pollution (PERSGA 2006).

In addition, PERSGA supported the development of the National Programmes of Actions (NPAs) for the Protection of the Marine Environment from Land-Based Activities in Jordan. In 2007 PERSGA organized, in coordination with ASEZA, a national workshop on the NPA in Aqaba. Yemen has developed a National Programme of Action for the Protection of the Marine Environment from Land-Based Activities (NPA) in 2003 with support from the UNEP/GPA Coordination Office. Litter was addressed as a high priority problem in this NPA. Beach clean-up campaigns were launched in the Gulf of Aden. A monitoring programme for coastal and marine litter exists in Jordan However, it can be stated that there is a general lack of regional and national monitoring and sustainable actions addressing marine litter in many of the Red Sea countries (PERGA 2006).

PERSGA's environmental awareness programme concentrated on conservation including the production of an environmental education and implementation of community participation projects including clean-up campaigns. Five public information centres and 150 school nature clubs have been established within the region. The activities which were carried out through the Strategic Action Programme (1998-2003), have raised awareness at the national, regional and international levels. In addition, national awareness projects were executed by PERSGA in Jordan and Djibouti. Efforts, including clean-up campaigns, were conducted in Jordan, Egypt, Saudi Arabia and Yemen. NGOs and volunteer citizens participate in such activities. Jordan management activities include visual monitoring; daily beach clean-ups; monthly clean-up dive campaigns; participation in "Clean-up the World" campaign**;** and Public awareness activities and programmes for management of marine litter. In addition ASEZA is implementing and enforcing legislation and coastal management policies such as the Aqaba Marine Park Regulation No. 22 year 2001 and the Environmental Protection Regulation No. 21 year 2002.

In order to limit, reduce, and enhance the appreciation of the litter problem along the Gulf of Aqaba, Abu Hilal and Al Najjar (2004) suggested the following actions.

initiate local and regional research and long-term marine litter monitoring to assess the changes and trends in marine debris accumulation and the actual threat posed by plastics and other debris to marine species. The scientific information would provide input for conservation management and evidence that could be used to demand from local and regional authorities more efforts;

assist passengers and merchant shipping lines to comply with MARPOL 73/78 and its annexes;

develop a strategy that integrates land-based solid wastes management issues with those associated with ship and boat generated marine litter;

increase of existing co-operation among scientists, decision makers, general public on local, national, regional and international scales;

implement within the GAEAP the GEF project a solid waste management plan and enforce a Marine Peace Park management plan that will help to control the transboundary solid waste impacts on the marine and coastal water resources of the area;

promote sound solid waste management practices in Aqaba town, Aqaba ports and in the whole region of the Gulf of Aqaba and the Red Sea;

Develop a long term strategy for conducting a marine litter cleanup and outreach campaign and establish a region -wide public education programmes that target local and international tourists, Aqaba town citizens, students, ports corporation and municipality employees and all workers involved in shipping, industry and transport activities;

Review, develop, implement and enforce a legislative and regulatory framework for the management protection and control of pollution in the study area including monitoring with a regional focus; and

Take measures by the Jordan Ports Corporation and similar port authorities along the Red Sea and Gulf of Aqaba and make available adequate port facilities in all ports of the region to ensure the compliance of vessels, ships and boats with MARPOL 73/78.

3.10.5 LOCAL AND NATIONAL LEGISLATIONS ADDRESSING MARINE LITTER

The Red Sea and Gulf of Aqaba region, has been designated under the terms of regulation 10 of MARPOL and its annexes as a ''Special Area''. Annex V, in particular prohibits and restricts the disposal of all garbage and other synthetic materials such as ropes, fishing gear and plastics from ships in any special area. The annex V applies also to all watercrafts including recreational vessels.

There would appear to be ample national legislation related to the coastal and marine environments of the PERSGA member countries. However, the implementation of such regulations is grossly inadequate mainly due to lack of sufficient capacities and coordination between different authorities, in addition to a lack of sufficient updating of the laws (PERSGA 2006).

By comparison, protection of the marine environment of the Jordanian Gulf of Aqaba has been the subject of many articles in many laws regulating the duties of the Aqaba Ports Corporation since 1961. The Shipping Law No. 51 (1961), the Aqaba Port Law No. 32 (1972), and the Aqaba Port Service Fees Law No. 49 (1976) included articles that limit and/or prohibit dumping of solid wastes and other harmful pollutants in the port area and Jordan territorial waters of the Gulf of Aqaba. Many other laws such as the Agriculture Law No. 20 (1973), the Environmental Law No. 12 (1995), the Aqaba

Special Economic Zone Law No. 32 (2000), Regulation for the Protection of the Environment in the Aqaba Special Economic Zone (Regulation No. 21 (2001), marine environment by-law No. 51 (1999), Aqaba Marine Park By-Law No. 22 (2001) and the Environmental Law No. 52 (2006) contain articles that prohibit dumping of solid wastes and other pollutants in the waters of the gulf.

Nowadays, the Commission of Environment of ASEZA is responsible for the implementation and enforcement of the laws and bi-laws that were put to protect, manage, and sustain the marine environment of the Gulf of Aqaba and its resources. The Maritime Authority and the Aqaba Ports Corporation which is operating now under the umbrella of ASEZA is cooperating with the Jordan Royal Navy Force to enforce these laws but particularly in monitoring the compliance of all ships visiting Aqaba Port with these laws.

The other important monitoring is the scientific research and environmental monitoring programmes. Unfortunately the on-going long-term environmental monitoring programme which is conducted by the Marine Science Station (MSS) for ASEZA does not include monitoring marine debris, which is an important issue for Jordan and other countries neighbouring the Gulf of Aqaba and the Red Sea (Abu Hilal and Al Najjar 2009).

3.10.6 REGIONAL AND INTERNATIONAL CONVENTIONS AND TREATIES PERTAINING TO MARINE LITTER.

Marine debris is not always specifically mentioned in international legal instruments. However, when these instruments include, for example, requirements to decrease or eliminate the discharge of ship-generated waste, or measures to stop the discharge of solid waste from land-based sources, or action to reduce the loss of fishing gear from fishing vessels, the issue of marine debris is implicitly covered. For example, the conventions on the protection and conservation of the marine and coastal environment adopted under the UNEP Regional Seas Programme and partner programmes regulate various sources of pollution and thus generally support the prevention and reduction of marine debris, even when the issue is not specifically addressed. Some regions have gone a step further and adopted specific protocols on the protection of the marine environment against pollution by land-based sources or by dumping, providing a more targeted approach to the problem of marine debris. In addition to the national laws, by-laws, regulations, and instructions which contain provisions on marine litter issues in Jordan, Box 1 lists examples of international conventions and treaties pertaining to marine litter.

Box 3.1: international conventions and treaties pertaining to marine litter.

(i) UNCLOS

Part XII of the Convention sets out the duties of States to protect and preserve the marine environment. UNCLOS requires States to take, individually or jointly as appropriate, all measures necessary to prevent, reduce and control pollution of the marine environment from any source. States have a duty not to transform one form of pollution into another and not to introduce alien or new species which may cause harm to the marine environment. States are required to develop international rules and standards for the prevention of pollution from land-based sources and take these into account when adopting national laws and regulations. They are also required to develop international rules and standards for the prevention of pollution by dumping from vessels, and to implement and enforce them at the national level. These international rules and standards represent the minimum standards for flag States. They can be enforced against a foreign vessel by a coastal State and also by a port State where there has been a discharge violation. Coastal States may adopt and enforce stricter rules and standards for the prevention, reduction and control of pollution from vessels in accordance with article 211. UNCLOS also requires coastal States to develop, implement and enforce international rules and standards for the prevention, reduction and control pollution of the marine environment from artificial islands, installations and structures.

(ii) MARPOL

The international rules and standards for the prevention, reduction and control of pollution from vessels referred to in UNCLOS are mainly contained in MARPOL, which regulates discharges from ships in six annexes. The discharge of garbage is regulated by annex V, which applies to all ships, including fishing vessels and pleasure craft, unless expressly provided otherwise.

The disposal of plastics (including fishing nets and gear) anywhere into the sea is prohibited, and discharges of other garbage from ships into coastal waters and MARPOL "Special Areas" is severely restricted. Foreign ships may be inspected in ports in cases where there are clear grounds for believing that the master or crew are not familiar with the essential shipboard procedures relating to the prevention of pollution by garbage, and to inspect the garbage record book. All parties to MARPOL are obliged to provide adequate reception facilities for ships calling at their ports. This requirement is especially necessary in the "Special Areas" where, because of the vulnerability of these areas to pollution, more stringent discharge restrictions have been imposed. The "Special Area" requirements have not taken effect in the Red Sea, Black Sea, Gulfs, Mediterranean Sea, and the wider Caribbean areas, as defined in MARPOL, because of a lack of adequate reception facilities.

The disposal of garbage is prohibited from fixed or floating platforms engaged in the exploration, exploitation and associated offshore processing of seabed mineral resources, and from all other ships when alongside or within 500 metres of such platforms. In order to assist States in the implementation of annex V, IMO has adopted guidelines for the implementation of annex V (resolution MEPC.59(33) as amended by resolution MEPC.92(45)), a standard specification for shipboard incinerators and guidelines for the development of garbage management plans (MEPC/Circ.317). An appendix to annex V provides a standard form for a garbage record book.

(iii) London Convention

"The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972", governs worldwide any dumping at sea of wastes and other matter from vessels, aircraft, platforms, etc. and, from this perspective, prohibits the disposal at sea of, inter alia, persistent plastics and other persistent synthetic materials. The London Convention adopts a black and grey list. approach, by which dumping of black-listed materials is prohibited and dumping of grey-listed materials is allowed provided a special authorization from a designated national authority is given. All other material or substances may be dumped after a general permit has been issued. The Convention 1996 Protocol prohibits all dumping except for a list of non-hazardous materials that may be dumped only if they pass an environmental assessment. Neither the London Convention nor its 1996 Protocol cover the disposal at sea of wastes derived from the normal operation of vessels.

(iv) Basel Convention

The Basel Convention establishes a notification and consent system among parties for transboundary shipments of .hazardous and other wastes (as defined in article 1 of the Convention) and prohibits trading in covered wastes with nonparties. Parties are also required to minimize waste volumes and to ensure the availability of disposal facilities for the environmentally sound management of hazardous and other wastes. The Basel Convention could therefore be applicable to land-based marine debris. Some non-hazardous land-based marine litter would also fall under the scope of the Basel Convention under the categories of wastes requiring special consideration (e.g. wastes collected from households). Solid plastic waste would not generally be considered as a covered waste, unless it exhibits any hazardous characteristics as identified in annex III to the Convention and is listed under annex IX, list B.

(v) Convention on Biological Diversity (CBD)

One of the main goals of the Convention on Biological Diversity (CBD) is the conservation of biological diversity. Some of its provisions are therefore relevant to the problem of marine debris and its impacts on marine biological diversity. In the context of the Jakarta Mandate on Marine and Coastal Biodiversity, the issue of marine litter is considered within the activities dealing with land-based and marine pollution. This issue is particularly relevant for the thematic areas on marine and coastal living resources (smothering of the seabed, and the effects of entanglement and ingestion of litter on fish, marine mammals and seabirds), and alien species (litter as a vector for transport of species).

(vi) Agreement on the Conservation of Albatrosses and Petrels

Under the Agreement, an instrument negotiated under the Convention on the Conservation of Migratory Species of Wild Animals (CMS**)**, the problem of marine debris is specifically referred to in the action plan contained in annex II. Section 3.3 of the action plan, on pollutants and marine debris, provides that the parties shall take appropriate measures, within environmental conventions and by other means, to minimize the discharge from land-based sources and from vessels of pollutants that may have an adverse effect on albatrosses and petrels either on land or at sea.

(vii) FAO Code of Conduct for Responsible Fisheries (1995 Code)

The 1995 Code is a voluntary instrument aimed at everyone working in and involved with fisheries and aquaculture, irrespective of whether they are located in inland areas or in the oceans. It generally requires that fishing be conducted with due regard to the protection of the marine environment. Therefore, the Code contains a number of provisions related to marine debris. It requires States to take appropriate measures to minimize waste, discards and catch by lost or abandoned gear. In this regard, the Code says that States should cooperate to develop and apply technologies, materials and operational methods that minimize the loss of fishing gear and the ghost fishing effects of lost or abandoned fishing gear (article 8.4.6). The Code also includes provisions on the minimization and treatment of garbage on fishing vessels (articles 8.7.2-8.7.4).

(viii) Global Programme of Action for the Protection of the Marine Environment from Land-based Activities

The Global Programme of Action (GPA) provides guidance to national and regional authorities for devising and implementing sustained action to prevent, reduce, control or eliminate marine degradation from land-based activities. Litter is one of the nine pollution source categories identified in GPA. Sewage is also identified as a pollution source, and at present the issue of municipal wastewater management is a priority in the implementation of GPA.

GPA sets a number of objectives in relation to marine litter, including:

(a) establishing controlled and environmentally sound facilities for receiving, collecting, handling and disposing of litter from coastal area communities; and **(b)** significantly reducing the amount of litter reaching the marine and coastal environment by preventing or reducing the generation of solid waste and improving its management, including through the collection and recycling of litter.

In order to achieve these objectives, national actions, policies and measures should focus on reducing the generation of solid wastes; installing garbage containers for citizens in public areas for the purposes of appropriate collection and recycling; establishing and properly operating solid waste management facilities onshore; launching awareness and education campaigns for all stakeholders on the need to reduce waste generation and to dispose of and reuse waste in environmentally sound ways; improving local planning and management capacity to avoid location of waste-dump sites near coastlines or waterways and to avoid litter escape to the marine and coastal environment; improving management programmes in small rural communities to prevent the escape of litter into rivers and the marine and coastal environment; and establishing campaigns and permanent services for collecting solid wastes that pollute coastal and marine areas.

Regional actions should include the promotion of regional cooperation for the exchange of information on practices and experiences regarding waste management, recycling and reuse and cleaner production, as well as regional arrangements for solid-waste management. International actions should include participation in a clearing house on waste management, recycling and reuse and waste-minimization technologies, and cooperation with countries in need of assistance, through financial, scientific and technological support, in developing and establishing environmentally sound waste-disposal methods and alternatives to disposal.

(ix) Agenda 21 and the Johannesburg Plan of Implementation

Chapter 21 of Agenda 21 addresses the issue of solid waste, underlining that environmentally sound waste management encompasses safe disposal or recovery but also the root cause of the problem, such as unsustainable production and consumption patterns. Chapter 17, in paragraphs 17.24 to 17.27, focuses on actions to address the problem of pollution from land-based activities. Paragraph 17.30 (d) calls upon States to facilitate the establishment of port reception facilities for the collection of oily and chemical residues and garbage from ships, especially in MARPOL Special Areas, and to promote the establishment of smaller scale facilities in marinas and fishing harbours. Paragraph 22 of the Johannesburg Plan of Implementation deals with, the prevention and minimization of waste, maximization of reuse and recycling, and the use of environmentally friendly alternative materials. Paragraph 32 deals with land-based sources, emphasizing the importance of the implementation of GPA, and paragraph 33 deals with marine pollution from shipping, stating that relevant international conventions should be ratified and implemented.

Source: UN (2005). United Nations A/60/63. General Assembly. Sixtieth session. Item 76 (a) of the preliminary list. Oceans and the law of the sea. Report of the Secretary-General

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CHAPTER FOUR

4 SEA-BASED ACTIVITIES AND SOURCES OF POLLUTION

4.1 SUMMARY

The numbers of ships that visit Jordan ports on the Gulf of Aqaba is increasing with time. Consequently, ports development is increasing very fast to accommodate for the vast growth in trade, cargo, container, and tanker shipping activities. Because of the small width and semi-enclosed nature of the Gulf of Aqaba of Aqaba, any spill of oil or chemicals will have detrimental effects on its coastal waters, ecosystem, habitats and flora and fauna.

In addition to land-sourced marine pollution, over-exploitation of living marine resources, and physical alteration or destruction of habitat, invasive species in ballast water has been considered the fourth greatest threats to the world's oceans. Ballast water on container ships, bulk carriers, and tankers, visiting the ports in Jordan and the neighbouring countries in the Gulf of Aqaba region, is a potential source of pollution that can carry and seriously pollute the marine environment of the Gulf in addition to the Red Sea with invasive species. Therefore, Port`s managers and other official responsible authorities should take all measures to deal with this threat.

Pollution from maritime transport to and from the ports in Jordan and neighbouring countries in the Gulf of Aqaba region that receive or export chemicals, oil and liquefied natural gas has to be monitored and carefully managed and controlled in case of pollution event.

To be able to combat such pollution, the countries in the region have witnessed many activities in connection with this subject. According to PERSGA, capacity building in combating oil pollution, in port state control, navigation safety, contingency planning and ballast water management has been improved through training workshops held throughout the region.

Jordan who is a party to the 1972 London Dumping Convention has already adopted a National Contingency Plan and national plans are now in place in Saudi Arabia. The Maritime Authority in Aqaba has built up its capacity to carry out Port State Control of ships.

Still however, the capacity for monitoring oil and chemical spills in the Gulf of Aqaba region remains limited and there is an urgent need to build up and strengthen the capacity, improve the level of understanding of the potential impact of ballast water and take actions to prepare the region to deal effectively with invasive aquatic species (IAS).

4.2 INTRODUCTION

Sea-based activities that lead to marine pollution include accidental and deliberate discharge. Accidental pollution may for example follow the collision of an oil tanker or the loss of cargo deliberate pollution is due to so called operational discharges: the release of waste water containing a certain quantity pollutants. Operational discharges are linked to the routine activity of a vessel. They include the washing of tanks and machinery and the release of ballast water. Some 20% of sea pollution comes from the deliberate dumping of oil and other wastes from ships, from accidental spills and offshore oil drilling. But of all the sources of marine pollution, the discharge of oily engine wastes and bilge from day-to-day shipping operations may be the worst, because it is steady and occurs everywhere (UNEP 2014).

The numbers of ships that visit Jordan ports on the Gulf of Aqaba is increasing with time. Consequently, ports development is increasing very fast to accommodate for the vast growth in trade, cargo, container, and tanker shipping activities. Because of the small width and semi-enclosed nature of the Gulf of Aqaba of Aqaba, any spill of oil or chemicals will have detrimental effects on its coastal waters, ecosystem, habitats and flora and fauna. Pollution from maritime transport to and from the ports, in Jordan and neighbouring countries in the Gulf of Aqaba region, that receive or export oil and liquefied natural gas, and chemicals has to be monitored and managed and controlled in case of pollution event.

In addition to land-sourced marine pollution, over-exploitation of living marine resources, and physical alteration or destruction of habitat, invasive species in ballast water has been considered the fourth greatest threats to the world’s oceans. Ballast water on container ships, bulk carriers, and tankers, visiting the ports in Jordan and the neighbouring countries in the Gulf of Aqaba region, is a potential source of pollution that can carry and seriously pollute the marine environment of the Gulf in addition to the Red Sea with invasive species. Therefore, Port`s managers and other official responsible authorities in the region should take all measures to deal with this threat.

Oil spills entering the marine environment from shipping activities, incidents and from offshore oil exploration are of major concern to the countries of the Red Sea region and to all authorities responsible for the protection of the marine environment, despite the fact that oil spills around the world are reducing which reflects improvements in the shipping industry and the efforts of organisations such as the International Maritime Organization (IMO) and national governments,. In addition, the capacity building in combating oil pollution, in port state control, navigation safety, contingency planning and ballast water management has been improved through training workshops held in Jordan and throughout the whole region of the Red Sea. National contingency planning has also improved and national plans are now in place in Jordan, Egypt and Saudi Arabia (PERSGA 2006). However, the capacity for monitoring oil and chemical spills, and the level of understanding of the potential impact of ballast water in the Red Sea region still needs to be improved (PERSGA 2006).

It can be stated however, that the threat of oil pollution in the region can be dealt with based on the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment, 1982, or the 'Jeddah Convention', which includes a Protocol concerning Regional Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency. It is hoped that the Marine Emergency Mutual Aid Centre (MEMAC), which has been established in 2006 with a support from IMO, will play an important role in enhancing regional coordination and co-operation in the matter of oil spill capacity build up and response (PERSGA 2006).

Jordan has felt that there is an urgent need for actions to deal effectively with any oil, ballast water, and invasive aquatic species (IAS). Accordingly, a National Contingency Plan has been developed for Jordan who is a party to the 1972 London Dumping Convention.

4.3 WORLD OIL AND GAS PRODUCTION

Over the past six decades oil production in various countries of the Arab world has grown in a dramatic way. In 2010, four states bordering the Red Sea, namely Egypt, Saudi Arabia, Sudan and Yemen, accounted for 11,966,000 barrels of oil production per day (BPD) out of a total world production of 83.9 million BPD. This is equal to 14.25% of total world production. Most of this production is exported as crude and refined oil products from terminals in the Arabian Gulf and in the Red Sea region (RSGA). Oil produced by Saudi Arabia is exported from terminals in the Gulf or on its Red Sea coast. Similarly, two states bordering the RSGA; Saudi Arabia and Egypt, are important producers of natural gas. Together they produced 162.14 billion m^3 of gas in 2012 (Table 4.1), which equals 3.5% of total world production (US *EIA* 2013).

Table 4.1: Natural gas production in Saudi Arabia and Egypt during 2008-2012 compared to world production (US EIA 2013)

Year	**2008**	**2009**	**2010**	**2011**	**2012**
Egypt	2,083	2,214	2,166	2,163	2,141= **60627bcm^3**
S A	2,841	2,770	3,096	3,258	3,585= **101,516 bcm^3**
World 2012					120,116 bcf= **3401.300 bcm^3**

4.4 WORLD TRENDS IN OIL SPILLS

Figures indicate, the volume of oil spilt from tankers demonstrates a significant improvement through the decades. The volume of oil spilt also shows a marked reduction. Approximately 5.74 million tonnes of oil were lost as a result of tanker incidents from 1970 to 2013. It is interesting to note that an amount greater than the total quantity of oil spilt in the decade 2000 to 2009 (213,000 tonnes) was spilt in several single years in earlier decades (UNEP/GPA 2014).

The range of estimated worldwide input of oil (petroleum hydrocarbons) into the oceans varies widely, from 470,000 tonnes to 8.4 million tonnes per year. In 1985 the National Research Council (NRC) estimated the total input of oil into the marine environment as 3.2 million tonnes per year. However, in 2002, (NRC) gave an estimate of only 1.3 million tonnes of oil enter the sea worldwide each year from all sources: natural seepage, extraction, transport, and consumption. According to the report, the main categories of sources contribute to the total input as follows:

- natural seeps: 46%
- discharges from consumption of oils (operational discharges from ships and discharges from land-based sources): 37%
- accidental spills from ships; 12%
- extraction of oil: 3%

By comparison, in 1990, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) estimated the total annual global input of oils (hydrocarbons) into the marine environment at 2.35 million tonnes. (GESAMP) ranked the sources like this:

- Land-based sources (urban runoff, coastal refineries): 1,175,000 tonnes/yr (50%)
- Oil transporting and shipping (operational discharges, tanker accidents): 564,000 tonnes/yr (24%)
- Offshore production discharges: (2%)
- Atmospheric fallout/Air Pollution: 305,000 tonnes/yr (13%)
- Natural seeps: 258,000 tonnes/yr (11%)

This means that most of the oil transporting and shipping input (24%) comes from maritime transport (IMO 2012; GPA 2014. Operational discharges from ships make up186,000 tonnes/year (45%) of input of 457,000 tonnes/year, followed by shipping accidents at 36 % of the input. Fuel oil sludge from vessels is the major routine operational input (of the 186,000 tonnes/year), or 68% of ship operational inputs (GESAMP 2007). Oil tankers, which are often identified as being major routine polluters, account for 10.3% of ship inputs as tank washings and oil in ballast waters, an operational input. However, tanker and barge accidents are a major input (158,000 tonnes/year). Ship accidents are a major input still, even with the decline of large spills from tankers in recent years (GESAMP 2007; IMO 2012).

4.5 BALLAST WATER IMPACTS AND MANAGEMENT

All ships need to carry ballast water to keep them stable in the water. Shipping transfers approximately 3 to 5 MT of ballast water internationally each year. A similar volume may also be transferred domestically within countries and regions each year. Taking on ballast water and discharging it must be carefully controlled to ensure the safety of the vessel and the seafarers on board. But there is another challenge – the taking up of ballast water from one part of the world and discharging it elsewhere can introduce invasive aquatic species (IAS) into an environment where they can overrun natural local species. It is estimated that at least 7,000 different species are being carried in ships "ballast tanks" around the world (Globallast/IMO 2014; IMO 2012).)

IMO has developed and adopted "the International Convention for the Control and Management of Ships' Ballast Water and Sediments or (BWM Convention). The Convention was adopted in 13 February 2004. In accordance with article 18 of the Convention, the treaty will enter into force 12 months after ratification by 30 States, representing 35 per cent of world merchant shipping tonnage. The convention requires all ships to carry out ballast water management procedures to a given standard. It is important to ensure that the procedures will not have an adverse effect on the safety of the vessel, and will not solve one environmental problem by creating another. The Marine Environment Protection Committee at its 58th session in October 2008 adopted "Guidelines for ballast water sampling and Revised guidelines for approval of ballast water management systems, intended to assist in the effective implementation of the Convention", bringing to 14 the package of finalized guidelines required by the Convention. The Committee also approved the Guidance document on arrangements for responding to emergency situations involving ballast water. By 2014 43 States have ratified the BWM Convention, which was adopted in February 2004. As of 17 October 2014, 43 States have ratified the Convention, representing 32.54% of the world merchant fleet tonnage IMO 2012 and 2014; Musk 2012).

4.6 SEABORNE OIL TRADE

From a fall in the early 1980s during the worldwide economic recession, seaborne oil trade has grown steadily from 1970 (Fig. 4.1). While increased movements might imply increased risk, it is encouraging however, to observe that downward trends in oil spills continue since 1983 despite an overall increase in oil trading over the period (ITOPF 2013; Musk 2012).

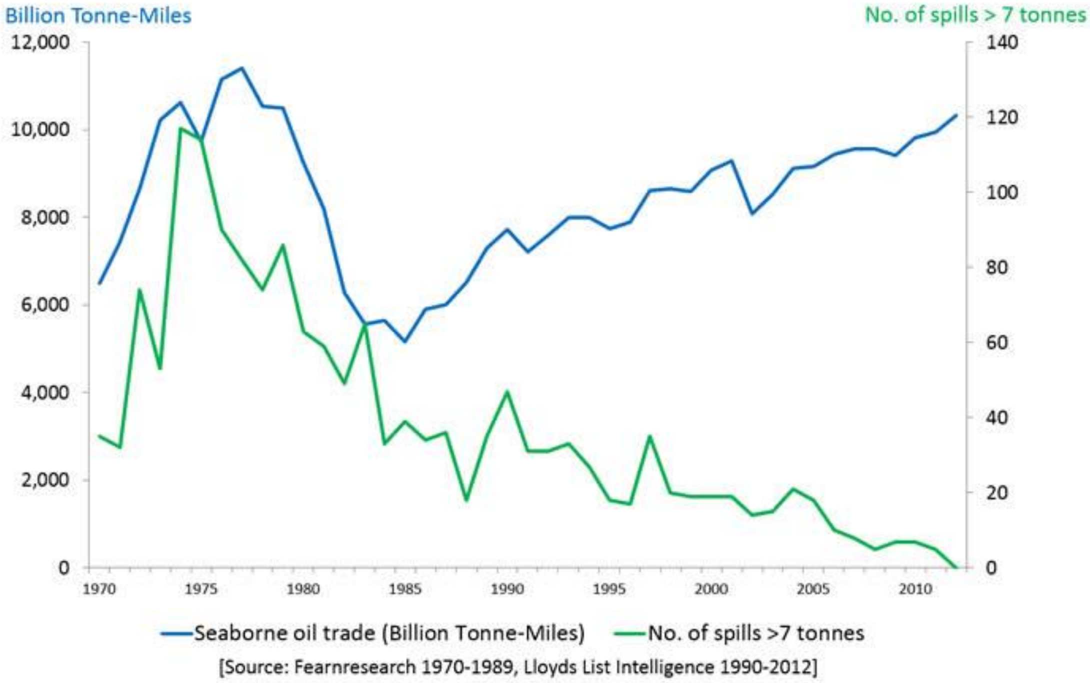

Figure 4.1: Seaborne oil trade and number of tanker spills > 7 tonnes, 1970-2012 (crude and oil product*) *Product vessels of 60,000 DWT and above. Barges excluded.

4.7 OIL SPILLS CATEGORTES, NUMBERS, AND TRENDS

Spills are divided by ITOPF into three categories, large spills (>700 tonnes), intermediate spills 7-700 tonnes) and small spills (<7 tonnes). The number of large spills has decreased significantly in the last 44 years during which records have been kept. The average number of major spills for the decade 2000-2009 is (3.5), one seventh of the average for years in the 1970s (24.5). Looking at this downward trend from another perspective, 54% of the large spills recorded occurred in the 1970s, and this percentage has decreased each decade to 8% in the 2000s. A decline can also be observed with medium sized spills (7-700 tonnes). Here, the average number of spills in the 2000s was close to 15, whereas in the 1990s the average number of spills was almost double this number (28.1).

There are many factors that contribute to the overall decline in the volume and frequency of spills, but it is most likely to be a combination of implementation and enforcement of conventions and regulations, training, assessments and communication, and development of technology. According to GESAMP (annual estimate) 1990 marine transport as a source of oil input into the marine environment is estimated at 564,000 tonnes/yr (24%). The three main contributions to the total oil entering the marine environment due to maritime transport are: (1) pollution from bilges and fuel oil generated by all types of ship; (2) day to- day tanker operations; and (3) tanker accidents.

A five year average for the frequency of oil spills in the >700 tonnes (Fig. 4.2) and 7-700 tonnes (Fig. 4.3) categories indicates that both categories show an overall decline in the number of spills since 1992; with the average number of large spills (>700 tonne) declining by approximately 3 times (7.2 to 2.2 spills per year), between 1992 and 2011 and the average number of 7-700 tonne spills declining by 3.5 times (25.6 to 7.2 spills per year). In the period (2002-2011) the average number of large (>700 tonnes) tanker incidents (Fig. 4.2) has almost halved (4 to 2.2 spills per year). Whilst these figures are encouraging and reflect improvements in the shipping industry and the efforts of organisations such as the International Maritime Organization (IMO) and national governments, it should be noted there were 4 incidents in 2010 showing there is deviation from this lower average. The quantities of spilt oil decreased parallel to the decrease in the number of spills.

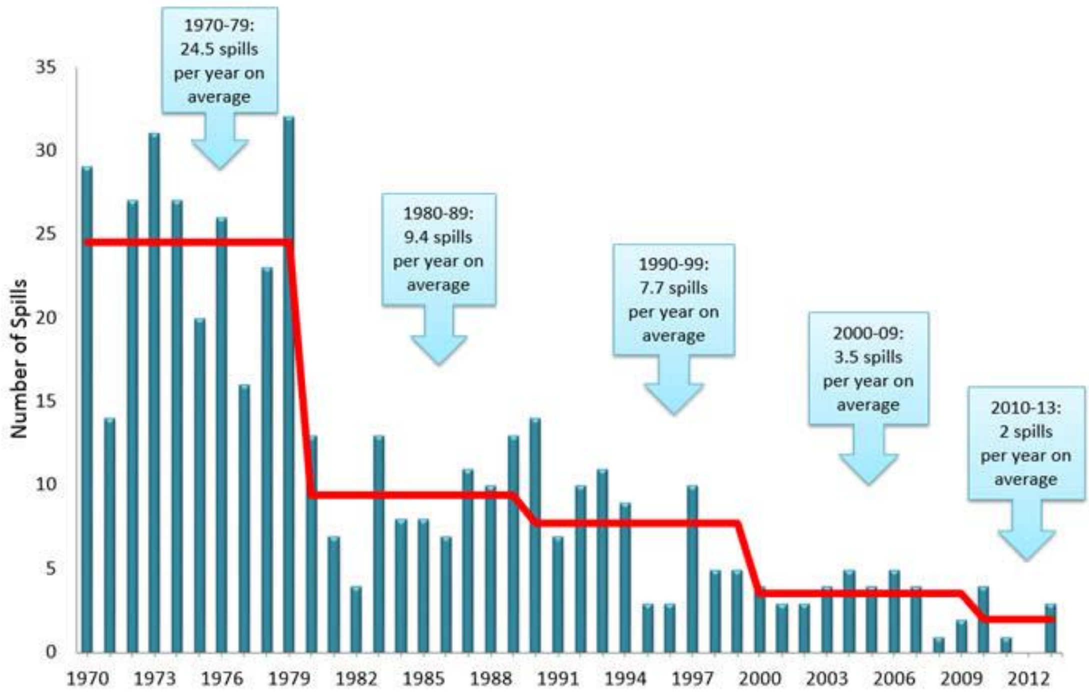

Figure 4.2: Numbers of spills of >700 tonnes 1970-2005 (ITOPF).

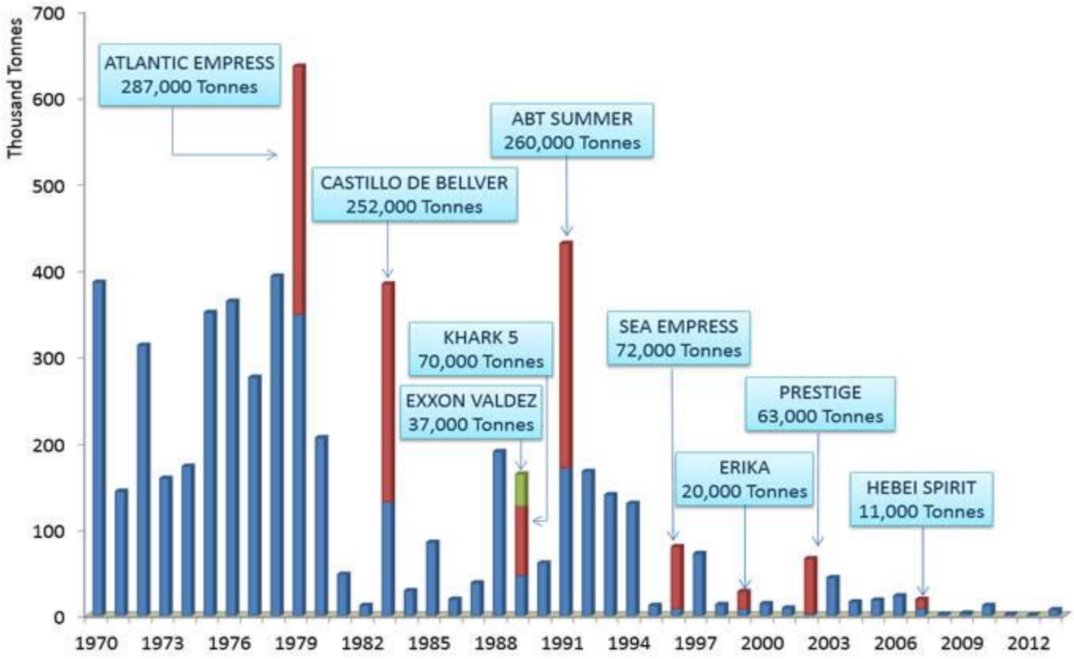

Figure 4.3: Quantities of oil spilt > 7 tonnes (rounded to nearest thousand), 1970 to 2013 (ITOPF).

This has been due to the combined efforts of the tanker industry and the International Maritime Organization (IMO), to improve safety and pollution prevention. Such improvement in recent years has also been helped by better training and education, greater adherence to IMO regulations, improved and more extensive port state control inspections and the sharing of information on sub-standard ships within a region through regional memoranda of understanding.

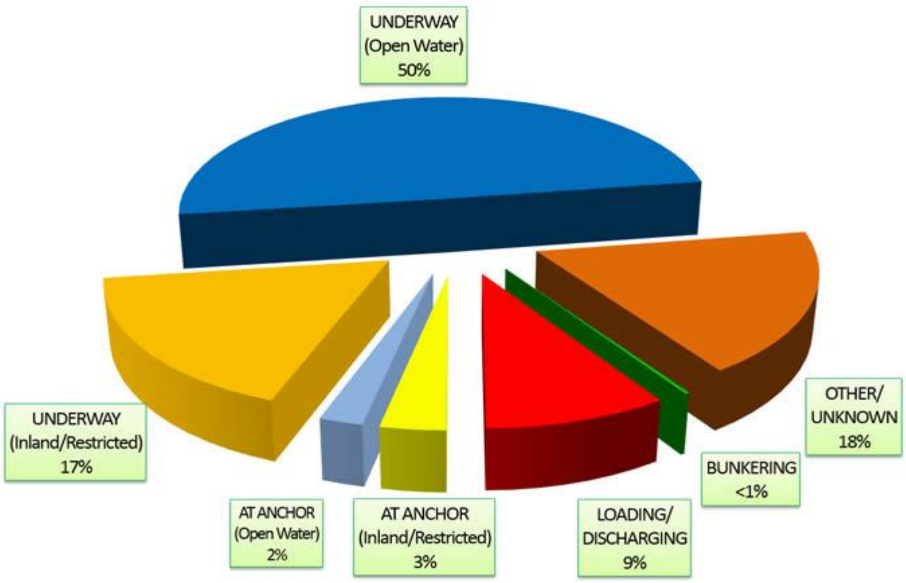

Figure 4.4: Incidence of small spills (<7 tonnes) by operation at time of incident, 1974-2013

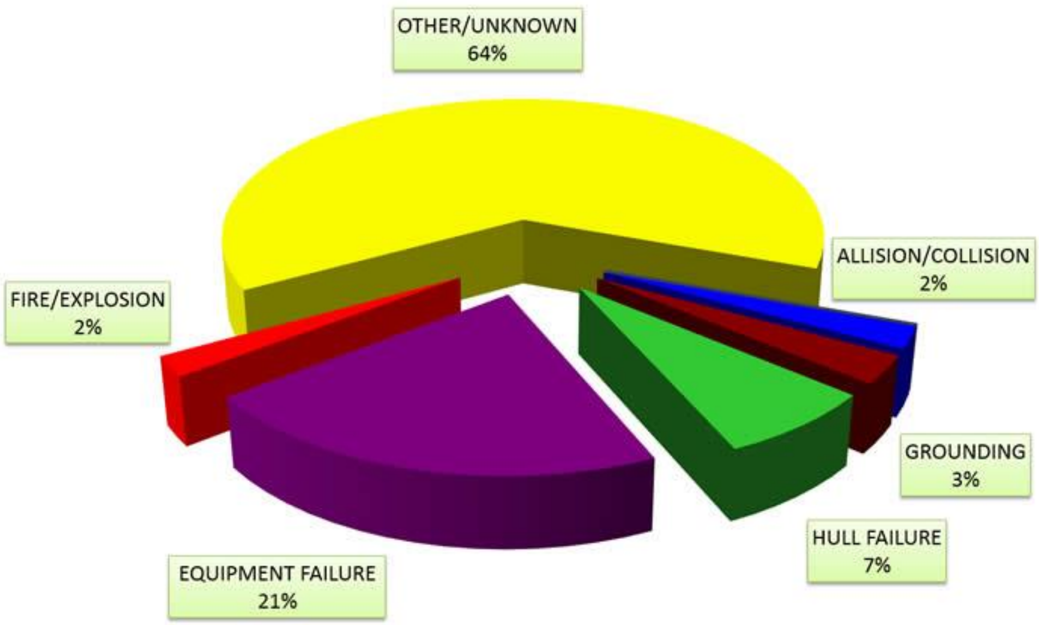

Figure 4.5: Incidence of small spills (<7 tonnes by) cause, 1974-2013 (ITOPF)

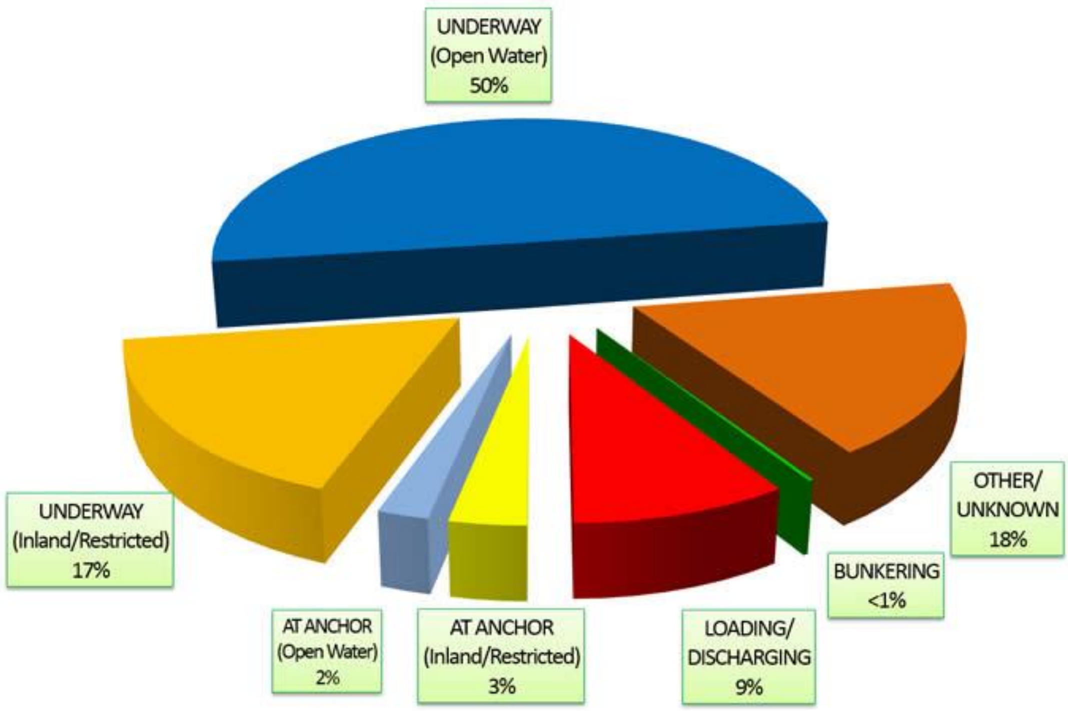

Figure 4.6: Incidence of large spills (>700 tonnes) by operation at time of incident, 1970-2013 (ITOPF)

Other factors include the improvements in ship design, safety equipment, back-up systems such as duplicated steering equipment, the use of improved and more accurate technological navigation aids such as the global positioning system (GPS). The other important factor relating to oil spills from shipping operations is the cause of the spill. An analysis by ITOPF for spills worldwide shows that between 1970-2013 collisions and groundings account for 30% and 33 of large spills respectively (Fig. 4.7), for about 50% of oil spills around the world.

The other 50% of spills are caused by loading and discharging operations, hull failures, fire and explosion, and other operations. Hull failure accounts for 13% of large spills (Fig.4.7) while, loading/discharging operations account for 29% of intermediate spills (Fig.8).

All these figures indicate clearly that IMO, through the "International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978" (MARPOL 73/78) was able to reduce oil discharges (Annex 1; Regulations for the Prevention of Pollution by Oil (entered into force 2 October 1983)) significantly due to tankers and other ships operations (Table 4.1).

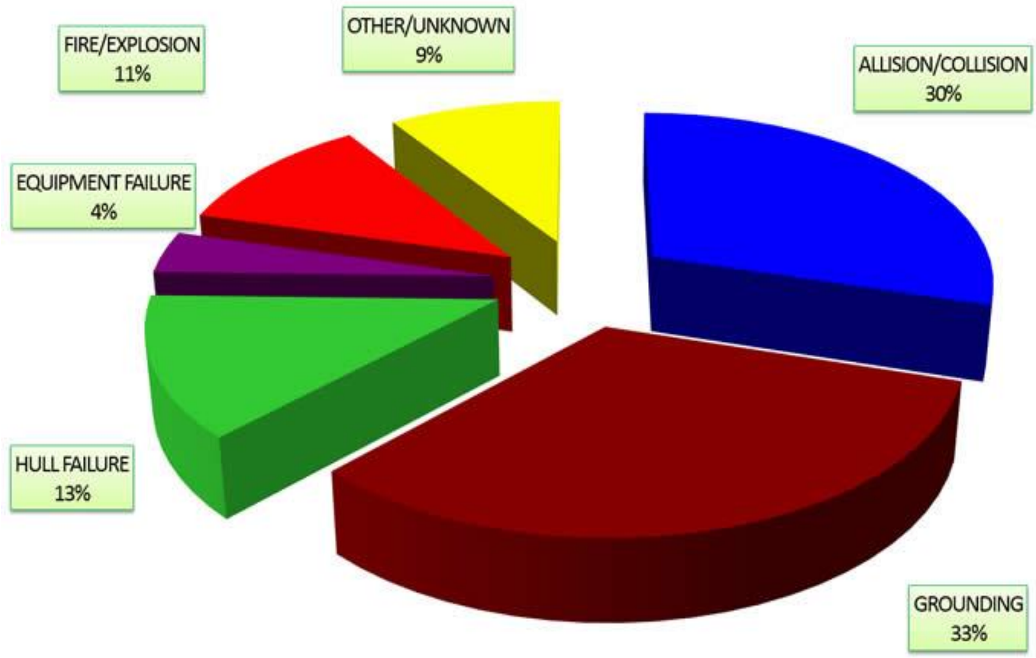

Figure 4.7: Incidence of large spills (>700 tonnes) by cause, 1970-2013

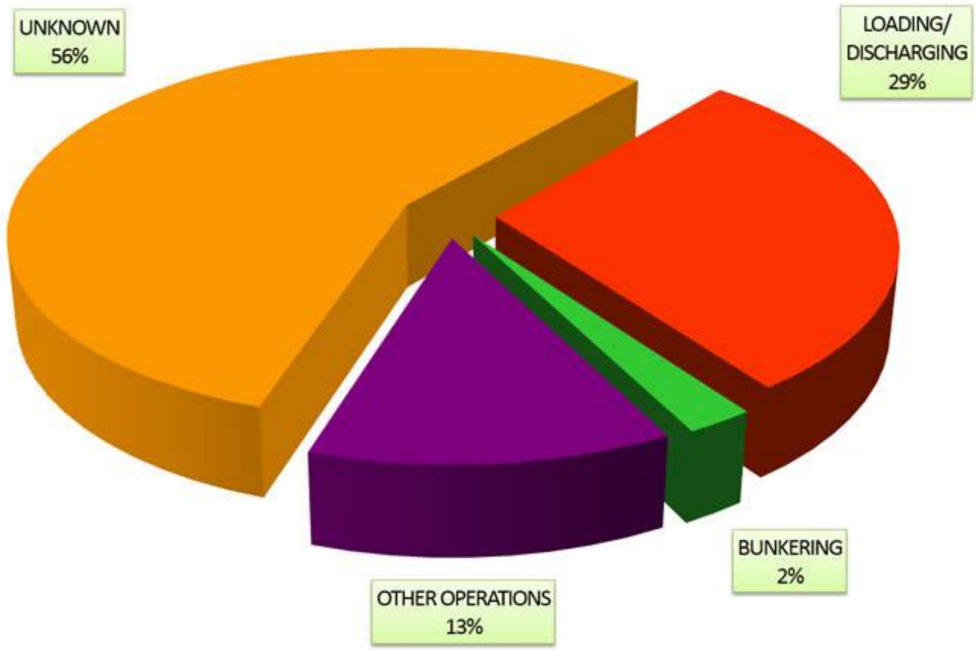

Figure 4.8: Incidence of medium spills (7-700 tonnes) by operation at time of incident, 1970 2013 (source: ITOPF).

Incidences by cause of medium spills (7-700 tonnes) between 1970 and 2013 are 26% and 20% for collisions and groundings respectively (Fig. 4.9).

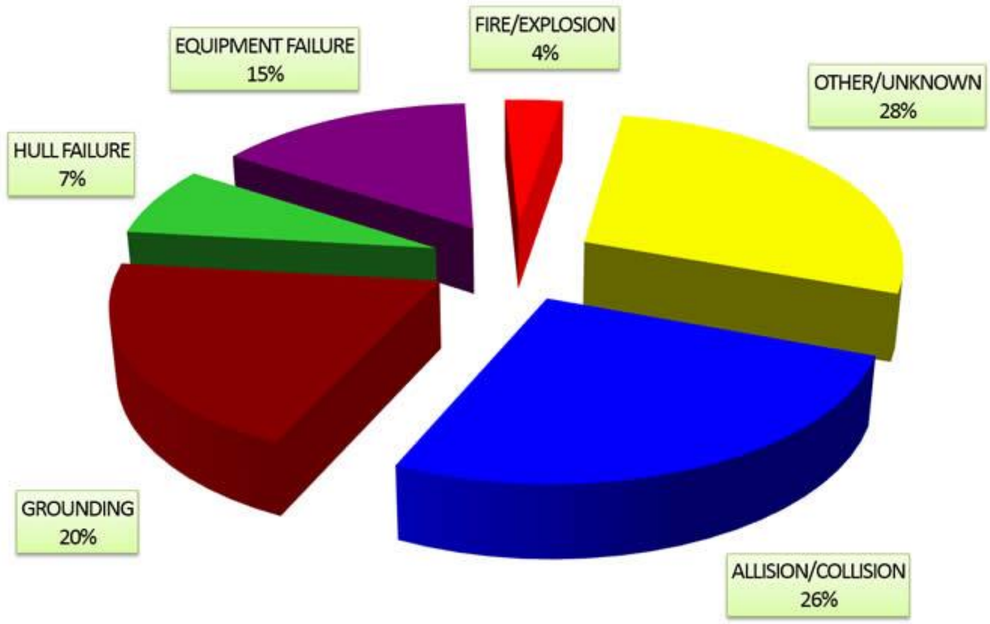

Figure 4.9: Incidence of medium spills (7-700 tonnes) by cause, 1970-2013

Table 4.2: Criteria for the discharge of cargo oil by tankers from Annex I of MARPOL 73/78.

Sea Area	Discharge Criteria
Within 50 nautical miles from land	No discharge except the discharge of clean or segregated ballast
Outside Special Areas more than 50 nautical miles from land	No discharge except either: • Clean or segregated ballast or when: • Tanker is *en route*; and • Rate does not exceed 30 litres per nautical mile and • Quantity does not exceed 1/30,000 of total quantity of cargo carried on the previous voyage; and The tanker has in operation an oil discharge monitoring and control system and slop tank arrangement (Annex 1 Reg. 9(1)(a) and Reg. 15)
Within a Special Area	No discharge - Except clean or segregated ballast (Regs.1(16) 10 (2), 10(3) (a)*

***For the past three decades, segregated ballast tanks (SBT), have been used as ballast tanks. The method has proved to be most effective in reducing oil pollution.**

Under MARPOL73/78 Regulation 10 (1) (d) RSGA has been designated as a "Special Area". However, this status will not come into effect until IMO determines the date, but after notification by the coastal states (in the Red Sea) that they have adequate reception and treatment facilities for ballast and tank washing water from tankers. Unfortunately, until now several ports in the Red Sea region do not yet have such adequate facilities.

Historically, small scale oil spills occur from time to time in the Gulf of Aqaba and most of the spilled oil finds its way to the beaches very quickly because of the very short distance (4-8 Km) between the source points of spills and beaches of the most northern narrow portion of the Gulf of Aqaba between Aqaba in Jordan and Eilat in Israel (Abu-Hilal and Al-Najjar 2009). Unfortunately, Jordan like other countries in the Red Sea and Gulf of Aqaba regions has not recorded the number of spills systematically. In 2006 PERSGA prepared a Record of Maritime Accidents and Incidents in the RSGA that provides a partial record (PERSGA 2006).

4.8 OIL TERMINALS, TANKER TRAFFIC AND OIL MOVEMENT IN THE RED SEA REGION

The Red Sea and the Gulf of Aqaba are considered unrestricted bodies of deep water in which ships can operate without any major obstacles except for some areas near some islands in the southern end of the Red Sea and southern end of the Gulf of Aqaba. In the past decades, countries neighbouring the Red Sea and its two gulfs have established many oil terminals and oil other facilities in the region. Examples are the oil (import/export) terminal at Aqaba, the King Fahd Industrial Port at Yanbu, the petrochemical complex at Rabigh 12, and the oil bunkering facilities in Jeddah. In addition huge development has occurred and will continue to expand in Aqaba in Jordan. Many other important ports used to export oil and oil products within the Red Sea region are found in Sudan, Djibouti in addition to many oil terminals in Yemen.

Oil transport includes movements of crude oil and products from the Gulf into the Red Sea and Gulf of Aqaba region from west coast of Saudi Arabia northwards to Ain Sukhna, or to the Suez Canal, and to other countries in other regions. Suez Canal Authority (SCA) statistics for 2013 show that 64.23 MT of oil and products were carried through the Suez Canal south bound and 89.285 MT north bound. In 2013, southbound oil and products quantities decreased by 1.3 MT (1.9 %) while northbound quantities increased by 10.5 MT (13.4 %). Figures 4.10 and 4.11 show the Red Sea region is an important oil transportation route via Suez Canal to Europe and other countries.

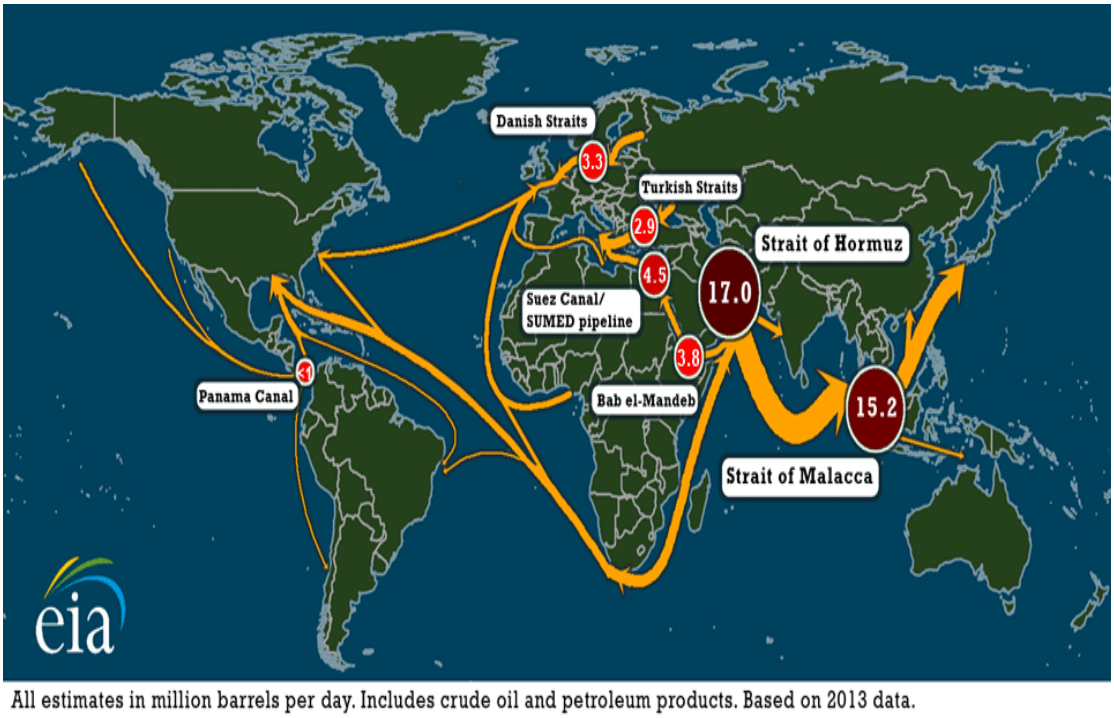

Figure 4.10: World oil transit chokepoints (US Energy Information 2015). Figures in the map represent estimates in million barrels/day and include crude oil and petroleum products, based on 2013 data.

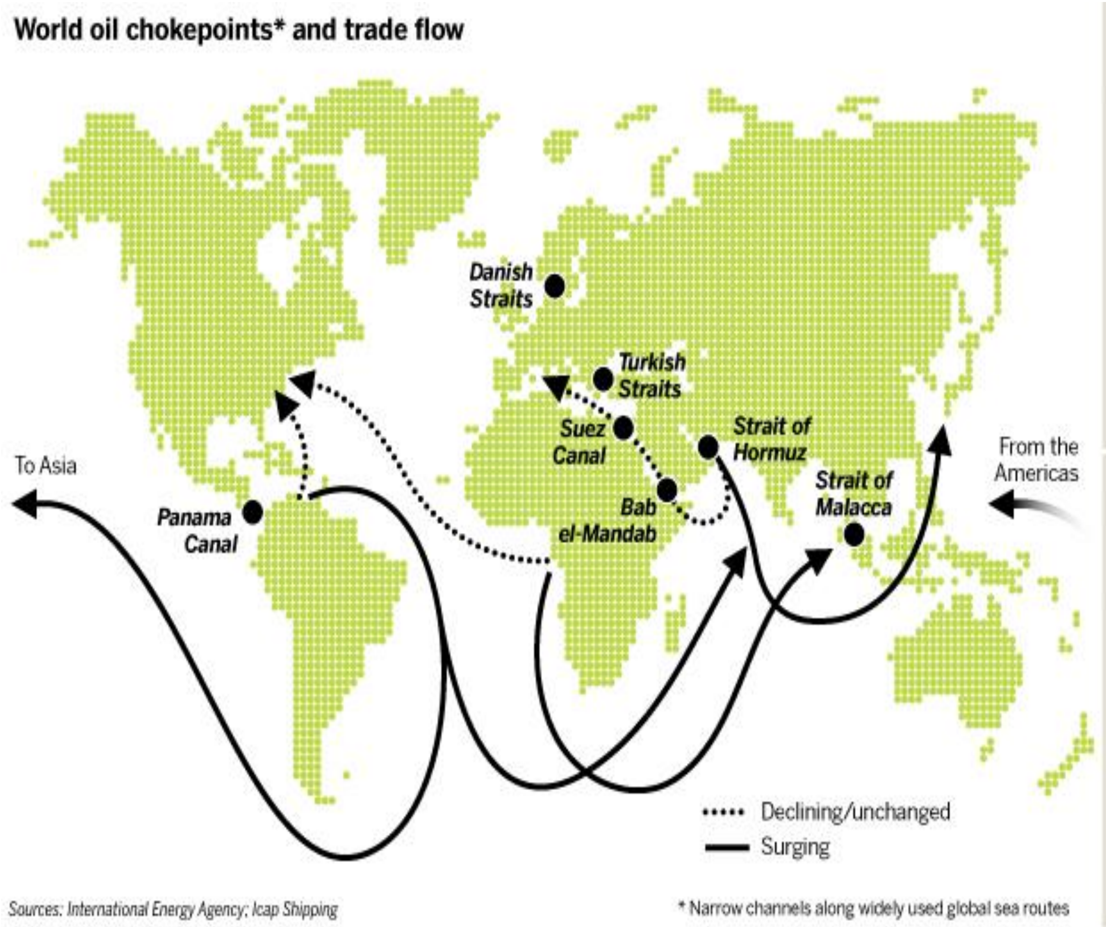

Figure 4.11*: Seaborne oil trade flow/ World shipping routes of crude oil* (Khalid 2011).

The number of tankers that passes Suez Canal during 2013 was 3594 compared to 3639 in 2012. Many of these tankers are using routes and ports within the Red Sea region. Therefore, port state control measures are important means of regulating the operations of such vessels. Sub-standard vessels represent a major threat to the environment of the whole Red Sea region, and therefore, Jordan should cooperate with other countries in the region to eliminate or reduce the numbers of such vessels operating in the region.

4.8.1 LIQUEFIED NATURAL GAS MOVEMENT

Global production and trade in liquefied natural gas (LNG) have increased continuously for the last thirty years. However, LNG flows fell in 2012 by 1.6% from 241.5MT in 2011 to 237.7MT in 2012. The contraction was largely driven by supply-side issues in Southeast Asia and domestic and political challenges in the Middle East and North Africa (MENA) region (IGA 2013).

Saudi Arabia and Egypt are two important producers of liquefied natural gas (LNG). Saudi Arabia produced 83.94 billion m^3 and Egypt produced 62 billion m^3 of gas in 2011. Though pollution from gas tankers has not yet been a significant cause for concern in the Red Sea region, the potential for pollution due to a collision and grounding of large gas carrier should not be ignored, and measures to monitor and improve the operational safety of gas carriers is a requirement for terminals in the whole Red Sea region. Records of the Industrial Port at Yanbu show that 655 tanker were loaded during 2013; 66 were gas tankers, 391 oil tankers, 122 chemical tankers and 346 other tankers. The records show also that about 2.78 MT of LNG and 28.34 million tonnes of petroleum products and other Liquid gases were loaded during 2013. The chemical loads were 2.219,506 tonnes (KFP 2013).

The figures of the Ministry of Energy and Mineral Resources show a substantial increase in the consumption of all types of oil products (LPG, Gasoline, Jet Fuel, Diesel, and Fuel Oil) except Kerosene. Consequently the total consumption of oil products increased from 4.81 MT in 2000 to 6.665 MT in 2012(Table 4.2).

The official records show also that about 2.491 MT of LG and 6.195 MT of crude oil and other petroleum products were imported during the period 2001-2012.

Table 4.3: Petroleum Products Consumption2000-2012 (000 Metric Tonnes)*

Product	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
LPG	298	290	299	313	335	319	339	312	378	377	
Gasoline	668	670	697	741	840	873	1022	1065	1083	1147	
Jet Fuel	215	228	314	300	297	216	318	351	354	379	
Kerosene	214	215	181	150	131	100	111	69	75	81	
Diesel	1439	1769	2005	1837	1794	1493	1614	1577	2407	3103	
Fuel Oil	1976	1509	1395	1333	1193	1100	823	1273	1670	1578	
Total	4810	4681	4891	4674	4590	4101	4227	4647	5967	6665	

***Source: Ministry of Energy and Mineral Resources/Jordan-Annual Report 2013.**

Table 4.4: Quantities (000 metric tonnes) of imported crude oil and oil products, 2001-2012 (Ministry of Energy and Mineral Resources 2013)

Year	**Crude**	**Fuel**	**Liquefied Gas**	**Diesel**	**Gasoline**	**Jet Fuel**	**Total**
2003	4023	570	171	292	040	-	5096
2004	4244	100	179	543	135	1	5202
2005	4602	019	178	785	093	1	5678
2006	4258	-	182	509	065	1	5015
2007	4040	0.0	233	429	166	1	4869
2008	3769	91	196	320	141	1	4544
2009	3633	0.0	234	414	231	1	4510
2010	3485	307	219	670	400	1	5078
2011	3189	674	288	1361	540	1	6137
2012	3623	703	288	2089	426	1	7130
Total	64667	9098	2491	7824	2262	9	63,195

4.8.2 MOVEMENT OF CHEMICALS

Petrochemicals are produced in Aqaba, Suez and at the King Fahd Industrial Port at Yanbu on the coast of Saudi Arabia. During 2013, 75 chemical tankers called at the King Fahd Industrial Port at Yanbu to discharge 337,975 tonnes of chemicals, and 12 tankers were loaded with 80,477 tonnes after discharges, whereas 122 tankers were loaded with 1,986,784 tonnes of chemical to be exported. Import and/or export of chemicals, have led to pollution and safety problems in many ports in the Red Sea region. More than twenty two petrochemical commodities were exported from or imported through the Industrial Port at Yanbu during 2013 (KFP 2013).

Increasing amounts of LNG are being produced and used within the Red Sea region and the neighbouring countries. More and more petrochemical complexes are likely to be established in the region, leading to a further increase in the tonnages of chemicals that will be in transported through the waters of the region. Consequently the possible incidents including the grounding or sinking of chemical carriers will cause damage to the marine environment of region if it occurred. Transported chemicals can cause fire on board and health hazards to workers and pollution in the cargo working area.

Table 4.5: Major industries and industrial production / approximate production per a year (Rasheed, Personal Communications).

Type of industry	Location / Industrial Area	Type of product	Quantity of production (specify unit of estimate)
Fertilizers and Chemicals	Jordan Phosphate Mines Co. (JPMC) Industrial Complex (IC)	Diammonium-Phosphate Fertilizer (DAP)	740,000 ton /year
Fertilizers and Chemicals	JPMC (IC)	Phosphoric acid	415,000 ton /year
Fertilizers and Chemicals	JPMC (IC)	Sulfuric acid	1,200, 000 ton /year
Fertilizers and Chemicals	JPMC (IC)	Aluminum Fluoride	20,000 ton /year
Fertilizers and Chemicals	JPMC (IC)	Fluorosilisisic acid	25,000 ton /year
Fertilizers and Chemicals	Arab Fertilizers & Chemicals Industries Ltd (KEMAPCO)	Potassium Nitrate Fertilizer	150,000 ton /year
Fertilizers and Chemicals	KEMAPCO	DicalciumPhospahteDihydrate	60,000 ton /year
Fertilizers and Chemicals	KEMAPCO	Nitric Acid	115,000 ton /year
Fertilizers and Chemicals	National Comapny for ammonia nd chemicals production	Ammonium and Fertilizers	4,000 ton/year
Fertilizers and Chemicals	Nippon Jordan Fertilizer Company (NJFC)	Diammonium-Phosphate Fertilizer (DAP)	300,000 Mton/year
Fertilizers and Chemicals	Nippon Jordan Fertilizer Company	Nitrogen-Phosphorus-Potassium (NPK)	
Chemicals	Arab Potash Company	Potasch	2,400000 ton/year
wood products	Red Sea Timber	wood panels, plywood and lathe	157,500 m^3 /year
Storage and Import of Chemicals	INDO-JORDAN Chemicals Company (IJCC)	Phosphoric Acid Chemicals Company	225,000 ton/year
Storage and Import of Chemicals	INDO-JORDAN Chemicals Company (IJCC)	Sulfuric Acid	660,000 ton/year

In Aqaba, fertilizers and potash production, transportation, export and import of these products and other related chemicals such as diammonium phosphate, dicalcium phosphate dehydrate, sulphuric acid, phosphoric acid, nitric acid, ammonia, sulphur, aluminium fluoride, fluosilisic acid, potassium nitrate and NLG, is increasing and will increase with time (Table 4.. The biggest industry in the industrial zone at the most southern end of the Jordan Gulf of Aqaba is that related to the fertilizers (e.g. JPMC, KEMAPCO, NJFC). Other industries are mainly import and storage of materials like chemicals, wood, and gas (Table 4.4). The production, export and /or import of these chemicals will increase in the future (Table 4.5) due to the expected increase in demand and development. Any incidents at the industrial area during loading, unloading, use, or transportation can cause serious environmental hazards and health hazards to workers. Incident at sea including collision, grounding or sinking of ships or chemical carriers will cause pollution, damage to the marine environment of region, and fire on board if it occurred.

Table 4.6: Dry and Bulk Liquid Quantities (1000 tonnes) Forecasts for the Fertilizer Industry Complex (based on figures up to 20 June 2007) (Rasheed, Personal Communications).

Dry Bulk	**2006**	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Phosphate rock export	3212	3673	3974	3772	5205	5205	5205	5205
Sulphur import	608	567	719	1175	1175	1175	1175	1175
Di Ammonium Phosphate (DAP) export	608	596	625	674	684	684	684	684
Nitrogen Phosphorus Potassium (NPK) export	236	210	210	210	210	210	210	210
Aluminium hydrate import	14	21	23	24	25	25	25	25
Liquid Bulk								
Phosphoric acid export (JPMC and IJCC)	363	379	580	1362	1353	1353	1353	1353
Ammonia import	255	217	231	244	246	246	246	246
Vegetable oil import	203	45	47	49	51	54	56	58
Mineral oil import	28	29	35	45	57	70	85	104
Chemicals import	61	56	67	86	110	135	164	200

4.9 GROWTH OF CONTAINER SHIPPING

The Red Sea region including the Gulf of Aden, Gulf of Suez and Gulf of Aqaba provides a vital route for maritime trade and commerce and is currently estimated to carry around 7−8% of world trade. The use of containers and container shipping to transport a greater tonnage of the world’s commodities by sea becomes increasingly competitive in comparison with other methods of cargo transport. Since 2005, the dry bulk fleet has almost doubled, and the containership fleet has nearly tripled. Container shipping is different from conventional shipping because it uses 'containers' of various standard sizes - 20 foot (6.09 m), 40 foot (12.18 m), 45 foot (13.7 m), 48 foot (14.6 m), and 53 foot (16.15 m) - to load, transport, and unload goods. The two most important, and most commonly used sizes today, are the 20-foot and 40-foot lengths. The 20-foot container, referred to as a Twenty-foot Equivalent Unit (TEU) became the industry standard reference. The 40-foot length container - literally 2 TEU - became known as the Forty-foot Equivalent Unit (FEU) and is the most frequently used container today. The importance of containerization for global trade is mirrored by the growth in the fleet of containers themselves. In early 1991, there were slightly fewer than 7 million TEUs of containers in use for transporting seaborne trade; by January 2011, this figure had grown more than fourfold, to 29 million TEUs. While the box fleet is growing, so is the efficiency of its deployment. In 1990, each container was loaded or unloaded approximately 14 times during the year. However, due to more transhipment, faster ships, and improved port handling and customs clearance, this figure had gone up to about 19 port moves per container by 2010. Figure 4.13 shows the seaborne worldwide containers movement, which shows also its movements in the Red Sea region.

Figure 4.12: Containers movements (LLOYDS 2015).

A similar trend is observed when the box fleet is compared with the total slot capacity on container ships (Table 4.6); the rate decreased from three to two boxes per slot between January 1991 and January 2011. This, however, is not only a reflection of the improved productivity of the containership fleet; it is also, to some extent, a result of the current oversupply of containership capacity against a shortage of empty containers. However, the production of containers reacts relatively quickly to shifts in demand (UNCTAD 2011).

Table 4.7: Long-term trends in the container ship fleet (UNCTAD 2011).

	1987	**1997**	**2007**	**2008**	**2009**	**2010**	**2011**
Number of vessels	1052	1054	3904	4276	4638	4677	4868
TEU capacity	1215215	3089682	9436377	10760173	12142444	12824648	14081957
Average vessel size (TEU)	1155	1581	2417	2516	2618	2742	2893

The Aqaba Container Terminal (ACT) is one of the active ports in Red Sea region. At the end of 2013 the capacity of the terminal increased reached 1.2 million TEUs. In response to the increasing demand for container shipping, the capacity of the four berths in the port was increased to 1.2 million TEUs. The reported figures (Table 4.6) show that the operational efficiency of the terminal has developed and increase in the period 2000-2013.The number of vessels was 529 in 2001, and a trend of increase prevailed after the low number (356 vessels) recorded in 2007 (Table 3.17). From 2006 the average TEUS per vessel in creased which was reflected on the total throughput (TTL) in the port The total throughput (TTL) has also increased rapidly and constantly with time from 215,000 in 2000 and 277,000 in 2002 to 405,660 in 2006 and more than doubled (872,810) in 2013 (Table 4.6).In 2013 the total exports (TEUs) increased by 20% (ACT 2013).

The revenues of the terminal have increased over the last four years from JD49 million in 2010 to more than JD74 million in 2012. In 2013, ACT increased its revenues by 16% to JD86 million. The number of employees has increased continuously over the same period from 727 in 2010 to 886 in 2013 (Table 4.6).

Table 4.8: Development of total throughput (TTL), number of vessels arrived at Aqaba Container Terminal (ACT) and revenues in Jordan Dinars (JD) in selected years between 2000 and 2012.

Year	TTL volume TEU*	Number of vessels	Average TEUS per VSL	Revenues (JD)	No. Of employees
2000	215,257	506	425	-	-
2002	277,307	509	545	-	-
2005	392,177	463	847	-	-
2006	405,660	378	1,073	-	-
2008	587,530	367	1,601	-	-
2010	605,659	532	1,138	49,084,571	727
2011	705,648	491	1,437	60,696,029	704
2012	817,434	445	1,837	74,262,738	802
2013	872,810	401	1,988	86,005,044	886

***Shipping cargo is measured in twenty-foot equivalent units (TEU). The most prevalent TEU containers are 20 feet long and 1,300 cubic feet in volume.**

4.10 CONTROL OF MARINE POLLUTION DUE TO MARITIME TRANSPORT IN THE JORDAN GULF OF AQABA

In the overall context of sustainable development, shipping is a very powerful and positive force, making a major contribution to global trade and prosperity in a way that has only a relatively small negative impact on the global environment. Shipping – which transports 90 per cent of global trade– is, statistically, the least environmentally damaging mode of transport, when its productive value is taken into consideration.

Countries through United Nations and other international and regional organizations, assumed responsibility for pollution issues and subsequently has, over many years, adopted a wide range of measures to prevent and control marine pollution caused by ships and to mitigate the effects of any damage that may occur as a result of maritime operations and accidents.

These measures have been shown to be successful in reducing vessel-sourced pollution. For example, of the 51 treaty instruments IMO has adopted so far, 21 are directly environment-related or 23, if the environmental aspects of the Salvage and Wreck Removal Conventions are included (IMO 2014b). The reductions of pollution generated by ships have been achieved by addressing technical, operational and human element issues and are all the more noteworthy when compared with the significant growth in the world's shipping industry – both in the size of the world fleet and the distances that it travels.

4.10.1 INTERNATIONAL CONVENTIONS RELATING TO PREVENTION OF MARINE POLLUTION

- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter **(London Convention)**, London, 1972.
- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto **(MARPOL 73/78**), London 1973 and 1978.
- International Convention for the Prevention of Pollution of the Sea by Oil, London 1954, 1962 and 1969.
- International Convention on Civil Liability for Oil Pollution Damage **(ICCL**), Brussels, 1969, 1976, 1984 and 1992.
- International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage **(FUND**) 1971 and 1992, Brussels, 1971/1992.
- International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea **(HNS)**, London, 1996.
- International Convention on Oil Pollution Preparedness, Response and Co-operation **(OPRC)**, London, 1990.
- International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties **(Intervention Convention),** Brussels, 1969.
- Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances (**OPRC-HNS Protocol)**, London, 2000.
- United Nations Convention on the Law of the Sea (**UNLOS** Convention), Montego Bay, 1982.
- International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended
- International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), 2001.
- International Convention for the Control and Management of Ships' Ballast Water and sediments, 2004.

4.10.2 MARPOL 73/78 – ANNEXES II-VI

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. The 1973 MARPOL Convention and the 1978 MARPOL Protocol entered into force on 2 October 1983. In 1997, a Protocol was adopted to amend the Convention and a new Annex VI was added which entered into force on 19 May 2005. MARPOL has been updated by amendments through the years. The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes. Special Areas with strict controls on operational discharges are included in most Annexes.

MARPOL 73/78 is considered the International instrument for the control of marine pollution by oil. It has been important in reducing oil losses due to tanker operations, and oil losses and other pollutants due to the operations of other ships. **Annex I** of MARPOL 73/78, dealing with discharges of oil by tankers. **Annex II**, "Control of Pollution by Noxious Liquid Substances" applies to the carriage in bulk of all noxious liquid substances in bulk, except oil. It covers also the carriage of chemicals in bulk. The carriage of such substances is only permitted in ships certified as chemical carriers, and offshore supply vessels which are also permitted to carry certain chemicals in order to support offshore drilling operations. **Annex III** of MARPOL 73/78, "Prevention of Pollution by Harmful Substances in Packaged Form", is the first of the 'voluntary' annexes. These substances are identified in the IMO's International Maritime Dangerous Goods (IMDG) Code. This latter Annex prohibits carriage of these substances except in accordance with the requirements of the Annex, which cover packaging, marking, labelling, documentation, and exceptions that relate to the safety of the ship or saving of life.

All dangerous goods must be declared on a separate list carried by the ship. **Annex IV** of MARPOL 73/78, "Prevention of Pollution by Sewage from Ships" which entered into force on 27 September 2003 restricted the discharge of sewage from ships. However, ports are required to provide adequate reception facilities for ships that are not equipped with sewage treatment plants. **Annex V** of MARPOL 73/78,"Prevention of Pollution by Garbage from Ships", applies to all ships of any size. Any type of plastic cannot be disposed of at sea and must be sent ashore for disposal. Food waste and other waste above the size 25 mm in diameter must be disposed of only when 12 nautical miles from land. In "Special Areas" only food waste can be disposed of at sea and only when the ship is more than 12 nautical miles from land. Ports must provide adequate reception facilities for garbage. **Annex VI** of MARPOL 73/78, "Prevention of Air Pollution from Ships", was adopted by IMO in 1997 and entered into force on 19 May 2005. It addresses the problems of the release of ozone depleting substances by ships and air pollution by ships. It is designed to control the emission of nitrous oxides (NOx) and sulphur oxides (SOx) from ship exhausts, and volatile organic compounds (VOCs) in ports and oil terminals. MARPOL 73/78 has only been ratified by Jordan Egypt, Saudi Arabia and Djibouti, within the RSGA. Egypt and Jordan have ratified MARPOL 73/78 Annexes I-V and Saudi Arabia has ratified MARPOL 73/78 Annexes I-VI. Accordingly, ratification of MARPOL 73/78 and its annexes, by all countries on Red Sea and Gulf of Aqaba is important to the whole region (PERSGA 2006).

4.10.3 IMPLEMENTATION OF CONVENTIONS, AND CONTROL AND COORDINATION ON SAFETY OF SHIPS: PORT STATE CONTROL (PSC)

When a government accepts an IMO Convention, it agrees to make it part of its own national law, and to enforce it just like any other law. The problem is that some countries lack the expertise, experience and resources necessary to do this properly. Demonstrated evidence indicated that there is a highly significant difference between the performances of states with a substantial and organized maritime safety administration, manned with experienced ship surveyors, and other ones that are not in a position to properly fulfil the different tasks and responsibilities of the flag State in relation with safety certification of ships. The most important IMO conventions contain provisions for Governments to inspect foreign ships that visit their ports to ensure that they meet IMO standards and requirements. If they do not, they can be detained until repairs are carried out. An efficient way of raising IMO standards is through Port State Control (PSC). Because IMO is concerned about this problem, the organization set up a special Sub-Committee on Flag State Implementation (FSI) to improve the performance of Governments. The Sub-Committee, in addressing the effective and consistent global implementation and enforcement of IMO instruments concerning maritime safety and security and the protection of the marine environment, considered technical and operational matters including the development of any necessary amendments to relevant conventions, as well as the preparation of new instruments, guidelines and recommendations, for consideration as appropriate (IMO 2014c).

Port State Control (PSC) is the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules. The Port State Control authorises ports to inspect national and foreign ships to ensure that they meet required construction, equipment safety and manning standards, and to detain the ships, which are considered to be sub-standard (IMO 2014c).

These inspections were originally intended to be a back up to flag State implementation, but experience has shown that they can be extremely effective, especially if organized on a regional basis. A ship going to a port in one country will normally visit other countries in the region before embarking on its return voyage and it is to everybody's advantage if inspections can be closely co-ordinated. This ensures that as many ships as possible are inspected but at the same time prevents ships being delayed by unnecessary inspections. The primary responsibility for ships' standards rests with the flag State - but port State control provides a "safety net" to catch substandard ships. Therefore, IMO has encouraged the establishment of regional port State control organizations and agreements on port State control - Memoranda of Understanding or MoUs - have been signed covering all of the world's oceans. Consequently, many states have coordinated their PSC activities so that they can inform other states in their region when a sub-standard ship has been located and may call at ports in another regional state through regional Memoranda of Understanding (MoU) on PSC. Many countries of the Arab world signed the Mediterranean (Mediterranean MoU) while the Arab countries on the Arabian Gulf have signed the Riyadh MoU. It is good to know that in 1999 Jordan and Egypt became members of the Mediterranean MoU on PSC (IMO 2014c).

4.10.4 DUMPING OF HAZARDOUS MATERIALS AND NOXIOUS SUBSTANCES (HNS) AT SEA

On global level, data available for the period from January 2006 to June 2011 indicates that of the 235 incidents involving 247 HNS products that cause or have the potential to cause pollution, 123 of these involved products in bulk goods (52%) (ISCO 2014; IMO (2012). An additional 82 involved products in packaged form. The International Spill Control Organization (ISCO) has analysed 291 HNS accidents that have occurred in the past. Of these, 25% led to an actual chemical release and 16% led to loss of packaged goods. Most cases, in which the distress situation actually led to a spill, resulted from a collision (a chemical release has occurred following a collision in eighteen cases). Groundings are also a frequent cause, with 21 of 106 recorded cases leading to a spill (ISCO 2014; IMO 2012).

Leak is the most common way for HNS substances to be released into the marine environment, representing 36% of the incidents involving some kind of release of HNS. Sinking of a ship also accounts for a substantial percentage (25%) of the number of spills. Most of the recorded accidents involved general cargo ships. A study by the European Maritime safety Agency (EMSA) of HNS releases in European countries identified one hundred incidents from 1987 to 2006, almost half of which resulted in an HNS release. The majority were in the Mediterranean Sea (40%), North Sea (22%) and Channel (20%) probably as a reflection of the volume of HNS trade in these areas (IMO 2012). A study conducted by France‘s Centre of Documentation Research and Experimentation on Accidental Water Pollution (Cedre) on HNS transportation accidents and the risks of chemical spills at sea (1917-2009) showed the number of HNS incidents, after a period of relative stability between 1963 and 2005, has risen sharply over the past several years. This is believed to be mainly due to increased shipping and a better information network, resulting in improved incident reporting and information sharing. Notwithstanding this increase, such accidents are more efficiently managed than in the past, with 50 per cent of accidents occurring today resulting in a spill, compared to practically twice as many in the past. This can partly be explained by the decrease in average ship age, as well as an improvement in spill prevention procedures (IMO 2012).

The main causes of HNS accidents were shown to be adverse weather conditions (17%) and structural damage (16%), followed by collisions (14%) and groundings (14%). Often, the latter two categories of navigational errors are the result of not adhering to established shipping routes or a lack of communication. In fifth place, were the explosion and fire (11%), and finally errors during loading and unloading operations (6%). The top ten most spilled substances calculated by weighing the frequency by the quantity spilt are listed in the following Table 4.7. Six of f these ten substances are either imported or exported via the ports of Aqaba (IMO (2012; and MEPC/OPRC-HNS/TG 2012).

Table 4.9: Top ten most spilled HNS substances calculated by weighing the frequency by the quantity spilt (IMO (2012; MEPC/OPRC-HNS/TG 12/5/3, 2012).

Substance	Frequency
iron ore	1
sulphuric acid	2**
caustic soda	3
fertilisers	4**
cereals	5**
ammonium nitrate	6
phosphate	7**
coal	8
sulphur	9**
vegetable oils	10**

Illegal dumping of waste materials at sea is prohibited by the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, 1972, often referred to as the "London Dumping Convention". The 1996 Protocol to the 1972 Convention regulates the use of the sea as a depository for waste materials. The Protocol which entered into force on 24 March 2006 emphasises that Contracting Parties should ensure that the Protocol should not result in transferring pollution from one part of the environment to another. Article 6 of the1996 Protocol states that “Contracting Parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea.”

From 14 June 2007, ships flying the flag of a Party to the OPRC-HNS Protocol must carry a pollution emergency plan to deal specifically with incidents involving hazardous and noxious substances, such as chemicals. This requirement is one of a list of measures included in the *"Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances (OPRC-HNS Protocol)*", of 2000, which entered into force on 14 June 2007. The Protocol defines HNS as substances other than oil, which, if introduced into the marine environment, have the potential to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea. States which are party to the OPRC-HNS Protocol are required to establish a national system for responding to HNS, including a designated national authority, a national operational contact point and a national contingency plan. This needs to be backstopped by a minimum level of response equipment, communications plans, regular training and exercises. States must also provide assistance, to the extent possible and feasible, to other States in the event of a pollution emergency. States should also try to conclude bilateral or multilateral agreements on preparedness for, and response to, pollution incidents involving HNS. IMO has developed manuals and guidance documents to assist countries in developing their capacity for dealing with incidents involving HNS and meeting their obligations under the Protocol.

Within the RSGA, Jordan is a party to the 1972 Convention but not the 1996 Protocol, Egypt is a party to the London Dumping Convention 1972 and its 1996 Protocol, and Saudi Arabia is a party to the 1996 Protocol but not the 1972 Convention. No other states in the region have become parties to the 1972 Convention or its Protocol. In view of the significance of the 1996 Protocol as an instrument to prevent illegal dumping, and the articles promoting regional cooperation that could be effective in helping to prevent pollution of the RSGA by toxic materials, it is important that other states in the region should become parties to this key Convention through the 1996 Protocol.

4.11 BALLAST WATER AND INVASIVE AQUATIC SPECIES

Shipping carries more than 80% of the world trade and in the process 12 billion tonnes of ballast water per year. Over the last 30 years, world seaborne trade has more than doubled from 2490 MT in 1970 to 5330 MT in 2000 (UNCTAD 2000a; UNCTAD 2000b). Larger vessels with larger ballast tanks and larger surfaces available to carry more fouling organisms are being developed. As the merchant fleet grows, the number of ship visits increases and the number of species that are given the opportunity to invade increases with it.

For example, it is estimated that Australia's 64 international ports receive more than 22,000 vessel visits originating in 300 overseas ports per year (Baxet al. 2003), and commercial shipping is just one of many vectors. International shipping and ocean-going recreational vessels offers transport opportunities via hull fouling, sea chests and ballast and a myriad of other compartments (Hayes 2002). There are 15 broad categories of vectors that transport marine organisms from shallow coastal waters to similar habitats outside the species' home range (Carlton 2001). Historically vectors have included hull fouling (and boring), dry and semi-dry ballast, ballast water, unintentional introductions associated with the importation of mariculture species, and deliberate introductions of exotic species for mariculture (Campbell and Hewitt 1999). More recent vectors include those associated with the aquarium trade, recreational water users, and the oil, gas and construction industries. More than half the recognized alien marine species in the United Kingdom are associated with shipping—fouling being the dominant mechanism (Eno (1996). In New Zealand, most alien marine species have been attributed to hull fouling (Cranfield et al. 1998).

The phenomenon extended to all regions of the Mediterranean (Galil, 2007, 2009) to the limit that marine invasive species are regarded as one of the main causes of biodiversity loss in the Mediterranean (Galil, 2006; Galil, 2007). They represent a growing problem due to the unprecedented rate of their introduction and the unexpected and harmful impacts that they have on the environment, economy and human health (Galil, 2007). Many invasive species in the Mediterranean is attributed to migration of species from the Red Sea through the Suez Canal. The flow of migration through the Suez Canal ***(Lessepsian migration*****)** is almost unidirectional from the Red Sea to the Mediterranean. More than 5% of the marine species in the Mediterranean are now considered non-native species (Zenetos *et al.*, 2012. According to the latest regional reviews, 13.5% of those species are classed as being invasive in nature, with macrophytes (macroalgae and seagrasses) the dominant group in the western Mediterranean and Adriatic Sea, and polychaetes, crustaceans, molluscs and fishes in the eastern and central Mediterranean (Galil, 2009; Zenetos *et al.*, 2012). By comparison very few Mediterranean species have moved in the reverse direction ***(Anti-Lessepsian migration***). A total of 53 species at different times have been considered Mediterranean immigrants tom the Red Sea. However, critical evaluation of these reports leads to a reduction in the number of species to 10-20; most of them are confined to the vicinity of Suez port band lagoons (Por, 1978).

Ballast water is among an ever-expanding list of vectors that mirror the worldwide expansion in trade and tourism (Thresher 1999; Thresher 2000; Baxet al. 2003). However, as ballast water has become cleaner, ship's transit speeds have increased, and environmental management of ports has improved, marine organisms are likely to find commercial shipping and other vectors increasingly hospitable means of transport worldwide. According to Mooney (2005) Perrings et al. (2010), invasive species are one of the great problems of the modern times. Globalization, increase of commercial trades and climatic changes make invasive species a general threat for all kinds of terrestrial, freshwater or marine ecosystems.

At any given moment some 10,000 different species are being transported between bio-geographic regions in ballast tanks alone (Carlton 1999; Baxet al. 2003). Invasive alien marine species threaten biodiversity, marine industries (including fishing and tourism) and human health, and unlike oil spills only get worse with time (Baxet al. 2003). Scientists and policy makers increasingly see the introduction of alien species as a major threat to marine biodiversity and a contributor to environmental change. The rate at which foreign organisms are establishing in ports worldwide has increased dramatically. Once an invasive alien species enters the local marine environment, it is most likely there forever. It will interact with existing communities and, in the process modify native habitats. Many invasive species can change their new environment. This can occur through increasing the predation pressure on native organisms (for example, the North Pacific seastar in Australia) or modifying the habitat by smothering (for example, *Caulerpa taxifolia* in the Mediterranean and California; black striped mussel in Southeast Asia and Australia), or providing new structural habitat (Japanese seaweeds in Europe, South Africa and Australia). Many of these invasive species work synergistically—the environmental modifications caused by one species provide increased opportunities for further alien species to invade. This escalating problem has been termed "invasional meltdown" (Simberloff and Holle 1999).

New Zealand scientists identified 159 alien marine species (Cranfield et al. 1998). In Hawaii, 91 of the nearly 400 marine species present in Pearl Harbor are alien (Coles et al. 1999). Based on historical data, a new marine or estuarine species establishes itself every 32–85 weeks in each of six ports studied in the US, New Zealand and Australia, a rate that appears to be increasing (Hewitt 2003). While many of the alien species become part of the background flora and fauna, others become invasive, reaching densities of 1000s m^{-2}, and come to dominate the native flora and fauna. Virtually every coastal habitat in the San Francisco Bay area is now dominated by one or more alien species. Three of the six most common benthic marine species in Port Phillip Bay (Australia) in 1996 were alien species, a statistic that does not include two recent and rapidly proliferating alien species, one of which—the North Pacific seastar, *Asterias amurensis*—has increased to over 100 million individuals covering 1500 km^2 that have a greater biomass than that of all fished species in the Bay. In the 15 years since its discovery off Monaco, the invasive green algae, *Caulerpa taxifolia*, has come to cover 97% of available surfaces between Toulon and Genes (France, Monaco and Italy) has already been spread to the Adriatic Sea, and is projected to eventually spread over most of the Mediterranean (Meinesz 1999).

The numerical dominance of invasive alien marine species swamps native species and alters ecosystem services. In the Black Sea, an invasive comb jelly, *Mnemiopsis leidyi*, has been blamed for the collapse of coastal fisheries worth many millions of dollars annually (Shiganova 1998). The Asian clam *Potamocorbula amurensis*, now reaches densities of over 10,000/m^2 in San Francisco Bay, and has been blamed for the collapse of local fisheries. An invasive crab, *Carcinus maenas*, a European species now found in Australia, Japan, South Africa and both coasts of North America, is blamed for the collapse of bivalve fisheries on the North American east coast, and it is it feared will outcompete migratory bird populations on the west coast of North America for favoured shellfish (Grosholz et al. 2000).

Ballast water is also capable of transporting viral and bacterial pathogens, including the bacteria that cause cholera (Ruiz et al. 2000) and the resistant cysts of toxic dinoflagellates that can lead to harmful algal blooms and shellfish poisoning. Ballast water and other vectors can carry invasive alien marine species that are intermediate hosts for parasites affecting humans—e.g. the Chinese mitten crab that has invaded Europe and the US West coast is an intermediate host of the human liver fluke (Baxet al. 2003).

Though less frequent, the alien marine species may also have positive impacts such as the improvement of aesthetic values and the creation of new economic activities (fisheries and aquaculture). The main economic and social impacts of invasive alien marine species are negative impacts on human health and decreases in economic production of activities based on marine environments and resources such as fisheries, aquaculture, tourism and marine infrastructure. These effects have related social impacts through decreases in employment in economic activities directly affected by invasive alien species but also through decreases in people's welfare from the reduced quality of their environments and natural surroundings (Baxet al. 2003).

It is widely accepted now, that the carriage of ballast water by ships can cause adverse impact to the marine environment much more than oil and other pollutants. As it has been noted before that invasive aquatic species (IAS) in ships' ballast water is now considered the fourth greatest threats to the world's oceans, in addition to land-sourced marine pollution, over-exploitation of living marine resources, and physical alteration/destruction of habitat. The IAS impact on environment will increase over time, because ships are getting faster and are carrying larger volumes of ballast water and are visiting increasing parts of the world. Therefore, cooperation among regional trading partners will be essential to effectively manage the threat (Baxet al. 2003)

While MARPOL 73/78 Annex I prohibits the discharge of any oil within a Special Area, Regulations 1 (16), 10 (2) and 10 (3) (a), allow clean or segregated ballast water to be discharged in a Special Area, which the Gulf of Aqaba and the Red Sea have been designated to become under MARPOL 73/78. The main ship types of concern in the waters of the Red Sea region are oil tankers which, since the early 1980s, have been required to carry their ballast in segregated tanks. Segregated ballast tanks (or SBT) have been regarded as the environmentally responsible way to carry ballast on tankers, as the ballast water should not, under normal circumstances, become contaminated by oil and therefore this water can be discharged overboard without being treated to deal with any oil content. However, the transfer of IAS in ballast water in tankers and water carried in bulk carriers is still a matter of concern to environment and ports authorities. Dry bulk carriers calling at ports in the Aqaba and other Red Sea ports often discharge their cargoes of bulk and take on ballast water. On the other hand, sometimes dry bulk carriers calling at these ports to load dry bulk cargoes and, before or during loading, discharge their ballast water into the sea or into port waters. Container ships, dry cargo ships and car carriers use ballast and may need to discharge ballast taken on board at distant places into the waters of ports in the Red Sea region.

Accordingly, in 2000 IMO joined efforts with GEF, UNDP, member governments and the shipping industry to assist less industrialised countries to tackle the ballast water problem. The project was *"Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries"*. It was more simply referred to as the *"Global Ballast Water Management Programme"*, or *"GloBallast"*. It allows parties to the Convention to impose more strict measures than those required by the Convention. It requires reception facilities to be provided for sediments from ballast tanks, and provides for the certification and inspection of ships carrying ballast water. Following the completion of the GloBallast Programme (2000-2007), the second phase of the Programme, *Building Partnerships to Assist Developing Countries to Reduce the Transfer of Harmful Aquatic Organisms in Ships' Ballast Water*, simply referred to as GloBallast Partnerships (GBP**),** was initiated in late 2007 and is intended to build on the progress made in the original project. The project which is being implemented by UNDP and executed by IMO, under the GEF International Waters Portfolio, was initially planned as a five-year project, from October 2007 to October 2012, but in 2010, the Project Executive Committee agreed to extend the project for another two years i.e.to the end of 2014. The broad development objectives of the Project are to assist developing countries to reduce the risk of ballast water mediated bioinvasions and prepare the countries for implementation of the IMO. The Project is focussed on national policy, legal and institutional reforms in targeted developing countries with an emphasis on integrated management. The approach encompasses promoting collaboration with industry to facilitate the successful transfer of new technologies from developed to developing countries. The GBP is being implemented in 5 high priority sub-regions which include among others, the Mediterranean, the Red Sea and the Gulf of Aden (MEPC 2006; MEPC 2012; Globallast/IMO).

The level of interest in the new Convention and the willingness of the Red Sea countries to participate in the GBP and to cooperate with the next phase of the GloBallast Programme in order to protect the marine environment from IAS are high. Accordingly, PERSGA is working closely with IMO and the GloBallast Programme to provide solutions to the problem of ballast water control and management in the region (PERSGA 2006). Unfortunately, the problems associated with the ballast carried on bulk carriers arriving at ports in the region to load various cargoes, such as raw phosphate, potash and rock, have not been appreciated to date. But those involved in ports where there is a potential problem, such as Aqaba, are eager to see mitigating action taken.

4.12 SEA-BASED GARBAGE AND MARINE LITTER

Marine litter (Debris) is another type of sea-based pollutants. According to Valavanidis and Vlachogianni (2011), the main sea and ocean-based sources of marine litter are:

a. Merchant shipping, ferries and cruise liners (litter from used items and passengers throwing litter (plastic, paper, boxes, bottles, aluminium cans, etc),
b. Fishing vessels (discarding nets, fishing tackle),
c. Military fleets and research vessels,
d. Pleasure crafts (yacht, boats),
e. Offshore oil and gas platforms (environmental risks, most notably oil spills from oil tankers, pipelines leaks and accidents on the platform, strict regulations, waste management).
f. Fish farming (aquaculture, raising fish commercially in tanks or enclosures, usually for food and producing marine waste).

In the last decades all countries have initiated projects and practical measures to reduce or to prevent marine litter as part of a larger issue of waste management (Frost and Cullen 1997**;** NRC 2008; IMO 2002). The first practical efforts to reduce marine litter started with merchant ships, offshore platforms and pleasure crafts: waste management plans advanced with storage onboard and discharged ashore in an organized waste facility. However, this measure requires adequate space onboard for storage, and the provision of reception facilities in all commercial harbours and marinas. It also calls for harmonized regional and global regulations. Fishing vessels is another source of marine litter and reduction of waste discharged in open seas must be prohibited by regulations. Also, facilities for marine litter collection and treatment must be organized in all harbours. In some countries fishing vessels must mark their fishing gear and particularly drift nets, so that to make possible to find them again if they are lost at sea (Horsman 1982).

In the past few decades, the enforcement of when and where, to dispose of all types of wastes produced on a ship's voyage has become better regulated through MARPOL Annex V (Garbage). The requirements are much stricter in a number of "Special Areas" but perhaps the most important feature of the Annex is the complete ban imposed on the dumping into the sea of all forms of plastic. However, although the Annex obliges governments to ensure adequate provision of facilities at all ports and terminals for the reception of garbage, more work needs to be done to ensure availability in every port. Despite actions taken nationally and internationally, the situation with regard to marine litter is continuously getting worse according to the United Nations Environment Programme (UNEP 2005).

Globally, no systematic regional measurements of the amounts of marine litter were conducted in 12participating regions worldwide. Only the Baltic Sea, Black Sea, Mediterranean, Northeast Atlantic, North west Pacific and the Wider Caribbean were able to provided UNEP with some data on the amounts of marine litter in their respective regions. The great majority of these reported marine litter on beaches, some reported litter in open waters, and a few addressed marine litter on the sea floor (UNEP 2009). In 1997, the US Academy of Sciences estimated the total input of marine litter into the oceans, worldwide, at approximately 6.4 MT per year. According to other calculations, some 8 MT of marine litter have been estimated to enter oceans and seas every day, about 5 million of which are thrown overboard or lost from ships. Furthermore, it has been estimated that over 13,000 pieces of plastic litter are floating on every square kilometre of ocean surface. In 2009, more than 498,818 volunteers picked up 7.4 million pounds of marine debris in 108 countries around the world. They removed marine litter from more than 21,000 kilometres of coastline and waterways collecting more than 6.2 million pieces of marine litter, weighing over 4,000 tonnes. Almost 58% of the marine litter found could be attributed to shoreline and recreational activities, such as beach picnicking and general littering (UNEP 2005).

Regionally, various regional figures on quantities and distribution of marine litter are available (UNEP 2009). In a 1998 survey, 89% of the litter observed floating on ocean surface in the North Pacific was plastic. The Algalita Marine Research Foundation (AMRF) has conducted surveys to compare the quantities of plastic fragments floating on the ocean surface to the availability of food with which they are mixed. In the central Pacific gyre, the AMRF in 2002 found 6 kilos of plastic for every kilo of plankton near the surface. About 3,500 plastic resin pellets per km^2 have been reported floating on the surface in the Sargasso Sea. Near industrial centres in New Zealand, concentrations of up to 100,000 pellets were observed in one km^2 of beach. In 1990, American scientists reported a 200–400% increase from 1972 to 1987 in the number of pellets present in the North Atlantic Ocean. According to figures from the North Sea, as well as from the water around Australia, it has been estimated that up to 70% of the marine litter that enters the sea ends up on the seabed, whereas half of the remaining amount is found on beaches and half floating on the water surface (UNEP 2005).

In 2002, the United States National Oceanic and Atmospheric Administration (NOAA) collected 107 tonnes of nets and lines and other fishing gear on the Pearl and Hermes Atoll (northern Hawaiian Islands) alone. In 2003, another 90 tonnes were found near the Pearl and Hermes, and Midway Islands. Heavy fishing gear litters the beaches, but probably much more serious is the fact that the gear gets snagged in the coral reefs, tearing the corals apart. It also traps endangered monk seals and threatens green sea turtles. There are strong indications from many regions that the quantities of marine litter are increasing. Consequently, the resulting environmental and socio-economic problems are worsening. Despite international and national efforts made during the last two decades, there are no clear indications that the quantities and distribution of marine litter are decreasing, either globally or regionally (UNEP 2005).

The largest beach cleaning event is operated by the Ocean Conservancy's International Coastal Cleanup. Nearly 500,000 volunteers in 2009 from 108 countries collected 7.4 million pounds of trash (Marine litter Solutions 2015). In the 2013 the International Coastal Cleanup (2013), 648,015 volunteers in 92 countries and location joined the effort International Coastal Cleanup by gathering more than 12,329,332 million pounds from miles 12,914 miles of beaches and waterways. They collected 313,652,376 pieces of which 1,034,667 are plastic pieces (Ocean Conservancy report 2014).

In RSGA region PERSGA has published a document on the status of marine litters in this region. According to PERSGA, this document provides a Regional Action Plan (RAP) for combating the marine litter problem and achieving its sustainable management within the Red Sea and Gulf of Aden. The RAP is consistent with global, regional and national initiatives; it was developed to meet the need for proper management of coastal and marine litter in the region. The strategies, objectives and priority actions in this RAP are based on an assessment of coastal and marine litter in the PERSGA member states. The assessment is derived from information gathered through a standard questionnaire distributed to the member countries of PERSGA; data available from previous regional and national surveys; and relevant reports and documents. The document provides an account of the status of coastal and marine litter in the region and a set of priority actions pertaining to a number of objectives concerning the issues public awareness and education; legal and institutional frameworks; and research and monitoring (PERSGA/UNEP 2008).

In Jordan, a two years period (1994-1996) monitoring programme was carried out to investigate the type, sources, magnitude, and distribution, in the north-eastern portion of the Gulf of Aqaba along the Jordanian coastline by Abu Hilal and Al Najjar (2004). They concluded that most of the litter on the Jordanian coastline of the Gulf of Aqaba results from two sources; recreational and shipping activities. The trends in composition and distribution of the litter indicate that the cargo and passengers' ships are a major source of debris. In a later investigation of marine litter in coral reef areas within the coastal waters of the Jordan Gulf of Aqaba, the relatively high counts of fishing gear items (90% of the total debris) in one of the coral reef areas was attributed to the relatively high fishing boats activities in the reef off this site compared to other sites (Abu Hilal and Al Najjar 2009). They concluded that the types of benthic marine debris indicate that the passenger ships, recreational fishing, boating activities, and commercial fishing activities are among the important sources of debris (Abu Hilal and Al Najjar 2009).

4.13 SHIP ROUTEING MEASURES

The main deep water body of the Red Sea does not include any routeing measures. Vessels operating between the southern and northern ends of the Red Sea currently follow many routes to reach their destinations. Such ship movements in the RSGA result in a mix of through traffic heading roughly north/ south in the Red Sea and east/west in the Gulf of Aden, combined with movements between ports in the RSGA that frequently result in traffic needing to cross the main shipping route (PERSGA 2006). In addition, many ferries carry passengers between the east and west coasts of the Red Sea and Gulf of Aqaba between Sudan and Saudi Arabia, Egypt and Saudi Arabia, Egypt and Jordan, that cross, join or leave the main busy shipping route in order to call at ports in these countries (Fig. 4.13).

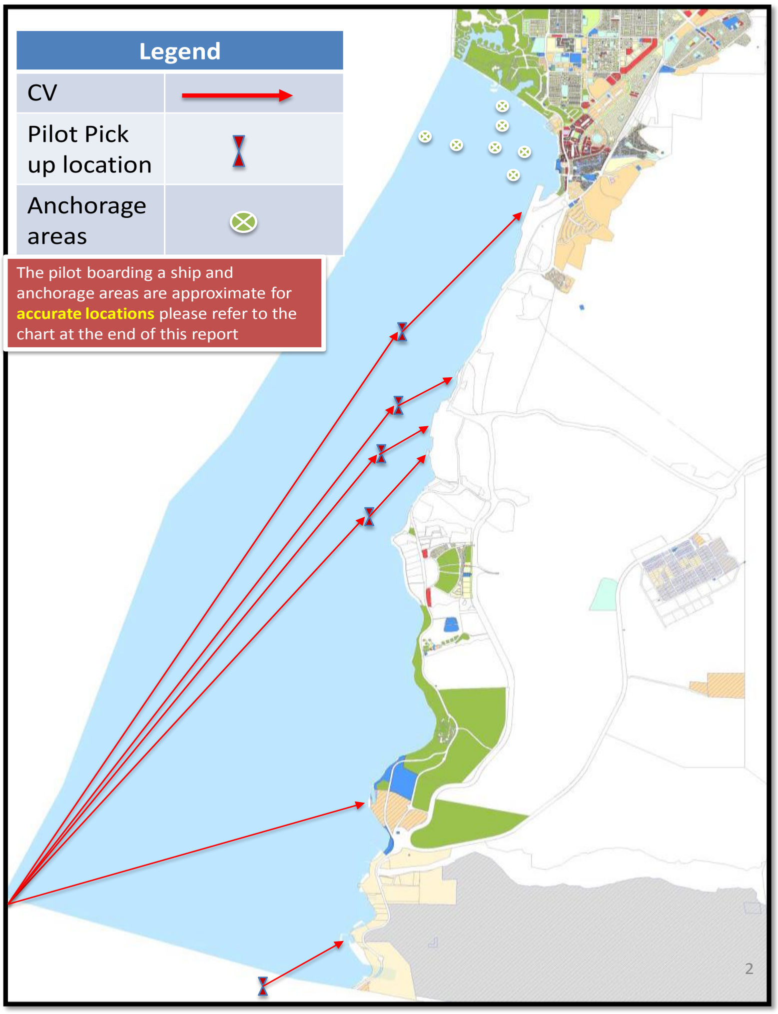

Figure 4.13: Routes used by ships and ferry boats entering or leaving Jordan territorial waters and Aqaba ports (Al-Btoush 2015).

In order to assist ship master and to protect sensitive ecosystems in the region, a number of ship routeing measures, including traffic separation schemes (TSS), have been introduced in this region (Fig. 4.14). For example, Routeing measures for ships entering and leaving the ports of Yanbu Al Bahr and Al Malik Fahd on the coast of Saudi Arabia have been established and the Admiralty Chart No. 5501, "Mariner's Routeing Guide-Gulf of Suez", showing the routes and providing guidance notes on precautions to be taken when navigating in the Gulf of Suez is available.

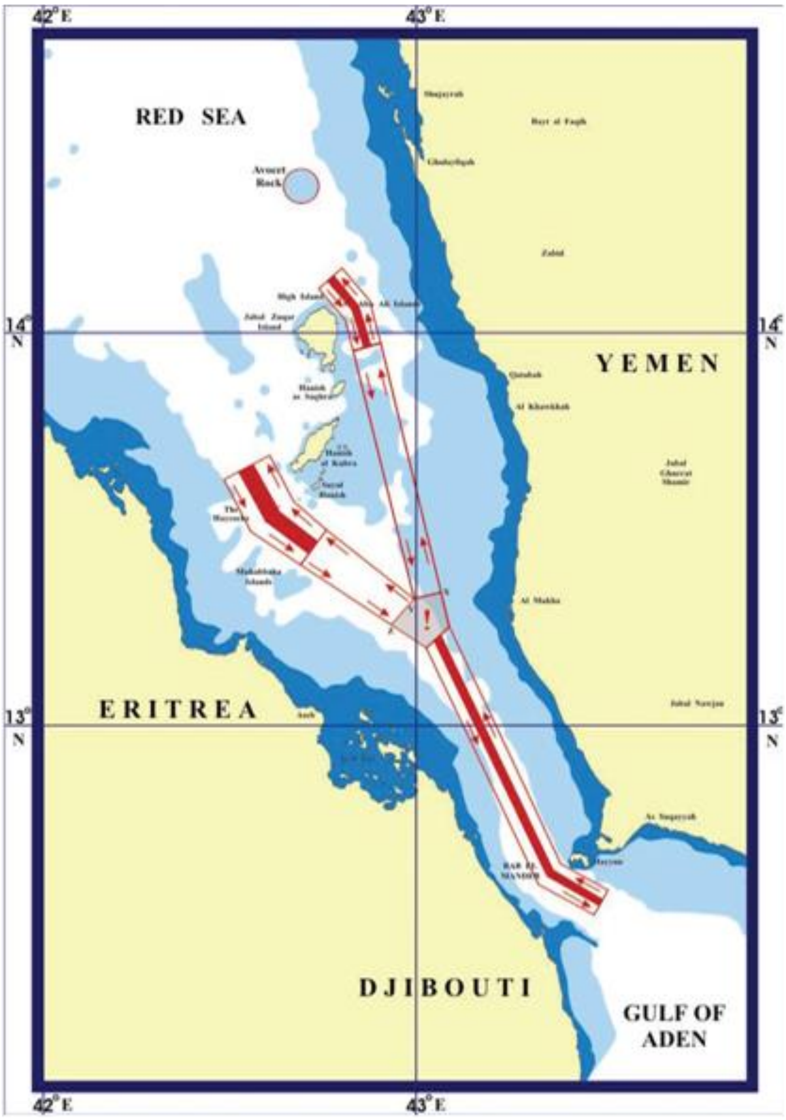

Figure 4.14: Routeing measures in the southern Red Sea-General layout of measures (PERSGA 2006).

At the southern end of the Red Sea, Navigation Working Group of PERSGA proposed new measures consisted of an extended TSS through Bab el Mandeb. The measures were adopted by IMO in December 2002 for use by international shipping and entered into force on July 2003 (PERSGA 2006). The establishment of carefully located routeing measures for the main through traffic of the Red Sea could bring a level of control to the ships in transit while the establishment of other routeing measures can assist in reducing pollution of the marine environment. These include "Areas to be Avoided", which are designated areas that are not to be entered by certain ships which include all vessels carrying dangerous or toxic chemical cargoes (PERSGA 2006).

4.14 PORT AND TERMINAL DEVELOPMENT

4.14.1 JORDAN/AQABA

Many new ports and terminals have been developed along the Jordan Gulf of Aqaba and in the Red Sea region over the past 40 years, while many other established ports have been expanded, to handle the growth in trade and hence cargo volumes (PERSGA 2006). Port development is always associated with impacts on the environment. Building or extending ports often result in dredging, reclamation, deposition of materials and damage to coral reefs. The environment is also be affected by the industry that grows up in association with the port, such as ship movement, ship repair, oil refineries, grain and cement silos, petrochemical plants, wood plants, factories with their associated pollution problems of dust, noise water turbidity, and by the polluted or hot effluents (thermal pollution). Other impacts result from the construction of roads, trucks movements and from the construction of pipelines carrying oil or oil products to the loading or discharging point (ADC 2014).

According to ACT (2014 and the ASEZA new ports will be established on the south coast of Aqaba to replace the old ports located on the north-eastern coast of Aqaba. The project includes the construction of a General Cargo and Ro-Ro Terminal, a Ferry Terminal, and a New Grain Terminal. It includes also a Liquefied Natural Gas Terminal which (LNG) is consisted of (1) Berth (with 2 berthing Dolphins and 4 mooring Dolphins), unloading and gas processing equipment and connections to current gas pipeline (ADC 2014). Another component of the project is a Liquefied Petroleum Gas Terminal (LPG). An Oil Terminal will be established to maximize the Aqaba Oil Terminal handling capacity for crude oil and refined products. It includes upgrading the oil Jetty and berth facilities to allow safe berthing and de- berthing operations for the full range of tankers. The associated transfer pumps and pipelines will enable the terminal to handle approximately 14 million tons annually of crude oil, refined products and miscellaneous chemical liquids. The Miscellaneous Liquids Jetty is consisted of (1) berth that will be used to import, loading and unloading and store miscellaneous liquids, miscellaneous chemical liquids, crude oil light products and vegetable and mineral oils (ADC 2014). The development of the port includes a New Phosphate Terminal and a new Dry Bulk Jetty which will be used be provided with Dust and Spillage Controls facilities (ADC 2014). The development of the port of Aqaba included plans to increase the handling capacity of dry bulk potash and expansion of current industrial terminal by adding a New Industrial Jetty and increase maritime safety and marine environment (ADC 2014).

The EIA study for the ongoing new Aqaba Port development project has pointed out all the adverse potential impacts during the construction works and operational activities in the port area which need management and mitigation measures to protect coastal and marine ecosystems, coastal habitats, marine biodiversity, and human safety and health (ADC 2014). The list includes:

1- **Direct impacts** from dredging, anchoring, piling, construction activities, and land reclamation:
   Anchoring, piling, construction activities, and land reclamation will cause loss of marine habitat which include the physical removal of benthic habitat (including hard and soft coral and other marine flora and fauna) and the removal of migration and spawning sites for certain fish species; Reclamation will damage an area of 160,000 m^2 of beach, shoreline and seabed; Additional impacts could result from spillage or rolling of imported fill material and rocks on the sloping shoreline; Dredging and filling of land will remove shallow reef flat; coral damage due to port construction activities approximate total of 32,500 m^2 of live hard coral will be removed; Ship anchorage will also be a risk to corals and benthic communities; and The

construction of Ferry Terminal will remove 5,476 m^2 of live hard coral where the Ferry Terminal will be located; **Indirect impacts** on the marine habitat associated with development include; decreased populations of marine flora and fauna; disorientation of marine organisms; beach disturbance; flora and fauna displacement and community structure change; and decreased quality and quantity of corals due to extensive sedimentation.

2- **Direct impacts** from dredging, anchoring, piling and land reclamation construction activities on water quality associated with development include; increased turbidity and particle suspension in the water column; and contamination from marine or land-based construction plant and equipment. **Indirect impacts** on water quality associated with development include; reduction in live coral cover and lower depth limit of corals and other benthic habitats; lowered growth rates, reduced productivity, reduced recruitment, substantial reduction in sexual reproduction and rates of decolonization of coral.

3- **Direct impacts** from leakage or discharge of solid or liquid materials during Construction on marine environment associated with leakage/discharge during development could include; reduced water quality due to presence of pollutants' increased nutrient levels resulting in eutrophication; and build up of solid waste on the seabed. **Indirect impacts** on marine environment associated with leakage/discharge during development include; disturbance of natural marine cycles; risk of contamination of marine flora and fauna; risk of toxicity to flora and fauna in the event of an accidental spill of waste material such as oil and/or oil compounds; risk of coral suffocation and death; increased mortality and risk to health of marine flora and fauna

4- **Direct Impacts** on Existing Marine Intakes and Outfalls for the water intakes of KEMAPCO, JPMC and the Aqaba Thermal Power Plant (ATPP) could include; disruption of the existing infrastructure; disruption to cooling water flow; and higher turbidity water to the cooling system.

5- **Other impacts** include: aesthetic Impacts from quarrying rock armour which include; scarring of landscape; and reduced value of quarry vicinity for tourism or recreational purposes, and impacts associated with damage to the natural gas pipeline and other existing construction.

In addition, activities and operations in the port can adversely affect the marine environment during loading and unloading operations. Therefore, Prince Hamza Pollution Combating Centre (PHPCC), located within the Aqaba port, has been provided with craft and significant stocks of equipment to assist it in combating pollution incidents up to Tier 1 level. This is in addition to the limited stock of equipment at the Al Mushtaraq Tanker Terminal.

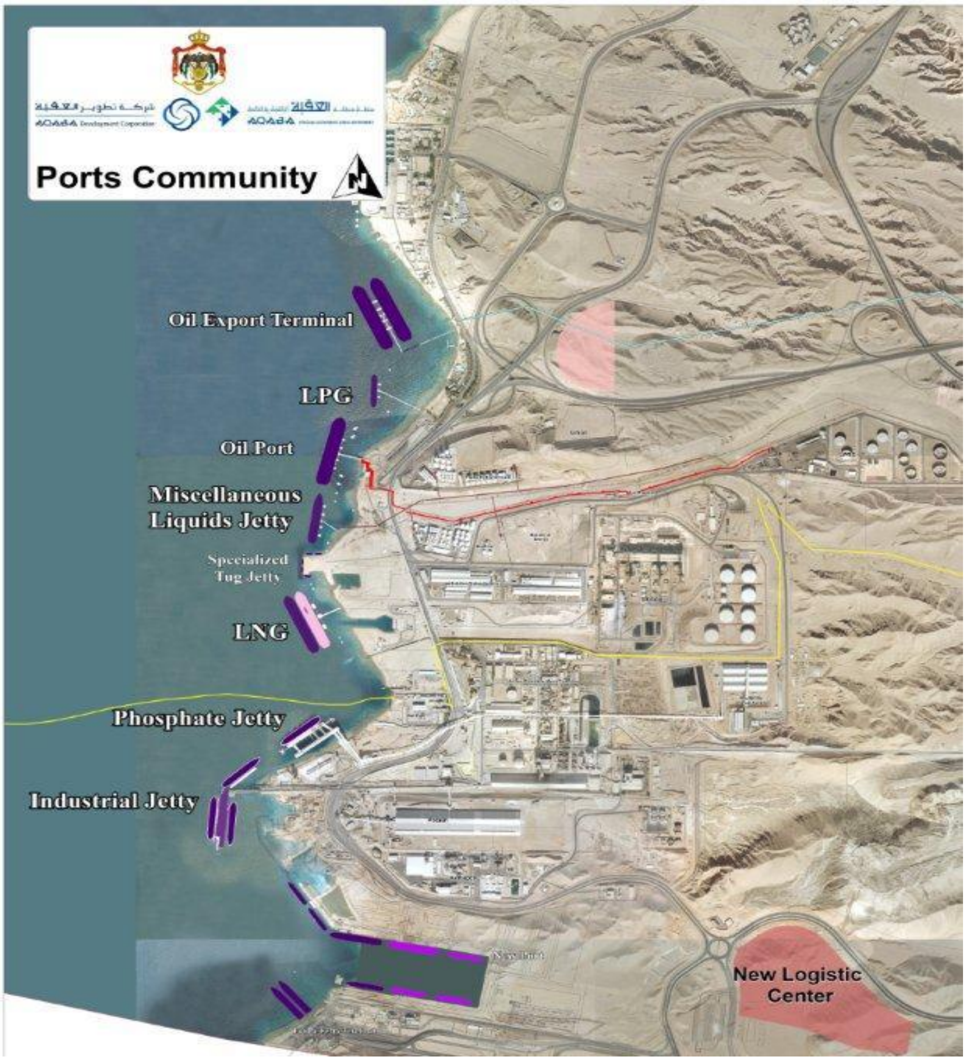

Figure 4.15: The components of the new Aqaba Port.

4.14.2 EGYPT PORTS ON THE GULF OF AQABA

Sharm El-Sheikh is a tourist port on the Sinai Peninsula which is mainly used by large passenger cruise liners and ferries operating from the western Red Sea coast of Egypt. Sharm El-Sheikh port is 380 km south of Suez Governorate, 156 mile from Suez port and 490 km from Cairo. It is located on top of the triangle of Sinai Peninsula, at the confluent of Suez and Aqaba Gulfs in South Sinai Governorate. It has a total port area 88.3 km^2, a water area of 88.1 km^2 and a maximum capacity of 100,000 passengers. Nuweiba El Muzina, in the Gulf of Aqaba has three berths, maximum depth alongside 8.0 m. The main business comes from passengers travel between Aqaba in Jordan and Nuweiba in Egypt and the RoRo traffic carrying loaded trailers of general cargo and other goods between Egypt and Aqaba, Jordan.

4.14.3 DIBBA PORT IN SAUDI ARABIA

Dhiba Port

Dibba, the northernmost port on the Red Sea coast of Saudi Arabia, is a relatively new port located 28 km north-west of the town of Dibba. It is located at the north end of the Red Sea coast of Saudi Arabia. It is a natural harbour protected on all three sides by hills. This port has vast hinterland on the inland frontier up to the northeast coast of Saudi Arabia and extends up to the Mediterranean Sea on the maritime front. It is the nearest Saudi port to the Suez Canal and other Egyptian ports. The distance between Dhiba Port and Suez Canal is 253 nautical miles (Arabian Supply Chain 2014). It handles ferries carrying passengers between Egypt, Jordan and Saudi Arabia, as well as cargo. Cement is exported from Dibba, and livestock, foodstuffs and general cargo are the main imports. The main berths in the port lie on a quay 600 m long, providing three berths at a depth of 10.5 m. A passenger terminal is situated on the quay. There is a RoRo berth at the south end of the main quay, a service quay for service vessels, a fishing vessel quay and a quay for use by the coastguard. About 4.5 km east-south-east of the town of Dibba is a tanker terminal handling bulk oil, where storage tanks are connected to a jetty that extends across the reef to a berth consisting of mooring buoys and two concrete piles. The port handled 650721, 5352861 and 143,289 Bulk Cargo (solid), General Cargo, and Ro-Ro & Vehicles, and received 339968, 343575 and 1,143,289 passengers during 2010, 2011, and 2012, respectively (Saudi Ports Authority 2014).

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CHAPTER FIVE

5 COASTAL AND MARINE RESOURCES

5.1 SUMMARY

Sandy, Muddy and Rocky Shores

The beaches along the north coast consist of varying amounts of fine-grained, wind-blown sand, in addition to larger-sized particles. This part of the Jordanian coastline is characterized by sandy and seagrass meadows, especially in the hotels area, and the public coffees' area.

In the east-northern coast of Aqaba, high mountains produce a shoreline largely comprised of rocky shore and cliffs plunging directly into the sea. There may be flat terraces extending out to fringing reefs, rock platforms, cobble beaches, or 1,000 m high vertical cliffs. Major groups of invertebrates occupying this zone include gastropod molluscs, rock oysters, barnacles, and chitons.

The sand beaches along the southern coast of Aqaba are composed of coarse particles, originating from the disintegration and decomposition of terrestrial rocks, and varying amounts of calcareous, sand sized particles of biological origin.

Status of Coral Reefs in the Jordan Gulf of Aqaba

The Jordanian coast of the Gulf of Aqaba is relatively small with much of the sea-related activities are focused. About 30% of the coastline is used for port activities, while 7 Km of the coast has been declared as marine protected area (About 25% of the total coast area).

The Gulf of Aqaba is among the most diverse high latitude reefs in the world, with about 200 species of hard corals and more than 500 fish species. The Jordanian Gulf of Aqaba coast supports relatively small total coral reef area, composed entirely of narrow and steep fringing reefs. Jordan's coral reefs were maintained in relatively good conditions during the past period, before the most recent developments of sea ports. No major bleaching events were recorded in the past.

At present, the most important threats to coral reefs in Jordan are the constructions of new ports and the expansions of existing ports that took place in the past years. This sector is still fast growing, as many new ports are being constructed, especially in the southern part of the coast. Massive death of corals and its associated fauna and flora have resulted from the construction and expansion of ports.

Additional and significant threats resulted from flooding, which happens every few years. The amount of coral death occurring upon such event is so detrimental to the coral reefs, where a whole reef flat can be killed as a result of the heavy load of sediments, which remain suspended in the water for about two weeks after the flood.

Adding to the above mentioned threats, the coral diseases, souvenir collections, damage by recreational diving, drifting of some ships by accidents, accidental oil spills, damaging fishing methods are the most important.

A long-term monitoring for basic coral reef ecosystem parameters such as percent cover and diversity of corals, as well as assessment of the associated fauna like sponges, algae and macro-invertebrates has been implemented as part of an overall

monitoring programme during the past years. Other benthic habitats such as the seagrass meadows and the sandy bottoms are also included in the monitoring programme. Additional monitoring includes those that are associated with certain coastal projects, such as the industrial complex and the Ayla Oasis project. Additional studies are carried out according to the needs of some facilities before and after construction of the project.

From the national monitoring programme results, the benthic habitat in the Jordanian Gulf of Aqaba can be described as follows; generally the southern sites of the Jordanian coastline has more coral cover compared with the northern sites. Also, the deeper transects in all sites have more percent cover of corals compared with the shallower transects. The deep transects contained higher percent cover of healthy corals, which might be due to the better protection from possible damaging factors, which affect the shallower reef corals. The rest of the items;for example,sponge, clams, sea anemone, ascidians, algae and others are less significant in terms of their distribution along the Jordanian coast of the Gulf of Aqaba.

The recently killed corals, as the most important indicator for reef destruction,were low in all sites with a percent cover of less than 1%. But this does not imply that there is no coral death on the other un-studied parts of the coast, where significant coral damage was seen in other areas such as those that were impacted by the floods.

Many types of man-made litter were found in areas of the coast where human activities are intensified.

Macroalgae in Jordanian Coast of Gulf of Aqaba, Red Sea

Eighteen genera of benthic macroalgae were identified in the Gulf of Aqaba coast including seven chlorophytes, eleven rhodophytes, and ten phaeophytes. Both biomass and mean absolute cover (MAC) were high for the brown algae (Phaeophyceae). The industrial complex coastal water has the highest cover and biomass and is significantly different from those observed at the Phosphate loading port. The highest cover and biomass are in spring.

No significant differences in macroalgae biomass were observed among seasons, but there are distinct seasonal shifts, in which, genera are dominant and habitat is the most important factor determining algal composition, followed by season and site. However, the yearly fluctuations of algal community pattern do not show any clear trend.

Coral-turf algae in fringing reefs of Jordan's Gulf of Aqaba

Along the coastline of the Gulf of Aqaba, turf algae exhibits higher cover in the shallower depth (8 m), and more live reef occurs at the deeper water (15 m). Sites with the most turf algae and least live reef coverage are within close proximity to heavy industrial developments, while the site with the least turf algae and most live reef cover lies within a public beach, inside the Marine Park, which prohibits fishing.

The average turf algae cover in relation to the total reef area for all the sites and both depths is 28%, while bare dead coral to total reef proportion constitutes greater percentage (40%). This may indicate that the potential phase-shift from coral reef to turf algae is not yet incurable; but with significant action, it can be slowed, halted, or even reversed specially at sites in close proximity to anthropogenic influences such as construction activities and nutrient (i.e. Phosphorus and Nitrogen) over-enrichment.

Marine Turtles at Jordan's Gulf of Aqaba, Red Sea

The foraging sea turtles at all diving spots along the coastline of the Jordanian Gulf of Aqaba revealed that all turtle captured as well as those observed in the field were Hawksbill. The majority of the turtle population was at sub-adult stage (45-60 cm CCL, curved carapace length). The highest abundance of turtles is at the Black Rock, compared with other sites such as the Moon valley, Seven Sisters, and Oliver Canyon

The gender ratio of population showed variation throughout a one year cycle with males consistently more abundant between July and December. In January-February only females were seen. An overall estimation of the total number of both genders in one year indicated that there are superiority of females over males. The majority of turtle population (85%) was observed in the coral reef habitat.

Turtle population along the coast is suggested to be present solely to forage and then migrate for nesting to Saudi Arabian or Egyptian coasts or even farther. Rapid urbanization have reduced nesting habitat at the Jordanian coast. The Jordan's National Action Plan for Conservation of Marine Turtles suggested actions for management, enforcement of legislation and securing funding for successful conservation measures.

5.2 SANDY AND MUDDY SHORES

Sandy and muddy shores and rocky shores are common intertidal habitats in most of the coastline of the Red Sea region. Sandy shores in the north -central Red Sea exist as narrow beaches behind coral reef flats, but as wider beaches behind lagoons. Vertical zonation of beach fauna is common on sandy beaches, while muddy shores are dominated by large populations of gastropods (Sheppard et al. 1992). Mud flats are usually found in sheltered bays or harbours protected from wave action. They are composed of fine sediments with the predominant particle sizes being silt (3.9 – 62 μm) and clay (less than 3.9 μm) (Jones 2004).

The sand beaches of Aqaba, especially those along the south coast, are composed of primarily of coarser particles, originating from the disintegration and decomposition of terrestrial rocks. The particles have been transported to the beach by water during flash floods in the wadis. Varying amounts of calcareous, sand sized particles of biological origin, such as fragments of shells and coral, are also usually present. The beaches along the north coast also consist of varying amounts of fine-grained, wind-blown sand, in addition to larger-sized particles (Hulings and Wahbeh 1988).

The sandy beach is porous, allowing the flow of water when covered as well as the retention of water, or at least moisture, when uncovered at low tide. The porosity varies, however, with grain or particle size and the shape of the grains as dose the amount of the interstitial space between the grains. In general, the porosity and interstitial space is greater in sand that is coarse in size and rounded in shape; at the other extreme, fine and angular-grained sand has low porosity and little interstitial space. The particles on a sand beach are easily transported from one place to another by waves and currents and may be in constant motion with water movement. There is, in fact, considerable long-shore movement of sand along the coast of Jordan. In addition, the gradient, or slope, and particle size of a particular beach change with the semi-annual changes in sea level (Hulings and Wahbeh 1988).

The casual observer is unlikely to see the marine organisms living on a sand beach, the reason being that they are beneath the surface of the sand. Yet here it is teeming with a very diverse group of marine animals, covering a wide size range and possessing a variety of structural and behavioural adaptations.

The animals living in the intertidal sand are divided into three groups based on size; the largest includes the macrofauna which displace the sand surrounding them by digging and burrowing; the meiofauna, or interstitial fauna, generally occupy the interstitial spaces between the grains; and the microfauna which are usually one-celled animals.

The largest and highest occurring marine occupant of the sand beach macrofauna is the ghost crab *Ocypode saratan* (Forskal, 1775), occupying gently sloping beaches at or above the high tide level (Fishelson 1971). It has been seen only on beaches protected from human activity such as within the Marine Nature Reserve of the Marine Science Station.

Lower on the sand beach, beneath the surface and usually in the area washed by the breaking waves, are two macrofauna, the white-shelled clam *Mesodesma glabrurn* (Gmelin, 1791) and the mole crab *Hippa* which includes two species, *H. celaeno* (De Man, 1896) and *H. picta* (Heller, 1861). These inhabitants were first described by Por and Lerner-Seggev (1966) from the Gulf of Aqaba. Additional components of the macrofauna on the sand beach include a variety of worms and other crustaceans (Wahbeh 1976; Mastaller 1979; Spaargagen 1977; Fishelson 1983; Achituv and Siskind 1985). Many of the worms, referred to as bristle worms, or polychaetes, are carnivorous. The worms, crustaceans and other macrofauna can be collected and concentrated by sieving the sand. The meiofauna includes representatives of most of the major animal groups, as well as some groups that are restricted entirely to the interstitial habitat. Hulings (1975) characterized the sand beach meiofaunal community in Jordan as dominated by harpacticoid copepods with turbellarians, nematodes, archiannelids, polychaetes and ostracods as being significant component. Other taxa reported included cnidarians, gastrotrichs, oligochaetes, mollusks, halacarids and tardigrades. The major groups of meiofauna include thread worms called nematodes and shrimp-like benthic copepods called harpacticoids.

The microfauna possess numerous hair-like cilia and, for one-celled organisms, have evolved into an extremely diverse group in terms of shape and structure. There is also a wide variety of feeding habits among the ciliates including those that are herbivorous, carnivorous, bactivorous and omnivorous.

When exposed at low tide, the marine occupants of a sand beach occur, at a minimum, in a moist habitat (Hulings and Wahbeh 1988). Little information is available information on the status of intertidal sandy and muddy shores and associated species However, the presence of tar balls has been reported on many sandy beaches of Saudi Arabia (Gladstone 2000) and Marine litter and plastic pellets has been found on many beaches and coastal waters of Aqaba-Jordan (Abu Hilal and Al Najjar 2004; Abu Hilal and Al Najjar 2009).

Standard survey methods for sandy and muddy shores and for relevant indicator species in the Red Sea were developed by Jones (2004). The number of burrows of the ghost crab *Ocypode cordimana* has been considered a useful indicator of anthropogenic disturbance to sandy beaches (Barros 2001). At present, no such burrows are found on the coasts of the Jordan Gulf of Aqaba which indicate the disturbed conditions of the coasts. Urban constructions on the beaches of Aqaba and many other cities on the Red Sea coastline, has altered the shape of shorelines.

5.3 ROCKY SHORES

Rocky shores provide an intertidal habitat that occurs in the Red Sea region on ancient coral reefs occurring now above the tidal limit (i.e. 'fossil reefs'), where coral sand has formed beach rock, and where coastal geological formations (e.g. lava flows) protrude into the sea. This habitat may be restricted to a very narrow zone on vertical raised coral reefs or cliffs or a wide and extensive zone on gently sloping volcanic formations. Fossil reefs are derived from uplifting or they were formed during the early part of the Holocene when sea levels were up to 1 m higher than present (Sheppard et al. 1992). Twenty per cent of the Egyptian Red Sea coast is rocky shore (Chiffings 1995). In Saudi Arabia, rocky shores occur on the undercut surfaces of raised coral reefs and as beach rock in the northern and central Red Sea. Areas of volcanic rock run down to the coast in the southern Red Sea producing a sloping and topographically complex rocky shore (Ormond et al. 1984). High mountains produce a shoreline largely comprised of rocky shore and cliffs plunging directly into the sea are found in the eastnorthern coast of Aqaba There may be flat terraces extending out to fringing reefs, rock platforms, cobble beaches, or 1,000 m high vertical cliffs (PERSGA/GEF 2001; Jones 2004). Major groups of invertebrates occupying this zone include gastropod molluscs, rock oysters, barnacles, and chitons. Rocky shores in the central Red Sea are dominated by barnacles during winter when sea levels are higher

5.3.1 STATUS, TRENDS, ISSUES

The rocky beach is a habitat where the substratum is solid and usually not mobile or transported as is sand. There is comparatively little information on the status or ecology of intertidal rocky shores in the RSGA (Jones 2004). The limited regional distribution of rocky shores and their unique biota emphasises the importance of conserving representative samples in MPAs (PERSGA 2006). In the case of Jordan, the intertidal rocky shores and their biota are generally better studied.

The rocky intertidal zone is a complex habitat, one in which both biological and physical factors govern the occurrence of a characteristic biotic community. Biological interactions such as predation and competition between and within species are factors. However, it is the physical factors that have largely determined the evolution of complex behavioural, structural and physiological adaptations, enabling a variety of species to successfully inhabit the most severe of the marine habitats.

Because of the daily regularity of the mixed tides in Aqaba, the rocky intertidal habitat is subjected to two alternating periods of submersion and two of emersion each day. Unlike the sand beach habitat, the organisms inhabiting the rocky intertidal cannot entirely escape the exposure to environmental stresses since refuges are limited mostly to small pits, cracks and crevices in the substrata (Hulings and Wahbeh 1988).

In the case of the intertidal zone of Aqaba, this means the organism is surrounded for a few hours by seawater ranging in temperature between 21˚C and 27˚C, depending on the time of the year, followed by exposure to an annual mean air temperature that ranges from a minimum of 11°C to a maximum of 37°C and a substrate temperature that may reach 50°C. It is obvious therefore, that temperature is one of the major environmental stresses faced by inhabitants of the rocky intertidal zone .

The other major stress is desiccation, which prevails during exposure to aerial conditions. In Aqaba, this stress is at its maximum during the warmer period of the year when the air is hot and dry.

However, in spite of the severity of the environmental parameters and stresses in the rocky intertidal zone, one finds a diverse array of animals including molluscs and crustaceans (Table 5.1) algae, microscopic one-celled types, or microalgae, and macroalgae. The substrata of the rocky intertidal beaches along the south coast of Jordan are composed of boulders, pebbles and slab. The boulders have become colonized by a characteristic suite of intertidal plants and animals. The pebbles are extremely variable in composition and colour. The slab beaches consist of near to horizontal expanses of solid substratum that varies from eroded fossil coral reefs to conglomerate, to beachrock. Tide pools occur on some slab beaches, especially those that are nearly horizontal and composed of beach rock.

The rocky intertidal or littoral zone is subdivided into zones that are recognized throughout the world. The zones are, from the highest to the lowest, the supralittoral fringe, the midlittoral and the sublittoral fringe. Vertical zonation of beach fauna is common on rocky beaches of the Jordan Gulf of Aqaba (Table 5.1).

Another indicator of the various zones is the organisms. The pattern of vertical zonation of various species which occupy vertical levels within the intertidal zone is universally recognized. Thus, the upper limit of the littorinid snails and the isopod indicate the supralittoral fringe, the upper limit of the barnacles that of the midlittoral zone and the upper limit of the red algae that of the sublitoral fringe. There are, of course, other organisms in the various zones as seen below. Above the supralittoral fringe is the supralittoral or terrestrial zone which is dry and, in the immediate vicinity of the intertidal zone, devoid of vegetation. Below the sublittoral fringe is the sublittoral or subtidal zone, in which marine environmental conditions prevail, with the inhabitants always covered with seawater.

Table (5.1) shows the occurrence of the major species of molluscs and crustaceans in the supralittoral fringe and midlittoral zones of the rocky intertidal along the coast of Jordan. The table shows the type of substratum on which the species occur in greatest abundance. To be noted (in the table) is the range of three species, *Acanthopleura gemmata*, *Cellana radiata* and *Nerita sanguinolenta*, in middle and lower midlittoral. Among the fauna of the rocky intertidal zone are those that are sedentary or permanently attached to the substratum, and those that are free and mobile. In the former group are those that cement themselves substratum and include the giant barnacle *Tetraclita squamosa rufotincta*, the smaller barnacle *Tetrachthamalus oblitteratus* and the oyster *Ostrea forskali*. The mussel *Brachidontes variabilis* and the clam *Isognomon* cf. *recognittis* attach themselves to the substratum by byssus threads. The mussel occurs in cracks and depressions on slab, while the clam can be found in crevices and on the underside of pebbles.

Table 5.1: Vertical zonation and the most abundant substrate occurrence of the dominant rocky intertidal molluscs and crustaceans in the Jordan Gulf of Aqaba. Abbreviations in parentheses refer to substrate: S = slab; B = boulders; P = pebbles (After Hulings and Wahbeh 1988).

Supralittoral Fringe:		
		Nodilittorina subnodosa (Philippi, 1847) (S)
		Nodilittorina millegrana (Philippi, 1848) (B)
		Ligia exotica Roux, 1828 (P)
Supralittoral Fringe-Midlittoral (Upper):		
		Littorina scabra scabra (Linnaeus, 1758) (B)
Midlittoral:		
	Upper:	
		Celiana radiata (Born, 1778) (B, S)
		Clypeomorus moniliferum (Kiener, 1841) (P)
		Monodonta dama (Philippi, 1848) (P, B, S)
		Nerita polka orbignyana (Recluz, 1842) (P)
		Nerita quadricolor (Gmelin, 1791) (B)
		Planaxis sulcatus (Bom, 1780) (P, S)
	Middle	
		Acanthopleura gemmata (Blainville, 1825) (S)
		Brachidontes variabilis (Krauss, 1848) (S)
		Cerithium caeruleum (Sowerby, 1855) (S)
		Clibanarius signatus (Heller, 1861) (S)
		Clypeomorus tuberculatum (Linnaeus, 1758) (S)
		Grapsus albolineatus (Lamarck, 1818) (B)
		Grapsus granulosus (H. Milne Edwards, 1853) (S)
		Grapsus tenuicrustatus (Herbst, 1783) (B)
		Isognomon cf. recognitus (Mabille, 1895) (S, P)
		Nerita sanguinolenta (Menke, 1829) (P, S)
		Ostrea forskali (Chemnitz, 1795) (S, B)
		Peasiella cf. isseli (Semper, 1867) (S)
		Plagusia tuberculata (Lamarck, 1818) (B)
		Siphonaria laciniosa (Linnaeus, 1758) (S)
		Tetrachthamalus oblitteratus (Newman, 1967) (S, P)
		Tetraclita squamosa rufotincta (Pilsbry, 1916) (S, B)
		Thais hippocastanum (Linnaeus, 1758) (S)
	Lower	
		Acanthopleura gemmata (S)
		Cellana radiata (S)
		Nerita sanguinolenta (S)

The mobile forms are represented by the chiton *Acanthopleura gemmata*, the patellid limpet *Cellana radiata* and the pulmonate limpet *Siphonaria laciniosa*. Other mobile gastropods include the nerites, *Nerita sanguinolenta*, *and N. polita orbignyana*; the littorinids *Nodilittorina sub-nodosa*; *and N. millegrana*; the ceriths *Cerithium caeruleum*, *Clypeornorus moniliferum* and *C. tuberculatum*; the trochid *Monodonta dama*; the smallest gastropod *Peasiella* cf. *isseli*; the black *Planaxis sulcatus*; and the rock shell *Thais hippocastanum* gastropods, *Nerita quadricolor* and *Littorina scabra scabra*, are very rare along the coast of Jordan and are, and unlikely to be observed. The mobile crustaceans occurring in the rocky intertidal include the isopode *Ligia exotica* and the amphibious grapsoid crabs *Grapsus granulosus*, *G. albolineatus*, *G. tenuicrustatus* and *Plagusia tuberculata*. *G. granulosus* is the most abundant, inhabiting in the upper and mid midlittoral on slab where refuges are available. The other grapsoids are characteristic of the mid midlittoral boulder habitats, with *G. albolineatus* being the most common.

The sympatric species of gastropods living in the rocky intertidal zone include the supralittoral fringe *Nodilittorina subnodosa* and *N. millegrana*, the midlittoral *Nerita sanguinolenta*, *N. polita orbignyana* and *N. quadricolor*; and *Clypeamoms moniliferum* and *C. tuberculatum*. Among the rocky intertidal crustaceans, sympatric species include those of the crab *Grapsus, G. albolineatus, G. granulosus and G. tenuicrustatus.* There are varying degrees of spatial and reproductive isolation within the sympatric species that prevent interbreeding. The occurrence of so many sympatric species in the rocky and sand beach (*Hippa celaeno and H. picta*) intertidal zone of Jordan is unusual when compared with other geographic areas.

In terms of geographic distribution, usually one of the sympatric species is restricted to the Red Sea while the other is more widely distributed. For example, *Hippa picta* is restricted to the Red Sea whereas *H. Celaeno* ranges into the Indo-Pacific; *Grapsus granulosus* occurs only in the Red Sea while *G. albolineatus* and *G. tenuicrustatus* are widely distributed in the Indo-Pacific; *Nerita polita orbignyana* and *N. sanguinolenta*are restricted to the Red Sea and the Gulf of Aden while *N. quadricolor* occurs in the Red Sea, the western Indo-Pacific and the Persian Gulf; its occurrence in the Gulf of Aqaba is restricted to southern Sinai. Among the littorinids, the distribution of *Nodilittorina subnodosa* is limited to the Red Sea and the Arabian Gulf while *N. millegrana* has a wider distribution throughout the Indo-West Pacific. Both species of *Clipeomorus, C. moniliferuni* and *C. tuberculatum,* range into the Indo-Pacific. Such patterns of distribution are indicative of the Red Sea being an area of species evolution. In addition, the nerite *N. san-guinolenta* has been reported in the eastern Mediterranean Sea. This represents an example of one of numerous marine organisms that have migrated from the Red to the Mediterranean Sea via the Suez Canal since its opening in 1869.

Other components of the rocky intertidal fauna that can be seen at low tide are groups of shells in various positions. Throughout the cooler part of the year, these are commonly seen on top of slab whereas, during the warmer period, they are under stones. Fishes are represented in the rocky intertidal zone by ten or so species along the coast of Jordan, some of which are amphibious. An example of the latter is the comical, leaping blenny *Alticus kirkii magnusi* (Klausewitz, 1964) which can be seen on boulders. Though it is well adapted for life out of water, it remains close proximity to the water level or sprays from breaking waves and follows the flooding and ebbing tide levels. Another common intertidal species is *Antennablennius hypenetes* (Klunzinger, 1871) which can be seen on submerged slab. Unlike the previous species, it does' not leave the aqueous medium. Both species feed on algae.

Components of the flora that can be seen in the rocky intertidal zone include large or macroalgae. Particularly notable are the green algae, including the leafy *Ulva lactuca* (Linnaeus) Le Jolis and the thread-like or filamentous *Enteroinorpha cornpressa* (Linnaeus) Grev. Brown algae, such the sac-like *Colpornenia sinuosa* (Mert.) Derbes et Solier, and the fan-shaped *Padina pavonia* (Linnaeus) Gaillon, can also be seen. Common red algae include *Galaxura Iapidescens* (Sol.) Lamour, and the filamentous *Erythrotrichia* sp. These algae are most obvious during the cooler part of the year, the major period of macroalgal growth and abundance, in the vicinity of the large barnacle *Tetraclita*, which is indicative of the middle part of the midlittoral zone (Table 1). The algae is common on horizontal slab and pebble beaches, except for the red algae *Erythrotrichia* sp., which is more common on wave-exposed boulders.

5.4 CORAL REEFS AND CORAL COMMUNITIES

Extremely high complex ecosystems, the coral reefs are considered one of the most biologically diverse regions on Earth. They are tropical ecosystems found in waters that are warm, clear with low nutrients and temperatures that range between 18 and 30^{o}C, which usually occurs within 30 degrees latitude of the equator. The coral reefs are classified into three main types: barrier reefs, which occur offshore, separated by water from the mainland, fringing reefs that are continuous with the land mass, and atolls that are islands made of corals surrounding a central lagoon.

The main constituents of coral reefs are corals. There are two main types of corals: hard corals, the major reef-building species (i.e. hermatypic) and soft corals. In addition to corals, many marine vertebrates and invertebrates co-exist with the corals. The corals are complex mix of animal and plant life with microscopic forms of algae (called zooxanthellae) living within the coral. The small units that make up the corals are called polyps. Most corals are colonial and consist of polyps that secrete calcium carbonate skeletons. The outermost layer of the coral colony contains the living tissues. The zooxanthellae perform photosynthesis, using light energy to convert water and carbon dioxide into food. Although coral polyps are carnivorous, they receive much of their energy from this photosynthesis. This type of relationship (called mutualistic symbiosis) is crucial for the coral life and is reason why corals live in shallow waters where sunlight can penetrate.

Coral reefs have many benefits. The coral reefs provide food source and living resources for many people, especially in developing countries. For example, the annual income from recreational diving and other reef associated activities in Hawaii is estimated to be more than US$3.5 billion. Anti-cancer drugs and painkillers have been developed from coral reef products. Additionally, coral reefs play an important role in biogeochemical cycles, especially the carbon cycle. Because of this, many countries began to better manage their coastal areas in order to protect and restore reefs.

5.4.1 STATUS OF CORAL REEFS IN THE JORDAN GULF OF AQABA

The Jordanian coast of the Gulf of Aqaba is relatively small with much of the sea-related activities are focused. About 30% of the coastline is used for port activities, while 7 Km of the coast has been declared as marine protected area (About 25% of the total coast area). The Jordanian Gulf of Aqaba coast supports relatively small total coral reef area, composed entirely of narrow and steep fringing reefs. Though, the Gulf of Aqaba is among the most diverse high latitude reefs in the world, with about 200 species of hard corals and more than 500 fish species (Al-Horani and Khalaf, personal communication, personal observations). Jordan's coral reefs were maintained in good condition during the past period, before the most recent developments of sea ports (Al-Horani et al., 2006). No bleaching events were recorded in the aftermaths of the global warming events, possibly as a result of the extreme northern latitudes compared with the warmer seas. At present, pollution is limited and localized. The main threats are oil spills and discharges, industrial discharges, ship-based sewage and solid waste. The development of the tourism sector might also further threaten the coral reefs (Pilcher and Al-Moghrabi, 2000; Wilkinson, 2000). Additional threats include coral predation, and various forms of pollution and littering. For example, high number of gastropods feeding on corals was recorded in 1994 ($212/m^2$) (Al-Moghrabi, 1996). Also, black band disease was found to infect 61 colonies in a survey area of 10 m diameter at reefs near the Industrial Area, and only 6 colonies in the MSS in 1997 (Al-Moghrabi, 2001). The development of marine tourism may pose a future threat if not well managed. Some localized damage to Jordan's reefs has also resulted from expanding tourism, through walking on exposed reefs, souvenir collection, aquarium fish collection, diver damage and anchor damage (Al-Moghrabi, 2000). In addition to this, the constructions along the Jordanian coast result in increased rates of sedimentation that may lead to coral death. The major threats to coral reefs are now coming from the ports constructions and operations, where many thousands of square meters of corals were destroyed.

At present, the Jordanian coastline is under continuous monitoring of the major benthic organisms and other chemical and physical parameters. The study of benthos is useful in aquatic ecological research to evaluate the short term and long term effects of any marine pollution or damaging process. This is because benthic assemblages consist of largely sessile organisms that must tolerate any anthropogenic changes within a specific marine ecosystem. The continuous survey is important because it can detect subtle changes in the environment before more drastic changes can happen. Thus, a long-term monitoring for basic coral reef ecosystem parameters such as percent cover and diversity of corals, as well as assessment of the associated fauna like sponges, algae and macro-invertebrates has been implemented as part of an overall monitoring program during the past years. Followings are summarized data for the benthic habitat structure in selected sites along the Jordanian coastline, which shows the nature and health status of the bottom habitat in each site studied.

The average percent cover of the various macrobenthos were studied at three depths; the reef flat (RF), the 8m depth and the 15 m depth, in 7 sites along the Jordanian Gulf of Aqaba. These are sites that are studied in the national monitoring program and are distributed along the Jordanian coastline from the north to the south, close to the Saudi Arabia boarder (Fig. 5.1). They also cover various coastal activities on the coast, such as the touristic areas, the ports, the public beaches, the marine reserves and the industrial areas. The benthic habitat components presented include the hard corals, the soft corals, sea anemones, sponges, clams, algae, and seagrasses (Fig. 5.2-8). The figures show the average percent cover of each macrobenthic habitat in each studied site; the reef flat (RF), the 8m depth and the 15 m depth.

The distribution of hard corals is different in all sites, where MSS, PB, ASD, IC and the CP sites have the highest percent cover of hard corals in all depths studied (Fig. 5.2). Generally the 15m deep transects have higher percent cover of hard corals than the shallower depths. In all sites, hard corals comprise less than 50% cover percentage, although higher percent cover can be found in other sites or depths that are not part of the national monitoring program.

Unlike the hard corals, the soft corals distribution are highest in areas that are subject to more intensive human activities such as the PB, ASD and CP and to a lesser extent in the other sites (Fig. 5.3).The sea anemone in most cases has less than 3% coverage in all sites (Fig. 5.4). The situation is similar for the sponges and clams distributions and cover percentages (Fig. 5.5 and 5.6). The algae on the other hand follows a seasonality mode, where it appears during spring time, and disappears during the other seasons, except for the species that do not show seasonality. Figure 5.7 shows the cover percentages of algae in the sites studied. The seagrasses in the Jordanian coast is found in certain areas such as the HA, PP and TB sites and constitutes the major benthic habitat in such areas (Fig. 5.8).

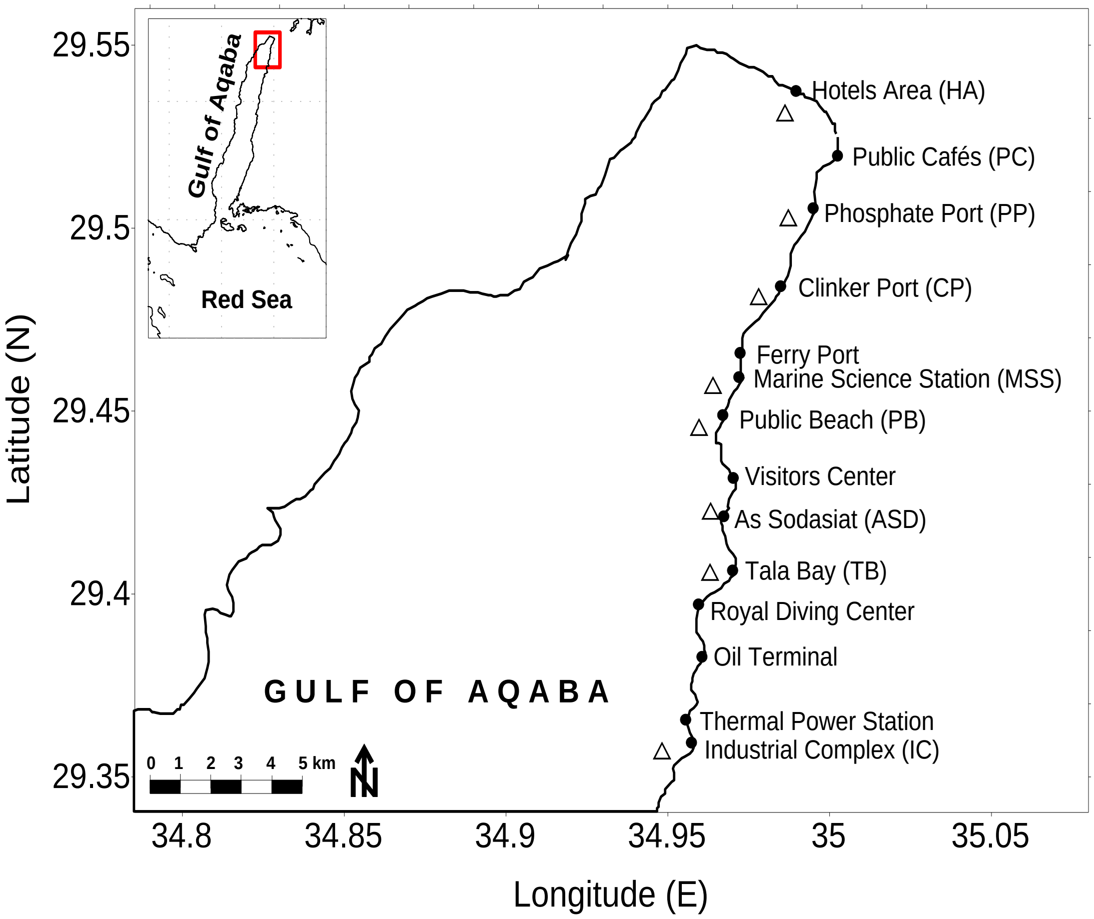
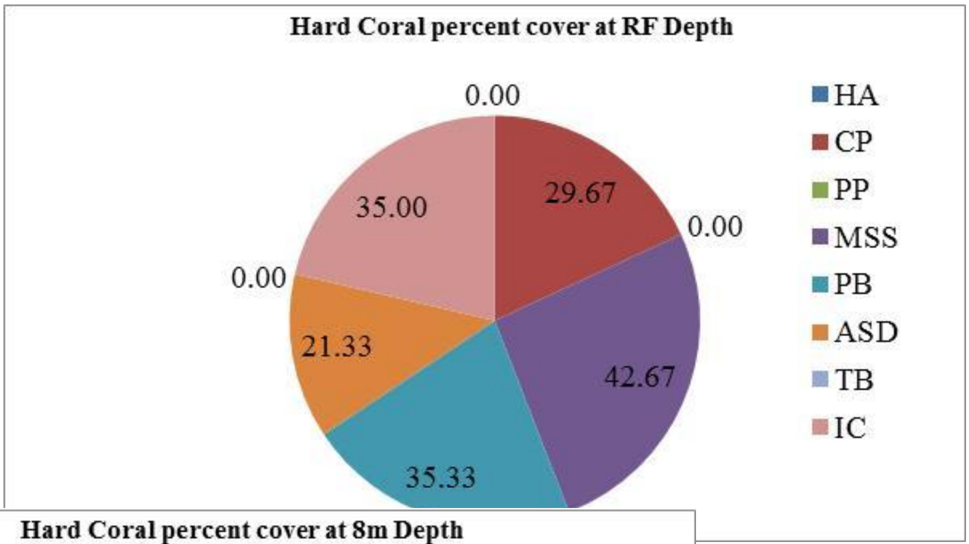
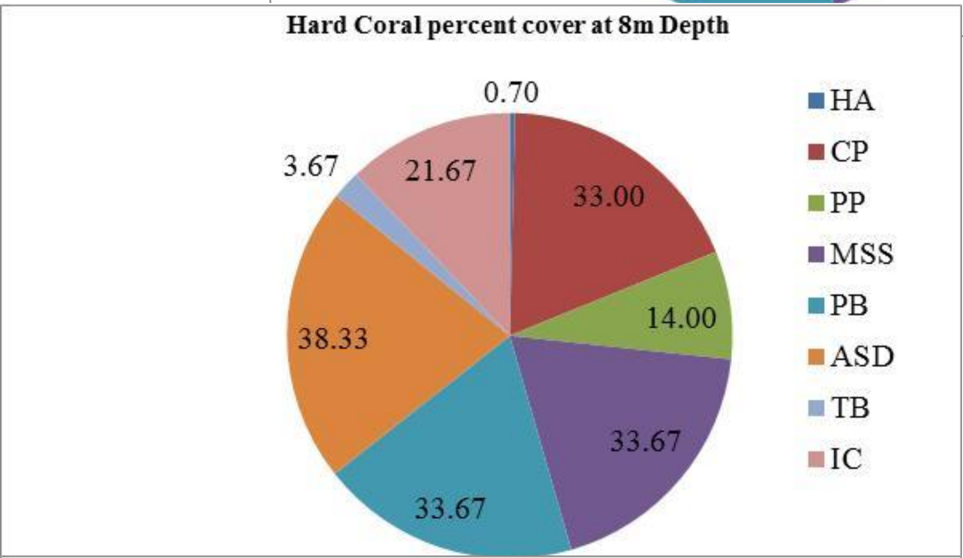


Figure 5.1: Gulf of Aqaba map showing the sites used in the benthos monitoring. Triangles are the sites surveyed.


Hard Coral percent cover at RF Depth
0.00
29.67
0.00
42.67
35.33
21.33
0.00
35.00
HA
CP
PP
MSS
PB
ASD
TB
IC


Hard Coral percent cover at 8m Depth
0.70
33.00
14.00
33.67
33.67
38.33
3.67
21.67
HA
CP
PP
MSS
PB
ASD
TB
IC

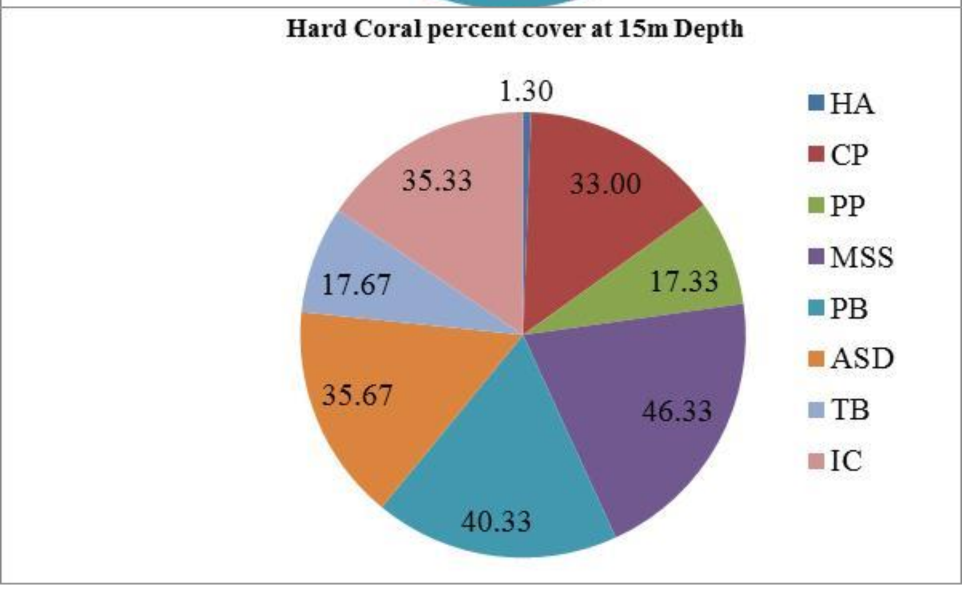

Hard Coral percent cover at 15m Depth
1.30
33.00
17.33
46.33
40.33
35.67
17.67
35.33
HA
CP
PP
MSS
PB
ASD
TB
IC

Figure 5.2: cover percentage of hard corals in seven sites along the Jordanian coast of the Gulf of Aqaba at three depths; the reef flat (RF), the 8m depth and the 15m depth.

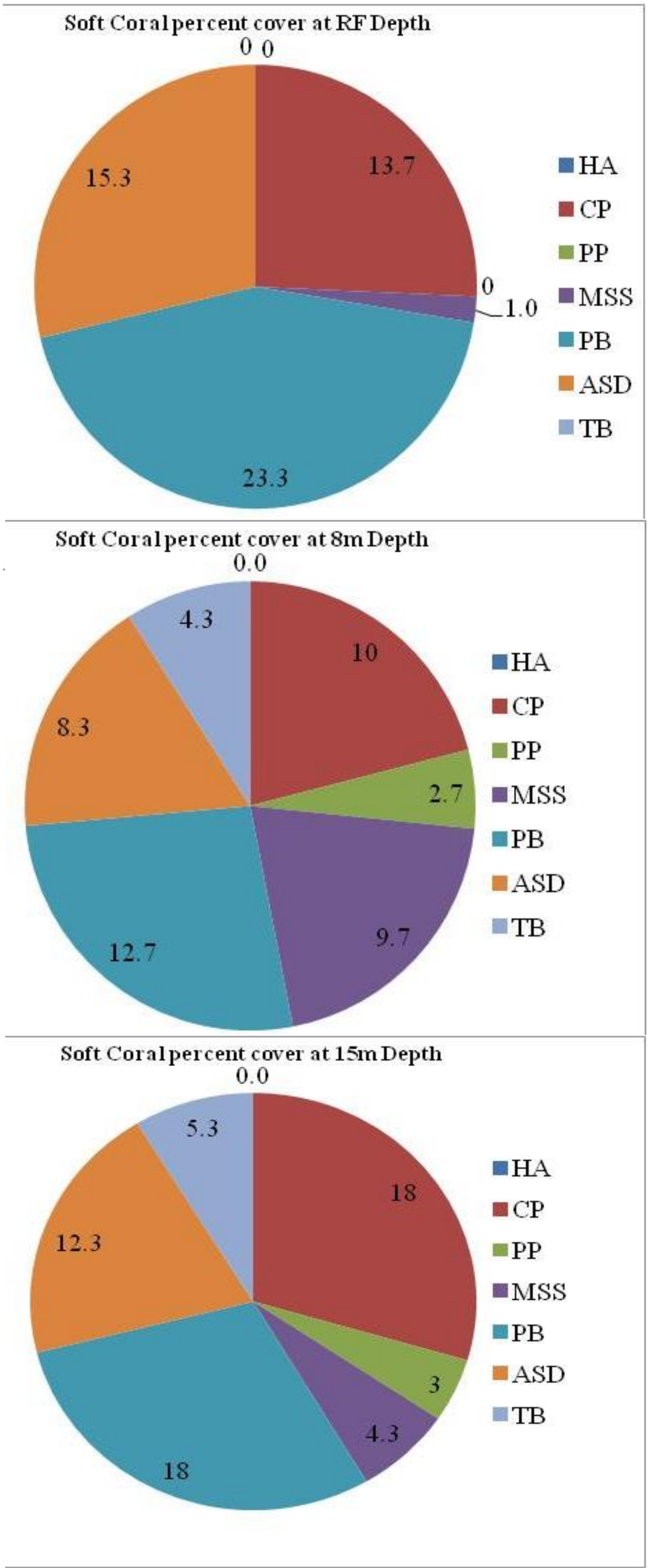


Figure 5.3: cover percentage of soft corals in seven sites along the Jordanian coast of the Gulf of Aqaba at three depths; the reef flat (RF), the 8m depth and the 15m depth.

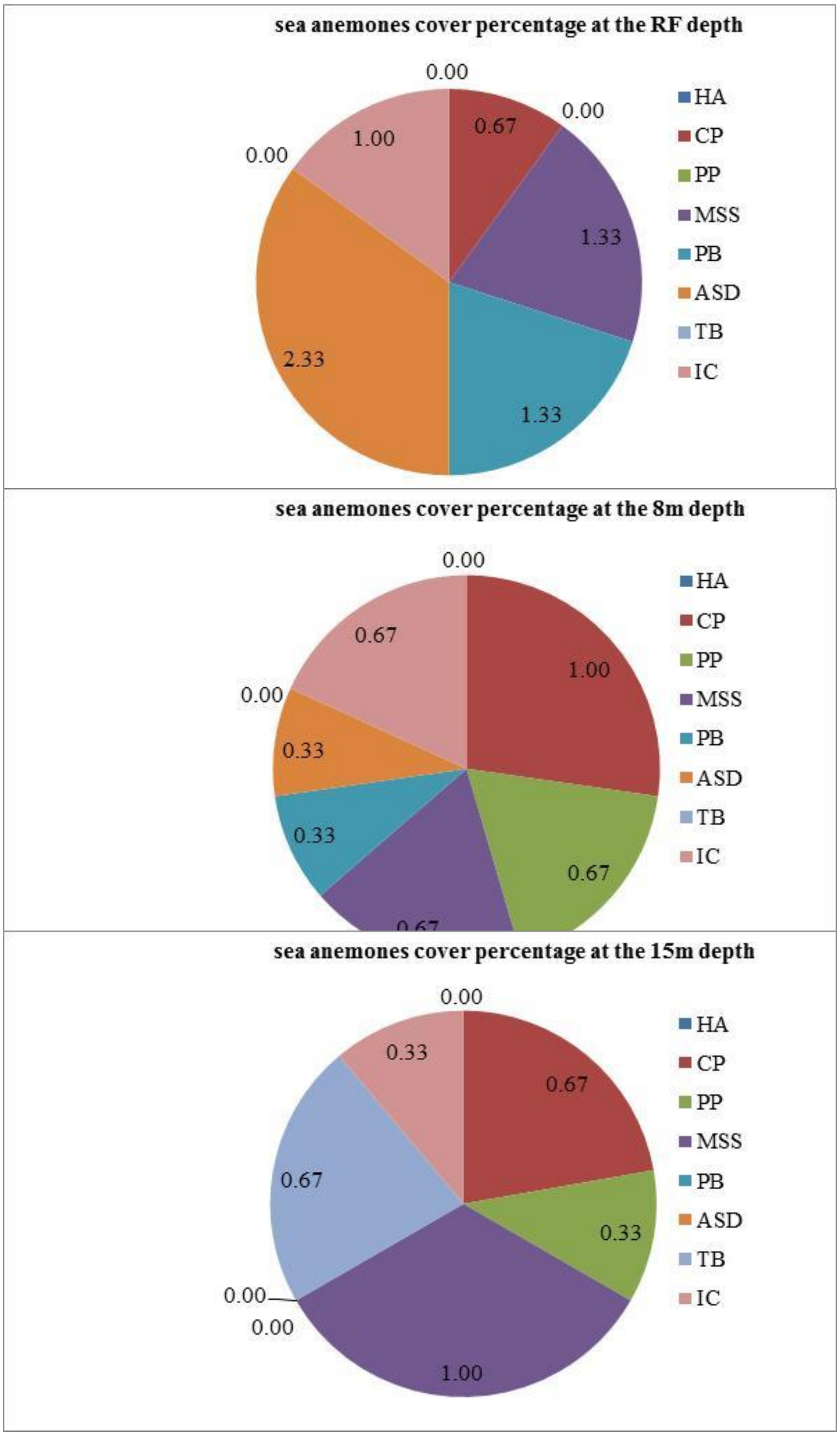


Figure 5.4: cover percentage of sea anemones in seven sites along the Jordanian coast of the Gulf of Aqaba at three depths; the reef flat (RF), the 8m depth and the 15m depth.

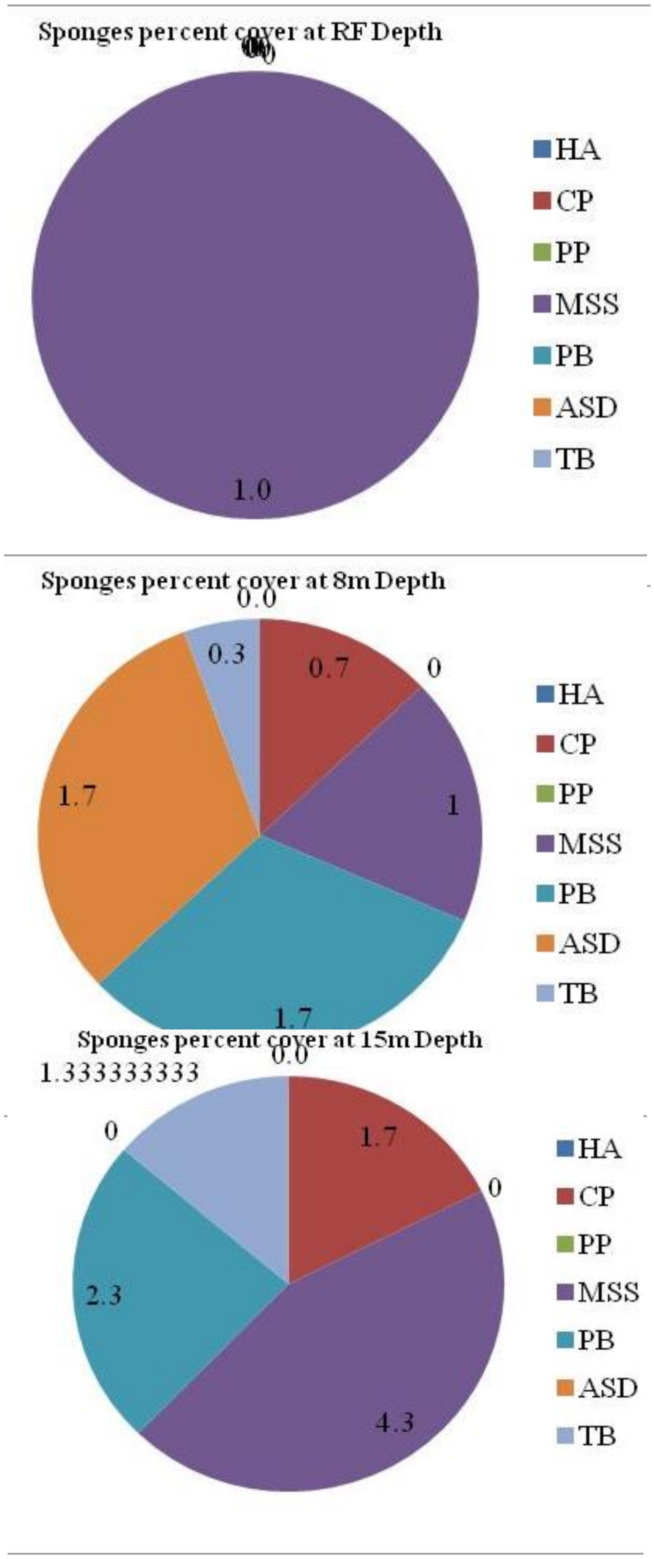


Figure 5.5: cover percentage of sponges in seven sites along the Jordanian coast of the Gulf of Aqaba at three depths; the reef flat (RF), the 8m depth and the 15m depth.

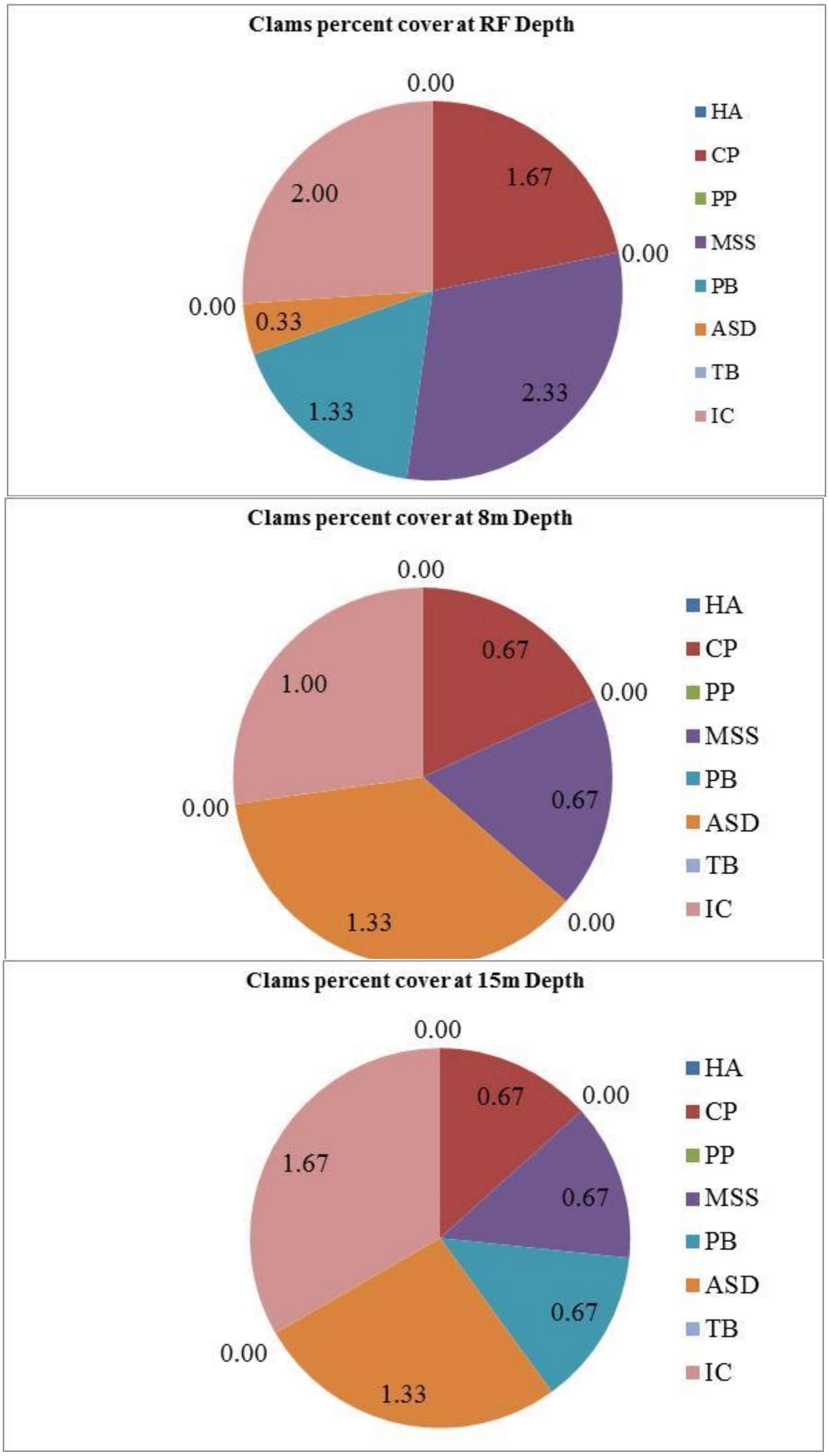


Figure 5.6: cover percentage of clams in seven sites along the Jordanian coast of the Gulf of Aqaba at three depths; the reef flat (RF), the 8m depth and the 15m depth.

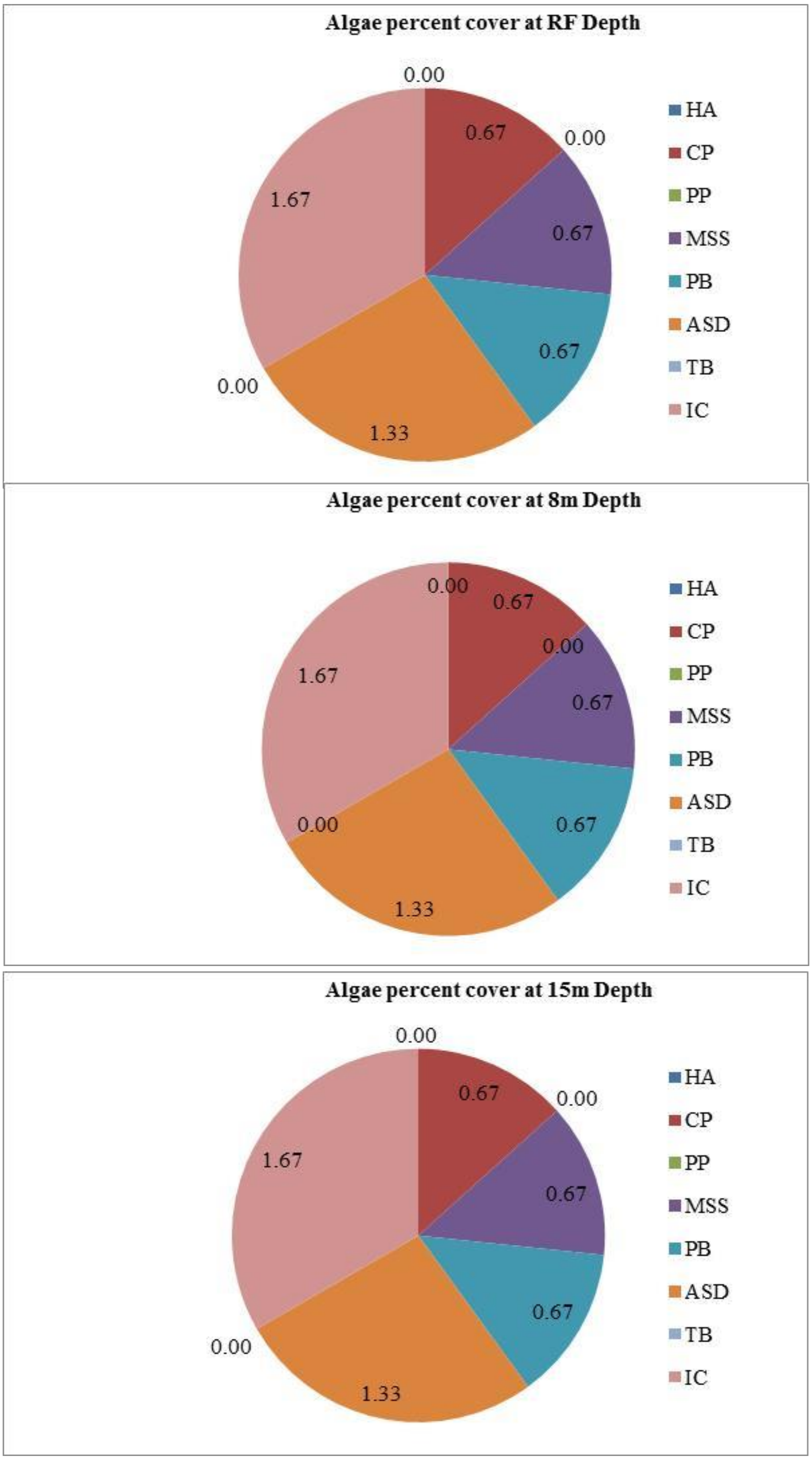


Figure 5.7: cover percentage of algae in seven sites along the Jordanian coast of the Gulf of Aqaba at three depths; the reef flat (RF), the 8m depth and the 15m depth.

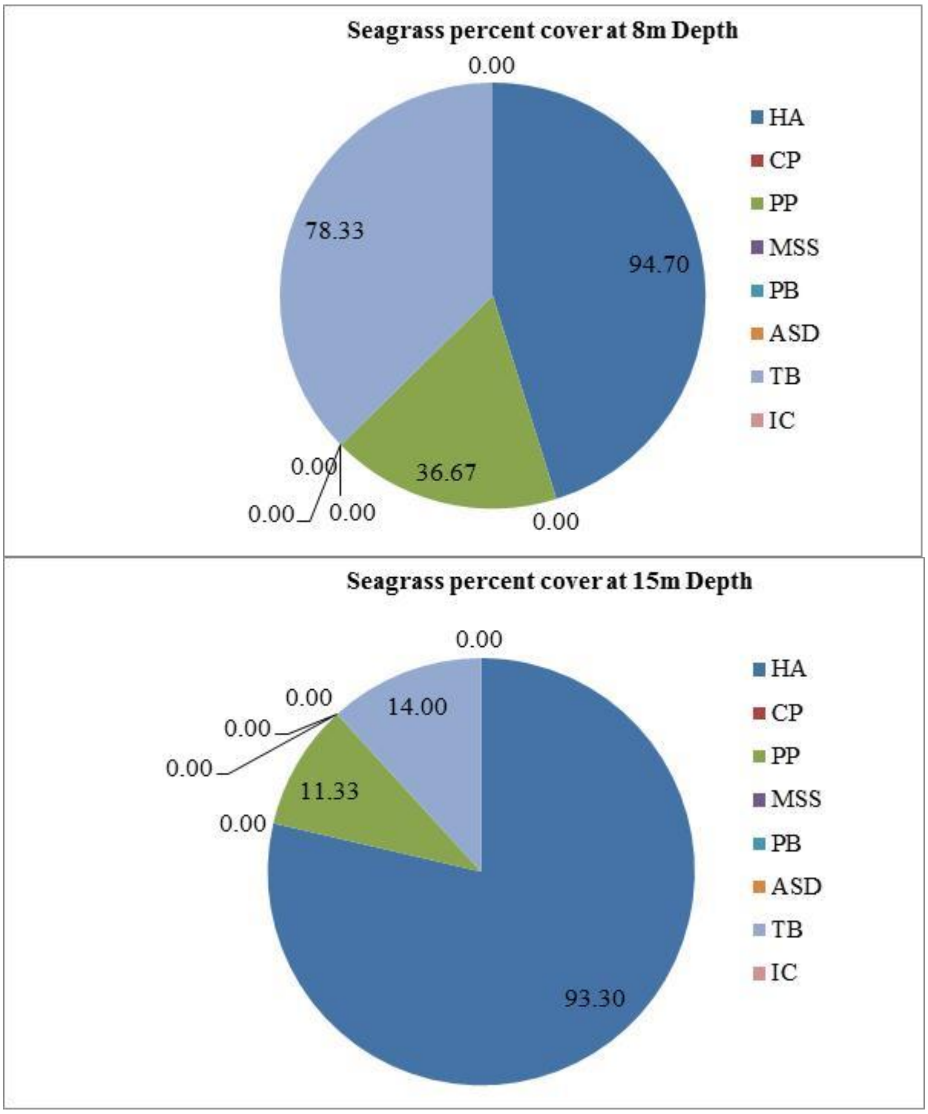


Figure 5.8: cover percentage of seagrasses in seven sites along the Jordanian coast of the Gulf of Aqaba at two depths; the 8m depth and the 15m depth.

5.4.2 THREATS TO CORAL REEFS

Coral reefs are much endangered and are deteriorating in many regions around the world. Some experts suggest that 10 percent of the Earth's coral reefs have already been destroyed and that another 60 percent are seriously endangered. Causes of destruction are anthropogenic (i.e. man-made) and/or natural. Among the natural cause of destructions is the phenomenon of low tide, which happens sometimes in the Gulf of Aqaba, and it is most destructive when it happened during long hot summer days. Plates 5.1A and 5.1B show an example of the low tide, which occurred at the Marine Science Station (MSS) coral reef in 2009.

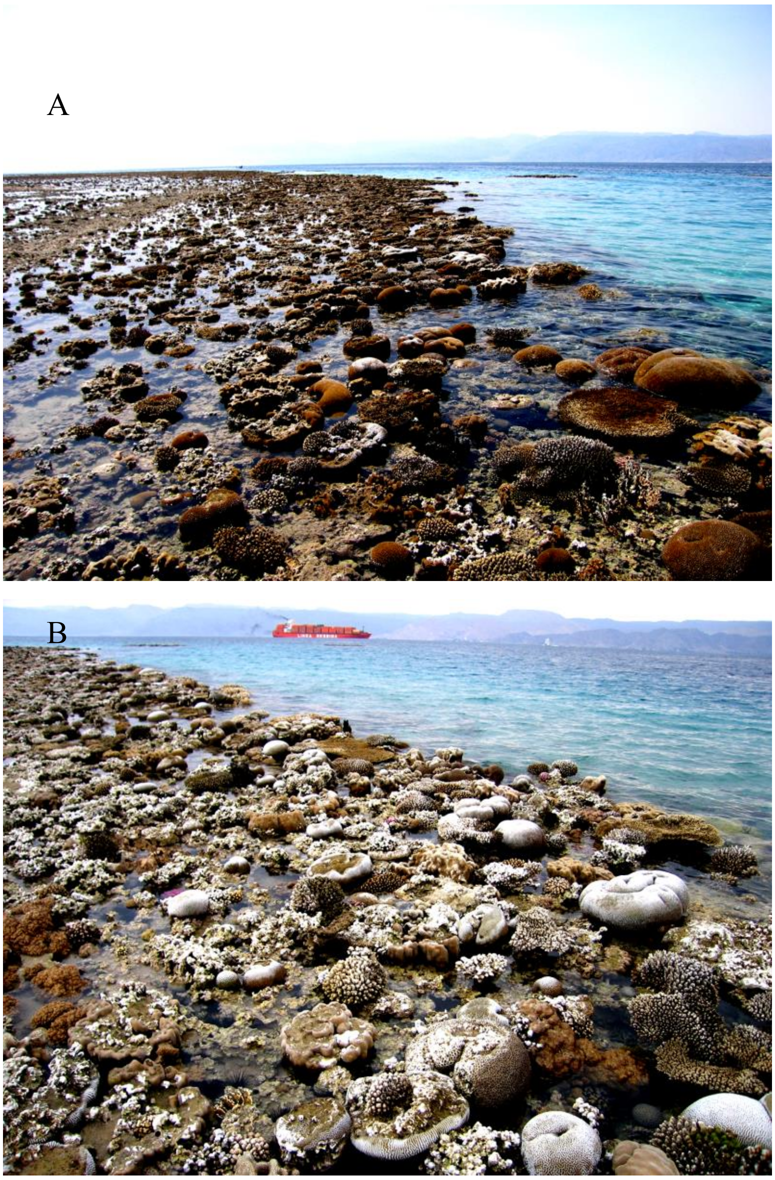


Plate 5.1: Low tide at the Marine Science Station (MSS) coral reef.

The Man-made factors include among others, the use of destructive fishing methods, which catch the small juvenile fish and severely damage the corals in the fishing sites, and souvenir collectors who usually select the healthiest corals from the natural reefs are important damaging factors. Coral reefs also receive much damage from commercial and private vessels through leakage of fuels, boat anchors, and grounding of large and small ships. Antifouling usually found in the boats paintings, contain toxic substances and cause major mortality of coral communities, significantly reduce coral recruitment and is an inhibitor of coral photosynthesis (Nagri et al., 2002; Owen et al., 2002; Smith, 2003). The increased sedimentation rate may affect the reefs by; 1) causing a slow but steady reduction in live coral cover and other benthic habitat or 2) by reduction in sunlight penetration, which reduce the lower depth limit of coral and other benthic organisms. The presence of suspended sediments reduces recruitment to a population because of its effects on larval survival and settlement (Gilmour, 1999). Hypoxic and anoxic water conditions, which usually develop in confined areas such as lagoons and marinas, may kill bottom-dwelling organisms and lead to loss of valued biological resources from the affected area. The anoxic water environment kills coral polyps since they are obligate aerobes. Nutrient enrichment, or eutrophication, which may result from sewage disposal, fertilizer runoff and irrigation, illegal sewage disposal coming from motor boating and yachting can lead to drastic changes in ecosystem structure and function. The increased nutrient loading causes increased macroalgal biomass, decreased seagrass biomass, decreased fish diversity and disrupt reproduction in corals (Smith et al. 1999; Deegan et al. 2002; Cox and Ward 2002). Solid wastes disposal like plastic bags, packets, metal cans, glass bottles and various left over materials, lead to suffocation and eventual death of corals and seagrass when they settle on them. Other common threats to coral populations include predators like the crown-of-thorns, *Acanthaster planci*, coralivorous fishes and gastropods. Breakouts of these predators have been linked to regions of increased development and eutrophication (Birkeland 1989). In the global warming phenomenon, when ocean temperatures increase the coral polyps lose the symbiotic algae inside them, causing them to turn white and die. This is referred to as "bleaching". This phenomenon has been responsible for massive death of coral reefs around the world in the last century (Lesser et. al. 1995).

In Jordan, the rapid development in the various economical fields have increased pressure on the marine life in the Gulf of Aqaba due to the increased land based and sea based activities. The city of Aqaba, have shown phenomenal growth rate during the last twenty years with many coastal utilization including industrial and commercial activities. Growth in this area is expected to continue during the coming few years, due in part to governmental policies encouraging growth and facilitating increased tourism infrastructure. These human activities are of particular environmental concern with regard to maintaining healthy coral reefs in this area**.** Nonetheless, a number of positive steps have been taken by the Governmental institutions to address some of these concerns. However, still many problems remain and will continue to increase as both tourist and human population grow.

At present, the most important threats to coral reefs in Jordan are the constructions of new ports and the expansions of existing ports that took place in the past few years. This sector is still fast growing, as many new ports are being planned to be constructed, especially in the southern part of the coast. For example, the recent ports expansion has resulted in massive death of corals (personal observations); the surface area of coral reefs that were damaged by the construction works in the ports site so far is more than 60,000 m^2 of hard corals and the associated fauna and flora. It is expected that similar number will be damaged in the planned projects as well. This has happened despite the local authority in Aqaba The ASEZA has issued and enforced several laws and by-laws that require for each new investment or development project to carry an Environmental Impact Assessment (EIA), which identifies the expected negative impacts and suggest mitigation measures that overcome or reduce the effect of the project on the environment, before the official permission is given. Though, the ports expansion resulted in massive death of corals (References Please). Based on the recommendation of the EIA of the project some attempts for transplantation of corals taken from the site of construction into other sites were done (Abu Awali, personal communications), but those were limited in size due to the lack of funding, the time given to accomplish the work, and the few number of people involved.

Additional and significant threat results from flooding, which happens every few years (Plate 5.2). The amount of coral death occurring upon such event is so detrimental to the coral reefs, where a whole reef flat can be killed as a result of the heavy load of sediments, which remain suspended in the water for about two weeks after the flood (personal observations). A main reason for such massive killing of corals ~~is~~ is the lack of proper drains for the water coming from the wadis. In the past, the inputs of the floods were used to drain into areas that have no corals, but the constructions of ports and other residential and industrial facilities have closed these drains.

Plate 5.2: Photos from the flood, which took place in Aqaba during May, 2014

5.4.3 5.3.4. CORALIVOROUS ORGANISMS (DRUPELLA SNAILS AND CRWON OF THORN) AND CORAL DISEASES

There is a general agreement among scientists and researchers that predators like the corallivorous gastropods, such as *Drupella cornus* (Plate 5.3) and the crown-of-thorns (*Acanthaster planci*) (Plate5.4) as well as coral diseases (Plate 5.5) represent common threats to coral populations in many countries around the world (Birkeland 1989; Schumacher 1992). Coral predation and diseases are threatening the coral reefs in Jordan (Al-Moghrabi 1996 and 2001; Al-Horani et al. 2006; personal observation).

Theoutbreaks of gastropod *Drupella cornus* and the crown-of-thorns can lead to the loss of certain coral species reduce biodiversity and coverage of the impacted coral reef areas (Al-Horani et al., 2011). During the last two decades, gastropod predation of *Drupella sp*. on corals has caused significant destruction to many reefs across the Indo-Pacific region (Turner 1994a; Johnson and Cumming 1995; Cumming et al. 1999). Furthermore, the gastropod predation (including *Drupella sp.*) is largely blamed for the decline of the threatened coral species, *Acropora palmata* and *Acropora cervicornis*, in addition to its interference with coral recruitment and prevention of juvenile coral growth (Miller 2001; Schuhmacher et al. 2002; Baums et al. 2003).

There are three distinguished species belonging to the genus *Drupella; D. cornus, D. rugosa* and *D. fragum*. Of these genera, only *D. cornus* is found in the Red Sea (Johnson and Cumming 1995). *D. cornus* prey almost exclusively on living coral tissues (Turner 1994b) and display outbreaks similar to the outbreaks of *Acanthaster planci* (Turner 1994a; Black and Johnson 1994; McClanahan 1997). The field observations along the Jordan Gulf of Aqaba revealed that this snail is mostly infects branching corals such as *Acroporaspp*. and *Stylophora spp.*, with an average of about 14 and 10 snails per colony for the *Acropora* and *Stylophora*, respectively, while only 4 snails per colony on the massive coral *Porites* (Al-Horani et al., 2011).

Plate 5.3: *Drupella cornus* is a common corallivorous snail that feeds on corals in the Gulf of Aqaba.

The grazing rates of the *Drupella* snail are unexpectedly high and therefore it has been recommended that mitigation measures should be taken when outbreaks happen as this snail can lead to significant coral community changes by lowering biodiversity of the reefs and might lead to disappearance of the preferred coral prey from the impacted reefs, especially the genus *Acropora* (Al-Horani et al., 2011). Crown of Thorn (COT) outbreaks are able to destroy whole reef areas within few days. The first report of COT outbreaks in the Red Sea appeared in 1994 in Ras Mohammed National Park. The second outbreak occurred in 1998 and infested numerous reefs along the Egyptian coasts of the Red Sea starting from Dahab on the Gulf of Aqaba to the Sudanese border on the Red Sea. More than 100,000 COTs were removed from the infested sites, thus saving hundreds of hectares of living corals. In the Jordanian coast of the Gulf of Aqaba, the Crown of Thorn did not form serious problems in the past, although sometimes individuals of COT are encountered in some places, but no actual outbreaks were recorded.

Plate 5.4: Crown of Thorn (COT) feeds strictly on corals and can lead to total damage of coral reefs upon outbreaks.

Plate 5.5: Coral diseases are now commonly seen everywhere in the Gulf of Aqaba during the past few years.

5.4.4 ECONOMIC IMPORTANCE Of CORAL REEF COMMUNITIES

Coral reefs make significant contribution to the economy of many tropical countries. The Gulf of Aqaba and its coral reef could play a major role as a revenue earner for Jordan. The Gulf of Aqaba holds valuable economic resources for pharmaceutical, recreational and tourist use, and for fisheries. However, the data available does not give a true picture of the worth of the goods and services provided by a reef.

5.4.4.1 Tourism

Tourism is now the leading revenue earner in many countries. The Florida reef tourism is considered to be worth US$1.6 billion in recreational earnings. Recreational divers from the US alone spend US$286 million each year in the Caribbean and Hawaii (Tabata, 1989). The economic value of reef tourism has only been partially determined in the developed countries. The Gulf of Aqaba, if managed properly, has several key elements, which can make it one of the most important contributors to Jordan's economy. These points can be summarized as follows: The Gulf of Aqaba is the nearest tropical sea to Europe, which can attract many tourists due to the low travelling and accommodation costs. The Gulf embraces one of the most unique, fascinating and highly diverse coral reef communities. About 1000 species of fish, 150 species of reef building corals, 120 species of soft corals and 1000 species of molluscs, flourish in the Gulf of Aqaba. Coral species in the Gulf represent about 40% of the maximum number of coral species found in any area of the Indo- Pacific (Jordan Country Study on Biological Diversity). The warm, clear and calm waters of the Gulf make it suitable for many aquatic sports, such as snorkeling, diving, water-skiing, wind surfing, boating etc.

5.4.4.2 Pharmaceutical Applications

As a result of the recent scientific development, there is growing interest in reef species as a source of compounds for drug industry. Many species, sea fans, sponges, fishes, corals and nudibranches, living in the Gulf of Aqaba contain pharmacologically active substances (Abu-Helo, 1989; Mebs, 1984, 1985; Mebs et al., 1983, 1985; Qar, 1987; Qaret al., 1986). Recently, small pieces of corals have been used as bone graft substitutes (Guillemin et al., 1993; Ouhayoun et al., 1993; Kehr et a1., 1993). In addition, the UV-light absorbing pigments in coral tissues have been investigated as a source of a new ingredient for sunscreens (Dunlap et al., 1988).

5.4.4.3 Aquarium Trade

Many reef species, including fish, shrimps, molluscs and corals, have been taken for the aquarium trade. Tropical marine fish for aquarium in Asia started in Sril Lanka in the early 1930, then the trade expanded gradually during the 1950s (Jonklaas, 1985). In the early 1980s, the import value of marine fish and invertebrates for the aquarium trade was estimated to be between US$ 24-40 million annually, with more than 40 countries are participating in supplying the market (Wood, 1985). It is important that capture of reef animals for aquarium trade does not add to the problems. The export of Aquarium trade from the Red Sea appeared to have started in Egypt in 1985. Several companies in Egypt, Saudi Arabia, Yemen and Djibouti have been involved in this trade. The size, status and profile of fishery, export market volume and value of trade in addition to the regulation, management and monitoring in the region was summarized by Wood (2001). Barrat and Medeley (1988) made an assessment of the aquarium reef fishery in Djibouti. As a result of this study most of the countries in the region such as Saudi Arabia, Yemen and Egypt stopped this trade and closed the companies. Recently Yemen restarted this aquarium trade and the company asked

Yameni people from local coastal community to get live fishes and selling them to the company. According to our latest knowledge Sudan gave permission to three companies dealing with aquarium trade. There are positive and negative aspects in the aquarium trade. On the positive aspects, visiting public aquaria can help educate the public and increase their awareness of the need to conserve reef ecosystems. In addition, this industry provides jobs and income for many people, particularly in supplying countries. On the negative aspects, the aquarium trade has raised concerns about the conservation of reef fish and their coral habitats. The main issues are possible over-exploitation of target species; other issues are damaging methods as a result of collection and post-harvest mortalities. A detailed study on fish aquarium trade in the Red Sea and Gulf of Aden was carried out by Khalaf and Abdallah (2003). The distributional pattern of 50 coral reef fishes that was used for aquarium trade in the Red Sea and Gulf of Aden was reported by Khalaf and Abdallah (2014). In Jordan, laws and regulations prohibit the catch of and trade in ornamental fishes, and the only few cases of catching coral reef ornamental fish for trade purposes were caught reported (Khalaf, personal communication), and sent to court. This possibly explains why there is no information about the economic value of this practice and its effect on the marine environment of the Gulf of Aqaba.

5.4.5 TRENDS, ISSUES AND MANAGEMENT OF THE CORAL REEFS IN THE JORDAN GULF OF AQABA

The present activities of new ports constructions and expansion and anticipated increase in maritime trade and shipping activities, in addition to the plans for urban, tourism and industrial development in Aqaba, indicate that the pressure on coral reefs will increase in the coming years. Consequently, the deteriorating rate of coral reef ecosystem is expected to increase. In addition, the lack of implementation and enforcement of regulations and laws to protect the marine environment of the Gulf of Aqaba in Jordan and neighbouring countries will not help in the implementation of the sound management of this environment and its unique coral reef ecosystem. The lack or limitation of the available funding to support good management and to mitigate the impact of the present and future activities and development will not make it possible to overcome or limit the expected damages or to restore previously damaged reefs. Overall, the coral reefs are declining in Aqaba, due to the reasons mentioned above.

It is worth mentioning that despite of the limited resources which are necessary of research and restoration of the impacted reefs, efforts have been made to initiate and construct two main artificial reefs in the coastal water of Aqaba (Al-Horani and Khalaf, 2013). In addition, a number of ships were sunk to act as bases for artificial reefs in more than one site. Coral nurseries were also constructed in the aim of reproducing corals for restoration and for research purposes (Al-Horani, 2013). However, despite all these efforts, the status of coral reefs in the Jordan Gulf of Aqaba deal with the following issues, which represent special concern to the coral reefs in Aqaba.

At the present time, the coral reefs in Aqaba are declining at a fast rate due to many reasons that range from high-impact activities such as the ports construction, to medium-impact activities such as fishing and disorganized tourism activities.

Though EIA is a requirement for new projects in many cases, but the follow-up procedure to ensure that the projects are using the best practices during construction and operation should be enforced.

Funding for mitigation measures and restoration activities is very limited, and therefore, mitigation measures and the number of staff involved are not enough to support scientific research, develop strategies for restoration of damaged reefs, and reduce the rate of coral reef damages. In addition, the private sector is not contributing to the conservation of the coral reef.

There is no enough coordination among all stakeholders, or involvement and participation of the private sector in taking decisions that might cause major destruction to the environment.

The sites used for recreational diving are decreasing and the access to existing sites is not always easy-going. This is expected to affect the diving industry in Aqaba and as a result impacting an important component of the tourism in Aqaba.

The private sector (specially the sea-based enterprises and ports) who benefits from the limited coastal resources is not contributing financially to the conservation of the coral reef environment at all, which necessitates the need for laws and by-laws to enforce such contribution.

Flooding during raining seasons is an important threat to coral reefs. Draining system in the right site is urgently required due to the lack of drains and the random organization of the water passageways (Wadis).

Within the territorial coastal waters of Jordan in the Gulf of Aqaba, coralivorous snail, *Drupella cornus* did not cause major problems in the past, although relatively high numbers were found associated with corals, especially in places that are subject to human activities. Surprisingly, high numbers of the snail were found on corals that were transplanted in the Aqaba Marine Park Visitors' Centre (Abu Awali, personal communications). However, there are no specific studies or follow up on the distribution of the snail *Drupella cornus* or the COT in the coral reefs of Jordan, and therefore it is not possible to report a clear trend of their occurrence. By comparison, local field observations show a noticeable increase in the occurrence of coral diseases everywhere in the Jordanian coast (Al-Horani, F., personal observation). It can be easily observed that the coral diseases have increased to an alarming number However, unfortunately no study was carried out on this specific. Therefore, there is a need to include the study of *Drupella cornus* and COT in the national monitoring program, as this can help reporting their occurrence distribution and changes in their numbers, to take management actions to mitigate their effects. In addition, there is also a need to conduct studies on coral diseases their causes, and reasons behind their increased incidence and the ways to counteract their negative impacts.

5.5 MARINE TURTLES IN THE COASTAL WATERS OF THE JORDAN GULF OF AQABA

The RSGA contains globally important feeding and nesting grounds for green (*Chelonia mydas*), hawksbill (*Eretmochely imbricata*) and loggerhead (*Caretta caretta*) turtles. All species of marine turtle (except the loggerhead which is classified as Vulnerable) have been classified as Endangered or Critically Endangered and listed in CITES Appendix 1 (PERSGA/GEF 2004). Marine turtles need a number of different habitats to complete their life cycle. Shallow foraging sites such as seagrass beds and coral reefs are utilised. Nesting sites are chosen on the basis of a complex of beach characteristics and the likelihood of anthropogenic disturbance. Nesting is unlikely on cluttered, developed beaches or close to bright lights. Important requirements include relatively clean sand and a suitable depth at the dune area that is not flooded by the high tide. All these requirements are not found in Aqaba. In addition, accumulated debris such as logs, discarded nets, solid waste and plastics can deter nesting females (PERSGA/GEF2004d). Despite a comprehensive survey effort by PERSGA in 2000, there is still a shortage of data on the distribution of habitats, particularly foraging sites, within the region (PERSGA/GEF2004d).

Five species of marine turtles can be found in the Red Sea, of these, the green, loggerhead and hawksbill are the most common with the leatherback and olive ridley being infrequently seen and with no recorded nesting. All marine turtles share a similar lifestyle which has made them similarly threatened by anthropogenic activities. Until recently, most research on marine turtles in the Red Sea dated back to more than 15-20 years and was relatively limited in scope (ROSS & BARWANI 1982). Of the major nesting populations found in the Red sea, the green, hawksbill and loggerhead are the most common. Green turtle populations were surveyed in detail in Saudi Arabia (MILLER 1989; AL-MERGHANI et al., 2000). Green turtles were also studied in Yemen over 20 years ago (HIRTH & CARR 1970; HIRTH et al. 1973), and more recently in 1996 through a UNEP study (UNEP/IUCN 1996). Recent survey on turtles in the region estimated about 500 females nesting populations of Hawksbill in the Egyptian Red Sea each year (FRAZIER & SALAS 1984), and briefly in Somalia (IUCN 1997; SCHLEYER & BALDWIN 1999). A Turtle Watch-Egypt programme was officially launched in March 2011, with participation of dive centres along the Red Sea coasts. The results of the programme which was conducted at 35 dive sites and extended to November 2011 indicate the sighting of 240 positive sighting, of which 80 green turtles (33% of the positive sightings), 145 hawksbill turtles (60% of the positive sightings) and 15 unidentified turtles (7% of the positive sightings) (HEPCA 2011).

Five of the seven sea turtle species existing in the world, has be found in the Egyptian Red Sea: the green turtle (*Chelonia mydas*), the hawksbill turtle (*Eretmochelys imbricata*), the leatherback turtle (*Dermochelys coriacea*), the loggerhead turtle (*Caretta caretta*) and the olive-ridley turtle (*Lepidochelys olivacea*). They are considered extremely vulnerable to all kinds of over-exploitation and population recovery can take decades. All five species are enlisted in the IUCN Red List either as critically endangered (leatherback and hawksbill turtles), endangered (loggerhead and green turtles) or vulnerable (olive-ridley turtles). Furthermore they are all enlisted in Appendix I of the Convention on International trade of Endangered Species (CITES), meaning that trade in sea turtles and derived products is forbidden in signatory countries. While green and hawksbill turtles are known to nest along the Egyptian coastline, olive-ridley, loggerhead and leatherback turtles are seen more sporadically only in the feeding areas (HEPCA 2011).

5.5.1 TURTLES IN JORDAN COASTAL WATERS

In contrast to other parts of the Red Sea, very little information is documented on sea turtles in the Jordan Gulf of Aqaba. A preliminary and limited programme was conducted with the participation of 10 volunteered divers in 13 diving sites along the coastline of the Jordanian Gulf of Aqaba (Fig. 5.9). Almost all of the observed turtles were Hawksbill species indicating that it is the dominant and probably the only turtle species in the Jordanian Gulf of Aqaba. Moreover, all observations revealed that the majority of the turtle population is in its juvenile stage (30-60 cm CCL). None have been recorded in other development stages. Specimens were classified as adults if the carapace length was above 65-80 cm. Population abundance and frequency by site are shown in Figure 5.10. The Black Rock showed the highest turtle population. The calculated CPUE have shown that this site the highest population of turtles, have received the least CPU. Those with high CPU showed to be the least populated. Black Rock has a highly developed coral reef habitats while the other sites have coral reef but with mixed batches of grass beds and sandy areas. The main habitat of Hawksbill is coral reef and the turtles exhibit both carnivorous and foraging behaviours associated with fauna and reef habitat.

The sex ratio of the observed population showed fluctuation in number between males and females during the months of the study period (Fig. 5.11). It was noticed also that males were more frequent in appearance than females. Only females were seen during winter (Jan-Feb). However, during the second half of the study period, the number of males was obviously decreasing as compared to those of females. An overall estimation of the total number of both sexes during the survey period indicated that females are slightly exceeding males (Fig. 5.12). The majority of the turtle population was observed in coral reef habitat in the Gulf of Aqaba (Fig. 5.13). Grass beds and sandy seafloors have shown the least number of turtle specimens.

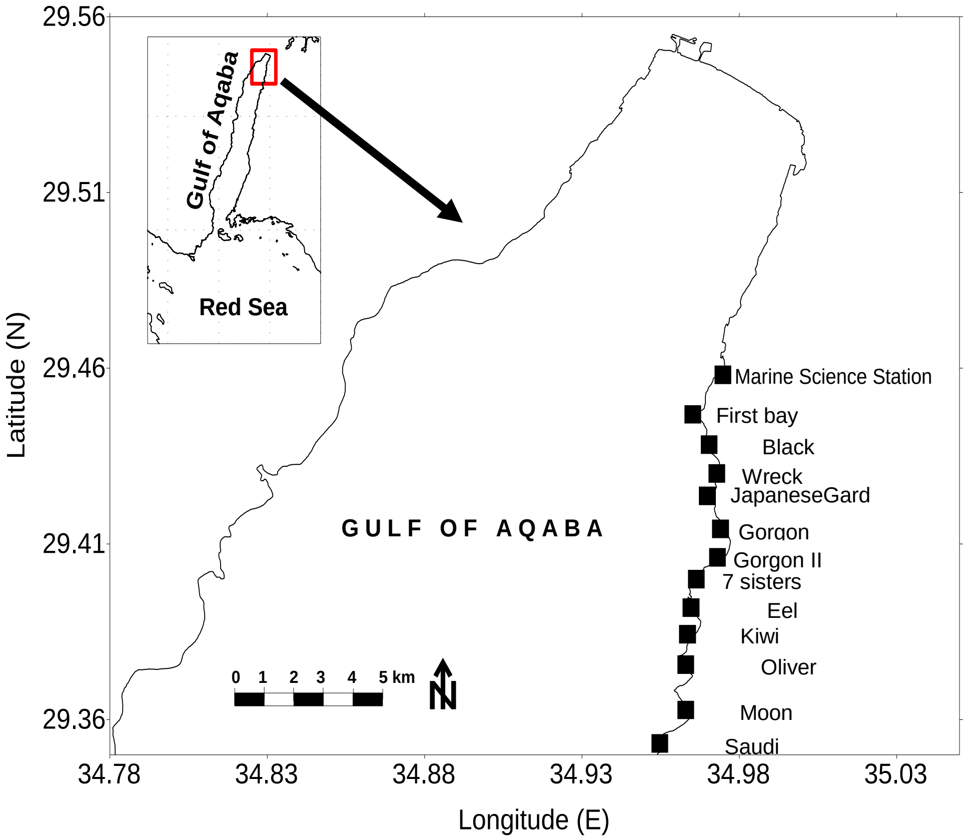


Figure 5.9: Turtle study sites at the most popular diving sites along the Jordanian coast of Gulf of Aqaba, Red Sea.

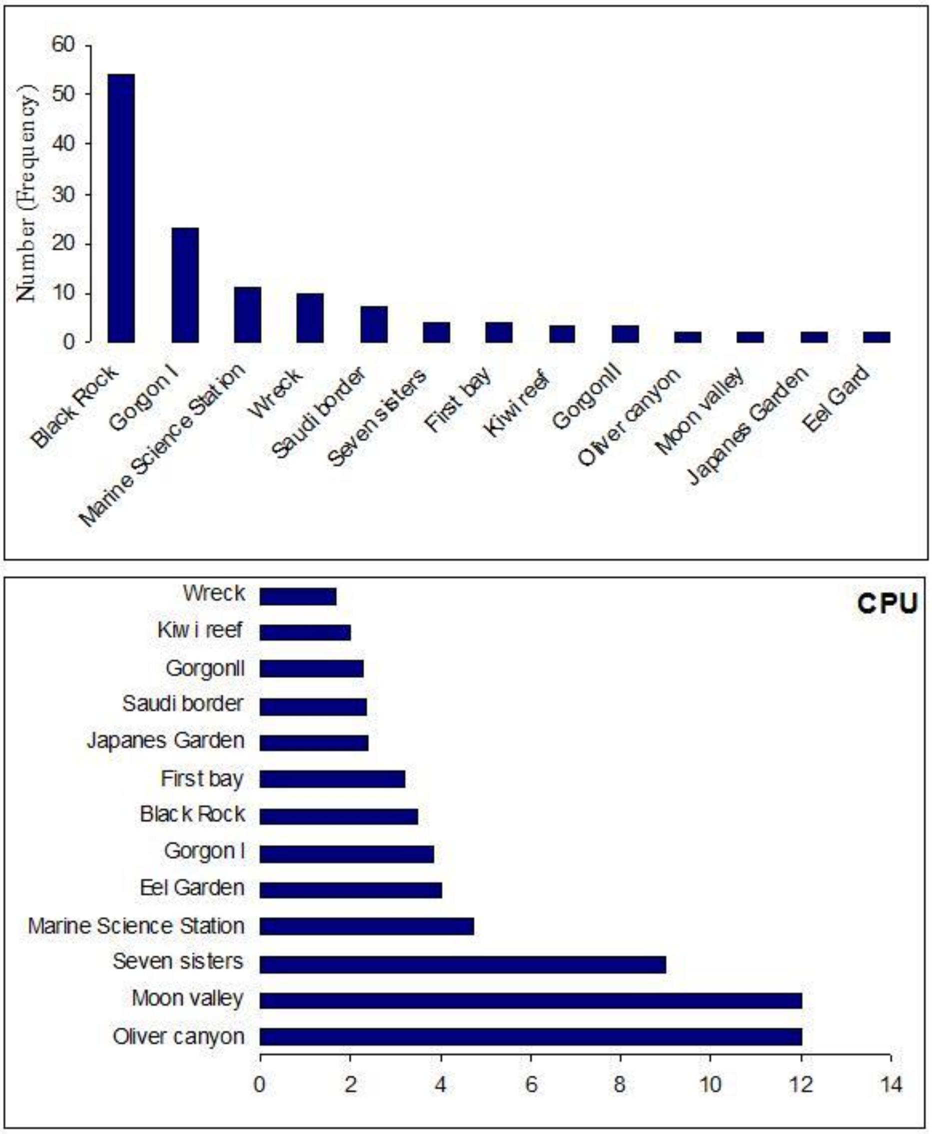


Figure 5.10: Total number of the observed turtles in all sites in Gulf of Aqaba (above). CPUE (below) implemented at the similar sites of the present study.

No nesting turtles were sighted in this area due to the absence of nesting beaches. This can be attributed to the effect of the rapid urbanization and ports development that the Jordanian coast has witnessed in the past three decades, which certainly limited the space allowed for nesting along. Other factors that have adversely affected the nesting beaches include artificial lighting, coastal sand mining, and beach front stabilisation structures.

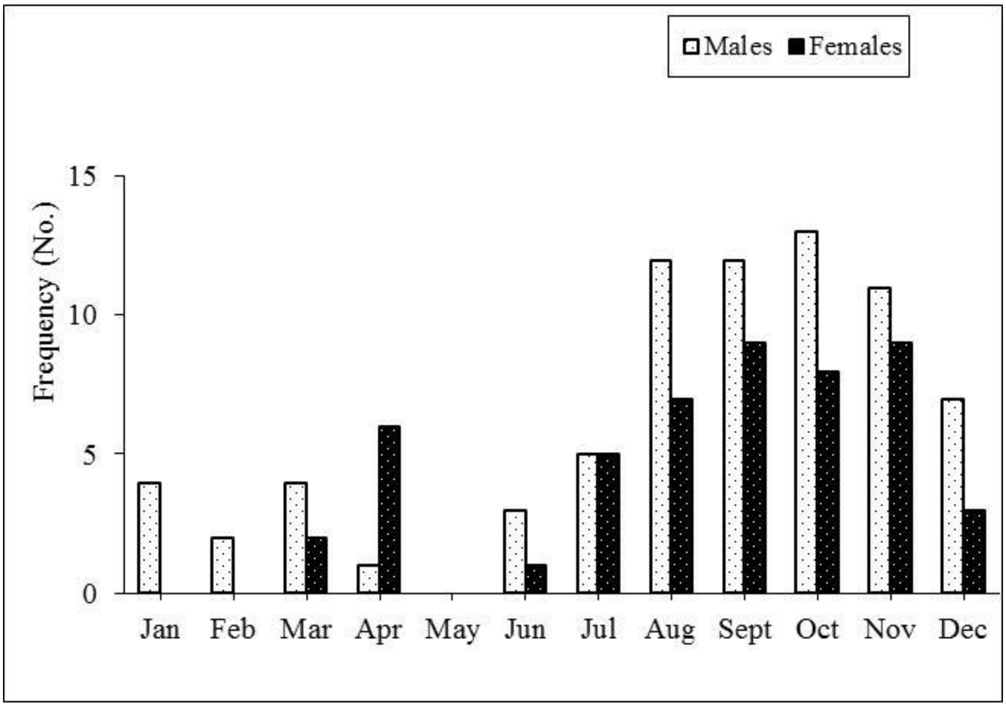


Figure 5.11: Number of males and females and frequency of appearance per month during the study period.

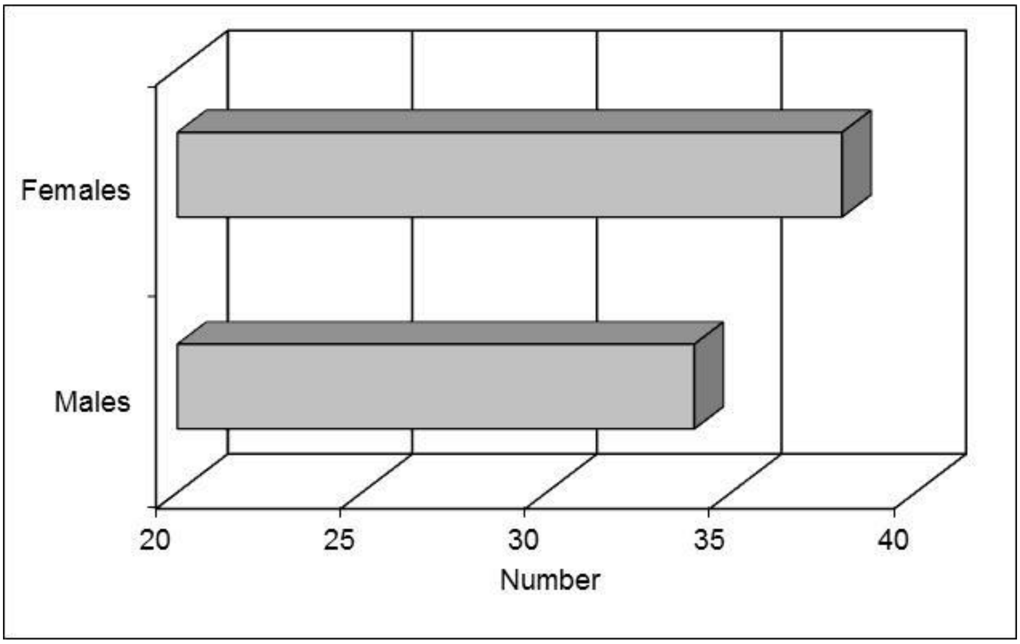


Figure 5.12: Number of observed males and females of turtle population in the Jordan Gulf of Aqaba during the study period.

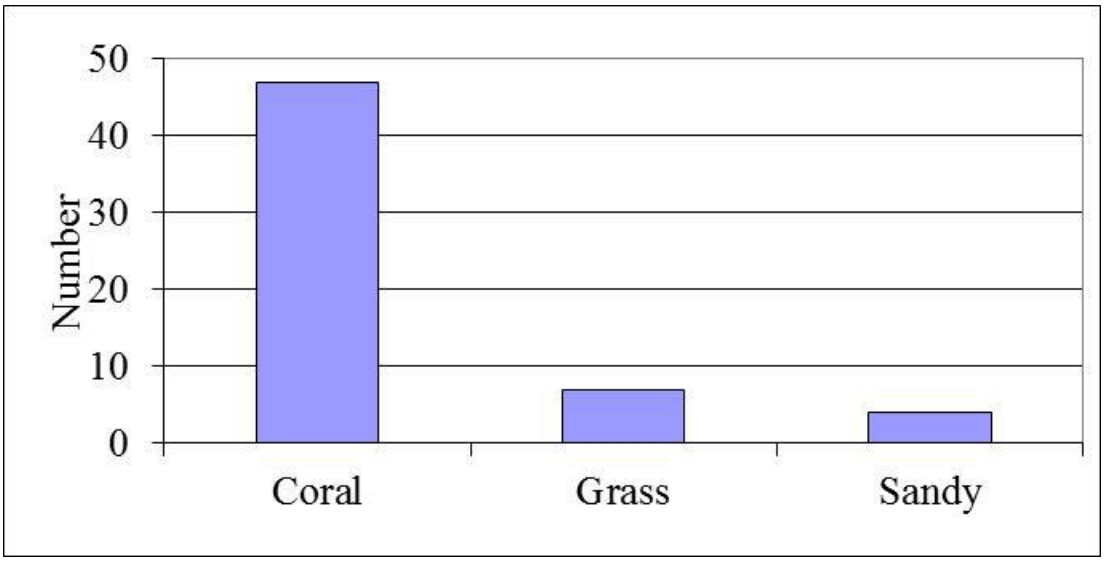


Figure 5.13: Abundance of turtles at three investigated habitats in Gulf of Aqaba.

The few numbers of marine turtles might be also due to the presence of coral boulders and knolls surrounding such habitats. Gorgon 1 and Wreck sites recorded the highest.

The two sites are well recognized coral reef habitats with a high biodiversity of sponges and they could provide both shelter and food sources for these species. Foraging habitats are still under. However, the major threats to foraging grounds in Jordan include industrial activities, fishing practices and to some extent other forms of marine pollution, including persistent marine debris (POINER & HARRIS 1994; HUTCHINSON & SIMMONDS, 1992). The current data suggests that there has been a decline in the population in terms of species and even number. While some progress has been made with regard to determining the effects of human actions on regional turtle populations, there is a wide gap between present knowledge and information needs.

Marine turtles face a multitude of threats on nesting beaches and at sea, that vary in severity between species and geographic region. The main global threats, as reported in published literature (IAC, 2006b; IUCN MTSG, 2011; UNEP-WCMC. 2011) are: Fisheries impacts, primarily by-catch/incidental capture but also habitat destruction and food web alterations; Direct take of eggs, turtles at sea and nesting females (for food, oil, leather and shell); Coastal development, including loss and degradation of shoreline and seafloor habitats due to construction, coastal armouring, sand mining and dredging, tourism and artificial lighting (disorienting hatchlings; Pollution and pathogens, such as petroleum by-products, discarded fishing gear, plastics, agricultural run-off marine debris, contaminants and sediments on habitats, plastic waste and entanglement in nets and ropes; Climate change, leading to loss of nesting beaches with sea-level rise, changes in beach and sea temperature and skewed primary sex ratios, changes in food availability and changes in dispersal patterns of hatchlings from alterations to currents; and Natural threats, such as nest predation.

The Red Sea harbours major shipping lanes due to rapid urbanization along the entire coastline. Therefore, environmental threats (notably from habitat destruction, over-exploitation and pollution) are increasing rapidly, requiring action for conservation measures of coastal and marine environment. The Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) has a Regional Action Plan for the Conservation of Marine Turtles and their Habitats in the Red Sea and Gulf of Aden (PERSGA/GEF, 2004). Major issues for marine turtles in the Gulf of Aqaba/Jordan are presented in Table 5.2.

Table 5.2: Threats and conservation initiatives matrix for marine turtles in the Jordan Gulf of Aqaba (extracted from PERSGA/GEF 2004d and PERSGA 2006).

Major Threats	**Major Threats Scale**
Dredging /Land-filling	2
Commercial Fisheries	3
Artisanal Fisheries	1
Habitat Destruction	2
Oil Industry	2
Conservation Initiatives	**Conservation Initiatives Scale**
Legislation & Coordination	2
Research & Monitoring	3
Enforcement & Implementation	1
Education & Awareness	2
Community Participation	2

Notes:
Major Threats Scale: (1)-None; (2)-Small; (3)-Moderate; (4)-High; (5)-Critical
Conservation Initiatives Scale: (3)-Negligible; (2)-Moderate; (1)-Established & Operational\ Artisanal (Traditional) Fishing includes egg collection

5.6 OTHER MARINE INVERTIBRATES

The coastal waters of the Jordanian Gulf of Aqaba and its coral reef ecosystem is hosting thousands of marine fauna including hundreds of species of marine invertebrate (Table 5.3).

5.6.1 SARCODINA

Foraminiferans, in addition to algae, cnidarians, sponges, bryozoans, molluscs and echinoderms, contribute to the calcareous sediments of coral reefs. Most foraminiferans are benthic, but species of *Globigerina* and related genera are common planktonic forms.Many foraminifera contain endosymbiotic algae. Unlike the symbiosis found in scleractinians, foraminiferan endosymbionts include representatives from several algal classes including, Chlorophyceae, Bacillariophyceae and Dinophyceae.The scientific research dealing with this phylum, on the Jordanian side of the Gulf of Aqaba (Table 5.3), was limited to the foraminiferans group.

Table 5.3: Total number of species and genera of invertebrate phyla recorded from the Jordanian side of the Gulf of Aqaba. REF

Group	Number of species	Number of genera
1. Sarcodina	58	54
2. Porifera	72	44
3. Cnidaria	237	101
a. Hydrozoa	24	21
b.Scyphozoa	3	3
c. Total Anthozoa	219	77
c1. Hard corals	158	51
c2. Others	52	26
4. Nematoda	242	129
5. Mollusca	645	300
a. Gastropoda	479	207
b. Polyplacophora	17	8
c. Bivalvia	162	82
d. Cephalopoda	2	2
e.Scaphopoda	2	1
6. Annelida	37	34
7. Crustacea	1202	131
8. Echinodermata	125	82
a. Asteroidea	21	17
b. Ophiuoidea	29	16
c. Echinoidea	29	25
d. Holothuroidea	32	11
e. Crinoidea	14	13

5.6.2 PORIFERA

Sponges, which constitute the phylum Porifera, are the most primitive of the multicellular animals. All members of the phylum are sessile and exhibit little detectable movement. Many sponges, like corals, contain symbiotic algal cells and are at least partly autotrophic. The number of Porifera species and genera reported from the Jordanian coasts of the Gulf of Aqaba are presented in Table 5.3.

Sponges depend on their ability to filter large amounts of water through their bodies to survive. They provide habitats for many organisms and play a role in recycling calcium. Sponges are mostly beneficial to man and animals. Several sponge species e.g. Sigmosceptrella and Prianos produce compounds that show great promise as a drug to combat malaria, tuberculosis and other infectious diseases. Many compounds extracted from sponges have also anti-viral, anti-neoplastic and anti-cancer properties. There are 72 species of sponges known from the Jordanian coast of the Gulf of Aqaba (Al-Sabi', 2000) (Table 5.4). However, there are no reports, from Jordan, on the use of any species of sponges in any type of industries, production of chemical compounds, or for medicinal applications.

Table 5.4: Sponge species reported from the Jordanian coast of the Gulf of Aqaba (After, AL-Sabi', 2000).

Spong species	**Spong species**	**Spong species**
Acanthella carteri	*Clathrina coriacea*	*Leucosolenia tenuipilosa*
Adocia dendyi	*Clathria (Microciona) lamda*	*Negombata corticata*
Agelas marmarica	*Cliona vastifica*	*Negombata corticata*
Agelas marmarica	*Diacarnus erythraeanus*	*Negombata magificia*
Amphimedon viridis	*Dictyodendrilla praetensa*	*Negombata magificia*
Aplysina mollis	*Dycidea cinerea*	*Niphatis sp.*
Arenosciera Arabica	*Dycidea herbacea*	*Petrosa pellasarc*
Batzell sp.	*Erylus proximus*	*Phorbas epizoaria*
Biemna ehrenbergi	*Fasubera quadrangulata*	*Psammaplysill arabica*
Biemna mucronata	*Forma assabensis*	*Rhaphoxa typica*
Callyspongia communis	*Geodia micropunctata*	*Siphonochalina communis*
Callyspongia densa	*Grayella cyathophora*	*Siphonochalina siphonella*
Callyspongia fibrosa	*Haliclona* sp.	*Siphonochalina tabernacula*
Callyspongia fistularia	*Halisarcina cruenta*	*Spirastrelila decumbens*
Callyspongia maculate	*Hymedesmia tenuissima*	*Spirastrelila decumbens*
Callyspongia siphonella	*Hymeniaciodon coccinia*	*Spongia officinalis var. arabicus*
Callyspongia spinosissima	*Hyrtios erectus*	*Stelletta purpurea*
Callyspongia viridis	*Ircinia echinata*	*Suberea labouti*
Callyspongia sp.	*Jaspid reptans*	*Sycettusa (Grantessa) glabra*
Callyspongia tubulosa	*Latrunculia coricata*	*Tedania anhelans*
Callyspongia viridis	*Latrunculia magnifica*	*Tethya seychellensis*
Chondrillastra mixta	*Latrunculia* sp.	*Theonella swinhoei*
Chondrilla nuculua	*Leucetta chagosensis*	*Theonella swinhoei*
Chondrillastra sacciformis	*Leucetta* sp.	*Toxadocia toxius*

5.6.3 CNIDARIA

The phylum includes three classes:

Hydrozoa: Hydrozoans display either the polypoid or the medusoid structure, and some species pass through both forms in their life cycle. Twenty four hydrozoan species belonging to 21 genera were recorded from the Jordanian side of the Gulf of Aqaba. The most famous hydroid species is the fire coral or stinging coral (Millepora exesa).

Scyphozoa: Most frequently referred to as Jellyfish. In this class the medusa is the dominant and conspicuous individual in the life cycle; the polypoid form is restricted to a small larval stage. Only three species belonging to three genera were recorded from the Jordanian side of the Gulf of Aqaba.

Anthozoa: Anthozoans are either solitary or colonial polypoid cnidarians in which the medusoid stage is completely absent. This class includes the major constructors of tropical reefs, the scleractinian corals. Scleractinian corals live in symbiotic association with brown coloured dinoflagellates known as "zooxanthellae".

Cnidarians, on the Jordanian side of the Gulf of Aqaba, received much attention since the early seventies. A total of 158 species of scleractinian corals belonging to 51 genera were recorded from the Jordanian side of the Gulf of Aqaba. The number of some Cnidaria species and genera reported from the Jordanian coasts of the Gulf of Aqaba are presented in Table 5.3. However, these species represent limited areas of the Gulf of Aqaba, and the taxonomic validity of some species must be revised.

5.6.4 GASTROPODA

Modern revisions indicate that approximately 950 to 1000 species of marine shells are living in the Red Sea. The molluscan fauna of the Red Sea is entirely of Indo-Pacific origin. The rate of endemic species proportion is less than 5%. Out of a total of 950 species of molluscs occurring in the whole Red Sea basin about 850 species live in its southern and central parts, while 637 species are recorded from the Gulf of Aqaba. Molluscan assemblages were studied on fringing reefs (reef flats, Millepora-fringing reefs, fringing reefs with massive corals) and fore-reef hard substrata (coral patches, coral carpets and small patch reefs) in the Gulf of Aqaba at water depths ranging from the intertidal to 26 m. A total of 1,665 molluscan individuals from 51 taxa was counted on 44 transects, which covered 220 m² at eight diving sites. The most important molluscs in the assemblage were the parasitic gastropod *Coralliophila neritoidea*, the encrusting gastropod *Dendropoma maxima* and the coral-associated bivalve *Pedum spondyloideum* (Zuschin and Stachowitsch 2007).

On the Jordanian coast of the Gulf of Aqaba, a total of 645 species of mollusc were recorded (REF) The number of mollusc species and genera reported from the Jordanian coasts of the Gulf of Aqaba are presented in Table 5.3.The phylum mollusca is represented by 5 classes in the Jordanian coastlines of the Gulf of Aqaba. These classes are as follows: Gastropoda is represented by 462 species, which equals about 71 % of the phylum (some of the names are synonyms); Bivalvia or Lamellibranchia is represented by 162 species, which equals about 25% of the phylum (some of the names are synonyms); Polyplachophora is represented by 17 species, which equals about 2.6% of the phylum (some of the names are synonyms); Cephalopoda is represented by 2 species only, which equals about 0.3% of the phylum; and Scaphopoda is represented by 2 species only, which equals about 0.3% of the phylum.

5.7 MARINE VERTEBRATES

Twelve species of Urochordata, two Chaetognatha and 510 species of fishes were reported from the Gulf of Aqaba. REF

5.7.1 CHAETOGNATHA

The Chaetognatha, known as arrow worms, are common animals found in marine plankton. From the Jordanian side of Gulf of Aqaba, only four species representing two genera were recorded. These species are: *Sagitta enflata, Sagitta hexaptera, Sagitta pacifica* and *Spadella* sp (Table5.5).

Table 5.5: Total number of genera and species of vertebrate phyla recorded from the Jordanian side of the Gulf of Aqaba.

Group	Number of species
l. Urochordata	**20**
2. Chaetognatha	**4**
3. Fishes	**507**

5.7.2 UROCHORDATA

Urochordata is a subphylum of the phylum Chordata. Adult urochordates are commonly known as tunicates. A total of 20 species were recorded from the Jordanian side of the Gulf of Aqaba.These species were divided among three classes as follows: Ascidiacea, 6 species; Larvacea, 8 species; and Thaliacea, 6 species.

5.7.3 FISHES

The Red Sea ichthyofauna is quite well known compared to other parts of the tropical Indo- Pacific Ocean. Over 1248 fish species have been recorded from this almost land looked water body (Goren and Dor, 1994). Ichthyological research in the Red Sea dates back more than 200 years to collection and descriptions of fishes by Peter Forsskål (Klausewitz, 1964; Nielsen, 1993).

5.7.3.1 Fish Community Indices

The total numbers of species along the Jordanian coasts are eighteen in Chondrichthyes and 492 in Ostichthyes or 510 in total belonging to 109 families, an average 4.7 species per family. The distribution of species among families was found that 79 fish families are represented by only 1-3 species, 14 families are represented by more than 10 species. In terms of species richness per family the ichthyofauna showed the following ranking (given as n number of species in the family, n% of the total fish fauna): Wrasse labridae (51, 10.1), Pomacentridae (29, 5.7), Serranidae (25, 4.9), Apogonidae and Blenniidae (24, 4.7 each), Gobbiidae (21, 4.1 each), Carangidae (17, 3.4) and Syngnanthidae (16, 3.2). These 8 families account for 40.8% of all species. Seventy six fish species are indicated with (*) in the inventory represents a new reports to the Jordanian coast, including *Gymnothorax monochrous*, *Myripristis xanthacra*, *Corythoichthys haematopterus, Syngnathus macrophthalmus, Istiblennius flaviumbrinus*, *Enneapterygius destai* and *Grammatorycnus bilineatus* are the first confirmed report from the Gulf of Aqaba. The family Scombridae includes the most important commercial species in Aqaba. It represents more than 70% of the Jordanian marine catch, specially the most abundant migratory species Skipjack Tuna (*Katsuwonus pelamis*) and Kawakawa (*Euthynnus affinis).* Other important commercial fish species are Mackerel Scad (*Decapterus macarellus),* Shortfin Scad (*Decapterus macrosoma),* Fusillers *(Caesio lunaris, Caesio suevica* and *Caesio varilineata).* Ecological analysis of the Jordanian marine fishes indicates that majority of the species (82.8%) inhabit benthic habitat while the rest are true pelagic fish. Among benthic habitat, 51.1% of the fish species inhabit coral and boulders, 11.7% inhabits sandy bottoms, 11.1% are deep benthos, 8.3% live in sea grass meadows, and 0.6% is bathydemersal species. Whereas, among, pelagic habitat 9.6% of the fish species are living in open waters, 3.0% are associated with reef, 2.6% are benthopelagic, 1.7% lives in shallow water, and only 0.4% are bathypelagic species. The most abundant shallow water pelagic species are the silver side fish *Atherinomorous lacunosus,* and the clupeid fish, *Spratelloides gracilis*. The most common inhabitant of deep sea fishes are *Iago omanensis, Rhinobatos punctifer, Mureanesox cinereus, Carangoides equula, Paracaesio sordida, Polysteganus coeruleopunctatus, Argyrops spinifer, Upeneus davidaromi, Trichiurus lepturus, Thyrsitoides marleyi*. An analysis of the feeding behavior of the Jordanian marine fishes indicates that 30.6% of the species feed on fish and invertebrates, while 24.8% feed on invertebrates, the planktivorous fish constitute only 15.9%, 15.0% are omnivorores, 7.4% are herbivorous, 4.5% piscivore, 1.6% corallivore and only 0.5% detrivore feeders. In comparison with the number of fish species collected from the Red Sea 1,248 species (Goren & Dor, 1994) which extends for 1,932 km, this study indicates that the Jordanian coast with only 27 km at the Gulf of Aqaba, hosts 507 fish species which accounts for about 40.6% of the Red Sea fishes. In comparison Golani *et al.* (2002) reported that the Mediterranean Sea hosts 650 fish species, and Carpenter *et al.* (1997) published the most comprehensive account of fishes of the Arabian Gulf, reporting 535 species from the Gulf. This clearly indicates that the Jordanian coast is characterized by a high fish diversity, which is attributed to the diversity of habitats existing along the coast such as: Coral reef, seagrass meadows, sandy habitats and deep sea fish fauna. Roberts and Ormond (1987) indicated that the species richness is also positively correlated with habitat diversity. Two families, Lutjanidae, and Haemulidae were not common in the Jordanian coast in comparison with their abundance, frequency of appearance and number of species as in the central and southern Red Sea. It is very rare to see a member of these families while diving in Aqaba. Reef structure in the Jordanian coast of Aqaba Gulf is smaller in size than central and southern Red Sea. Accordingly, the existing habitat would not provide the suitable shelter for them. Moreover, the photic zone in Aqaba is confined to a narrow zone, which would affect the productivity in a negative term for large commercial fish.

5.8 ALGAE IN THE GULF OF AQABA

More than 500 taxa of benthic algae have been recorded from the Red Sea (Papenfuss 1968). Shallow coral reef areas of the northern and central Red Sea are often seasonally dominated by filamentous greens, small browns and tuft-forming red algae (Leliaert & Coppejans 2004). Perennial brown algae, like *Sargassum*, *Cystoseira* and *Hormophysa* are dominant over shallow, hard substrates in the southern Red Sea. Macroalgae often form the major cover of hard substrates in areas too turbid for coral growth (Gladstone 2000; PERSGA/GEF 2001). Red algal reefs are essentially built by red coralline algae of the genera *Porolithon* and *Lithothamnium* occur in shallow coastal waters (2–4 m) from the Saudi Arabian border south to Yemen, and on many nearshore islands. Fleshy macroalgae mainly *Caulerpa* spp., *Sargassum* spp. and *Padina* spp. are also present (PERSGA/GEF 2003b). Fifty taxa of seaweeds belonging to Chlorophyta, Phaeophyta and Rhodophyta have been reported from the Red Sea coast of Sudan (Mistafa & Ali 2005). Ormond & Banaimoon (1994) reported 163 taxa of macroalgae from the Hadhramaut region of the Gulf of Aden coastline of Yemen. Schils & Coppejans (2003a) reported 124 species of marine algae from the Socotra Archipelago. The occurrence of different algal communities is related to the degree of exposure to upwellings and sedimentation.

Algal vegetations along the coast of the Jordan Gulf of Aqaba have successive appearance, abundance and dominance depending on season (Mergener and Svoboda, 1977). Natour et al. (1979a) listed 92 species of green and brown algae from the Gulf of Aqaba and recorded the presence of 25 species of green and brown algae in the Jordanian coastal waters of the Gulf of Aqaba. Natour et al (1979b) listed 63 species of red algae from the Gulf of Aqaba and recorded the presence of 28 species in the coastal waters of the Jordanian Gulf of Aqaba. High diversity of algae was observed at localities having minimal exposure to environmental stresses at the different sites along the coast of Gulf of Aqaba (i.e. wave action, substrate stability, slopes etc. Seasonal fluctuation of different macro-algae species were reported with maximum living coverage observed between February and March with a significant increase from April to May, while the minimum coverage occurred during July to August (Benayahu and Loya, 1977; Mergner and Svoboda, 1977). They indicated that such fluctuation appeared to produce a sequential peaking of different species at different times of the year and the rhythm in algal population dynamics leads to a change in mobile fauna living conditions. According to Littler et al., (1983) six functional groups of algae were identified in the coastal region of the Gulf of Aqaba, filamentous algae, joint calcareous algae, sheet-like algae, thick lathery algae, coarsely-branched algae and crustose algae.

A recent study was carried out to monitor the spatial and temporal occurrence of algal communities five protected or impacted sites along the Jordanian Gulf of Aqaba. A Public Beach with sandy bottom and scattered seagrass beds at the most northeastern tip of the coast, the raw phosphate loading Port at the southernmost portion of the cargo main port of Aqaba, and the Industrial Complex (JFI) at the southernmost part of the Jordanian coast, represent the impacted sites. The Marine Science Station (MSS) protected coast at the beginning of the Aqaba Marine Park Zone, and Tala Bay (other older names are Big Bay and Al Mamlah**)** at the end of the Aqaba Marine Park Zone, represent the not impacted sites (Fig. 5.1).

5.8.1 SPATIAL AND TEMPORAL DISTRIBUTION OF ALGAL VEGETATIONS

Spatial and temporal distribution of macro-algae was monitored at five coastal stations. This include total algae coverage, species coverage and biomass measurement. Survey of the coastal algal communities consist the following taxonomy and distribution as well as the floral dynamic of the different algal community due to natural and induced modifications.

All algal vegetations observed and are presented in Table 5.6. The results show that brown and red algae species were more abundant than the green algae; and both red and brown algae occupied depths range between 1-5 meters while the green algae usually occurred within the intertidal zone.

Table 5.6: Algal species observed along the Jordanian coast of Gulf of Aqaba. REF

Chlorophycea (green)	**Phaeophyceae (Brown)**	**Rhodophyceae (Red)**
Enteromorpha compressa	*Padina pavonia*	*Glacularia arcouata*
Caulerpa serrulata	*Cystoseira myrica*	*Chnoospora sp*
Ulva lactuca	*Dilophus fasciola*	*Spyridia filamentosa*
Enteromorpha flexuosa	*Hydroclathrus clathratus*	*Jania sp*
Halimeda sp	*Sargassum subrepandum*	*Centroceras clavulatum*
Enteromorpha clathrata	*Sargassum sp*	*Laurencia sp*
Codium sp	*Ectocarpale sp*	*Laurencia papillosa*
Cladophora sp	*Colpomenia sinuosa*	*Liagora*
Boergensnia fobessii	*Turbinaria sp*	*Champia irregularis*
	Dictyota sp	*Hypnea valentiae?*
	Actinotrichia fragilis	
	Laurencia sp1	
	Catenella repens	
	Gelidiella acerosa	

5.8.2 DISTRIBUTION, BIOMASS AND PERCENT COVER OF ALGAL VEGETATIONS

The three major families (Chlorophyceae, Pheophyceae and Rhodophyceae) of macro algae were observed at the five sites (Tables 5.7 & 5.8). Pheophyceae exhibited the highest percent cover as well as biomass (Table 5.9). Green and red algae exhibited almost similar cover and biomass. Higher abundances of algal vegetations were recorded at Big (Tala) Bay and JFI, as compared to other sites. The least abundance however was observed at the phosphate port.

Table 5.7: Percent cover and biomass (gr/m^2) of the three major macroalgea families during three year period. REF

Family	Cover (%)	Biomass (gr/m^2)
Chlorophyceae	1.48	1.39
Phaeophyceae	2.88	2.88
Rhodophyceae	1.04	1.22

Table 5.8: Percent cover and biomass (gr/m^2) at five sites along the Jordanian coast of Gulf of Aqaba. REF

Site	Cover (%)	Biomass (gr/m^2)
Public Beach	1.80	1.91
Phosphate port	1.35	1.34
Marine Science Station	1.73	1.71
Big Bay	2.00	1.93
Jordan Fertilizer Industry	2.10	2.31

Highest values were recorded in spring (March, April and May), while the least values were recorded in summer months, particularly in July. Unfortunately, algal monitoring and the data generated during fall were not sufficient to be presented. In total, 31 algal species were observed with *Badina bavonia* (Phaeophyceae) have the highest percent cover and biomass. REF

Table 5.9: Monthly and seasonal changes in percent cover and biomass (gr/m^2) along the Jordanian coast of Gulf of Aqaba. REF

Month	Cover (%)	Biomass (gr/m^2)	Season	Cover (%)	Biomass (gr/m^2)
December	0.20	0.97	Winter	1.44	1.40
January	1.68	1.24			
February	1.82	1.84			
March	2.29	2.07	Spring	2.40	2.45
April	2.80	3.14			
May	2.05	2.13			
June	0.72	0.83	Summer	0.61	0.70
July	0.40	0.46			
August	-	-			
Sep- Nov	-	-	Fall	-	-

Vertical distribution of macroalgae at different sites demonstrated that the pattern was green algae at upper zones of the water edge followed by brown and then red to reach mostly the reef front margins (Jibrin, 1986). This pattern of zoning scheme was suggested for the Gulf of Aqaba coastal areas by Safareil and Lipkin (1964). Algal turf is the most dominant component in reef habitats. At intertidal zone as well as at the reef flat down to 2-3 meter depth turf algae as well as fleshy algae were the most abundant groups. Turf algae were found growing above dead coral skeletons, reaching highest development in the partially exposed areas of the reef flat. Fleshy algae were the second most common group on the reef flat. At the reef border, the density of *P. pavonia* increases and in areas of high abundance, *pavonia* colonies were covering most of the available substrate. Such scheme of zoning could minimize competitive interactions for bare space among macroalgae during coloni zation processes (Eston *et al.*, 1992). Biomass showed a tendency to increase during winter throughout spring. By comparison, abundance of algal vegetation was extremely limited during summer and fall. This is expected if the water mixing was taken into consideration when comparable and relatively higher levels of dissolved nutrient are observed during winter and spring compared to other seasons (Al-Najjar 2000; Badran 2001).

5.9 CORAL-TURF ALGAE ASSOCIATION IN FRINGING REEFS OF JORDAN COASTAL WATERS OF THE GULF OF AQABA

In many areas the loss of coral cover and diversity is coupled with an increase in algal biomass and shift in algal community structure (Szmant 2002; McManus and Polsenberg 2004). The coral reefs of the Gulf of Aqaba, as with many other reefs in the world, are currently experiencing such coral-algae phase shift from reefs dominated by coral, toward turf algae-dominated reefs (Bahartan et al. 2010). The Gulf of Aqaba coral reefs are greatly jeopardized by such expansion of this phase shift, as the ailing reef becomes overgrown by bushy algal turfs that trap sediment and do not serve as healthy habitat for marine life, or many of the various other advantages provided by live coral reefs. Despite the ecological and conservation significance of the phase-shift phenomenon and the socio-economic implications for the thriving tourism industry and local fisheries in the Gulf of Aqaba, little is known about the factors responsible for the appearance and proliferation of the TA on the Gulf of Aqaba reefs.

Zibdeh (2002) conducted a survey (English et al., 1997) on the occurrence and spatial distribution of turf algae (TA) on coral reefs, coralline algae, and stony (reef-building) corals at seven sites along the Jordan coast of Gulf of Aqaba each of which is impacted by industrial and/or recreational activities (Fig. 5.1).

Table 5.10: Turf algae survey sites and description along the coasts of the Jordan Gulf of Aqaba.

Name of Site	Description of Activities
Clinker Port (most northern site, north of the container port and ferry port)/ **CP**	Imports livestock such as sheep and rice Across two-lane street (towards mountains) is a clinker packing factory. Releases of clouds of dust. Fishing is permitted
Marine Science Station I (**MSS I**)	No public access since 30 years, diving is permitted for research only. Ferry Port at ~100m to the North (upwind), a source of large amounts of solid wastes
Marine Science Station II /**MSS II**)	About 100m to the South, less influenced by the Ferry Port effects
Tourist Camp /**TC**	Public beach, within the Marine Park, No-fishing, but swimming, snorkelling, and SCUBA diving are permitted
Shooting Club /**SC**	Similar conditions as those of the Tourist Camp, about 1Km from the Tala Bay (Big Bay) Resort area
Big Bay (Tala Bay)/**BB**	Major hotels` construction area, lots of sediments are released offshore. Area of poor mixing and circulation due to topography
Saudi Border/**SB**	

At each site scuba divers surveyed transects at 8 m and 15 m depth. Surveys were conducted during winter, which is the period of water column mixing and high levels of available nutrients (Westhaus-Ekau, 2000).

The results of the survey of Turf Algae coverage in different sites and depths showed that Turf Algae coverage varied between sites; the shallower transects consistently contained higher percentages of turf algae than the deeper transects; the size of the algae was subjectively bigger at 8 m than at 15 m; and the average turf algae percentage cover was consistently higher at 8 m than at 15 m. The results of the survey showed also that more dense turf algae were observed in branching corals compared to the massive; the dense turf algae average coverage on massive corals was 20 % less than the on the branched corals; and algae-free massive corals were about 24% less than algae-free branched corals.

Big Bay and Saudi Arabian Border have significantly more overall turf algae coverage and more dense coverage of algae than the other sites. The Big Bay site is just in front of major hotels construction site while the Saudi Arabian Border, is next to ~~a~~ the fertilizer plant that produces phosphate fertilizers, close to the industrial port where fertilizers are exported, and in close proximity to the cooling system of plant which dumps hot water back into the sea. In contrast, the sites with the least amount of algae and the most live reefs (e.g. TC, SC and SB) are sites with similar human activities, including snorkelling, diving, swimming, tourist boating, This indicates that industrial activity has a more adverse impacts on coral reefs than recreational activity. The results showed an inverse relationship between live reef and turf algae coverage, suggesting that the less the amount of turf algae coverage in an area, the more the potential for the area to have live reef coverage. About 70% of all the dead coral was covered with turf algae and as algae kills more corals, more space is created for algae on the dead reef.

5.10 SEAWEEDS

Seaweeds are known as marine macroalgae, are multicellular algae that inhabit the oceans. Seaweeds are important in the economy of coastal seas, they create habitat for many marine organisms, contribute substantially to primary production and are consumed by a wide variety of animals, particularly sea urchins, snails and fish. Humans use seaweeds manufacture a variety of dietary, medicinal, and industrial applications in many of the affluent countries. Some red and green algae deposit calcium carbonate in their cell walls and are important contributors to the formation of coral reefs. Algae are a food source for many organisms, including humans, and they provide a habitat for many species. The three groups of seaweeds red algae (phylum Rhodophyta), brown algae (phylum Phaeophyta), and green algae (phylum Chlorophyta) are reported along the Jordanian coast (Zibdeh and Dumhouria, 2009). In Jordan, however, no algae are collected for consumption or for industrial purpose such as the production of food or medicinal drugs. Sometimes, the fishermen mix algae with fish pieces and flour to make a paste which is used as bait in fish traps.

Zibdeh (2006) reported on the presence, in the Jordan Gulf of Aqaba, of 33 species belonging to 3 families, Green (Chlorophyta, 9 species), Brown (Phaeophyta, 11 species) and Red (Rhodophyta, 13 species) algae (Table 5.11).

Table 5.11: Algal species observed along the Jordanian coast of Gulf of Aqaba (After Zibdeh 2006).

Family	Species	Family	Species
Chlorophycea	*Enteromorpha compressa*	Phaeophyceae	*Turbinaria sp*
Chlorophycea	*Caulerpa serrulata*	Phaeophyceae	*Dictyota sp*
Chlorophycea	*Ulva lactuca*	Rhodophyceae	*Glacularia arcouata*
Chlorophycea	*Enteromorpha flexuosa*	Rhodophyceae	*Chnoospora sp*
Chlorophycea	*Halimeda sp*	Rhodophyceae	*Spyridia filamentosa*
Chlorophycea	*Enteromorpha clathrata*	Rhodophyceae	*Jania sp*
Chlorophycea	*Codium sp*	Rhodophyceae	*Centroceras clavulatum*
Chlorophycea	*Cladophora sp*	Rhodophyceae	*Laurencia sp*
Chlorophycea	*Boergensnia fobessii*	Rhodophyceae	*Laurencia papillosa*
Phaeophyceae	*Padina pavonia*	Rhodophyceae	*Liagora*
Phaeophyceae	*Cystoseira myrica*	Rhodophyceae	*Champia irregularis*
Phaeophyceae	*Dilophus fasciola*	Rhodophyceae	*?Hypnea valentiae*
Phaeophyceae	*Hydroclathrus clathratus*	Rhodophyceae	*Actinotrichia fragilis*
Phaeophyceae	*Sargassum subrepandum*	Rhodophyceae	*Laurencia sp1*
Phaeophyceae	*Sargassum sp*	Rhodophyceae	*Catenella repens*
Phaeophyceae	*Ectocarpale sp*	Rhodophyceae	*Gelidiella acerosa*
Phaeophyceae	*Colpomenia sinuosa*		

5.11 SEAGRASSES

Seagrasses are hydrophytes, which can grow, flower, go to seed, and germinate while fully submerged. They inhabit soft bottomed, shallow water areas of temperate, subtropical and tropical seas where they may form large meadows (Edwards & Head 1987; Kirkman 1990). Seagrasses play several key ecological roles in the marine environment; they are considered primary producers, food for herbivores, important in depositing and stabilizing coastal sediments and they provide habitats for many marine species.

Eleven species of seagrass have been reported in the Red Sea (den Hartog 1977; Lipkin et al., 2003). Out of the six species reported in the Gulf of Aqaba, only *Halophila stipulacea*, *Halophila ovalis* and *Halodule uninervis* were found at the Jordanian coast.

The distribution and abundance of seagrass communities have been investigated from 3 sites along the Jordanian coast of the Gulf of Aqaba (Fig. 5.14). The investigation showed that the seagrass *Halophila stipulacea* has the widest distribution in all sites. The other two s species *Halodule uninervis, and Halophila ovalis* were less abundant and were found only at shallow depths at the Tala Bay site. The seagrass distributions increased with increasing depth up to 12 m, and thereafter decline. However, in some shallow areas seagrass is completely absent (e.g. 2 m depth at Hotel Area) mainly due to the extensive human activities including swimming and boating in the area. Such activities can increase sedimentation and turbidity which is lethal to seagrass beds (Hulings 1979; Al-Rousan et al. 2005).

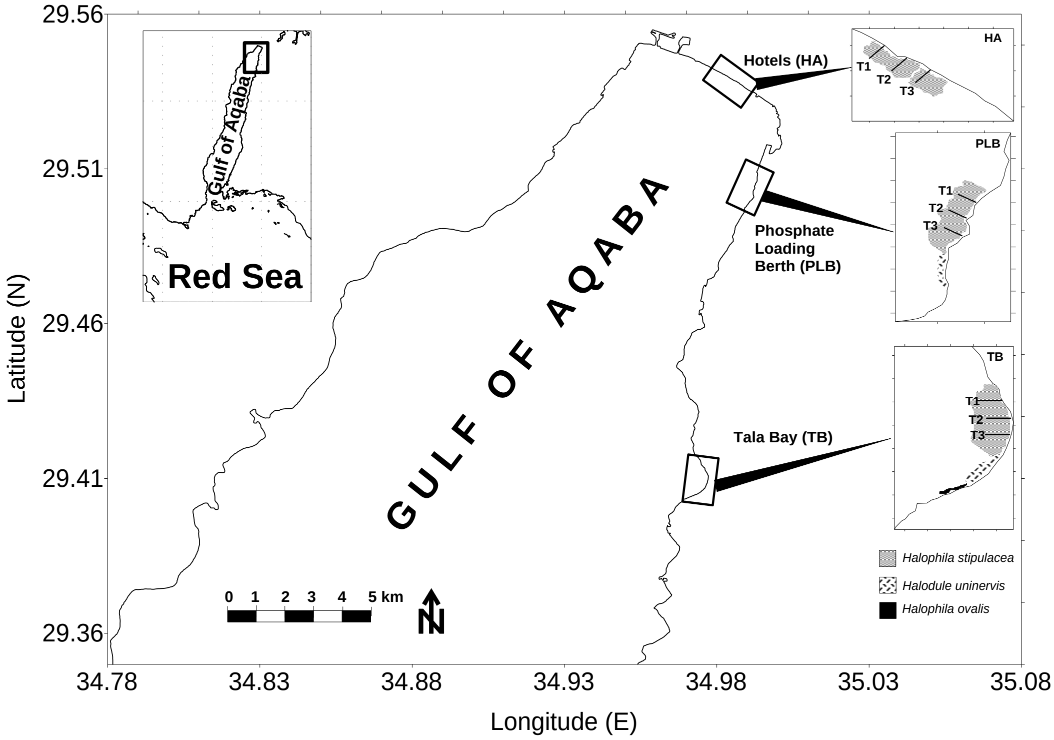


Figure 5.14: Location of occurrence of seagrass species and survey transects along the Jordanian coast (Al-Rousan et al., 2010).

Seagrasses have great economic value for fisheries that depend on the presence of coastal seagrass meadows. Human populations in some coastal countries have put various parts of these plants to good use over the centuries. Blades are by far the part most often used, primarily harvested as wrack blown ashore by storms. Some cultures have used seeds, rhizomes, and sheath fibres, as well as peat accumulated over hundreds or thousands of years. By comparison, human population in Aqaba did not inherit the culture of utilizing seagrass for such purposes.

5.12 ZOOPLANKTON

Despite the importance of zooplankton in marine food chains, most of the relatively few systematic seasonal studies in the Gulf of Aqaba focused on isolated taxonomic groups (Al-Najjar 2002). The zooplankton community > 150µm in the Gulf of Aqaba comprises 73 species included in 45 genera within 10 taxa namely; Tintinnidea, Foraminifera, Trachymedusea, Thecosomata, Cladocera, Ostracoda, Copepoda, Malacostraca, Chaetognatha and Urochordata. The zooplankton is represented mainly by holoplanktonic forms, which constitute about 91.5% of the total zooplankton abundance. These are mainly Copepoda and Chaetognatha, which together comprise more than 90% of the total zooplankton. Copepods alone contribute numerically 87% of the total zooplankton abundance with annual average of 693 organism/m^3. The adult forms constituted 65% of the copepoda. Hence production of this group is often considered to be equivelant to the secoundary production. The adult forms constituted

65% of the copepods, while the copepodite stages and nauplii constitute 29 and 6% respectively.

In total 56 copepod species belonging to 30 genera within 24 families in four orders; Calanoida (35 species); Cyclopoida (3 species); Pocilostomatoida (14 species) and Harpacticoida (4 species) which constitute 61, 17, 21, and 1% of the total copepod abundance, respectively. Most species (36 species) are classified as oceanic, while 10 species as neritic – oceanic, 8 species as neritic and 2 species as coastal neritic. 6 species were observed as a new geographical record for the Gulf of Aqaba. The annual average of the total zooplankton abundance in the Gulf of Aqaba is 803organisms/m^3. High abundance occurs in early summer (average 1089 organism/m^3) with a peak in June due to the high population densities of copepods (average 693 organism/m^3). Zooplankton density is lowest (average 553 organism/m^3) during autumn, which coincides with the lowest counts of copepods (average 470 organism/m^3) (Fig. 5.15).

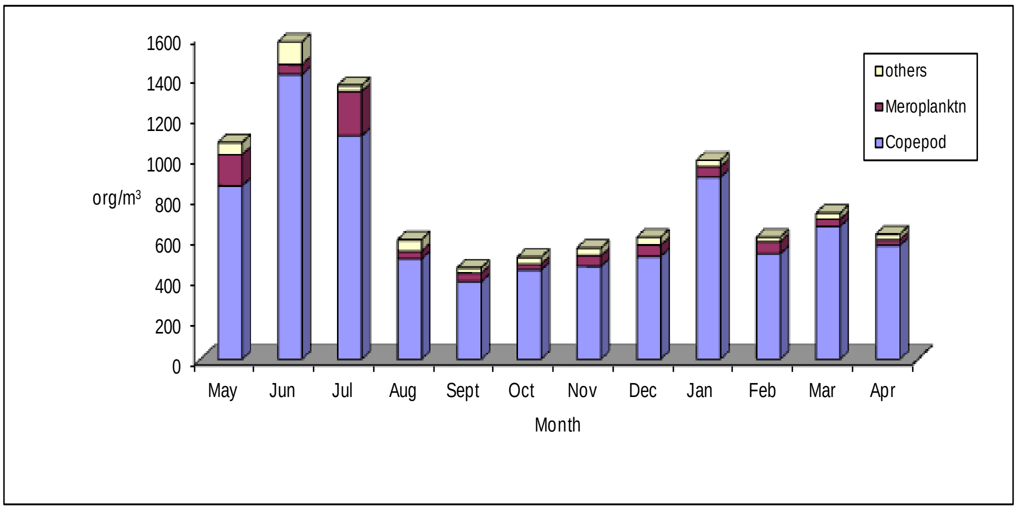


Figure 5.15: Monthly variation of total zooplankton in the Gulf of Aqaba (AL-Najjar 2002).

An inverse relationship was observed between equitability and the magnitude of the standing crop of zooplankton. Such an inverse relationship is attributed to the increase in density of only one group; the copepods, which comprised 86.3% of the whole zooplankton community

Al-Najjar (2002) compiled information about the geographic distribution of the studied species of copepods in the Rea Sea. Most copepod species are classified as epipelagic. He concluded that the function of the epipelagic zone as the feeding and nursery ground of copepods is particularly pronounced in the Gulf of Aqaba. Seven species found in the Gulf of Aqaba; (*Paracalanus indicus, Calocalanus clausi, Phaenna spinifera, Clausocalanus ferrani, Calanua robstior, Euchirella messinensis, Candacia tenuimana*, and *Corycaeus subullatus)*, are not found in other parts of the Red Sea. Two of them *Euchirella messinensis* and *Corycaeus subullatus*were recorded for the first time in the Gulf of Aqaba (Al-Najjar 2002). He found a marked and progressive decline in the species diversity from the open Red Sea (107 species, Delalo, 1966), into the Gulf of Suez (65 species, Halim, 1969), Gulf of Aqaba (55 species, Al-Najjar, 2002) and the Suez Canal (23 species, Abdelrahman, 1997).

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CHAPTER SIX

6 FISHERIES AND MARICULTURE

6.1 SUMMARY

The Jordanian coastline is very short (27km), of which about 12 km is occupied by the industrial establishments, ports, resorts and hotels. The fishers are not allowed to fish in many of these areas as well as in the protected areas or the areas used for ship anchorages. Therefore, most of the catch is restricted to the northern part of the coast, which is characterized by sandy bottoms and seagrass meadows, where more fish species can be found.

The short coastline of Jordan has a narrow continental shelf which certainly limits the commercial fishing to artisanal methods. About 230 fishers are licensed but only 26 of them renew their licenses, and all of them focus their effort on reef associated species and some pelagic species.

Fishers use small fibreglass boats 2.5-9m long, equipped with outboard engines, mostly of not more than 60 HP. The number of boats which were operating during the period 2008 - 2012 range between 58 in 2009 and 28 in 2011.

Fishers use various types of fishing gears including fish traps (local name: Sakhawah; plural Sakhawi), gill nets, seine nets (local name: Shwar) and hooks and line (local name: Khait-Wa- Sinnara), long line (local name: Sharak) and short long line (local name Amra).

Fishing methods like trolling and line do not have significant impacts on the fisheries or environment. By comparison, other methods (for example fish traps and gillnets) are associated with high number of incidental captures of non-target coral reef fishes and sea turtles, and cause adverse impacts on the environment and on this limited coastal resource. In addition, lost traps and gill nets are known as ghost traps continue to catch non-target fishes.

There is only one landing site in Aqaba where all of the fishers bring their catches near the end of their fishing day to sell it at this site. The site is located in the fishers' port in front of the Royal Navy check point. However, some fishers sell their catches directly to fish shops in Aqaba.

The larval abundances of fishes varied seasonally, reaching maxima during July and minimal abundances during winter months (November-February). If larval abundance reached its maximum during July, the fishes may reproduce in April, May or even in June.

Scombridae represent the most important commercial species in Aqaba. It represents more than 70% of the Jordanian marine fish catch, especially the most abundant migratory species *Katsuwonuspelamis* and *Euthynnusaffinis*. Other important commercial fish species are *Decapterusmacarellus*, *Decapterusmacrosoma*n which belong to the family Carangidae*;* followed by other species of the Xiphiidae and Istiophoridae families. Other economic important species are *Caesiolunaris, Caesiosuevica* and *Caesiovarilineata.* Two families, Lutjanidae (Snappers), and Haemulidae (Sweetlips) are not common in the Jordanian coastal waters, compared

with their abundance, frequency of appearance and number of species in the central and southern Red Sea.

Local fish consumption varies from year to year. The average fish consumption per capita was (2.7) kg in 1998 and (2.8) kg in 1997. The maximum consumption was highest in 2011 (32,902 tonnes). This increase can be attributed to the millions of refugees who came to Jordan from Syria and Iraq as a result of the political conflicts in the region. The ratio of the local fish production to the imported fishes is very small as it ranges between 0.02 in the year 2011 and 0.05 in 2012.

The Ministry of Agriculture Jordan started collecting data on fisheries during the fifties, sixties, seventies and mid eighties (1985) of the last century. Unfortunately, after then, this effort has been stopped. Recently however, Department of Statistics started new efforts to collect such useful data, which covers the period from 2008 to 2012.

There are two Cooperative Fishers' Societies in Aqaba. The first society with 139 members has cool storage room just near the Royal Navy check point and another cool room near the town centre. The second cooperative society is "Thagher Jordan Cooperative Fishing and Agriculture Society "with 89 members. The two societies rarely receive support from the government or from other funding agencies. Therefore, they cannot provide their members with financial loans or any other type of support.

Fisheries are considered important renewable natural resources, which have important economic role and therefore, it is important to enforce fishing regulations pertaining to nature conservation and place increased emphasis on marine species of fishes. This should include the development of marine environment strategies that guarantee the protection of marine environment in general, and fishes in particular.

Fisheries in Jordan are facing increasing pressure from the demand created by the continued population increase, habitat degradation, pollution and global climate change. The main areas that can be identified as requiring action to facilitate the conservation of marine biodiversity are the promotion of the conservation and sustainable use of fish stocks and feeding grounds through control of exploitation rates and the establishment of technical conservation measures, reduction of the impact of fishing activities and other human activities on non-target species, avoidance of aquaculture practices that may affect habitat conservation through occupation of sensitive areas (coral reef), improved target species size selectivity to reduce discards of juveniles, temporal or spatial closures, and introduction and promotion of fishing methods that have a reduced physical impact on the environment.

Though Jordan has issued many laws, regulations, and instructions that pertain to the protection of the coastal and marine environment of the Jordan Gulf of Aqaba and its resources, it is however, of utmost importance to firmly enforce these legislations. In addition, it is important to develop a management plan for fishery resources based on outputs of scientific research and on consultation with the local scientific community. The management plan should include monitoring, control and surveillance (MCS) of fish stock. Conservation of fishes is a multi-disciplinary task, and cooperation at the regional level is important. It is also very important for Jordan to conserve its marine resources through education and awareness and implementation of legislations.

The current national fish production from fresh and marine water resources is about 300 tonnes per year, which comprises only about 1% of the national fish consumption.

Thus, environment friendly aquaculture may be a future choice to increase fish production. Since Jordan is depending heavily on healthy coral reefs for the development of their growing tourist industry, researchers in the MSS are attempting to develop an integrated aquaculture system in which minimum wastes go into the natural marine environment, in addition to the development of low cost waste treatment technology for use in intensive land-based coastal aquaculture.

6.2 FISHERIES IN AQABA MARINE WATERS

6.2.1 INTRODUCTION

Fish are among the most important food resources of the world (FAO, 1994). Fish and shellfish, including crustaceans and molluscs are considered as an excellent source of high-grade protein consumed by humans. Fish of the Red Sea support marine fisheries of the countries surrounding its coastline such as Egypt, Jordan, Sudan, Saudi Arabia, Yemen, Djibouti and Ethiopia. The importance of these marine resources varies from total dependence in the case of Djibouti to only minor importance as in the case of Sudan (FAO, 1989).

The Jordanian coastline runs south for about 27 km from the most northern eastern tip of the Gulf that extends for about 180 km to the sill of Tiran in the south. Sea water within this northern portion is characterized by its low productivity (Levanon and Spanier, 1979) and the absence of any fresh waters feed from inland sources except rare and very occasional fresh floods that come through wadis (small valleys) between the mountains. The marine environment in this area had suffered for sometime before 1970 from the illegal use of dynamite for fishing purposes. It suffered also from the use of depth charges by the Israeli military forces. In addition, during the last three decades, intensive industrialization, and trading and recreational activities has adversely affected the water communities including the fringing coral reefs and fishing yield in this part of the Gulf of Aqaba. The short coastline of Jordan has a narrow continental shelf which certainly limits the commercial fishing to artisanal methods. About 230 local fishers are licensed, but only 26 of them renew their licenses in 2014, and all of them focus their effort on reef associated species and some pelagic species. Although, commercial fishing in Jordan is of little significance, a gradual decline of commercial fish production has been observed during the last few years. Jordan fishers operate about hundred of medium and small boats, which vary in length from 2.5 to 9.0 m, and usually use hand lines, traps and gillnets as fishing gears. Their fishing grounds vary from time to time, mainly due to security restrictions. Few years ago they were able to go as far as Tiran Island and other fishing grounds in Saudi Arabia and Egyptian waters in the southern part of the Gulf of Aqaba, the use of which for fishing is not possible any more. This was reflected by law fish catch from the Gulf, despite the efforts made to benefit from the FAO UNDP, Arab Fishing Company, the Arab League and recently from the FAO project; "RAP/18/ 2001 Development of fisheries in the areas of the Red Sea and Gulf of Aden".

One of the most significant environmental management tools adopted in Jordan is the declaration of 7 km (25%) of the Jordanian coast as a marine reserve. This has pronounced benefits for the marine environment, but creates tremendous pressure on the fishers' community because it limits their already extremely limited fishing grounds. Industry and tourism which occupy a substantial part of the Jordanian coast are restricting fishing activities even further.

6.3 FISHERIES, FISHING EFFORTS AND MANAEMENT WITHIN THE JORDANIAN COASTAL WATERS OF THE GULF OF AQABA

6.3.1 FISHERIES DATA COLLECTION/FISHERIES STATISTICS

The Ministry of Agriculture in Jordan started collecting the fishery data during the fifties, sixties, seventies and mid eighties (1985) of the last century. In 1985 the Ministry stopped collecting the data due to the very low catch per unit effort and after Jordan fishers were unable to have permits to fish in the Egyptian and Saudi coastal waters down south to Tiran Straits in 1982. In recent years, however, and particularly during the period 2008-2012, Department of Statistics made started a new attempt to collect some data on fisheries. In addition, researchers from the University of Jordan in Aqaba made several, but scattered attempts to collect data on marine fisheries in Aqaba. Very recently and still ongoing research is being conducted to establish a base line data on the status of fisheries in Aqaba, to explore the deep sea fish stocks, and to develop a fishery management plan in Aqaba.

6.3.2 FISHING GROUNDS

The Jordanian coastline is very short (27km) of which about 12km are occupied by the industrial activities, ports, resorts and hotels. Most of the catch is from offshore water, more than 400m from the favourite locations for the fishers in the northern part of the coast, which are characterized by sandy bottoms with seagrass meadows, where more fish species can be found. In addition, these locations are closer to the fishers' port and the cost of the consumed fuel by fishing in them is much less than going far offshore. The Jordanian fishers are not allowed to fish in these and many other areas because they are protected or used for ship anchorages as indicated in Table 6.1. However, sometimes, in violation to the laws, fishers collect baits in the vicinity of the shoreline and piers, due to lack of enforcement of the laws by the official authorities.

Table 6.1: Prohibited sites for fishing within Jordan waters in the Gulf of Aqaba

Prohibited sites
Aqaba Marine Park
Anchorages area unless free from ships
Area Southern to Tala Bay
In the vicinity of Royal Palace
Borders Area
In the vicinity of Piers

6.3.3 FISHING EFFORT/ FISHING BOATS

Obviously, the fishery resources are small or limited due to the narrow continental shelf and the very limited shoreline of the Jordanian coast. Fishers use small boats of length range between 2.5-9m. Boats are made mostly of fibreglass, though few boats are made of wood. All the working boats operated during the year 2012 use out board engines mostly of not more than 60 HP. Fishing boat license is required to obtain the fishing permit. The mandated Ministry of Agriculture gave this authority to the Aqaba Special Economic Zone Authority (ASEZA)/Aqaba Marine Park to issue such license. The record of each boat includes type, length, and engine type and power. The number of boats operating during the period the years 2008 to 2012 is shown in Table 6.2. Private and recreational boats and in some cases glass boats used to fish especially during Swordfish and tuna seasons. Usually, there are no foreign boats fishing in the Jordanian coast.

Table 6.2: Type of most common fishing boats used in the Jordanian coastal waters of the Gulf of Aqaba during the years 2008 to 2012 (Extracted from Department of Statistics reports).

Length of Boat	2008	2009	2010	2011	2012
	Number of Boats				
less than 6 meter	37	44	25	21	38
6-9 meter	5	14	6	7	8
24 meter and more	1	0	0	0	0
Engine Power					
less than 20 horse power	3	8	7	0	3
21-50 horse power	36	44	14	24	36
51-100 horse power	4	6	9	4	7
101 horse power and more than	0	0	1	0	0

The number of operating fishing boats varies from one year to another (Table 6.2). In 2014 however, the number of operating fishing boats has increased to 59. The length of most boats ranges between 4 and 6m, and most of them are provided with outboard engines that range between 25 and 50HP, but few of which are using outboard engines between 51 and 100HP. As a consequent, the number of fishing movements has increased significantly during the first three quarters of the year 2014 to 11214 movements compared to 9125 movement in the year 2012.

6.3.4 FISHING METHODS AND GEAR

Different types of fishing gears and methods are practiced in Aqaba. However; most fishers are still using artisanal methods. Sometimes Jordanian fishers use more than one fishing gear during single fishing trip. The gears include fish traps (local name: Sakhawah; plural Sakhawi), gill nets, seine nets (local name: Shwar) and hooks and line (local name: Khait-Wa-Sinnara), long line (local name: Sharak) and short long line (local name Amra). The various fishing gears such as hand lines, nets and other fishing logistics like ropes and floats are available in Aqaba, but their prices are considered quite high since most of these are imported from outside the country. This certainly does not help fishers not to continuously maintain their fishing tools.

6.3.4.1 Baited Wire-Mesh Fish Trap - (Local Name: Sakhwah; plural Sakhawai)

The most common type of (Sakhwah) in the area is a rectangular wire-mesh construction with a flat base and a funnel like entrance. The length of the base varies between 1-2m. The mesh size of the trap is generally between 2 and 5cm. The funnel acts as non- return valve; a fish will swim into the trap to reach the bait inside but is unlikely to be able to find its way out and escape. Bait varies according to the target species. Bread and trash fish are widely used, but sometimes green algae is collected from the shore and used as bait. The trap is fixed with a rope which is tied to a float. The most common fish species caught by such traps are listed in Table 6.3.

Table 6.3: Fish species observed or reported to have been caught by the use of traps.

Scientific name	English name
Synodus variegatus	Variegatus lizardfish
Epinephelus fasciatus	Blacktip grouper
Variola louti	Moontail seabass
Parupeneus forsskali	Red Sea goatfish
P. macronema	Longbarbel goatfish
Scarus sordidus	Bullethead Parrotfish
Calatomus viridescens	Dotted Parrotfish
Leptoscarus vaigensis	Marbeled parrotfish
Siganus luridus	Squretail rabbitfish
S. rivulatus	Rivulated rabbitfish

6.3.4.2 Bottom-Surround Gill Net (local name-Hakoora or Shwar)

The gill net comprises a sheet of netting up to 10m in depth and about 60m long. It is mounted on polypropylene ropes, top and bottom; one rope is weighted with stones or lead weights while floats are fixed to the other, causing the net stand up vertically from the seabed. Mesh size is variable, depending on the target species; the mesh sizes of the nets inspected in this area varied between 2.5 and 8cm. In the "Hakoora" several nets may be tied together to make a total length 200m or more. About 6 to 8 permanent floats are attached either with cement blocks or with coral heads. The attached nets array is then arranged in a cylinder-like shape and fixed to these floats. Most of the times the nets "Hakoora" are left in the water for several weeks and the commercial fishes only are collected daily by a skin diver. However, this type of fishing gear is not practiced any more in Aqaba. They have been banned since 8 years ago.

Impact: In Aqaba, gillnets are associated with high numbers of incidental captures of non target coral reef fishes, and sometimes they catch sea turtles.

6.3.4.3 Bottom Gillnet

The construction of this type of net is nearly similar as the above one, but the way of set up of this net is different, this is positioned on the sea bottom either straight or zigzag.

Impact: In Aqaba, some concern with this method is ghost fishing by lost nets and by-catch of small size fishes, non-commercial fishes, sea turtles, and diving seabirds.

6.3.4.4 Longline

This method is used as a commercial fishing technique. It uses a long line, called the main line, with baited hooks attached at intervals by means of branch lines. Lines can also be set by means of an anchor (weight) on both sides of the line. Floats such as empty plastic and tightly closed gallon are usually tied to both ends of the line and floats at the surface.

Impact: Longline fishing is controversial in some areas because of by-catch; fish is caught while seeking another species or immature juveniles of the target species. In Aqaba various moray eels were caught with this method (Khalaf, unpublished data

6.3.4.5 Short Longline

The structure of the short long line is similar to the long line, but the baited hooks are about 25.

Impact: Negative impacts are much less than in the long line.

6.3.4.6 Handline

This is primarily a monofilament with single or multiple barbed hooks, baited with lure or bait with cut pieces of fish or complete live silver-sided fish. These are used by most of the fishing crafts. This is a selective method used to catch mainly Tuna and Jacks.

Impact: It is a selective method of catch and has the least impact compared to other fishing gear.

6.3.4.7 Trolling (Local name: Jurjaera)

Trolling is a method of fishing where one or more fishing line, baited with lure or bait, are drawn through the water. This may be behind a moving boat. Trolling is used to catch pelagic fish such as tuna, mackerel and kingfish.

Impact: It is a selective method of catch and has the very little negative impact compared to other fishing gear. Table 6.4 shows the most common deep fishes caught by each fishing methods that are used by fishers in Aqaba, Table 6.5 shows the most common coastal water fishes caught by fish traps, longline, gill nets and hook and line.

Table 6.4: Most common fish species caught in deep sea of the Gulf of Aqaba.

Fish traps	Long line	Short long line
Polysteganus coeruleopunctatus *Lethrinus borbonicus* *Argyrops spinifer* *Epinephelus morrhua* *Upeneus davidaromi*	*Gymnothorax johnsoni* *Variola louti* *Epinephelus fasciatus* *Gymnothorax griseus* *Epinephelus morrhua* *Argyrops spinifer* *Argyrops filamentosus* *Cephalopholis oligosticta* *Polysteganus coeruleopunctatus* *Decapterus russelli* *Synodus variegatus* *Cephalopholis hemistiktos* *Thamnaconus modestoides* *Saurida tumbil*	*Xiphias gladius* *Iago omanensis* *Trichiurus lepturus*

Table 6.5: Most common fish species caught in Jordanian coastal waters of the Gulf of Aqaba

Fish traps	Long line	Gill net	Hook and line
Siganus luridus *Siganus argenteus* *Calotomus viridescens*	Sidera grisea *Cephalopholis sexmaculata*	*Lethrinus variegatus* *Caesio varilineata* *Pterois miles*	*Coryphaena hippurus* *Euthynnus affinis*

Chromis pelloura *Scarus fuscopurpureus* *Chaetodon paucifasciatus* *Heniochus diphreutes* *Parupeneus macronema* *Scarus ferrugineus* *Apolemichthys xanthotis* *Lutjanus kasmira* *Sufflamen albicaudatum* *Tetrosomus gibbosus* *Pterois miles* *Cephalopholis miniata* *Variola louti* *Genicanthus caudovittatus* *Bodianus anthioides*	*Epinephelus fasciatus* *Parupeneus heptacanthus* *Abalistes stellaris* *Parupeneus rubescens* *Gymnothorax elegans*	*Mulloidichthys flavolineatus* *Lethrinus borbonicus* *Parupeneus rubescens* *P. heptacanthus* *Pomacentrus trichourus* *Tetrosomus gibbosus* *Scolopsis ghanam* *Sphyraena flavicauda* *Decapterus macarellus* *Terapon jarbua* *Gerres oyena* *Dascyllus trimaculatus* *Pterocaesio chrysozona* *Centropyge multispinis* *Priacanthus hamrur* *Fistularia petimba* *Mulloidichthys vanicolensis* *Epinephelus areolatus* *Decapterus russelli* *Sphyraena putnamae* *Aluterus monoceros* *Caesio suevica* *Heniochus diphreutes* *Lethrinus nebulosus*	*Katsuwonus pelamis* *Gymnosarda unicolor* *Katsuwonus pelamis* *Scomberomorus commerson* *Thunnus albacares* *Thunnus tonggol* *Istiophorus platypterus* *Sphyraena barracuda* *Sphyraena flavicauda* *Sphyraena forsteri* *Sphyraena putnamae*

6.3.4.8 Fish Landing

Nowadays, there is only one landing site in Aqaba where all of the fishers bring their catches near the end of their fishing day to sell it at this site. The site is located in the fishers' port in front of the Royal Navy check point. However, some fishers sell their catches directly to few fish shops in Aqaba.

The annual fish landing of the most common marine fishes caught by Jordanian fishers during the years 2008 to 2012 are given in Table 6.6. The table shows clearly the large fluctuation in the landing size during the five years (DoS Reports-NSSAD 2008, 2009, 2010, 2011 and 2012). It shows also the absence of some species from the record after 2009, a matter which deserves some kind of investigation.

6.4 SPAWNING AND FISHING SEASONS

Froukh (2000) indicated that the larval abundances varied seasonally, reaching maxima during July while the minimum abundances occurred during winter months (November-February). If larval abundance reached its maximum during July, the fishes may reproduce in April, May or even in June. Table 6.7 indicate the spawning season for fishes in Aqaba.

Table 6.6: Fish landing for the most important species in Aqaba during 2008-2012(Extracted from Department of Statistics reports).

Family	Local name	2008	2009	2010	2011	2012
Carangidae	sardeena	52054	10770	10873	12609	69766
Scombridae	Tuna	77447	10371	66105	73388	92057
Sparidae	Fareedin	2522	3528	5270	1084	1660

Xiphiidae	Faras	23378	94556	27306	14943	32029
Siganidae	Sigan	3136	34	371	2639	1359
Carangidae	Reem	1970	0	815	1146	1419
Mullidae	Sultan ibraheem	1103	614	86	0	0
Lethrinidae	Shaoor	3777	2710	1768	0	693
Triakidae	Qersh	1201	285	8746	5363	3620
Istiophoridae	Saif	265	1986	231	0	
Scombridae	Jamberio	1138	0	0	0	0
Scombridae	Fatlah	2355	0	0	0	0
Scombridae	shik	0	0	6138	2431	1568
	Total	**170346**	**124854**	**127709**	**113603**	**204171**

Table 6.7: Spawning season for some fishes in the Jordanian coastlines of the Gulf of Aqaba.

Fishes	Spawning season
Mullet	Januaryto December
Damselfish	Aprilto August
Grouperspecies	Mayto August
Parrotfish	Aprilto September
SilverSides	Januaryto June and November to December

More than 70% of Aqaba fish production is tuna fish. Fishing tuna season starts in October and extends till March. This is reflected on the increased number of monthly fishing trips from October to March or even April as indicated by Table 6.8.

Table 6.8: Average of boat trips per month between April 1996 and March 1997.

Month	Average number of trips
Apr-96	33.3
May-96	25.8
Jun-96	21
Jul-96	21
Aug-96	17.3
Sep-96	24
Oct-96	43.1
Nov-96	44.3
Dec-96	40.8
Jan-97	38.5
Feb-97	31.3
Mar-97	35.1

6.5 COMMERCIALLY IMPORTANT SPECIES

The collected data (Khalaf, unpublished) indicate that the family Scombridae represents the most important commercial species in Aqaba. It represents more than 70% of the Jordanian marine fish catch, specially the most abundant migratory species *Katsuwonus pelamis* and *Euthynnus affinis*. Other important commercial fish species belonging to the family Carangidae are *Decapterus macarellus,Decapterus* *macrosoma;* followed by species of the families Xiphiidae and Istiophoridae. Other economic important species are *Caesio lunaris*, *Caesio suevica* and *Caesio varilineata*.

Two families, Lutjanidae (Snappers), and Haemulidae (Sweetlips) were not common in the Jordanian coast compared to their abundance, frequency of appearance and number of species in the central and southern Red Sea. It is very rare to see a member of these families in the fish catch or while diving in Aqaba waters. Reef structure in the Jordanian coast of the Gulf of Aqaba is smaller in size than those of the central and southern Red Sea. Accordingly, the existing habitat would not provide the suitable shelter for them. Moreover, the photic zone in Aqaba is confined to a narrow zone, which would affect the productivity in a negative term for large commercial fish (Khalaf 2004).

The most abundant shallow water pelagic species are the silver-side fish *Atherinomorous lacunosus* and the clupeid fish *Spratelloides gracilis*, both of which are used by Aqaba fishers as bait. The most common fish inhabitant of the deep water of the most northern part of Gulf of Aqaba are (Family: Tiakidae:*Iago omanensis*); (Family: Rhinobatidae, *Rhinobatos punctifer*); (Family: Muraenesocidae, *Mureanesox cinereus*); (Family: Carangidae, *Carangoides equula*); (Family: Lutjanidae, *Paracaesio sordid*); (Family: Sparidae, *Polysteganus coeruleopunctatus*, *Argyrops spinifer*); (Family: Mullidae, *Upeneus davidaromi*); (Family: Trichiuridae, *Trichiurus lepturus*); (Family: Gempylidae, *Thyrsitoides marleyi*) and (Family: Xiphiidae , *Xiphias gladiu*) (Khalaf, personal observation).

6.6 FISH CONSUMPTION VS. IMPORTS

Figure 6.1 shows accumulated data collected on fish consumption and the ratio between the locally produced and imported fish during the years 2000 to 2012 in Jordan. Fish consumption was calculated from the total imported fish including fresh, frozen, smoked and canned fish, in addition to the local net production of marine fish and cultured freshwater fish in Jordan. Local fish consumption varies from year to year. The maximum consumption was highest (32,902 tonnes) in the year 2011. This increase can be attributed to the increasing number of refugees who fled to Jordan from Syria and Iraq as a result of the political conflicts in the region. The ratio of the local fish production to the imported fish ranges between 0.02 in 2011 and 0.05 in 2012 (Table 6.9).

This indicates that the fish consumption as well as the net imported and produced fish are exhibiting similar pattern of increase with time. But, the percent ratio of the net fish production to the net imports of fish is still very low even if marine fish and freshwater culture fish were included. This ratio could be smaller if marine fish only was considered. The data suggest that the catch size of marine fish could support less than 0.05% of the total consumption of fish in Jordan.

The average consumption of fish per capita is always fluctuating; it shows decrease or increase from year to year, this change is according to the undulation of fish imports due to the international market prices which are strongly affected by the general political and economical situation. The average of fish consumption per capita was (2.7) kg in 1998, while the average was (2.8) kg in 1997. The average of fish consumption per capita showed a decrease by an average (0.1) kg (Khalaf 2000).

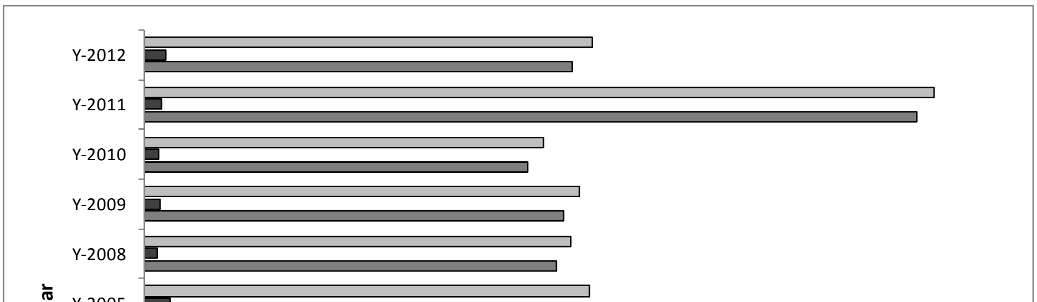

Figure 6.1: Quantity of fish imports, local production and local consumption for the years 2008-2012.

Table 6.9: Fish imports, local production, ratios of inland and marine production and local consumption (tonnes) during the years 2008-2012(Extracted from Department of Statistics reports).

Fish	Year 2008	Year 2009	Year 2010	Year 2011
Imported	17,190	17,453	16,003	32,197
Inland production	382	441	486	586
Marine production	173	219	255	119
Local production Inland + marine	555	660	741	705
Ratio of Inland Production	0.02	0.03	0.03	0.02
Ratio of Marine Production	0.01	0.01	0.02	0.00
Ratio of Local production	0.03	0.04	0.05	0.02
Local consumption	17,745	18,113	16,744	32,902

6.7 COOPERATIVE SOCIETIES

There are two Cooperative Societies of fishermen in Aqaba. The first and oldest society is the Fishermen Cooperative Society with139 members**.** The second society is Thagher Jordan Fishermen and Agriculture Cooperative Society with 89 members.

6.7.1 ROLE OF COOPERATIVE SOCIETIES FOR THE MEMBERS

The Fishermen Cooperative Society owned storage rooms just near the Royal Navy checkpoint at the fishers' port in addition to a cool storage room near the town centre. The two societies rarely receive financial support from the government or other funding agencies. Therefore, they cannot provide the members with any financial loans or any other type of support.

6.8 PROTECTION OF FISHERIES

Fisheries are considered renewable natural resource, and therefore it is important to enforce fishing regulations pertaining to nature conservation and place increased emphasis on marine species of fishes. This should include the development of marine environment strategies that guarantee the protection of marine environment in general, and marine fish in particular.

Jordan has issued many laws, regulations, and instructions that pertain to the protection of the coastal and marine environment of the Jordan Gulf of Aqaba and its resources (Box 6.1). However it is of utmost importance to firmly enforce these legislations. Furthermore, and because conservation of fishes is a multi-disciplinary task, it is very important for Jordan to conserve its marine resources through education and awareness.

Box 6.1: Laws, regulations and instructions relating to fishing in the Jordan Gulf of Aqaba.

1. **Fishing Law No. 5 for the year 1943:**

   This law is known as Fisheries Law, it says: the term "fish" in this law means fishes, sponges, clams, echinoderms, sea turtles, and marine mammals. It has provisions on licensing, prohibited methods of fishing which include the use of explosives and poisonous materials. It has provisions on the importance of determination of fishing areas and seasons without specifying them, fish sizes to be caught and net mesh sizes used for fishing without specifying them. Unfortunately, the law does not specify the fishing grounds; net and traps mesh size; or fish reproduction season during which fishing is not allowed.

2. **Agriculture Law No. 30 for the Year 1973: (*it has been replaced by 2002 law which was adopted and implemented at 2014*)**

   Chapter 12 of this Law was devoted for fishery resources and articles 180 to 186 are on fishery. It is almost similar to what has been indicated in Law no. 5 for the year 1973.

3. **Agriculture Law No. 44 for the Year 2002:**

   Article 55 is dealing with fishing times, methods, areas, types of fishes, and prohibits the use of wrong fishing methods such as poisons and explosives. It also lists the fines on violations.

4. **Law of Protection of Marine and Coast Environment. Issued Under Article (34) of the Environmental Protection Act No. (12) for the Year 1995:**

   This law deals mainly with marine protections and regulates fishing in the marine protected areas. Article (5) prohibits breaking, possession transport, sell or rent any kind of coral skeleton or living or dead animals or marine rocks except for scientific purposes or any other purposes, approved by the Minister upon the recommendation of a committee formed for this purpose. It states also that it is prohibited to fish or practice any malicious activity in the protected areas. Article (6) organizes permits for marine environment research. Other articles deals with environmental inspection for the ships and ports, oil spills and compensation fee as a result of environmental pollution of any polluted substances. However, this law does not regulate fishing outside marine protected areas.

5. **Law No. 21 for the Year 2001: Environmental Protection By-Law in Aqaba Special Economic Zone Issued Under Articles (52) and (56) of The Aqaba Special Economic Zone Law No (32) for the Year 2000:**

This law deals and organizes sea water uses, solid wastes, dangerous materials, radioactive materials, wastewater, and cooling water disposal. According to the law, no permits are granted to any establishment that exercises economic activity that produce and dispose solid wastes, except after The Responsible authority check that the establishment has complied with environmental requirements prescribed for this purpose. It also has articles that deal with environmental impact assessment, environmental auditing, protection of air, and protection of marine environment. It includes 7 annexes; Annex (1) explains what are the required information from the project owner; Annex (2) describes the projects that require a full environmental impact assessment (first category); Annex (3) Lists the projects that need initial ecological assessment (category II); Annex (4) Lists the project types that require the application for a preliminary environmental impact assessment; Annex (5) showed the standards of environmental risk for the projects in the second category i.e. initial ecological assessment; Annex (6) explains what are the information that must be included in the environmental assessment document; Annex (7) indicates the experiences related the environmental impact assessment process. However, this By-Law, does not deal in a direct way with issues pertaining to the organization of fisheries sector in Aqaba.

6. **By-Law No (22) for the Year 2001. The Aqaba Marine Park By-Law and amendments:**

This by-law deals with the Aqaba Marine Park borders, aims, structure and tasks of the park committee, and annual plan for park management. Article (12a) prohibits in the park zone any work or actions or activities or measures that would destroy, damage or deteriorate the natural environment, destroy terrestrial or marine life, or prejudice the aesthetic level of the park area. Article (12b) prohibits catching transporting harming, or killing wild terrestrial or marine animals. It also prohibits introducing any exotic species of plants or animals to the park area. Article (13) authorizes the employees (rangers) of the park, and the public security to do the necessary actions in accordance with the provisions of the legislation to enforce the law and the by-law provisions.

7. **Instructions No. (83) For the Year 2005: Special Instructions to Organize Access to the Aqaba Marine Park**

These instructions organize cars entry to the park, tourists and sports activities within the park. These instructions prohibit all forms of fishing, including fishing coloured coral reef fishes. It also prohibits the transferring or taking any organisms, sediments, or corals for any purpose except by a special permit from the chief commissioner.

8. **Instructions No. (84) for the year 2005: Special Instructions to Organize the Work of the Boats Within Aqaba Marine Park:**

These instructions organize boat entry to the park, what is prohibited, and what diving boats should do when they enter the park.

9. Instructions Numbers (g/5 to g/15) for the Year 2006. Issued by the Minister of Agriculture Under the Agriculture Law No (44) for the Year 2002, Instructions No. (g/5) for the Year 2006 for the Regulation of Fishing in Aqaba:

These are the latest and detailed instructions. It was issued in order to organize fishing in Aqaba. It has provisions on fishing permits, net mesh size, trap mesh size, and define No-fishing areas. The instructions prohibit the collection of ornamental fishes, and rare and endangered species such as marine turtles, dolphins, and sharks. It prohibit fishing by the extended and permanently fixed gill net construction (Local name: Hakoora) which were used before to catch target and non-target fish. Banning this damaging method is considered a success for the management of fishery resources in Aqaba. However, these instructions lack the list of organisms and fish species which should not be collected or fished. This list should be prepared in collaboration with the scientific community and should contain the season or months during which fishing is permitted. Provision on the necessity for monitoring of the fish catch should be included in the instructions in any future amendments.

However, it is important to develop a management plan for fishery resources based on the scientific research and in consultation with the scientific community. The management plan should include Monitoring, Control and Surveillance (MCS) for the fish stock. It is necessary to build up and develop the monitoring and surveillance capabilities of the environmental institutions and departments in ASEZA as well. United Nation Developing Programme (UNDP) is supporting a running research project entitled ``The Establishment of Baseline and Development of Management Plan for Fisheries in Aqaba``. Among the aims of the study is to examine the unexploited deep-sea populations targeted toward deep sea fishing and minimize the pressures on coral reef fish species and assess the fish stocks for developing a management Plan for fisheries in Aqaba. The results of this research will serve to develop a fishery management plan in Aqaba in harmony with the laws and regulations in the Red Sea neighbouring countries.

6.8.1 OVER EXPLOITATION OF FISHERIES

Fisheries within Jordan are facing increasing pressure from the demand created by the population increase, habitat degradation, pollution and global climate change. The industrial, ports, tourism, economic development, fishing practices and fishing methods have adversely affected the marine and coastal environment and its resources including fisheries. The uncontrolled fishing practices and fishing in the same and very limited fishing grounds has led to overexploitation of fishes within the territorial waters of Jordan. This situation requires urgent management actions to control this serious exploitation.

With respect to fisheries the main areas that can be identified as requiring action to facilitate the conservation of marine biodiversity are:

(1) The promotion of the conservation and sustainable use of fish stocks and feeding grounds through control of exploitation rates and through the establishment of

technical conservation measures to support the conservation and sustainable use of fish stocks. Measures available include inter-alia fishing exclusion areas (mainly for the protection of dense aggregations of juvenile fish), more sustainable trap building material, and mesh sizes. Each measure should be applied according to its merits and expected conservation effect and monitored to ensure efficacy.

(2) The reduction of the impact of fishing activities and other human activities on non-target species and on marine and coastal ecosystems to achieve sustainable exploitation of marine and coastal biodiversity.

(3) The avoidance of aquaculture practices that may affect habitat conservation through occupation of sensitive areas, i.e., coral reef and inter-tidal areas, pollution by inputs and outputs from fish farms and genetic contamination by possible releases or escapes of farmed species or varieties.

(4) Improved target species size selectivity with the aim to reduce discards of juvenile fish and new or amended minimum landing sizes for target species.

(5) Temporal or spatial closures to enhance survival of juveniles or spawning concentration, including sub-populations, to maintain genetic diversity especially for species listed in environmental legislative instruments.

(6) Introduction and promotion of fishing methods that have a reduced physical impact on the environment.

6.9 AQUCULTURE IN GULF OF AQABA

6.9.1 FISH PRODUCTION FISH FARMING AND FISH FARMING IN JORDAN

A number of inland fish farming projects began in the mid 1960s. Most of them were established in the Jordan Valley due to the availability of water. All these farms reared various *Tilapia* species such as *Oreochromis niloticus, O. zilli* and *O. galilaea.* Very modest overall aquaculture production fluctuating with a downward trend over a six years period (2000-2006) between 563 tonnes in 2000 to 420 tonnes in 2006 Tilapia or (*Musht-Arabic*) is the most produced fish in Jordan representing 71 percent of total local production.

Coastal aquaculture, or as it is called Mariculture, has also been investigated although Jordan has a very short (27 km) coastline in the northern parts of the Gulf of Aqaba. In Aqaba, the port infrastructure, tourism facilities and the pollution prevention laws and regulations put additional constraints toward the establishment of mariculture projects except for some experimentation carried out by the Marine Science Station (University of Jordan and Yarmouk University) located in Aqaba.

Early experiments in mariculture have started in Jordan (Marine Science Station, Aqaba) in mid 1980s. The purpose of this pilot experiment was to establish mariculture in Jordan and study the technical and economic feasibility of industrial scale farming activities. The Mediterranean species Sea bass *Dicentrachuslabrax* was introduced into the Jordanian Gulf of Aqaba. The experiment, proved that the environmental condition at Aqaba were suitable for the development of such mariculture. However, because the fry, raw material, feed were all imported in addition to the high cost prevented moving with it further to the commercial scale and therefore the experiment was not repeated both for the high cost and environmental concerns.

6.9.2 DEVELOPMENT OF ENVIRONMENTALLY FRIENDLY MARICULTURE

Environmentally friendly aquaculture practices that allow for the generation of high-value commodities without harming the environment do exist. Realizing the essential need of mariculture to Jordan and the threats associated with it to the coral reef, experimentation at the Marine Science Station (MSS) with both approaches are ongoing in an attempt to provide Jordan with needed living resources and yet exert no harmful impact on the highly valuable and extremely limited coastal habitats (Plate 6.1). Research is currently underway on the reproduction of the coral reef species giant clam (Tridacnidae). The mixotrophic life-style enables giant clams to tap different nutrient sources and achieve high growth rates in spite of low ambient nutrient concentrations. This makes them particularly amenable, conceptually, for integrated farming with other marine ornamentals in closed systems. Production of the organism results in a suite of products: the shell, mantle and adductor muscle that all have good market value. The end goal is to establish an ecological model that results in waste level well below the assimilative capacity of the coastal ecosystem. Such a system is targeted via effective recycling of both, nutrients and suspended organic matter, giant clams and other filter feeders will serve as the reactor in the integrated system, with positive feedbacks on both water quality and live matter return. Early results show that one couple of broad stock may reproduce three to four times in one season.

In collaboration with the private sector, national and international funding agencies, a pilot plant can be established, to form the building block of a regional centre for the integrated culture of Red Sea coral reef animals. It will adapt the already established culture methods for giant clams and other popular molluscs of marine "reef" to the conditions prevailing and organisms living in the Red Sea. Profitability, acceptance and environmental impact of clam farming are under continuous assessment.

Plate 6.1: The aquaculture plant at MSS has been built in a modular fashion, in order to allow for future scaling-up. It consists of a working area including hatchery, an outdoor nursery and two race ways for rearing different marine organisms. In addition, a special building to hold a newly installed re-circulating water system.

6.9.3 POLYCULTURE

Ployculture is basically land-based mariculture technology that builds on having different species at different trophic levels aligned in series in one culture system that ideally has zero waste discharge. The challenge is not only to build systems with zero discharge, but also to make sure that water quality remains suitable for all cultured species at all different levels of the system. The pilot experimental system at the Marine Science Station (Fig. 6.2) incorporates fish, bivalves and seaweed. Fish are well known to the Jordanian taste and will be readily consumed in the market. Mussels (bivalves) need to be introduced to the Jordanian taste and are consumable by tourists. Algae (seaweed) will be used in preparing fish feed, and when reaches commercial scale suitable species will be produced for exportation. Other systems incorporating corals and sponges with good markets in the aquarium industry will also be built.

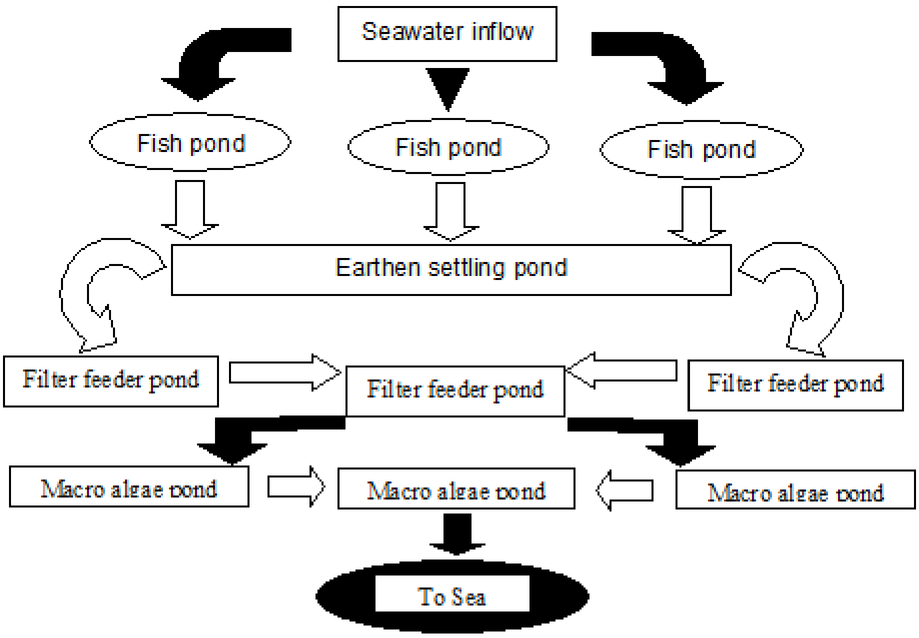

Figure 6.2: Proposed poly culture system in Aqaba-Jordan.

6.9.4 CAPACITY BUILDING/ESTABLISHMENT OF A FISH FARMING RESEARCH CENTRE

For a more sustainable aquaculture and mariculture industry in Jordan, the establishment of a governmental fish farming research centre (FFRS) is a necessity. Such a centre will pioneer a study of the possibilities that exist in order to provide an overall general management planning and supervision of the sector. Its main objective would be to establish research and training facilities to carry out experimentation on species suitable for fish farming in Jordan and disseminate information to potential private investors. Among the Centre's main functions would be:

- On-the-job training and/or training abroad of fish farmers to upgrade human resources;
- Establish hatchery and nursery for the production of fingerlings of species to be farmed for distribution to farmers and brood-stock holding facilities;
- Establish physical facilities and laboratories for water testing, analysis and supply systems, research on genetically improved breeders, domestication of new species, live-food production systems, and fish diseases;
- Economic and financial analysis/consulting unit to review fish farming feasibility studies presented by investors;
- Establish a reference library for research workers and provide access to information and consultations; and
- Conduct studies to formulate reasonably priced feed from locally produced raw materials.

For initiating the proposed FFRC, Jordan may call upon FAO or UNDP to provide technical expertise for its establishment as the case in Saudi Arabia which established such a centre in 1982 and still running. Jordan could also activate the “Cooperation Agreement in the Field of Fisheries” signed in September 1999 with Egypt. The Agreement calls for the exchange of expertise, studies, information, etc. in fisheries matters.

6.9.5 ISSUES TO BE CONSIDERED FOR THE FUTURE OF AQUACULTURE IN JORDAN

In view of the reports on the severe deterioration of the coral reefs of Eilat and their critical state of health, due to the effects of nutrients released from the fish farms and the eutrophication originating from the fish farms and their direct harmful effects on some coral's reproduction, and continued deterioration of the unique coral reefs and to the serious threat to their very existence, coastal and offshore fish farming aquaculture practices that may affect habitat conservation through occupation of sensitive areas, i.e., coral reef and inter-tidal areas, pollution by inputs and outputs from fish farms and genetic contamination by possible releases or escapes of farmed species or varieties should be totally avoided. This means that mariculture in floating cages along the Aqaba coastline will remain to be not possible for the same reasons that prevent a sustainable artisanal marine fishery. Consequently;

- Any expansion of mariculture in Jordan and the use of seawater will have to resort to more technically advanced and more responsibly managed methods of fish farming taking great care in water management by recycling.
- It is essential to use modern techniques in fish farming; more productive methods that have already been proven elsewhere should be employed.
- An important technology of modern mariculture is by the use of re-circulating aquaculture systems. Re-circulating aquaculture systems (RAS) are considered to be a potential technology for land based fish culture.
- The RAS development at MSS, Aqaba is a very important component in the on-going research in mariculture advancement in Jordan. Pilot fish stocks for

consumption were produced and the future prospect is to disseminate this technology to private enterprise

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CHAPTER SEVEN

7 EMERGING ISSUES, OPTIONS FOR ACTIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

An emerging environmental issue has been defined as an issue (positive or negative) that is not yet generally recognized but which may have significant impact on human health, ecosystem integrity and the economy in the future(Munn et al. 1999; NIEAR (2004; ROPME 2007; Wells 2010; UNEP 2014). Changes in the nature and scale of human activities may give rise to emerging environmental issues. Such specific emerging issues should be relevant to the development goals of the country, and help to show how environment relates to national policies and programmes. An emerging issue is not necessarily an issue no one has heard of, or that comes as a shocking surprise". The emerging issues clearly include those of pressures (i.e., human activities), impacts (i.e., environmental change), and societal response, following the DPSIR (driver-pressure-state-impact-response) frame work (Munn et al. 1999).

Emerging environmental issues are associated with one or more of the following situations:

1. One or more of political, social, economic, financial, institutional or technological developments that may cause changes in current trends of human activity which in turn may lead to significant environmental changes;
2. New evidence or theory which suggests potential environmental changes, but which are currently either not widely accepted or are considered unproven. This would include new recognition of synergisms in human activity which produce significant environmental change; and
3. Lack of adequate policy, action or leadership on an existing issue which may become more significant or more urgent in the future.

According to Pederson (2009), the criteria for choosing the issues include:

- Already recognized issues that need additional research and/or management and policy action;
- New or overlooked topics critically important to integrated coastal and ocean management (ICOM) and ecosystem based management (EBM);
- Issues of importance to the maximum number of stakeholders in the region; and

- Issues offering opportunities for collaborative efforts.

The reasons why identifying and reporting on emerging environmental issues include the following:

- Raise awareness of the issues;
- Start timely policy and management actions before the issue reaches crisis level;
- Guide environmental research, data and information collection;
- Increase understanding of ecosystem dynamics and the effects of human activities; and
- Promote learning and proactive management in society.

In Jordan as the case in many other member states of PERSGA, very important progress in conservation of the marine environment of the Jordanian Gulf of Aqaba has been made in the past twenty years. However, a number of important issues still need to be addressed as pointed out in the regional action plans produced as part of the Strategic Action Plan (SAP) (PERSGA 2006).

This section attempts to look into the future for two reasons. First, it is evident that present day actions have consequences that reach far into the future. Second, there is need to look at the environmental issues that are likely to require priority attention in the future – those that affect resources irreversibly, or result in having a significant impact on the population. In addition, the section makes recommendations for future action by policy and decision-makers.

7.2 EMERGING ENVIRONMENTAL ISSUES AND PRIORITIES

The following are some common emerging environmental issues related to coastal activities in the Jordanian Gulf of Aqaba:

- Emergence of new economies.
- Changes and increase in demographic patterns, water demand, and the future need for desalination projects
- Changing attitudes of the business community towards the environment.
- Increase in tourism
- Trade and its effects on the marine environment ecosystems and habitats
- Climate change, Ocean acidification and Sea level rise
- Sustainable fisheries and fisheries management
- Loss of biodiversity
- Increased protection of species at risk
- Invasive species; introduction of new species, with unknown ecological and economic consequences, especially those introduced through ballast water.
- Offshore finfish aquaculture
- Interaction of increased nutrients and increased algal blooms due to climate change
- Coral reef bleaching
- Increase in marine traffic and impact of potential large spills (particularly oil spills)in the Gulf of Aqaba
- Sprawling urbanization along the coast,
- Degradation of major habitats, particularly the seagrass beds;
- Conservation and restoration of coral reefs,
- Pollution from coastal areas, ports activities and ships;
- Lack of harmonization of environment regulations;

- Adoption of Environmental Quality Standards (EQS) as a powerful tool to assess the environmental changes and trends for sound environmental management;
- Lack of continuity and cooperation in regional monitoring and research programmes to fill the data gaps, improve the consistency, quality and reliability of data and information;
- Lack of political well in participation and follow-up of international conventions.
- Lack of research and scientific information on the effects of tourism on the coastal environment and resources.
- Adoption of ecotourism principles and strategy

The following are some **priorities for action** to be considered by official authorities, scientific institutions and stakeholders:

- The development and implementation of improved management strategies that integrate economic and environmental concerns;
- Development and implementation of classical and modern (DNA barcoding techniques) research techniques (where possible), and strategies for the conservation of biodiversity.
- The improved management and regulation of the fisheries industry;
- The improved management and regulation pertaining to MPA (AMP);
- Measures to prevent or mitigate effects of climate change associated ones;
- Address emerging problems such as sea level rise;
- Measures to prevent or mitigate effects of coastal runoffs;
- Address emerging problem of invasive species;
- Address emerging problems of marine litter on the beaches and coastal waters; and
- Address the issue of conservation of some uplifted terraces

7.3 RECOMMENDATIONS

The following are recommendations put based on the information gathered in this report.

7.3.1 RESEARCH AND MONITORING

Successful and sound environmental management requires a well designed research and sustainable monitoring programmes which requires sustainable and enough financial support to undertake research on some of the topics and information gaps pointed out in this report as for example:

- Monitoring and risk assessment needs to be conducted on the impact, levels, distribution and dumping of wastes in the Gulf of Aqaba. This should take into consideration the most recent information on current regimes in the northernmost sector of the Gulf of Aqaba.
- The status of the coral reefs and coral species including associated cryptofauna in the Gulf needs to be re-evaluated along the Jordanian coasts with focus on the new port site, and utilizing (where possible) DNA metabarcoding and incorporate this data in global barcoding database.
- The status and ecology of the limited intertidal rocky shores throughout the Jordanian Gulf of Aqaba needs to be re-evaluated. There is an urgent need to conserving representative samples, and elucidate their DNA barcode within the

boundaries of the protected areas in the Marine Science Station and in the Aqaba Marine Park.

- The detailed distribution of seagrass beds habitat is poorly known in parts of the Gulf of Aqaba. Mapping of their occurrence and monitoring of their presence, status and changes in their distribution are required.
- The status of marine turtles needs to be monitored.
- The population status of all seabirds has to be monitored and determined. Information is especially needed on the endemic species if any.
- The status of some marine fauna identification in the Gulf of Aqaba is not well known. There is a great need for properly designed surveys and monitoring to assess the presence of the threatened species and the trends in their population.
- The impacts on the marine environment of contaminated runoff arising from the coastal zone and catchments have not been studied. An initiation of a record for their occurrence and monitoring programme on their effects on coral reef is required.
- There is an urgent need for further distribution and taxonomic studies for many groups. Inventories for the flora and fauna should be established for the species occurring in this sector of the Gulf of Aqaba. Such studies will be useful in environmental assessments, sensitivity mapping, ecological research and conservation planning. The implementation of modern techniques (DNA barcoding and metabarcoding) for such inventory can help documenting taxonomic groups which are hard to survey using conventional surveys. The establishment of a national Marine Genetic Resources unit in Aqaba (MaGRA) shall prove useful in providing invaluable information about sustainability and conservation indexes of marine groups in the GOA.
- Marine microbiology and molecular biology laboratory at the University of Jordan Aqaba Branch, Laboratory for Molecular Marine Ecology (LaMME), started conducting coast-wide metagenomic surveys and DNA barcoding project as part of the global “Census of Marine Life” initiative. The support of ASEZA for this project would help to establish a marine-life database, in the GOA.
- The research and monitoring programmes will be useful in outlining future state of the environment reports to assess trends and impacts on the environment.
- Long-term national monitoring programmes should utilize the most available modern analysis techniques, and include all potential sources of variation at temporal and spatial scales.
- Responding to the extensive and continuing coastal development and ecosystem degradation requires a monitoring programme that includes more biological bioindicators (sea urchins, herbivorous fishes), in addition to chemical variables such as dissolved nutrients and hydrocarbons, and using modern molecular biology techniques. Accordingly, the National Environmental Monitoring Programme (NMMP) that has been implemented by ASEZA/Jordan is a very useful initiative and must be continued and extended to include other parameters such as marine debris and soft bottom and seagrass fauna.
- The results of research and monitoring which is conducted by universities, research institutions, regional and international research programmes and collaborating overseas scientists which are usually published in the international scientific literature, should be incorporated in a national database maintained in ASEZA and shall be made available to the scientific community and to all interested parties or institutions.

- SOCER suggests that a significant gap still exists between marine science and marine environmental management, reflecting that perennial barrier between science and management. As a consequence, existing scientific knowledge has not been adequately applied in marine environmental management. Accordingly, cooperative research programme which involve science, industry and management are an important initiative to overcome this problem
- ASEZA should compile, benefit and use the excellent source of scientific information in the collected reprints of the Marine Science Station at Aqaba, which include all the publications on the Jordanian Gulf of Aqaba, which have been conducted in the station by Jordanian and other overseas scientists during the period 1974- 2012. These publications, in addition to the review of Hulings (1989) which reviews all the publications on the Gulf of Aqaba until 1989, and all other relevant documents and reports should be forwarded to PERSGA headquarters for inclusion in the PERSGA library. ASEZA should cooperate with PERSGA to maintain an up-to-date database of scientific publications on all aspects of the marine environment of the RSGA.
- Systematic records of oil spills within the Jordan Gulf of Aqaba are not available. There is no list that shows number of spills each year, and the volume and types of oil spilled. Information available from ports and maritime authorities, in addition to maps showing the locations of spills would be very useful for scientists, environmental managers, and decision makers.
- Although thorough bathymetric surveys has been recently conducted for the benthic habitats of the Gulf of Aqaba (ASEZA 2011), there is a lack of studies or efforts to collect data capable of mapping such benthic habitats efforts. It is imperative for these direct observation studies to take place in an organized and systemic manner to produce fine detailed assessment of the biological status of marine habitats and present time-lapse maps of the biological life and how is it affected by climate change and mega development projects taking place on the coastline of the Gulf of Aqaba.
- ASEZA shall make benefit of all provided biodiversity mapping and incorporate it into Aqaba's Marine Spatial Planning (MSP) strategy, to monitor any degradation of marine habitats through time.
- Monitoring and risk assessment needs to be conducted on the impact, levels, distribution and dumping of wastes in the Gulf of Aqaba.
- The sustainability of production of national state of the environment reporting programme requires quantitative, statistically-based, long-term monitoring using a nationally agrees set of indicators.

7.3.2 MARITIME TRANSPORT, AND SHIP INSPECTION AND CONTROL

- ASEZA should take every opportunity to support hydrographic survey of the Jordan Gulf of Aqaba waters to modern international standards in order to provide data for up-to-date charts.
- The Gulf of Aqaba as part of the Red Sea is a Special Area under MARPOL 73/78, when states bordering the sea in the region have established suitable reception and treatment facilities for dirty ballast and tank washing water from tankers. The ecological and the economic damage caused by invasive marine species brought by ballast water are huge. Early in 2014 the Jordan ratified the International Convention for the Control and Management of Ships' Ballast Water and

Sediments - the Ballast Water Management (BWM) Convention (2011). Although the convention will not come into force, since a few states still need to ratify in order to achieve 35% of the world´s merchant shipping tonnage, experts expect the convention will become reality soon, Therefore, it is imperative for Jordan to establish suitable reception and treatment facilities for dirty ballast and tank washing water from tankers as soon as possible. In addition, Jordan has to cooperate with PERSGA efforts to review the need for reception facilities in the region, and encourage the major ports to establish such facilities.

- A map of the region showing what reception facilities are available at each port should be produced, published, and communicated to responsible parties.
- The provisions contained in the 1996 Protocol to the IMO Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 are very important. It will be necessary for Jordan to become party to this Protocol, and regional cooperate with countries on the Red Sea on the prevention of illegal dumping in the waters of the region is urgent.
- Sub-standard shipping is being controlled to some extent by Port State Control (PSC) inspections. It is the role of the Maritime Authority to carry out these inspections in the Jordan territorial waters
- At present Jordan is a member of the Mediterranean Memorandum on PSC, However, for the purposes of coordinating control of substandard shipping that could seriously harm the marine environment in the region. Jordan as a member of PERSGA should seek a mechanism through which Jordan become members of the Indian Ocean MoU on PSC, to link with the control of sub-standard shipping activities in the wider Indian Ocean.

The following actions are suggested to limit, reduce, and enhance the appreciation of the litter problem along the Gulf of Aqaba.

- initiate local and regional research and long-term marine litter monitoring, providing input for conservation;
- assist passengers and merchant shipping lines to comply with MARPOL 73/78 and its annexes;
- develop a strategy that integrates land-based solid wastes management issues with those associated with ship and boat generated marine litter;
- increase of existing cooperation among scientists, decision makers, general public on local, national, regional and international scales ;
- promote sound solid waste management plans and practices in Aqaba town, Aqaba ports and in the whole region of the Gulf of Aqaba and the Red Sea;
- Develop a long term strategy for conducting a marine litter cleanup and outreach campaign and establish a public education programs that target local and international tourists, Aqaba town citizens, students, ports corporation employees and all workers involved in shipping, industry and transport activities;
- Review, develop, implement and enforce a legislative and regulatory framework for the management protection and control of pollution including monitoring with a regional focus; and
- Take measures by the Jordan Ports Corporation and similar port authorities along the Red Sea and Gulf of Aqaba and make available adequate port facilities in all ports of the region to ensure the compliance of vessels, ships and boats with MARPOL 73/78.

- Enhance the quality and proper implementation of the national regulations and other regional and international conventions by member states, though focusing on capacity building and coordination between different authorities, in addition to a proper and continuous amendment of the environment laws.

7.3.3 BIODIVERSITY PROTECTION AND CONSERVATION

- Many species of fish in the Gulf of Aqaba and are under great pressure and their long-term conservation requires efficient management to minimise the impacts of human activities on them. This should include a ban on fixed fishing nets (Hawakir) in the whole area.
- Marine protected areas are significant and representative of all levels of marine environmental diversity. However, the protection provided by the Aqaba Marine Park (AMP) suffers from management problems and conflicts of responsibilities with other authorities. Effective and well-designed management plans for AMP has to be developed, implemented and enforced
- Biological diversity is the main pillar of ecosystem functioning, and the provision of ecosystem services essential for human well-being. Maintaining healthy biodiversity is essential in providing food security, human health, clean air and water. Its healthiness also contributes to economic development, and is essential for the achievement of the national development goals. Despite its fundamental importance, marine biodiversity continues to be lost. Therefore, ASEZA should adopt a long-term strategic plan targeting biodiversity conservation.
- It is imperative for Jordan to follow an efficient implementation and enforcement of "The Strategic Plan for Biodiversity 2011-2020". This strategic plan is a ten-year framework organized by the United Nations (UN) for action by all countries and stakeholders to save biodiversity and enhance its benefits for people. To be capable of implementing this strategic plan, ASEZA should collaborate with national experts to achieve the following actions:
  - Review, update, and revise Jordan's National Biodiversity Strategies And Action Plans (NBSAPs) in line with the Strategic Plan for Biodiversity 2011-2020;
  - Develop national targets, using the Strategic Plan and its Aichi Biodiversity Targets as a flexible framework, and integrating these national targets into the updated NBSAPs. These national targets should take into consideration the national priorities and capacities, and contribute to achieve the global Aichi Biodiversity Targets.
  - Adopt the updated NBSAPs as a policy instrument;
  - Use the updated NBSAPs to integrate biodiversity into national development, accounting and planning processes; and
  - Monitor and review the implementation of the NBSAPs and national targets, using proper biodiversity indicators.

7.3.4 FISHERIES RESOURCES

Fisheries resources are facing several emerging issues, such as:

- Over-fishing and its associated socioeconomic consequences for coastal populations;
- Ocean acidification and its effect on coral reef ecosystem of GOA, which may affect the associated fish communities;
- Sea level rise and impact of global climate change and warming; and
- Appearance of and spread of invasive marine species;

It is important in all cases to take the following priorities and recommendations into consideration:

- The urgent need to develop a co-management plan for fishery resources based on the scientific research and in consultation with the scientific community.
- The urgent need to support research focusing on the effect of unregulated fishing practices on fish stocks and on the marine environment, in addition to research with objectives to support management of other living marine resources. Where possible, research must involve fishermen and make use of their experience in fisheries management plan.
- Funding is required to establish strategies for fisheries management plan which include Monitoring, Control and Surveillance (MCS) for the fish stock. It is imperative to develop and build monitoring and surveillance capabilities of the environmental institutions and departments in ASEZA, capabilities may include a trained staff members and enumerators.
- Improved and efficient monitoring of artisanal activities is urgently required.
- Enforcing fishing regulations is a key component guaranteeing successful plan for nature conservation management. Enforcement of legislations that regulate fishing activities according to season and prohibit the use of poisons in fishing is urgently required.
- Temporal and/or spatial closures to enhance survival of juveniles or spawning concentration, including sub-populations, to maintain genetic diversity especially for economically important species.
- Institutional and legal capacity building of the environmental and fisheries management authorities is needed to strengthen capabilities and coordination towards sustainable use of this important resource.
- The promotion of the conservation and sustainable use of fish stocks and feeding grounds through control of exploitation rates and through the establishment of technical conservation measures to support the conservation and sustainable use of fish stocks.
- In view of the reports on the severe deterioration of the coral reefs of Eilat and their critical state of health, due to the effects of nutrients released from the fish farms and the eutrophication originating from the fish farms and their direct harmful effects on some coral's reproduction, and continued deterioration of the unique coral reefs and to the serious threat to their very existence, coastal and offshore fish farming aquaculture practices that may affect habitat conservation through occupation of sensitive areas, i.e., coral reef and inter-tidal areas, pollution by inputs and outputs from fish farms and genetic contamination by possible releases or escapes of farmed species or varieties should be totally avoided.
- However, scientific research and closed system onshore experimental fish farming pilot projects should be initiated by scientific institutions and supported by governmental and private sector.

- In addition, any land-based closed system aquaculture and mariculture projects must subject to environmental impact assessments procedure.
- Integration of fisheries resources management with the environmental management plans, coastal areas management, and with the socioeconomic conditions of coastal communities is an essential requirement for a sound management.
- Prepare in collaboration with the scientific community, the list of organisms and fish species which should not be collected or fished and the season or months during which fishing is permitted. Closed seasons should be declared only after carrying out extensive biological research such as fish life cycle, reproductive biology and only after a completion of a well designed and continuous monitoring programme for the fish stock.
- Reduce the impact of fishing activities and other human activities on non-target species and on marine and coastal ecosystems to achieve sustainable exploitation of marine and coastal biodiversity.
- Encourage the use of new fishing techniques to fish in deep waters and support research to find new fishing grounds far from coral reef in deep.
- Improving the infrastructure of the landing sites and storage areas of fish are needed.
- Fishermen should be instructed to abandon destructive fishing practices such as gill netting and educated on the benefits of using the more sustainable fishing practices such as the longlines.
- The process of collecting baseline information on fisheries should be adopted and sustained in order to design and implement an efficient fisheries management plan.
- Fisheries statistical data collection from landing sites requires the involvement of well-informed fishermen and well-trained staff who understand the purpose of this action.
- Training of policy and decision-makers in agencies responsible for fisheries management on the concepts and objectives of fisheries management plans are also needed.
- Educating of fishers and members of fishermen cooperatives on the benefits of the integrating fisheries in coastal areas management is required.
- Training of fishers and staff of fishers' cooperative societies on fish handling and marketing and the production of instructions for proper fish handling, transporting, and storing of fish must be undertaken.
- Training of fishermen on safety requirements in all aspects of fisheries sector including boats, shore facilities and transportation facilities is urgently needed.

7.3.5 INSTITUTIONAL CAPACITY BUILDING

- Building of scientific capacity is needed for research and monitoring and for the availability of scientific information and the implementation of management. In addition, capacity building is needed in technologies such as side-scan sonar and echo sounding, satellite mapping, remotely operated vehicles, and geographical information systems (GIS).
- The official staff responsible for the marine environment protection must be educated and trained on issues related to marine environmental management and species conservation and on other issues related to these aspects.

- Further needs for management capacity building include training in: planning and implementation of relevant control mechanisms (legislative or procedural), and development of maritime laws,

- Training in integrated coastal zone management (ICZM), environmental assessment methods, MPA management, pollution management, and implementation of maritime laws are needed.
- Knowledge on the monitoring and control of invasive marine species carried in ballast water needs to be improved through training courses and workshops on technologies for the detection of potential invasive and harmful species.
- Port and maritime authorities in Jordan to require ships carrying ballast water and calling at ports and terminals in Aqaba to maintain a 'ballast water record book', to allow for the tracking of the origins and destinations of ballast water.

7.3.6 COASTAL ENVIRONMENT MANAGEMENT

- The National Oil Contingency Plan of Jordan needs to be efficiently implemented, and Prince Hamza Oil Combat Centre (PHOCC) needs to be fully equipped with all necessary equipment and materials, in order to be able to perform its role very efficiently. This plan offers a good opportunity to develop the national systems and establish a regional mechanism for achieving a coordinated response to any major spills on the basis of the PERSGA/ IMO 'Action Plan for the Development of National Systems and Regional Mechanisms for Preparedness and Response to Major Marine Oil Spills in the Red Sea and Gulf of Aden. In addition, the capacity for monitoring oil and chemical spills in the Gulf of Aqaba region remains limited and there is an urgent need to build up and focus on human capacity building.
- Uplifted terraces need to be preserved, conserved and protected from pressures of development and investment projects. The remaining parts of these terraces should be fenced, managed and promoted as natural heritage sites worth visiting by tourist and Jordanians. Approvals for building on and excavation of coastal uplifted terraces are of considerable concern and should be subject to EIA procedure.
- Coastal hazards include events such as flooding from upstream sources, erosion, storm tides especially those caused by the strong south wind (local name: Azyab) need to be dealt with based on scientific information and gains from past experiences.
- There is a lack of policy integration and coordination between government authorities, and therefore, a better integration between departments that have coastal planning, management and protection roles is needed. Support for greater legislative powers to protect s coastal areas, especially from development pressures is also required.
- Greater public consultation in the environmental issues related to development projects and approvals process is always useful and needed
- Tourism developments were frowned upon where they were solely for economic gain and impacted adversely on the environment and social structure in communities. Tourism is very important for Jordan and Aqaba. However, tourism should be 'eco-friendly' and regulated to minimise adverse environmental impacts and preserve the benefits for future generations. In addition, monitoring, research and management are necessary in order to strike a balance between protection of biodiversity values and providing positive tourism experiences.

- The use of, and access to, the coastal environment is a significant societal and cultural factor, which should be protected by the coastal plan. Private development has limited public access to the coast and coastal waters. The desire for public access to beaches and coastal waters need to be maintained, protected and enhanced while providing for the operation of infrastructure of significance and protection of natural and cultural coastal resources. Therefore, high levels of support should be given to maintaining and expanding public access via any future coastal management plan, but with regard for the environment and the fragility and changing nature of beach systems.
- The information gathered for the purpose of preparation of the present report show the urgent need to design, adopt and implement an integrated coastal zone management (ICZM) plan because it helps dealing with various issues in a comprehensive manner.
- The plan needs to consider issues such as coastal development; demographical changes; increasing population growth; increasing water demand and domestic wastewater production, treatment and environmental impacts; port and shipping and other maritime activities; tourism and recreation activities; marine litter pollution; oil pollution and oil spill contingency planning; pollution control; fishing and aquaculture practices; storm water and flash flooding and impacts; industries and industrial wastewater and solid waste disposal; effective and enforced implementation of monitoring; and environmental assessment procedures.

7.3.7 CLIMATE CHANGE AND SEA LEVEL RISE

- Rising sea levels in the RSGA could have serious consequences for many areas near the coast and for man-made structures, including harbours (PRESGA 2006). Therefore, it is necessary for scientific community and management authorities to consider following up of this topic as one of present and future important issue.
- ASEZA should support a study of the Jordanian coastline to determine the likely impact of a sea level rise on coastal areas and resources. It should also support the establishment of modern tide gauges and sustain a record of the sea level in Aqaba. In addition to studies aiming at identifying species, functional groups and ecosystems that are most sensitive to ocean acidification and the rate at which organism can adapt to climate change. This shall include support for long-term monitoring of the most susceptible organisms, including coral, to ocean acidification, and estimating budgets of calcium carbonate through in-situ calcification and dissolution monitoring.
- ASEZA should support the ocean acidification research and the establishment of a national programme on monitoring the effect of ocean acidification on the GOA ecosystem and the deployment of systems for the autonomous measurement of CO_2 and other parameters such as particulate inorganic carbon (PIC), particulate organic carbon (POC), and physiological stress markers
- ASEZA should support attempts to reduce the emissions of greenhouse gases, as part of its attempts to conserve the marine environment, and monitor the incidence of coral bleaching which may increase in the future as sea temperatures rise and global climate change.
- ASEZA in cooperation with the Marine Science Station and Jordanian universities should facilitate the cooperation of its scientists with regional and international institutions engaged in monitoring global sea temperatures and coral reef research into the sensitivity of RSGA coral reefs to bleaching events. It is necessary to

ensure that this monitoring research is designed to provide results that are useful for policy and decision-makers.

- ASEZA should initiate climate change and ocean acidification literacy programme, with activities especially designed for education, training, and outreach.

7.3.8 EDUCATION AND OUTREACH

The long field experience and observations indicate that there is a need to develop community education programmes that highlight the impacts of coastal communities on the coastal environment and resources such as coral reef and fish resources. The impacts of community include coral degradation, anchor damage, destructive fishing and diving, littering, solid and liquid waste disposal and souvenir collection. Such programmes could be integrated with community-based monitoring programmes that include fishermen and recreational scuba divers and other sectors such as:

Seaweek

Special class or school-wide activities shall be developed in Aqaba schools once or twice a year which focuses awareness on various coastal and marine issues as well as the community practices on the terrestrial part of the environment and affect on the coastal environment. It is a good way to promote marine education to students and teacher and provide them with learning and teaching ideas. University staff and researchers and the Aqaba Marine Park (AMP) can contribute to this week.

Marine education in colleges

Thousands of students are enrolled in technical and other education courses. Marine courses are not offered on this level. Marine elements should be offered within courses such as biology, chemistry, tourism, and recreation.

Marine education in universities

The number of specialised marine courses offered by Jordanian universities is very limited. Few universities offer courses with some marine content and some offer courses on environment. University marine studies should have a greater emphasis on applied marine sciences and administration. Subject specialisations should reflect among others marine ecology, coral reef science, and marine, coastal and fisheries management.

Community marine education

Marine environmental education not only occurs formally in schools and universities but also informally in the community for people of all ages. Particular attention should be given to marine education of user groups, decision makers, local communities, non-Arabic speaking residents and other special groups. However, while some examples of community marine education efforts exist, most Jordanians are reached superficially, if at all.

Education for Aqaba local communities

The involvement of local communities in marine environmental management requires culturally appropriate education. It might be useful to implement the Great Barrier Reef Marine Park Authority who used art, role play and stories to explain its management programmes to Aboriginal communities, and employs local people in its community education programmes

Education for recreational fishers

The Commission of Environment and the Aqaba Marine Park of ASEZA should realise the importance of managing fishing activities in Aqaba. Simple programmes of education should be designed by the University of Jordan staff/Aqaba Branch for recreational fishers and glass boats owners. A Policy for recreational fishing which stresses the importance of developing strong fishing conservation ethics and awareness programmes to encourage a positive change in attitudes and values should be issued. Royal Yacht Club in Aqaba can play a key role in this education process. Sport fish tagging programmes can provide not only valuable information on fish breeding, growth and movements to researchers and managers, but help foster the conservation ethics.

Education for commercial fishermen

Habitat destruction and declining water quality are common issues amongst commercial and recreational fishermen, environmentalists, scientists and the general community. Commercial fishermen should recognise the importance of fisheries habitat and water quality, and that ecologically sustainable development equates with a decent living in the long-term and the chance to pass on the business to future generations. Full-time marine environmental officers and rangers should be appointed as a mean for moulding enforcement into education.

Education for marine protected area users

Various education programmes should be developed for groups who use marine protected areas; the Aqaba Marine Park (AMP). Rather than depending on controls through permits, regulations and fines, ASEZA through the AMP should encourage user-groups to develop their own 'codes of practice'. These have been effective in generating community support and 'ownership' attitudes for a marine protected area, for shaping appropriate behaviour by users, and for solving particular management issues. A 'Code of Practice' should be developed in various places for beach camping, waste disposal, minimal impact diving, anchor damage, marine litter, motorised water sports, and sports fishing. Brochures that tells people what to do and what not do will help protecting the environment and coral reefs of Aqaba in a sustainable way.

Education for divers and tourists

Skin and scuba-diving are popular in the warm water of Aqaba. Thousands of scuba dives are undertaken in Aqaba waters each year. There has been a marked change in divers' perceptions over the past three decades: emphasis has greatly shifted from spearfishing, to underwater photography and marine life viewing. Scuba courses may include an introduction to marine biology. Tourist divers are a generally environmentally aware and here again simple brochure that tells them what to do and what not do will help protecting the coral reefs of Aqaba on the long run. In addition, recreational divers also learn about marine environmental management through involvement with scientific projects and in marine debris cleaning campaigns.

Marine aquaria as a tool for education

The interest of the community in the sea is reflected in the growth of large aquaria to provide 'real-marine-life' underwater experiences to young and old people. A national marine aquarium should be established in Aqaba, which should carry a strong education messages about marine life, the importance of our coastal for commercial and recreational purposes, and the need for marine conservation. The aquarium should use interpretive staff and volunteers to operate educational programmes particularly for school children (Queensland 2009).

Marine education for the media

The most important sources of information about the environment is television and electronic media. News and current affairs programmes, and science shows, usually have the major influence (Queensland 2009). Other, less important sources are newspapers, radio and magazines. Educational programmes in marine environment pollution, protection and conservation issues, specially designed for news correspondents, reporters, and commentators will increase their understanding to these issues and improve the way of their coverage to environmental events or subjects.

Long-term national marine education programme

- ASEZA departments responsible for coastal planning and management are asked to increase efforts to provide effective public education and awareness services. There is an urgent need for more public education relating to coastal issues with focus on childhood education about coastal care. A long-term national marine education programme should be established by ASEZA to provide the community with:
- An awareness, appreciation and understanding of the marine environment and of the needs for its conservation;
- Environmentally responsible attitudes, a commitment to work for change, and proper behaviour in dealing with coastal environment.
- Ability to actively contribute to the planning and management processes; and
- A high level of commitment to future management programmes

7.3.9 GOVERNANCE AND DECISION MAKING

There is a need for integrated approaches to decision-making in all major coastal developments. In addition, there is a necessity for a political support to ensure the implementation and enforcement of the existed and yet to be enforced legislations and regulations.

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