We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Marine Ecosystem Diversity in the Arabian Gulf: Threats and Conservation

Humood A. Naser

Additional information is available at the end of the chapter

1. Introduction

The Arabian Gulf is a marginal and semi-enclosed sea situated in the subtropical region of the Middle East between latitudes 24º and 30º N and longitudes 48º and 57º E (Figure 1). The Arabian Gulf constitutes part of the Arabian Sea Ecoregion, and represents a realm of the tropical Indo-Pacific Ocean (Spalding et al., 2007). It is a shallow sedimentary basin with an average depth of 35 m and a total area of approximately 240,000 km² (Barth and Khan, 2008).

Due to the high-latitude geographical position, the relative shallowness and the high evaporation rates, the Arabian Gulf is characterized by extreme environmental conditions. Sea temperatures are markedly fluctuated between winter and summer seasons (15 - 36°C). Salinity can exceed 43 psu and may reach 70-80 psu in tidal pools and lagoons. Therefore, marine organisms in the Arabian Gulf are living close to the limits of their environmental tolerance (Price et al., 1993).

Despite these harsh environmental conditions, the Arabian Gulf supports a range of coastal and marine ecosystems such as mangrove swamps, seagrass beds, coral reefs, and mud and sand flats (Naser, 2011a). These ecosystems contribute to the maintenance of genetic and biological diversity in the marine environment and provide valuable ecological and economic functions as they form feeding and nursery grounds for a variety of commercially important marine organisms.

However, these ecosystems are under ever-increasing pressure from anthropogenic activities that are associated with the rapid economic, social and industrial developments in the Arabian Gulf countries. The Arabian Gulf is considered among the highest anthropogenically impacted regions in the world (Halpern et al., 2008). The coasts of the Arabian Gulf are witnessing rapid industrialization and urbanization that contribute to the degradation of naturally stressed marine ecosystems. Coastal and marine environments are affected by intensive dredging and

reclamation activities, and several sources of pollution, including industrial waste, brine waste waters, ports and refiners, oil spills, and domestic sewage (Sheppard et al., 2010). These threats warrant the designation of the Arabian Sea Ecoregion, including the Arabian Gulf as 'critically endangered' by the International Union for the Conservation of Nature (IUCN) and the World Wildlife Fund (WWF) (http://wwf.panda.org).

Due to its unique environmental setting, the Arabian Gulf is increasingly receiving international scientific interest to study the effects of environmental extremes on marine organisms, and to investigate the potential impacts of future climate change on the ecological integrity of marine ecosystems (Riegl and Purkis, 2012; Feary et al., 2013). This chapter identifies valued ecosystem components in the Arabian Gulf, characterizes natural and anthropogenic impacts on these ecosystems, and suggests measures for conservation that might contribute to the protection of the fragile marine ecosystems in the Arabian Gulf.
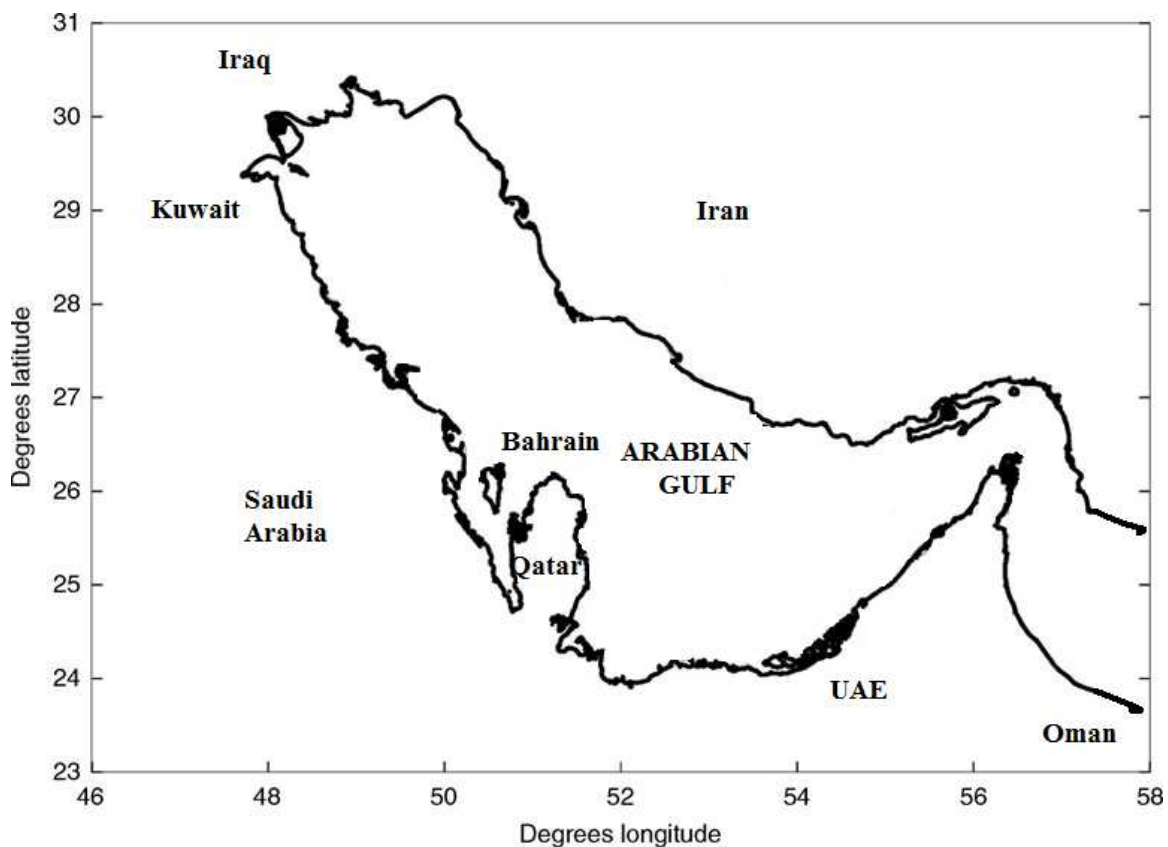
Figure 1. Map of the Arabian Gulf.

2. Valued ecosystem components

People of the Arabian Gulf are related economically, culturally and socially to the sea. Several ecosystems, including seagrass beds, coral reefs, mangroves, and mudflats contribute significantly to the productivity of marine resources in the Arabian Gulf (Khan et al., 2002). These

ecosystems are considered Valued Ecosystem Components (VECs) because they provide important ecological goods and services (Treweek 1999). Most of these habitats are rich in varieties of fish, which are a major source of food for people in the Arabian Gulf. Ecosystem benefits in the Arabian Gulf are not limited to the direct consumptive value of seafood, but extend to other services ranging from primary production and nutrient cycling to erosion and sedimentation control.

2.1. Seagrass beds

Seagrass beds are highly productive ecosystems that provide important ecological functions and economic services (Sheppard et al., 1992). Ecologically, seagrass ecosystems provide food sources and feeding grounds for several threatened species in the Arabian Gulf such as turtles and dugongs (Abdulqader and Miller, 2012; Preen et al., 2012). They can also improve water quality by stabilizing loose sediment and by filtering some pollutants out of the water (Duffy, 2006). Economically, they serve as important nursery grounds for penaeid shrimps, pearl oysters and other organisms of importance to the Arabian Gulf's commercial fisheries (Erftemeijer and Shuail, 2012).

Three species of seagrass occur in the Arabian Gulf; namely, *Halodule uninervis*, *Halophila stipulacea* and *Halophila ovalis* (Phillips, 2003). These species are generally tolerant to salinity and temperature extremes of the Arabian Gulf. For instance, seagrasses are thriving in the extreme thermosaline conditions of Salwa Bay, south of Bahrain, where sea temperature exceeds 31 °C and salinity may reach 70 psu in summer.

Seagrass beds are distributed along most of the shores of the Arabian Gulf. According to Erftemeijer and Shuail (2012), around 7000 km^2 of seagrass habitat have been mapped in the Arabian Gulf to date. Extensive growth of seagrass is typically associated with sandy and muddy substrates in nearshores and shallow waters (less than 10 m). The largest areas of seagrass beds occur off the coasts of United Arab Emirates and between Bahrain and Qatar with estimated areas of 5500 and 1000 km^2, respectively (Erftemeijer and Shuail, 2012). These seagrass habitats are of critical importance as they support the largest population of dugongs known outside Australia (Preen, 2004).

2.2. Coral reefs

Coral reefs ecosystems provide a variety of ecological services such as renewable sources of seafood, maintenance of genetic, biological and habitat diversity, recreational values, and economic benefits such as utilizing reefs for creating land. Numerous nearshore reefs have been reclaimed along the coastline of the Arabian Gulf. Coral reefs are featured by both biological diversity and high levels of productivity. The high diversity of coral reefs provides a wide range of habitats for other reef species and fish. Coral reefs in the Arabian Gulf have traditionally been important habitats for fisheries.

Coral growth occurs in most of the Arabian Gulf with best development on offshore shoals. Additionally, fringing corals occur along the coastlines of United Arab Emirates, Qatar, Saudi Arabia and Bahrain (Riegl and Purkis, 2012). Extremes in temperature, salinity and other

physical factors in the Arabian Gulf restrict the growth and development of corals to patchy forms (Sheppard et al., 2010). However, despite these harsh environmental conditions, corals in the Arabian Gulf exhibit remarkable resilience and vitality.

Recently, corals in the Arabian Gulf have been exposed to severe temperature anomalies at a recurrence faster than in any other coral regions in the world. Therefore, it is argued that corals in the Arabian Gulf already exist in a thermal environment that is equal to the 2099 projections of the Intergovernmental Panel on Climate Change (IPPC) in tropical oceans (Riegl and Purkis, 2012). This embarked regional and international interest in using the Arabian Gulf as a model ecosystem to understand the potential impact for future climate change (Burt, 2013). One aspect of that interest is the establishment the Mideast Coral Reef Society (MCRS) in 2013, with the aim of generating a deep understanding of these unique ecosystems and promoting their conservation and sustainable use.

Unfortunately, coral reefs in the Arabian Gulf have been severely affected by recent bleaching events as well as human impacts such as sediment runoff from dredging and reclamation activities and pollution from different land-based sources. Large-scale decline in coral reef has been observed. It is estimated that almost 70% of original reef cover in the Arabian Gulf may be considered lost and a further 27% threatened or at critical stages of degradation (Wilkinson, 2008).

2.3. Mangrove swamps

Mangrove habitats are ecologically important coastal ecosystems that provide food, shelter and nursery areas for a variety of terrestrial and marine fauna. Mangrove habitats of the Arabian Gulf support a variety of important species of fish, shrimps, turtles, and birds, and significantly contribute to the coastal productivity (Al-Maslamani et al., 2013). The Arabian Gulf coastlines are dominated by only one species of mangroves, *Avicennia marina*. The processes of osmoregulation and salt secretion allow *Avicennia marina* to cope with hypersalinity conditions in the Arabian Gulf (Dodd et al., 1999). Naser and Hoad (2011) investigated salinity tolerance and salt secretion in Bahrain and found that successful establishment of mangroves depends critically on the tolerance of these plants to salinity at the early stages of development.

Mangroves are largely distributed along the southern shores of the Arabian Gulf. Dense growth of mangroves is particularly confined to low-energy and sheltered coastal areas along the coastlines of United Arab Emirates, Saudi Arabia and Qatar. While mangroves are relatively widespread throughout the Arabian Gulf countries, there are variations in their distributions from one country to another. For instance, the total extent of mangroves in United Arab Emirates is estimated to be 38 km² (Dodd et al., 1999) compared with only 0.31 km² in Bahrain (Abido et al., 2011).

According to the IUCN Red List of threatened species, mangroves in the Arabian Gulf are classified as 'Least Concern'. The Red List assessment concluded that although there are overall range declines in many areas, they are not enough to reach any of the threatened category thresholds. However, it can be argued that this classification might not be applicable to certain

countries in the Arabian Gulf, particularly Bahrain. It is recognized that the IUCN Red List categories and criteria provide objective framework for the classification of studied species. However, these categories and criteria are primarily designed for global taxon assessments (IUCN, 2012).

Bahrain is a good example to demonstrate the effect of rough resolution assessment (i.e. globally or regionally rather than locally). Based on the Red List, mangroves in Bahrain are classified as 'Least Concern'. However, mangrove stands in Bahrain are severely subjected to human impacts that might affect the existence of this important ecosystem. The marine area of Tubli Bay, which hosts the last remaining mangroves in Bahrain, has been reduced from to 25 to 12 km^2 in 2008 due to intensive reclamation activities. These activities significantly destroyed mangrove stands and reduced their spatial distribution in Bahrain. Due to the severe reduction in mangroves distribution accompanied by continuous anthropogenic threats, mangroves in Bahrain should arguably be classified within the threatened categories (i.e. Critically Endangered, Endangered or Vulnerable). Consequently, urgent conservation measures, including rehabilitation and restoration should be carried out to sustain the remaining of mangrove ecosystem in Bahrain.

2.4. Mudflats

Due to the sedimentary nature of the Arabian Gulf, sand and mud substrata are the most widespread habitats. They extend from intertidal salt marshes to the maximum depth and account for more than 97% of the bottom substrate of the Arabian Gulf (Al-Ghadban, 2002). Tidal mudflats are generally restricted to low energy environment associated with low water movement mainly along the coastlines of Kuwait, Saudi Arabia and United Arab Emirates. These habitats are favorable areas for the colonization by mangroves, algal and cyanobacterial mats, which play important roles in primary productions and food chains. Subtidal and tidal muddy habitats are extremely rich in macrobenthic assemblages, which form the largest and most diverse marine ecosystem in the Arabian Gulf.

Generally, biodiversity and distribution of macrobenthos in the Arabian Gulf are primarily governed by sediment type, temperature, salinity, primary productivity, depth and physical disturbance (Coles and MacCain, 1990). Macrobenthic assemblages through their high secondary productivity contribute significantly to the overall fisheries and marine productivity. Additionally, mudflat habitats provide feeding and roosting grounds for important shorebird populations. Some of these important bird areas are declared as wetlands of international importance (Ramsar Convention of Wetlands). Tubli Bay in Bahrain is an example of a Ramsar site that supports large numbers of wintering and migratory shorebirds (Al-Sayed et al., 2008).

3. Environmental stressors

The Arabian Gulf is facing multiple natural and anthropogenic environmental stressors. The unique physical and chemical settings represented by extremes in temperature and salinity

accompanied by anthropogenic impacts may pose threats to marine species diversity and ecosystems integrity. The naturally stressed marine ecosystems are subjected directly or indirectly to human actions ranging from habitat destruction by coastal reclamation to pollution from a variety of land-based activities.

Environmental impacts on marine ecosystems could be generally attributed to natural or anthropogenic stressors. However, distinguishing between natural and anthropogenic stressors might be difficult due to the complexity of ecosystems responses to the variety of disturbances. For instance, anthropogenic impacts on ecosystems may not be detected until they are interacted with natural environmental stressors. Additionally, some environmental changes in ecosystems that appear to be natural may have been influenced by anthropogenic actions.

3.1. Natural stressors

Natural stressors in marine environment have a large number of forms and sources. Environmental extremes represent stressors that interfere with normal functioning of marine ecosystems (Breitburg and Riedel, 2005). The arid physical setting of the Arabian Gulf represented by extreme levels of salinity and temperature has pronounced effects on physiological aspects of marine organisms as well as their diversity, abundance and spatial distribution.

Physiological stresses are reflected in the dwarfism phenomena in fauna and flora inhabiting areas with high levels of salinity. For example, Price (2002) attributed the occurrence of dwarfism in echinoderms to the high salinity waters of the Arabian Gulf. Similarly, Naser and Hoad (2011) investigated morphological characteristics of mangroves in two distinctive coastal areas in Bahrain. The first area of mangroves receives input of low-salinity water from nearby farms, and underground seepage with salinity ranging between 5 psu in winter and 29 psu in summer. Salinity of the coastal water in the second area of mangroves can exceed 44 psu. This study reported differences in tree heights of mangroves ranging from 1.5 to 2.5 m in the coastal area compared with 4 to 5 m in the first area that receives low-salinity water.

Generally, extreme environmental conditions in the Arabian Gulf are reflected in reduced levels of species richness (Price, 2002). However, it is recognized that the Arabian Gulf has distinctive marine assemblages as well as habitats (Sheppard et al., 1992). Therefore, it can be argued that while species richness is relatively low, change in species composition along a spatial gradient is high (Price, 2002).

Stressors of biological sources such as invasive species and algal blooms could play important roles in ecosystems degradation in the Arabian Gulf. With more than 25 000 oil tankers navigating through the Strait of Hormuz each year (Literathy et al., 2002), the introduction of aquatic invasive species via ballast water is considered one of the major threats facing the marine environment in the Arabian Gulf. Hamza (2006) reported several exotic phytoplankton and zooplankton species in water samples collected from ballast water tanks of a gas tanker stopped along the United Arab Emirates coastal area. Some of these exotic species, particularly dinoflagellate organisms, are linked to the red tide and fish kill

that frequently reported in recent years in Kuwait, Oman, Saudi Arabia and United Arab Emirates (Hamza and Munawar, 2009).

Extensive blooms (i.e. red tides) have been causing severe ecological and economical impacts in the Arabian Gulf. For instance, the massive blooms affected the Arabian Gulf from August 2008 to May 2009 caused widespread fish kills, damaged coral reefs, restricted fishing activities, impacted tourism industry, and interrupted desalination operations. The 2008-2009 harmful algal blooms were associated with the dinoflagellate species *Cochlodinium*, which was the first time to be observed in the Arabian Gulf waters (Richlen et al., 2010).

Effects of climate change and global warming on natural ecosystems and human well-being are major global concerns (Sheppard, 2006). Although climate change is directly or indirectly attributed to anthropogenic sources, it generally results from large-scale interactions for several variables over a very long time. There are three main features of the global climatic changes; namely, extreme sea-surface temperatures, marine acidification, and sea-level rise that may pose potential risks to marine ecosystems in the Arabian Gulf.

Although ecosystems in the Arabian Gulf are adapted to extreme environmental conditions, anomalous sea-surface temperatures due to climatic changes may result in severe impacts on the integrity of theses vulnerable ecosystems. The massive bleaching and subsequent mortality of corals in the Arabian Gulf occurred in 1996 and 1998 with maximum sea-surface temperatures reaching 37.3 °C and 38.0 °C, respectively (Sheppard and Loughland, 2002; Burt et al., 2011). Although most of the Arabian Gulf countries were affected by these beaching events, Bahrain was the worst affected with an estimated overall loss of 97% of live corals. Recovery of Bahrain reefs was limited in the subsequent years due to continuing coastal developments that are associated with intensive dredging and reclamation (Burt et al., 2013). Additionally, warmer waters can also lead to oxygen depletion and suffocation of marine organisms. Higher temperatures where attributed to the massive fish mortalities along the coasts of Qatar (Al-Ansi et al., 2002).

The harmful effects of increasing atmospheric levels of carbon dioxide (CO_2) and other greenhouse gases are reflected on the environment and human health. The Arabian Gulf is a major sink for atmospheric CO_2, which may lead to acidification of the marine environment. Measurements of pH concentration in surface waters of the Arabian Gulf over a four year period (2007-2010) indicated that waters are becoming increasingly acidic with time (Uddin et al., 2012). Increasing acidity in the marine environment is critical for several organisms, including corals, molluscs and calcareous phytoplankton.

Sea-level rise is another effect of global climatic change that poses threats on coastlines of the Arabian Gulf. Bahrain as a group of low land islands is particularly threatened by any sea-level rise due to global climatic change. Al-Jeneid et al. (2008) have predicted that 77 km^2 of Bahrain's land could be inundated with seawater in the case of a rise of the sea level by 0.5 m. These areas are harboring sensitive ecosystems such as mangroves, and intertidal mudflats.

3.2. Anthropogenic impacts

3.2.1. Reclamation and dredging

Coastal and marine environments in the Arabian Gulf are the prime target for most of the major housing, recreational, and economic developments (Naser et al., 2008). Coastal developments along the Arabian Gulf have accelerated at an unprecedented rate in the past decade to accommodate large-scale projects, including artificial islands, waterfront cities, ports and marinas (Khan, 2007).

Habitat destruction due to intensive reclamation and dredging activities is the prime threat for biodiversity loss and ecosystem degradation in the Arabian Gulf. It is estimated that more than 40% of the coasts of the Arabian Gulf have been developed (Hamza and Munawar, 2009). Examples of large-scale coastal developments in the Arabian Gulf include 'Palm Islands' and 'The World' in Dubai, United Arab Emirates, 'The Pearl' in Qatar, 'Al Khaleej' and 'Half Moon Bay' in Saudi Arabia 'Pearl City' in Kuwait, and 'Durrat Al Bahrain', 'Amwaj', and 'Dyar Al Muharraq' in Bahrain.

It is likely that reclamation will accelerate in the coming decades in order to secure land for large-scale projects as populations in the Arabian Gulf countries continue to grow. This is reflected in the long-term land use strategies and master plans in the Arabian Gulf. For instance, Bahrain National Land Use Strategy 2030 recognizes reclamation as the major option for securing the future needs for land, indicating that coastal environment will continue to be the major focus for developmental projects in the coming future (Naser, 2011b).

Given its limited land area (762 km^2), Bahrain has markedly been affected by coastal developments. Presently, reclamation activities in Bahrain resulted in the addition of around 95 km^2 representing an increase of 12% of the total land area (Naser, 2011b). Additionally, more than 80 % of Bahrain's coastline has extensively been modified due reclamation activities (Fuller, 2005).

Typically, reclamation in the Arabian Gulf is conducted by extracting sand and mud from designated marine borrow areas then dumping them into the coastal and shallow subtidal areas (Figure 2). Alternatively, reclamation could be carried out by infilling the coastline by rocks and sands extracted from quarries (Figure 3).

Dredging and reclamation processes are associated with short and long term biological, physical and chemical impacts. These activities involve the direct removal of macrobenthos and permanent modification of the physical environment. Deposition of dredged material during reclamation process may result in physically smothering the coastal and subtidal habitats and deoxygenating the underling sediments (Allan et al., 2008). Reclaimed lands could also interfere with water circulation and subsequently alter the salinity (Al-Jamali et al., 2005). These physical and chemical alternations may reduce biodiversity, richness, abundance and biomass of marine organisms (Tu Do et al., 2012).

Additionally, dredging activities may contribute directly or indirectly to the loss of seagrass beds in the Arabian Gulf due to direct physical removal and burial, and the increase in turbidity

levels (Al-Wedaei et al, 2011). Dredging and reclamation activities have resulted in the loss of many prime mudflats that support shorebird populations (Figure 4), and the degradation of coral reefs due to sediment runoff and the increase levels of turbidity (Al-Sayed et al., 2008).

Figure 2. Sand and mud materials are pumped from a marine burrow area into the reclamation site. 'Dyar Al Muhar-raq' development in Bahrain (2013).

3.2.2. Industrial effluents

The Arabian Gulf countries have witnessed a rapid industrial growth, mainly in the sectors of oil refining and petrochemical industries. These major industries are discharging wastewater containing a variety of chemicals, including heavy metals, hydrocarbon compounds, and nutrients (Sale et al., 2010). Petroleum refinery wastewaters are composed of different chemicals, which include oil and greases, phenols, sulphides, ammonia, suspended solids, and heavy metals like chromium, iron, nickel, copper, molybdenum, selenium, vanadium and zinc (Wake, 2005). Coastal and marine environments receiving intensive industrial effluents along the coastline of the Arabian Gulf are recognized as hotspots for high concentrations of hydrocarbons (De Mora et al., 2004; 2010) and heavy metals (Naser, 2012a; 2013a).

Naser (2013b) investigated the effects of industrial wastewater discharges that characterized by high inputs of heavy metals and hydrocarbons on crustacean assemblages along the eastern coastline of Bahrain. This coastline is heavily occupied by industrial facilities including the oil refinery, aluminum smelters and desalination plants. This study indicated that the analyzed heavy metals exhibited higher levels of concentrations in sediments influenced by industrial discharges. The study also argued that the synergistic effects of industrial effluents that contain

Figure 3. Rocks and sands extracted from nearby quarries are used to reclaim a coastal area along the eastern coastline of Bahrain (2012).

Figure 4. A mudflat along the northern coastline of Bahrain that supports wader birds is proposed to be reclaimed, which my result in a loss of important feeding grounds for bird populations (2012).

high levels pollutants, brine discharges, and sedimentation due to intensive dredging and reclamation activities were reflected on the reduced levels of crustacean diversity and abundance in the sampling stations.

The flushing time of seawater in the Arabian Gulf is ranging between 3 and 5 years. Therefore, pollutants, including heavy metals and hydrocarbons are likely to reside in the Arabian Gulf for a considerable time. Continuous inputs of industrial effluents from different anthropogenic sources in the Arabian Gulf could be critical for both marine ecosystems and humans who rely on marine resources for food, recreation and industry.

3.2.3. Desalination effluents

The Arabian Gulf countries are witnessing rapid industrial development and population growth, which increase the need for fresh water (Smith et al., 2007). Due to the low precipitation and high aridity in the Arabian Gulf countries, most of the fresh water needs are being obtained from seawater through the various processes of desalination, including multi-stage flash (MSF), and seawater/brackish reverse osmosis (RO) (Hashim and Hajjaj, 2005). It is estimated that the amount of desalinated water in the Arabian Gulf countries accounts for more than 60% of the world's total production (Lattemann and Hopner, 2008).

Large quantities of reject water from desalination plants are being discharged on a daily basis to coastal and subtidal areas in the Arabian Gulf. Therefore, Hypersaline water discharges from desalination plants are increasingly becoming a serious threat to marine ecosystems in the Arabian Gulf (Areiqat and Mohamed, 2005).

Coastal and marine environments receiving these discharges are typically subject to chemical and physical alterations. Desalination effluents are commonly associated with harmful chemical components, including heavy metals, antiscaling, antifouling, antifoaming, and anticorrosion additive substances (Lattemann and Hopner, 2008). Additionally, discharges from desalination processes may alter physically and chemically the characteristics of receiving seawater, including water temperature and salinity. These alterations in seawater quality, temperature, dissolved oxygen and salt concentration may severely affect several marine organisms and assemblages.

Naser (2013c) investigated the effects of tow major desalination plants that use MSF and RO technologies on macrobenthic assemblages. The study found reduced levels of biodiversity and abundance in areas adjacent to the outlet of MSF reflecting severe impacts on macrobenthic assemblages caused by brine effluents that are associated with high temperatures, salinities, and a range of chemical and heavy metal pollutants (Figure 5).

The demand for desalinated water in the Arabian Gulf will increase in the coming future (Dawoud and Al-Mulla, 2012). This may result in cumulative impacts from the brine discharges leading to substantial fluctuations in salinity levels. It is forecasted that brine discharge will increase the salinity of the Arabian Gulf (Smith et al., 2007). Bashititalshaaer et al. (2011) predicted that brine discharge will increase the salinity of the Arabian Gulf by 2.24 g l^{-1} in 2050. This marked increase in seawater salinity could arguably be critical to the naturally stressed marine ecosystems in the Arabian Gulf.

Figure 5. Marine organisms at the proximities of desalination plants are influenced by chemical, physical and thermal pollution. Reduced levels of diversity and abundance of macrobenthos were recorded adjacent the outlet of this MSF desalination plant along the eastern coastline of Bahrain (2012).

3.2.4. Sewage discharges

Sewage effluents are considered one of the most common anthropogenic disturbances of marine ecosystems in the Arabian Gulf. Despite high standards of sewage treatment (i.e. secondary or tertiary) (Sheppard et al. 2010), large quantities of domestic effluents are discharged to coastal and marine environments in the Arabian Gulf. These effluents are characterized by high-suspended solids and high loads of nutrients such as ammonia, nitrates and phosphates (Naser, 2011a). Sewage effluents are generally accompanied by biological and chemical pollutants, including pathogen microorganisms and heavy metals (Shatti and Abdullah, 1999). Bioaccumulation and biomagnification of pathogenic organisms and chemical contaminants due to sewage discharges affect the quality of human food and subsequently pose threat to human health.

Shallow subtidal areas and semi-enclosed embayments are the receiving environments for most of the sewage discharges in the Arabian Gulf, which can cause localized eutrophication, nutrient enrichment and oxygen depletion. Kuwait Bay in Kuwait and Tubli Bay in Bahrain have witnessed several eutrophication conditions and fish mortality phenomena due to excessive sewage discharges (Al-Ansi et al., 2002; Glibert et al., 2002). Naser (2013b) studied crustacean assemblages influenced by sewage discharges from a major treatment station in Bahrain. The study reported a reduction in biodiversity, richness and evenness of crustaceans

reflecting severe habitat degradation in the nearby marine environment. Additionally, influenced areas were characterized by marked increase in organic enrichment, mainly ammonia and phosphate.

3.2.5. Oil pollution

The Arabian Gulf is considered the largest reserve of oil in the world (Literathy et al., 2002). Consequently, coastal and marine environments in the Arabian Gulf are under permanent threat from oil related pollution. Oil exploration, production, and transport have been major contributors to pollution in the Arabian Gulf. Sources of oil spills in the Arabian Gulf include offshore oil wells, underwater pipelines, oil tanker incidents, oil terminals, loading and handling operations, weathered oil and tar balls, illegal dumping of ballast water, and military activities (Sale et al., 2010).

The Arabian Gulf has been a scene for major oil spill incidents in the world. Bahrain experienced one of the earliest major oil spills in the Arabian Gulf in 1980. A large oil slick (20,000 barrels) invaded the north and west coasts of Bahrain causing severe ecological and economical damages (Brown and James, 1985). This major incident was a precursor for establishing the first governmental authority concerned with the protection of environment in Bahrain in 1980; namely, the Environmental Protection Committee (EPC). The most notorious oil spill reported in the Arabian Gulf occurred during the 1991 Gulf War. An estimated 10.8 million barrels of oil were spilled in the Arabian Gulf waters (Massoud et al., 1998).

Oil pollution adversely affects marine ecosystems by reducing photosynthetic rates in phytoplankton and marine algae, accumulating toxic chemicals in several benthic organisms, and contaminating human food chains with carcinogenic substances. Seabirds and intertidal waders are predominantly vulnerable to oil pollution. For instance, several seabirds suffered severe mortality (22–50%) during the 1991 oil spill in the Arabian Gulf (Evans et al., 1993). Environmental consequences of long-term chronic oil pollution include degradation of sensitive ecosystems such as seagrass bed, coral reefs and mangroves, which may subsequently lead to decline in fish stocks and other renewable marine resources.

4. Conservation and management

Conservation biology is an integrated, multidisciplinary scientific field that has developed in response to the challenge of preserving species and ecosystems. Valued ecosystem components in the Arabian Gulf are facing several challenges due to habitat destruction, fragmentation, degradation and pollution. These are reflected in the decline in regional coral reefs due to natural and anthropogenic stressors, the loss of prime mudflats and mangroves swamps and seagrass beds due to intensive dredging and reclamation activities and anthropogenic effluents. Therefore, effective conservation and management of marine ecosystems in the Arabian Gulf is becoming an urgent need in order to protect and sustain these vulnerable ecosystems. Additionally, effectively managed ecosystems provide a range of essential environmental services that contribute to economic, social and cultural aspirations in the

Arabian Gulf (Al-Cibahy et al., 2012). This section therefore suggests conservation approaches and management strategies that might contribute to the protection of the fragile marine ecosystems in the Arabian Gulf, including marine protected areas, Environmental Impact Assessment (EIA), environmental regulations, ecological restoration, and environmental monitoring and scientific research.

4.1. Marine protected areas

A marine protected area (MPA) is defined by the International Union for Conservation of Nature (IUCN) as "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Dudley, 2008).

Marine protected areas (MPAs) are globally recognized as the most important tool for in situ conservation (Chape et al., 2005). MPAs contribute significantly to both preservation and conservation of genetic characteristics, species, habitats and cultural diversity in coastal and marine environments. They can help in preventing or reducing the ongoing declines in marine biodiversity, habitats and fisheries productivity. MPAs can also improve ecosystem functions and services through maintaining ecological structure and processes that support economic and social uses of marine resources (Agardy, 1994). Additionally, MPAs can contribute towards climate change adaptation by protecting ecosystem resilience and protecting essential ecosystem services (McLeod et al., 2009).

Various relevant international conventions including Convention on Biological Diversity, Convention on Wetlands of International Importance (Ramsar Convention), and World Heritage Convention serve to advance the number and coverage of MPAs worldwide (Green et al., 2011). Similarly, regional conventions may promote the conservation benefits of marine protected areas in the Arabian Gulf. For instance, the Convention on the Conservation of Wildlife and their Natural Habitats in the Gulf Cooperation Council Countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates) provides the basis for integrating protected areas into national and regional environmental strategies and polices (GCC, 2010). This convention aims to effectively conserve ecosystems and wildlife habitats. It is also concerned with the protection of threatened species on a regional levels, especially when the distribution of these species exceed the international borders of two or more neighboring countries or when these species migrate across the boundaries of the member states.

The coastal and marine areas extended from Gulf of Bahrain to the United Arab Emirates have been identified as a potential transboundary marine protected area (Knight et al., 2011). These areas are shared by four countries (Saudi Arabia, Bahrain, Qatar, and United Arab Emirates) and characterized by high levels of species and habitat diversity.

Higher priority of conservation is typically given for areas that characterized by distinctive-ness, endangerment, and utility features (Primack, 2010). These characteristics are reflected on the proposed transboundary marine protected area. This area supports distinctive species, population and habitats, including vulnerable mega-fauna such as dugongs, turtles and dolphins, and ecological complex of seagrass beds, coral reefs and fisheries. However, it is

susceptible to anthropogenic threats due to coastal developments and pollution from a variety of land-based sources. Further, this area provides economic, touristic, cultural and educational benefits to the local people in the Arabian Gulf.

The archipelago of Hawar Islands, which is located in the Gulf of Bahrain, is characterized by varied coastal habitats, including muddy, sandy, and rocky shores as well as saline wetlands known locally as 'sabkha'. These islands are surrounded by shallow waters, which promote the growth of extensive seagrass beds and algal mats. These habitats support large populations of dugongs, green turtles and dolphins (Preen, 2004). Additionally, Hawar Islands provide undisturbed habitats for a variety of avian fauna. These islands host the largest breeding colonies of the endemic Socotra Cormorant (*Phalacrocorax nigrogularis*) in the world, with a winter population of 200,000 individuals (King, 1999). Due to the remarkable diversity in habitats and their associated fauna and flora, Hawar Islands were declared nationally as a wildlife sanctuary in 1996, and internationally as a Ramser site (convention on wetlands of international importance) in 1997.

Designation and implementation of MPAs are arguably critical for the protection of naturally stressed coastal and marine ecosystems in the Arabian Gulf. Toward this, about 38 officially designated MPAs covering around 18,180 km^2 have been established in the Arabian Gulf (Van Lavieren et al., 2011). However, number and coverage of MPAs may not provide an indication of the effectiveness of these MPAs in achieving their conservation goals (Chape et al., 2005).

Van Lavieren and Klaus, (2013) evaluated the management effectiveness of MPAs in the Arabian Gulf and revealed variable levels of performance. Several weaknesses in the MPAs in the Arabian Gulf were identified, notably the limitation in regulation enforcement, the lack of management plans, and the weak communication with local stakeholders, traditional communities, and local marine resource users (Van Lavieren and Klaus, 2013).

Local communities are recognized as the key focus for the success of conservation initiatives (Kideghesho et al., 2007). Public understanding, support and participation are important for the success of marine protected areas as a conservation management tool (Jameson et al., 2002). This could be promoted through reviving the concept of 'Hima' in the Arabian Gulf. Hima is considered a community based environmental resource management system that could help in building understanding and acceptance of protected areas and promoting the need to conserve and use marine resources wisely (Knight et al., 2011; Van Lavieren et al., 2011).

4.2. Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a systematic process of identifying, predicting, evaluating and mitigating the environmental consequences of a proposed project on the biological and physical environments. EIA aims at integrating environmental considerations in the decision-making system, minimizing or avoiding adverse impacts, protecting natural systems and their ecological processes, and implementing principles of sustainable development (Glasson et al., 2005).

EIA is considered a standard tool for decision-making in most countries throughout the world. It ensures that authorities are provided with necessary knowledge relating to any likely

significant effects of a proposed project on the environment prior to the decision-making process. The integration of environmental considerations may result in a rational and struc-tured decision-making process that maintains a balance of interest between the development action and the environment (Glasson et al., 2005). EIA minimizes or avoids the adverse effects of a proposed development on the environment by addressing effective designs, alternatives, mitigations, cumulative impacts, and monitoring (Cooper and Sheate, 2002).

Since the early stages of incorporating EIA in The National Environmental Policy Act in 1969, in the USA, considerations to protect ecosystems and biodiversity of natural resources and habitats have been an integrated part of the EIA process (Gontier et al., 2006).

EIA is one of the frequently used approaches in coastal planning and management (Kay and Alder, 2005). It is considered as an effective tool to minimize anthropogenic impacts and to induce the implementation of protection measures of coastal environment. The importance of EIA in protecting biodiversity and promoting the sustainable use of coastal and marine resources is represented in its fundamental role as a process for predicting the environmental effects of projects or programmes in coastal and marine areas. Therefore, EIA can be used to ensure that necessary measures needed to protect biodiversity and its sustainable use are addressed in the process of development planning (Khera & Kumar, 2010).

Additionally, EIA involves in facilitating consultation between various stakeholders as well as the public, considering alternatives for projects and locations, ensuring early identification of potential effects on coastal and marine environments, and implementing mitigation and compensation measures (Badr et al, 2004). Consequently, an effective EIA can contribute to the protection of biodiversity and to the sustainable use of coastal and marine environments in the Arabian Gulf.

Recognizing the role of EIA in protecting environment from degradation and pollution associated with rapid economic developments, Arabian Gulf countries have adopted EIA in their environmental policies (El-Fadl and El-Fadel, 2004). Coastal development projects, including reclamation and dredging activities, are required to be subjected to EIA in the Arabian Gulf. However, effectiveness of EIA in coastal and marine environments is constrain-ed by many factors that are also common in many other regions in the world. These include lack of adequate legal and regulatory frameworks, limited public participation, inadequate guidelines on procedural EIA, and lack of provisions related to cumulative impacts and strategic environmental assessment (Van Lavieren et al., 2011; Naser, 2012b).

Multiple anthropogenic stressors can lead to cumulative impacts on marine ecosystems (Crain et al., 2008). Coastlines of the Arabian Gulf are witnessing a rapid increase in the number and scale of coastal developments. The negative effects of these several separate developments may synergistically combine, additively or multiplicatively, to destroy biodiversity and marine ecosystems in the Arabian Gulf.

Planning of dredging and reclamation activities is typically carried out in the Arabian Gulf at a project-by-project basis, without assessing environmental impacts strategically. This approach may ignore the cumulative impacts of coastal reclamation on the valued ecosystem components in the Arabian Gulf. For instance, several reviewed EIA reports indicated that the

allocated sites of their projects were already impacted or degraded due to surrounding existing and ongoing projects (Naser, 2012b). Therefore, maintaining sustainable use of coastal and marine natural resources in the Arabian Gulf requires measures to holistically address the interactions among the several reclamation and dredging activities and their additive and cumulative impacts on valued ecosystem components.

Strategic Environmental Assessment (SEA), a tool to integrate environmental considerations into decision-making, may contribute toward achieving environmentally sound and sustainable development. SEA is defined as the process of evaluating the environmental consequences of proposed policies, plans and programmes, and addressing them into higher-level decision-making systems (Lamorgese and Geneletti, 2013). SEA has emerged as an important element in environmental decision-making process in developed countries, including Europe and North America. However, SEA is still relatively new or need to be introduced in the Arabian Gulf countries (Rachid and El-Fadel, 2013).

The need for a more strategic approach to environmental assessment in the Arabian Gulf can be illustrated by reference to coastal developments that associated with dredging and reclamation. The project-level EIA has been criticized for failing to ensure adequate considerations for potentially severe indirect, cumulative and synergistic environmental impacts on coastal and marine ecosystems (Naser et al., 2008).

Several reclamation and dredging activities are increasingly taking place within a relatively small geographical range on coastlines of the Arabian Gulf countries, which could have several cumulative consequences on the coastal and marine environments. SEA has the potential to promote sustainable development in coastal and marine environments through identifying cumulative impacts of exiting or planned projects, investigating feasible alternatives to coastal developments, and implementing effectively mitigation and compensation measures (Duisk et al., 2006).

SEA also has the advantages of integrating the coastal concerns into planning policies, facilitating consultation between various organizations as well as the public. Additionally, SEA can identify social, economic, and environmental issues associated with coastal development in the Arabian Gulf, and subsequently assist in the implementation of an important principle of sustainability (Barker, 2006).

Nonetheless, similar to many countries in the world (Liou and Yu, 2004), there are difficulties and challenges associated with the implementation of SEA in the Arabian Gulf. These include introducing and enforcing SEA law provisions, producing SEA related guidelines, clarifying administrative and procedural responsibilities of concerned bodies in SEA, institutionalizing networks, and encouraging public participation.

4.3. National, regional and international environmental regulations

Environmental legislations related to pollution prevention and biodiversity protection in the Arabian Gulf are based on a range of national laws and regulations as well as regional and international agreements. Nationally, there are several framework laws with respect to protecting the wildlife and their environment and combating environmental pollution in each

country. These general environmental laws facilitate the implementation of related regional and international regulations and agreements (Khan and Price, 2002).

Several laws and regulations dealing with protection of environment and biodiversity have been developed in the countries of the Arabian Gulf. These national instruments include laws with respect to environment, exploitation and protection of living marine resources, protection of wildlife and natural environment, environmental quality standards, environmental assessment, prevention of oil pollution, banning of catching endangered species, and establishment of marine protected areas. Although these national laws can, directly or indirectly, contribute to the protection of marine ecosystems in the Arabian Gulf, their effectiveness might be restricted by the lack of enforcement (Al-Awadhi, 2002).

Regionally, the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (Kuwait Convention), which was established in 1978, provides the basis for an integrated regional response to protecting biodiversity and combating pollution (Khan, 2008). The Regional Organization for the Protection of the Marine Environment (ROPME) was established under the Kuwait Convention to act as a focal point for regional cooperation (Khan and Price, 2002).

Currently, there are four Protocols under the Kuwait Convention; namely, protocol concerning regional cooperation in combating pollution by oil and other harmful substances in cases of emergency, protocol concerning marine pollution resulting from exploration and exploitation of continental shelf, protocol for the protection of the marine environment against pollution from land-based sources, and protocol on the control of marine transboundary movements and disposal of hazardous wastes. These protocols collectively address the pollution of marine environment and propose criteria for protection and management of ecosystems and marine resources (Khan and Price, 2002; Khan, 2008).

Internationally, the Convention on Biological Diversity (CBD) provides a legal, scientific and practical mechanism for biodiversity conservation. The CBD requires member states to develop national strategies and action plans for the conservation and sustainable use of biodiversity, integrate biodiversity into the relevant plans, programs and policies, identify activities likely to have significantly adverse impacts on biodiversity, develop a system of protected areas to conserve biodiversity, integrate consideration of conservation into national decision-making systems, and introduce environmental impact assessment to avoid or minimize adverse impacts of proposed projects on biodiversity.

Additionally, the Arabian Gulf countries have accepted or ratified several international agreements that can contribute to the protection of the coastal and marine environments. These include, among others, Convention on Wetlands of International Importance (Ramsar Convention), World Heritage Convention, United Nations Convention on the Law of the Sea, United Nations Framework Convention on Climate Change, International Maritime Organization (IMO) conventions, CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). These international agreements provide mechanisms for dealing with many aspects and concerns relating to the marine environment, and consequently contributing to the protection and conservation of marine ecosystems in the Arabian Gulf.

4.4. Ecological restoration

The Arabian Gulf is experiencing a substantial loss of productive habitat and ecosystem services (Price et al., 2012). Dredging and reclamation have transformed extensive coastal areas into artificial environments. Additionally, several types of pollution are contributing to ecosystem degradation. Ecological restoration is an approach that could help in minimizing or reversing the decline in ecosystem integrity in the Arabian Gulf.

Ecological restoration is described as an assisted recovery of degraded, damaged or destroyed ecosystems (Clewell and Aronson, 2006). Ecological restoration is increasingly playing an important role in conservation biology (Young, 2000). Ecological restoration provides the opportunity to conduct experiments to understand the structures and functions of ecosystems. Insight from such research can be invaluable for the conservation and the management of natural resources.

Although marine restoration lags behind terrestrial and freshwater counterparts (Elliott et al., 2007), restoration activities are increasingly conducted in coastal and marine environments worldwide. Similarly, several restoration projects have been conducted in the Arabian Gulf (Weishar, 2008). Planting projects to restore mangrove ecosystems have been conducted in most of the Arabian Gulf countries. The success of planting mangroves depends critically on the topographical and hydrological conditions of the selected site, including low energy shorelines with stable and non-eroding soil, gentle slop, sufficient depth, quantity and quality of water entering the site, and the requirement of low-salinity water (Field 1998).

Successful establishments and growth of mangrove plants have been reported in Qatar (Abdel-Razik, 1990; Al-Khayat and Jones, 1999) and Kuwait (Bhat et al., 2004; Bhat and Suleiman, 2005; Al-Nafisi et al., 2009; Almulla, 2013). However, only limited success of mangrove plantation has been reported in a sheltered bay in Bahrain (Al-Sayed et al., 2008). Therefore, there is an urgent need to investigate alternatives to restore the critically threatened mangrove ecosystems in Bahrain.

Planting mangroves in suitable intertidal areas in the Arabian Gulf is considered a sound approach for increasing coastal and marine productivity and supporting a wide range of biodiversity. For instance, coastal areas associated with planted and natural mangroves along the Qatari coastline support similar levels macrobenthos diversity (Al-Khayat and Jones, 1999). Likewise, Al-Nafisi et al. (2009) reported positive impacts for planted mangroves on coastal environment in Kuwait. Therefore, ecological and environmental benefits provided by planted mangroves may contribute positively to enhancing the overall productively of coastal and marine environments in the Arabian Gulf (Almulla et al., 2013).

Coral restoration could be carried out by creation of artificial reefs or translocation of healthy coral fragments to damaged reefs (Edwards and Gomez, 2007). Artificial reefs are frequently deployed in marine environment of the Arabian Gulf in an attempt to restore or enhance biodiversity and productivity of marine ecosystems. Generally, abundant and diverse communities of reef fish, coral and benthos organisms can develop on artificial structures (Feary et al., 2011). However, these communities may differ structurally and functionally from those in natural reefs (Burt et al., 2009).

Translocations of healthy corals have been conducted in some cases in the Arabian Gulf to avoid their distraction by large-scale marine projects. For instance, around 4,500 coral colonies from pipeline corridors which would have been affected by proposed expansion projects were relocated to another suitable location in Qatar (O'Donovan and McDonald, 2008). However, the success of such environmental initiatives in protecting affected corals remains to be investigated. Coral culture and transplantation within the Arabian Gulf is proposed as a feasible approach to maintain coral populations and preserve their adaptive capacities to future thermal stress events due to climate change (Coles and Riegl, 2013).

4.5. Integrated environmental monitoring and scientific research

Monitoring can be described as systemic observations and measurements of physical, chemical and biological variables to detect environmental changes over time (Lovett et al., 2007). Monitoring can provide decision makers with information on the state of biodiversity, and consequently, assist in identifying management goals and assessing priorities for conservation (Collen et al., 2013).

The key to protecting and managing biodiversity and marine resources is to characterize the structures of coastal and marine ecosystems (i.e. species and populations involved) and functions (i.e. flow of energy, growth and productivity). This could be achieved by adopting a holistic environmental monitoring approach that investigates, spatially and temporally, the physical, chemical and biological aspects of the valued ecosystem components in the Arabian Gulf (Naser, 2011a).

Several logistical and technical limitations may restrict the effectiveness of environmental monitoring in the Arabian Gulf. Van Lavieren and Klaus (2013) indicated that ecological monitoring and surveys in the Arabian Gulf are poorly designed and do not provide adequate information for decision-making systems.

Developing necessary plans and mechanisms for population and habitat conservation requires adequate knowledge and description of species. Therefore, there is a need to promote taxonomic research in the Arabian Gulf. Environmental impacts can be detected in a coarser level of taxonomic identification such as genus and family levels of biotic assemblages (Naser, 2010). However, effective conservation can only be achieved if the state of the environment is fully documented and understood, including species diversity. Therefore, it could be argued that while coarser taxonomic levels can be logistically useful in routine environmental monitoring, species-level is critically important to assess the biodiversity and to understand the structure and function of marine ecosystems in the Arabian Gulf.

Transboundary monitoring in the Arabian Gulf is needed to ensure that representatives of marine communities and habitats are included in the conservation measures. This could be addressed by increasing the cooperation between local and regional institutions and organizations concerned with ecological research and monitoring in the Arabian Gulf. The Regional Organization for the Protection of the Marine Environment (ROPME) may play an important role in strengthening the coordination of environmental monitoring and ecological surveys in the Arabian Gulf.

A key research need for marine conservation is to understand the individual and cumulative impacts of human disturbances on marine ecosystems. Therefore, monitoring should also be extended to processes and activities that are likely to have significant adverse impacts on the valued ecosystem components in the Arabian Gulf.

Feary et al. (2013) identified research topics that are considered to be the highest priority areas for future coral reef research in the Arabian Gulf, which could be extend to the other valued ecosystem components. These research areas include marine protected areas development, biological and ecological processes structuring marine ecosystems, climate change impacts on ecology and biology of ecosystems, effects of anthropogenic activities on marine ecosystems, connectivity of coral reef communities, disease biology, economic evaluation of ecosystems functions and services, monitoring and ecological surveys of species and communities, coral reef restoration and management, and mechanisms governing ecosystems' resistance and adaptation to environmental extremes. Strengthening cooperation between national, regional and international universities and scientific institutions in field of environment and conservation could facilitate the development and implementation of long-term research pograms in the Arabian Gulf.

Building capacity toward scientific research in the field of environment and conservation biology is important in order to effectively conserve and mange marine ecosystems in the Arabian Gulf. Therefore, there is a need for significant improvement in the number and quality of programs related to marine sciences in the Arabian Gulf universities (Burt, 2013).

5. Conclusions

The Arabian Gulf is one of the world's most enclosed, small-scale marine environments. It is characterized by shallow depth and restricted water exchange with the wider Indian Ocean. The Arabian Gulf represents one of the harshest marine environments in the world due to marked fluctuations in seawater temperatures and high levels of salinities. These environmental extremes may interfere with normal functioning of marine ecosystems and affect physiological aspects of marine organisms and their diversity, abundance and spatial distribution.

The Arabian Gulf hosts some of the world's most critically endangered species such as dugongs, green and hawksbill turtles, and supports a variety of marine ecosystems, including seagrass bed, mangroves, coral reefs and mudflats that are uniquely adapted to environmental extremes. These ecosystems are under ever-increasing pressure from anthropogenic activities that are associated with the rapid economic, social and industrial developments in the Arabian Gulf countries.

Marine environment of the Arabian Gulf is severely impacted. The coasts of the Arabian Gulf are witnessing rapid industrialization and urbanization that contribute to degradation of naturally stressed marine ecosystems. Coastal development associated with dredging and reclamation is particularly damaging to coastal and marine ecosystems. This is combined with

several anthropogenic factors, including industrial and domestic effluents, brine wastewater discharges and oil pollution.

Conserving species and communities and maintaining healthy ecosystems are important priorities in the marine environment of the Arabian Gulf. These could be achieved by adopting conservation approaches and management strategies that might contribute to the protection of the fragile marine ecosystems in the Arabian Gulf, including marine protected areas, environmental impact assessment, environmental regulations, ecological restoration, and environmental monitoring and scientific research.

Designation and implementation of marine protected areas are arguably critical for the protection of coastal and marine ecosystems in the Arabian Gulf. Although several marine protected areas have been established, lack of comprehensive management plans may hinder their effectiveness.

Environmental impact assessment can play an important role in the protection of biodiversity and in the sustainable use of coastal and marine environments in the Arabian Gulf. However, its effectiveness is constrained by the lack of adequate legal and regulatory frameworks, limited public participation, inadequate guidelines on procedural EIA, and lack of provisions related to cumulative impacts. Therefore, there is a need for a more strategic approach to environmental assessment that identifies environmental consequences of proposed policies, plans and programmes, and integrates environmental considerations into higher-level decision-making systems in the Arabian Gulf.

The Arabian Gulf countries have extensive national regional and international environmental legislations in place. Strengthening the implantation and the enforcement of the current regulations and agreements can substantially contribute to the protection of marine environment in the Arabian Gulf.

Ecological restoration principles could be adopted to minimize or reverse the decline in ecosystem integrity in the Arabian Gulf. Several restoration projects have been conducted in the coastal and marine environments of the Arabian Gulf. Planted mangroves provide several ecological and environmental benefits that may contribute to the productivity of coastal and marine habitats. However, the true impact of some restoration projects such as coral restoration remains to be investigated.

A holistic environmental monitoring and scientific research in the fields of marine sciences and conservation biology are integral part of any effort to conserve and manage biodiversity and marine resources in the Arabian Gulf. Improvement in both number and quality of academic programs related to marine sciences in the Arabian Gulf universities can contribute to building the long-term research capacity in the region.

Acknowledgements

Author details

Humood A. Naser

Department of Biology, College of Science, University of Bahrain, Kingdom of Bahrain

References

[1] Abdulqader, E., Miller, J. (2012). Marine turtle mortalities in Bahrain territorial waters. Chelonian Conservation and Biology, 11:133-138

[2] Abido, M., Abahussain, A., Abdel Munsif, H. (2011). Status and composition of mangrove plant community in Tubli Bay of Bahrain during the years 2005 and 2010. Arabian Gulf Journal of Scientific Research, 29:100-111.

[3] Abdel-Razik M (1990). Towards a prospective transplantation of the local mangrove Avicennia marina (Frossk.) Vierh. growing in coast of Qatar. Qatar University Science Bulletin 10: 199-211.

[4] Agardy, T. (1994). Advances in marine conservation: The role of marine protected areas. Trends in Ecology and Evolution, 9: 267-270.

[5] Al-Ansi, M., Abdel-Moati, M., Al-Ansari (2002). Causes of fish mortality along the Qatari waters (Arabian Gulf). International Journal of Environmental Studies, 59: 59-71.

[6] Al-Awadhi, B. (2002). Strengthening environmental law in state of Kuwait. Global judges symposium on sustainable development and the role of law. Johannesburg, South Africa, 18-20 August 2002.

[7] Al-Cibahy, A., Al-Khalifa, K., Boer, B., Samimi-Namin, K. (2012). Conservation of marine ecosystems with a special view to coral reefs in the Gulf. In: B. Riegal, S. Purkis (eds.) Coral reefs of the Gulf: Adaptation to climatic extremes. Springer, Dordrecht.

[8] Al-Ghadban, A. (2002). Geological oceanography of the Arabian Gulf. In: The Gulf ecosystem Health and Sustainability, N. Khan, M. Munawar, A. Price (Eds.), pp. 23-39, Backhuys Publishers, Leiden.

[9] Al-Jamali, F., Bishop, J., Osment, J., Jones, D., LeVay, L. (2005). A review of the impacts of aquaculture and artificial waterways upon coastal ecosystems in the Gulf (Arabian/Persian) including a case study demonstrating how future management may resolve these impacts. Aquatic Ecosystem Health and Management, 8: 81–94.

[10] Al-Jeneid, S. Bahnassy, M., Nasr, S., El Raey, M. (2008). Vulnerability assessment and adaptation to the impacts of sea level rise on the Kingdom of Bahrain. Mitigation and Adaptation Strategies for Global Change, 13: 87-104.

[11] Al-Khayat, J. Jones, D. (1999). A comparison of macrofauna of natural and replanted mangroves in Qatar. Estuarine, Coastal and Shelf science, 49: 55-63.

[12] Allan, S. Ramirez, C. & Vasquez, J. (2008). Effects of dredging on subtidal macrobenthic community structure in Mejillones Bay, Chile. International journal of Environment and Health, 2: 64-81.

[13] Al-Maslamani, I., Walton, M., Kennedy, H., Al-Mohannadi, M., Le Vay, L. (2013). Are mangroves in arid environments isolated systems? Life-history evidence of dietary contribution from inwelling in a mangrove-resident shrimp species. Estuarine, Coastal and Shelf Science, 124: 56-63.

[14] Almulla, L. (2013). Soil site suitability evaluation for mangrove plantation in Kuwait. World Applied Sciences Journal, 22: 1644-1651.

[15] Almulla, L., Bhat, N., Thomas, B., Rajesh, L., Ali, S., George, P. (2013). Assessment of existing mangrove plantation along Kuwait coastline. Biodiversity Journal, 4: 111-116.

[16] Al-Nafisi, R., Al-Ghadban, A., Gharib, I., Bhat, N. (2009). Positive impacts of mangrove plantations on Kuwait's coastal environment. European Journal of Scientific Research, 26: 510-521.

[17] Al-Sayed, H. Naser, H. & Al-Wedaei, K. (2008). Observations on macrobenthic invertebrates and wader bird assemblages in a tropical marine mudflat in Bahrain. Aquatic Ecosystem Health & Management, 11: 450-456.

[18] Al-Wedaei, K., Naser, H., Al-Sayed, H., Khamis, A. (2011). Assemblages of macrofaun associated with two seagrass beds in Kingdom of Bahrain: Implications for conservation. Journal of the Association of Arab Universities for Basic and Applied Sciences, 10: 1-7.

[19] Areiqat, A. Mohamed, K. (2005). Optimization of the negative impact of power and desalination plants on the ecosystem, Desalination, 185: 95-103.

[20] Badr, E., Cashmore. M., Cobb, D. (2004). The consideration of impacts upon the aquatic environment in environmental impact statements in England and Wales. Journal of Environmental Assessment Policy and Management, 6: 19-49.

[21] Barker, A. (2006). Strategic environmental assessment (SEA) as a tool for integration within coastal planning. Journal of Coastal Research, 22: 946-950.

[22] Barth, H., Khan, N. (2008). Biogeophysical setting of the Gulf. In: A. Abuzinada, H. Barth, F. Krupp, B. Boer, T. Abdessalam. Protecting the Gulf's marine ecosystems from pollution. Brikhauser Verlag/Switzerland.

[23] Bashitialshaaer, R., Persson K., Aljaradin M. (2011). Estimated future salinity in the Arabian Gulf, the Mediterranean Sea and the Red Sea consequences of brine discharge from desalination. International Journal of Academic Research, 3: 133-140.

[24] Bhat, N., Shahid S., Suleiman. M. (2004). Mangrove (Avicennia marina) establishment and growth under the arid climate of Kuwait. Arid Land Research and Management, 18: 127-139.

[25] Bhat, N., Suleiman, M. (2005). Classification of soils supporting mangrove plantations in Kuwait. Archives of Agronomy and Soil Science, 50: 535 - 551.

[26] Breitburg, D., Riedel, G. (2005). Multiple stresses in marine ecosystems. In: Marine conservation biology. E. Norse, L. Crowder (eds). Island Press, London, pp.167-182.

[27] Brown, D. James, J. (1985). Major oil spill response coordination in the combat of spills in Bahrain waters. Journal of Petroleum Technology, 37: 131-136.

[28] Burt, J., Bartholomew, A., Usseglio, P., Bauman, A., Sale, P. (2009). Are artificial reefs surrogates of natural habitats for coral fish in Dubai, United Arab Emirates? Coral Reefs, 28: 663-675.

[29] Burt, J. (2013). The growth of coral reef science in the Gulf: A historical perspectives. Marine Pollution Bulletin, 72: 289-301.

[30] Burt, J., Al-Khalifa, K., Khalaf, E., Alsuwaikh, B., Abdulwahab, A. (2013). The continuing decline of coral reefs in Bahrain. Marine Pollution Bulletin, 72: 357-363.

[31] Burt, J., Al-Harthi, S., Al-Cibahy, A. (2011). Long-term impacts of coral bleaching events on the world's warmnet reefs. Maine Environmental Research, 72: 225-229.

[32] Chape, S., Harrison, J., Spalding, M., Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of the Royal Society B: Biological Sciences, 360: 443-455.

[33] Clewell, A., Aronson, J. (2006). Motivations for the restoration of ecosystems. Conservation Biology, 20: 420-428.

[34] Coles, S. & McCain, J. (1990). Environmental factors affecting benthic communities of the western Arabian Gulf. Marine Environmental Research, 29: 289-315.

[35] Coles, S., Riegl, B. (2013). Thermal tolerances of reed corals in the Gulf: A review for the potential for increasing coral survival and adaptation to climate change through assisted translocation. Marine Pollution Bulletin, 72: 323-332.

[36] Collen, B., Pettorelli, N., Baillie, J., Durant S. (2013). Biodiversity monitoring and conservation: bridging the gap between global commitment and local action. John Wiley & Sons, London.

[37] Cooper, L., Sheate, W. (2002). Cumulative effect assessment: a review of UK environmental impact statements. Environmental Impact Assessment Review, 22: 415-439.

[38] Crain, C., Kroeker, K., Halpern, B. (2008). Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters, 11: 1304-1315.

[39] Dawoud, M., Al-Mulla, M. (2012). Environmental impacts of seawater desalination: Arabian Gulf case study. International Journal of Environment and Sustainability, 1: 22-37.

[40] De Mora, S. Fowler, S. Wyse, E. & Azemard, S. (2004). Distribution of heavy metals in marine bivalves, fish and coastal sediments in the Gulf and Gulf of Oman. Marine Pollution Bulletin, 49: 410-424.

[41] De Mora, S. Tolosa, I. Fowler, S. Villeneuve, J. Cassi, R. & Cattini, C. (2010). Distribution of petroleum hydrocarbons and organochlorinated contaminants in marine biota and coastal sediments from the ROPME Sea Area during 2005. Marine Pollution Bulletin, 60: 2323-2349.

[42] Dodd, R., Blasco, F., Rafii, Z., Torquebiau, E. (1999). Mangroves in the United Arab Emirates: ecotypic diversity in cuticular waxes at the bioclimatic extreme. Aquatic Botany, 63: 291-304.

[43] Dudley, N. (2008). Guidelines for applying protected area management categories. The International Union for Conservation of Nature (IUCN), Gland.

[44] Duffy, J. (2006). Biodiversity and the functioning of seagrass ecosystems. Marine Ecology Progress Series, 311: 233-250.

[45] Duisk, J., Fischer, T., Sadler, B., Steiner, A., Bonvoision, N. (2006). Benefits of a strategic environmental assessment. London: REC.

[46] Edwards, A., Gomez, E. (2007). Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme: St Lucia, Australia. 38 pp.

[47] El-Fadl, K., El-Fadel, M., 2004. Comparative assessment of EIA systems in MENA countries: challenges and prospects. Environmental Impact Assessment Review, 24: 553-593.

[48] Elliott. M., Burdon, D., Hemingway, K., Apitz, S. (2007). Estuarine, costal and marine ecosystem restoration: confusing management science- A revision of concepts. Estuarine, Costal and Shelf Science, 74: 349-366.

[49] Erftemeijer, P., Shuail, D. (2012). Seagrass habitats in the Arabian Gulf: distribution, tolerance thresholds and threats. Aquatic Ecosystem Health and Management. 15(S1): 73-83.

[50] Evans, M., Symens, P., Pilcher, C. (1993). Sort-term damage to coastal bird populations in Saudi Arabia and Kuwait following the 1991 Gulf War marine pollution. Marine Pollution Bulletin, 27: 157-161.

[51] Feary, D., Burt, J., Bartholomew, A. (2011). Artificial marine habitats in the Arabian Gulf: Review of current use, benefits and management implications. Ocean & Coastal Management, 54: 742-749.

[52] Feary, D., Burt, J., Bauman, A., Al Hazeem, S., Abdel-Moati, M., Al-Khalifa, K., Anderson, D., Amos, C., Baker, A., Bartholomew, A., Bento, R., Cavalcante, G., Chen, C., Coles, S., Dab, K., Fowler, A., George, D., Grandcourt, E., Hill, R., John, D., Jones, D., Keshavmurthy, S., Mahmoud, H., Tapeh, M., Mostafaci, P., Naser, H., Pichon, M., Purkis, S., Riegal B., Samimi-Namin, K., Sheppard, C., Samiei, J., Voolstra, C., Wiedenmann, J. (2013). Critical research needs for identifying future changes in Gulf coral reef ecosystems. Marine Pollution Bulletin. 72: 406-416.

[53] Field, C. (1998) Rehabilitation of mangrove ecosystem: an overview. Marine Pollution Bulletin, 37: 383-392.

[54] Fuller, S. (2005). Towards a Bahrain national report on the Convention on Biological Diversity. Report prepared for the General Directorate of Environment and Wildlife Protection, Kingdom of Bahrain and Unite Nations Development Program country office, Manama, Bahrain.

[55] GCC, Gulf Cooperation Countries, (2010). Guideline for the convention on the conservation of wildlife and their natural habitats in the Gulf Cooperation Council countries. Secretariat General, Riyadh.

[56] Glasson, J., Therivel R., Chadwick, A. (2005). Introduction to Environmental Impact Assessment. Spon Press, London.

[57] Glibert, P., Landsberg, J., Evans, J., Al-Sarawi, M., Faraj, M., Al-Jaeallah, M., Haywood, A., Ibrahem, S., Klesius, P., Powell, C., Shoemaker, C. (2002). A fish kill of massive proportion in Kuwait Bay, Arabian Gulf 2001: the roles of bacterial disease, harmful algae, and eutrophication. Harmful Algae, 1: 215-231.

[58] Gontier, M., Balfors, B. and Mortberg, U. (2006). Biodiversity in environmental assessment-current practice and tools for prediction. Environmental Impact Assessment Review, 26: 268-286.

[59] Green, S., White, A., Christie, P., Kilarski, S., Blesilda, A., Meneses, T., Samonte-Tan, G., Karrer, L., Fox, H., Campbell, S., Claussen, J. (2011). Emerging marine protected area networks in the Coral Triangle: Lessons and way forward. Conservation and Society, 9: 173-188.

[60] Halpern, B. Walbridge, S. Selkoe, K. Kappel, C. Micheli, F. D'Agrosa, C. Bruno, J. Casey, K. Ebert, C. Fox, H. Fujita, R. Heinemann, D. Lenihan, H. Madin, E. Perry, M. Selig, E. Spalding, M. Steneck, R. & Watson, R. (2008). A global map of human impact on marine ecosystems. Science, 319: 948-952.

[61] Hashim, A., Hajjaj, M. (2005). Impact of desalination plants fluid effluents on integrity of seawater, with the Arabian Gulf in perspective, Desalination, 182 373-393.

[62] Hamza, W. (2006). Observations on transported exotic plankton species to UAE coastal waters by gas tankers ballast water. In: A. Tubielewicz (Ed.), Living marine

resources and coastal habitats. EuroCoast-Littoral, pp. 47–53. Gdansk University of Technology, Poland.

[63] Hamza. W., Munawar, M. (2009). Protecting and managing the Arabian Gulf: Past, present and future. Aquatic Ecosystem Health & Management, 12: 429-439.

[64] Jameson, S., Tupperb, M., Ridley, J. (2002). The three screen doors: can marine protected areas be effective? Marine Pollution Bulletin, 44: 117-1183.

[65] IUCN (2012). IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. 32 pp.

[66] Kay, R., Alder, J. (2005) Coastal planning and management. Taylor & Francis, London.

[67] Khan, N. (2007). Multiple stressors and ecosystem-based management in the Gulf. Aquatic Ecosystem Health & Management, 10: 259-267.

[68] Khan, N. (2008). Integrated management of pollution stress in the Gulf. In: A. Abuzinada, H-J. Barth, F. Krupp, B. Boer, T. Al-Abdessalaam (Eds.), Protecting the Gulf's Marine Ecosystems from Pollution, pp. 57–92. Birkhauser, Basel.

[69] Khan, N. Price, A. (2002). Legal and institutional frameworks In: N. Khan, M. Munawar, A. Price (Eds.), The Gulf Ecosystem Health and Sustainability, pp. 399–424. Backhuys, Leiden.

[70] Khan, N., Munawar, M., Price, A. (Eds.) (2002). The Gulf ecosystem: Health and sustainability. Backhuys, Leiden.

[71] Khera, N., Kumar, A. (2010). Inclusion of biodiversity in environmental impact assessment (EIA): a case study of selected EIA reports in India. Impact Assessment and Project Appraisal, 28: 189-200.

[72] Kideghesho, J., Roskaft, E., Kaltenborn, B. (2007). Factors influencing conservation attitudes of local people in Western Serengeti, Tanzania. Biodiversity Conservation, 16: 2213-2230.

[73] King, H. (1999). The breeding birds of Hawar. Ministry of Housing, Bahrain.

[74] Knight, A., Seddon, P., Al-Midfa, A. (2011). Transboundary conservation initiatives and opportunities in the Arabian Peninsula. Zoology in the Middle East. 54 (sup3): 183-195.

[75] Lamorgese, L., Geneletti,D. (2013). Sustainability principles in strategic environmental assessment: a framework for analysis and examples from Italian urban planning. Environmental Impact Assessment Review, 42: 116-126.

[76] Lattemann, S., Hoepner, T.,(2008). Environmental impact and impact assessment of seawater desalination. Desalination, 220: 1-15.

[77] Literathy, P. Khan, N. & Linden, O. (2002). Oil and petroleum industry. In: The Gulf ecosystem: Health and Sustainability, N. Khan, M. Munawar & A. Price (Eds.), pp. 127-156, Backhuys Publishers, Leiden.

[78] Liou, M., Yu, Y. (2004). Development and implementation of strategic environmental assessment in Taiwan. Environmental Impact Assessment Review, 24: 337-350.

[79] Lovett, G., Burns, D., Driscoll, C., Jenkins, J., Mitchell, M., Rustad, L., Shanley, J., Likens, G., Haeuber, R. (2007). Who needs environmental monitoring? Frontiers in Ecology and the Environment, 5: 253-260.

[80] Massoud, M., Al-Abdali, F., Al-Ghadban, A. (1998). The status of oil pollution in the Arabian Gulf by the end of 1993. Environment International, 24: 11-22.

[81] McLeod, E., Salm, R., Green, A., Almany, J. (2009). Designing marine protected area networks to address the impacts of climate change. Frontiers in Ecology and the Environment, 7: 362–370.

[82] Naser, H. (2010). Testing taxonomic resolution levels for detecting environmental impacts using macrobenthic assemblages in tropical waters. Environmental Monitoring and Assessment, 170: 435-444.

[83] Naser, H. (2011a). Human impacts on marine biodiversity: macrobenthos in Bahrain, Arabian Gulf. In: The importance of biological interactions in the study of Biodiversity, J. Lopez-Pujol (ed.), INTECH Publishing. pp. 109-126.

[84] Naser, H. (2011b). Effects of reclamation on macrobenthic assemblages in the coastline of the Arabian Gulf: A microcosm experimental approach. Marine Pollution Bulletin, 62: 520-524.

[85] Naser, H. (2012a). Metal concentrations in marine sediments influenced by anthropogenic activities in Bahrain, Arabian Gulf. In: Metal contaminations: sources, detection and environmental impacts, Shao Hong-Bo (Editor), NOVA Science Publishers, Inc. New York, pp. 157-175.

[86] Naser, H. (2012b). Evaluation of the environmental impact assessment system in Bahrain. Journal of Environmental Protection, 3: 233-239.

[87] Naser, H. (2013a). Assessment and management of heavy metal pollution in the marine environment of the Arabian Gulf: A review. Marine Pollution Bulletin, 72:6-13.

[88] Naser, H. (2013b). Soft-bottom crustacean assemblages influenced by anthropogenic activities in Bahrain, Arabian Gulf. In: G. Sisto (ed.) Crustaceans: Structure, Ecology and Life Cycle. NOVA Science Publishers, Inc. New York. pp 95-112.

[89] Naser, H. (2013c). Effects of multi-stage and reverse osmosis desalinations on benthic assemblages in Bahrain, Arabian Gulf. Journal of Environmental Protection, 4: 180-187.

[90] Naser, H. Bythell, J. & Thomason, J. (2008). Ecological assessment: an initial evaluation of the ecological input in environmental impact assessment reports in Bahrain. Impact Assessment and Project Appraisal, 26: 201-208.

[91] Naser, H., Hoad, G. (2011). An investigation of salinity tolerance and salt secretion in protected mangroves, Bahrain. Gulf II: an international conference. The state of the Gulf ecosystem: Functioning and services. Kuwait City, Kuwait. 7-9 February 2011.

[92] O'Donovan, D., McDonald, I. (2008). Coral reef initiatives in the Middle East. Wildlife Middle East, 3 (2): 8

[93] Phillips, R. (2003). The seagrasses of the Arabian Gulf and Arabian Region. In: World Atlas of seagrasses, E. Green & F. Short. (Eds.), pp. 74-81, UNEP-WCMC.

[94] Preen, A. (2004). Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. Biological Conservation, 118: 205-218.

[95] Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012). Dugongs in Arabia; In: E. Himes, J. Reynolds III, L. Aragones, A. Mignucci-Giannoni, M. Marmontel (Eds.) Sirenian conservation: Issues and strategies in developing countries. University Press of Florida, Gainesville.

[96] Price, A. (2002). Simultaneous hotspots and coldspots of marine biodiversity and implications for global conservation. Marine Ecology Progress Series, 241: 23- 27.

[97] Price, A., Donlan, M., Sheppard, C., Munawar, M. (2012). Environmental rejuvenation of the Gulf by compensation and restoration. Aquatic Ecosystem Health & Management, 15 (S1): 7-13.

[98] Price, A. Sheppard C. & Roberts, C. (1993). The Gulf: Its biological setting. Marine Pollution Bulletin, 27: 9-15.

[99] Primack, R. (2010). Essential of conservation biology. Sinauer Associates. New York.

[100] Rachid, G., El Fadel, M. (2013). Comparative SWOT analysis of strategic environmental assessment systems in the Middle East and North Africa region. Journal of Environmental Management, 125: 85-93.

[101] Richlen, M., Morton, S., Jamali, E., Rajan, A., Anderson, D. (2010). The catastrophic 2008-2009 red tide in the Arabian Gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides. Harmful Algae, 9: 163–172.

[102] Riegl, B, Purkis, S. (2012). Coral reefs of the Gulf: adaptation to climatic extremes. Springer, Dordrecht Heidelberg.

[103] Sale, P., Feary, D., Burt, J., Bauman, A., Cavalcante, G., Drouillard, K., Kjerfve, B., Marquis, E., Trick, C., Usseglio, P., Van Lavieren, H. (2010). The growing need for

sustainable ecological management of marine communities of the Persian Gulf. Ambio, 40: 4-17.

[104] Shatti, J., Abdullah, T. (1999). Marine pollution due to wastewater discharge in Kuwait. Water Science and Technology, 40: 33-39.

[105] Sheppard, C., Price, A., Roberts, C. (1992). Marine ecology of the Arabian region: patterns and processes in extreme tropical environments. Academic Press, London.

[106] Sheppard, C. (2006). Longer-term impacts of climate change on coral reefs. In: coral reef conservation, I. Cote, J. Reynolds. Cambridge University Press, Cambridge, pp: 264-290.

[107] Sheppard, C., Loughland, R. (2002). Coral mortality and recovery in response to increasing temperature in the southern Arabian Gulf. Aquatic Ecosystem Health & Management, 5: 395-402.

[108] Sheppard, C. Al-Husiani, M. Al-Jamali, F. Al-Yamani, F. Baldwin, R. Bishop, J. Benzoni, F. Dutrieux, E. Dulvy, N. Durvasula, S. Jones, D. Loughland, R. Medio, D. Nithyanandan, M. Pilling, G. Polikarpov, I. Price, A. Purkis, S. Riegl, B. Saburova, M. Namin, K. Taylor, O. Wilson, S. & Zainal, K. (2010). The Gulf: A young sea in decline. Marine Pollution Bulletin, 60: 3-38.

[109] Smith, R. Purnama, A., Al-Barwani, H. (2007). Sensitivity of hypersaline Arabian Gulf to seawater desalination plants. Applied Mathematical Modelling, 31: 2347-2354.

[110] Spalding, M., Fox, H., Allen, G., Davidson, N., Ferdana, Z., Finlayson, M., Halpern, B., Jorge, M., Lombana, A., Lourie, S., Martin, K., McManus, E., Molnar, J., Recchia, C., Robertson, J. (2007). Marine ecoregions of the world: A bioregionalizaton of coastal and shelf areas. BioScience, 57: 573-583.

[111] Treweek, J. (1999). Ecological Impact Assessment. Blackwell Science Ltd, Oxford.

[112] Tu Do, V., Montaudouim, X., Blanchet, H., Lavesque, N. (2012). Seagrass burial by dredged sediment: benthic community alteration, secondary production loss, biotic index reduction and recovery possibility. Marine Pollution Bulletin, 64: 3340-2350.

[113] Uddin, S., Gevao, B., Al-Ghadban, A., Nithyanandan, Al-Shamroukh, D. (2012). Acidification in the Arabian Gulf – Insights from pH and temperature measurements. Journal of Environmental Monitoring. 14: 1479-1482.

[114] Van Lavieren, H., Burt, J., Feary, D., Cavalcante, G., Marquis, E., Benedetti, L., Trick, C., Kjerfve, B., Sale, P. (2011). Managing the growing impacts of development on fragile coastal and marine ecosystems: lessons from the Gulf. A policy report, UNU-INWEH, Hamilton, ON, Canada.

[115] Van Lavieren, H., Klaus, R. (2013). An effective regional marine protected area network for ROPME Sea Area: Unrealistic vision or realistic possibility? Marine Pollution Bulletin, 72: 389-405.

[116] Wake, H. (2005). Oil refineries: a review of their ecological impacts on the aquatic environment. Estuarine, Coastal and Shelf Science, 62: 131-140.

[117] Weishar, L., Watt, I., Jones, D., Aubrey, D. (2008). Evaluation of arid salt marsh restoration techniques. In: A. Abuzinada, H. Barth, F. Krupp, B. Boer, T. Abdessalam. Protecting the Gulf's marine ecosystems from pollution. Brikhauser Verlag/Switzerland.

[118] Wilkinson, C. (2008). Status of Coral Reefs of the World. Australian Institute of Marine Science, Townsville.

[119] Young, T. (2000). Restoration ecology and conservation biology. Biological Conservation, 92: 73-83.