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Positive Impacts of Mangrove Plantations on Kuwait's Coastal Environment

Reem S. Al-Nafisi
Environmental Science Department, Environmental and Urban Development Division
Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait
E-mail: rnafisi@safat.kisr.edu.kw
Tel: (00965) 4989173; Fax: (00965) 9089

Abdulnabi Al-Ghadban
Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait

Ismail Gharib
Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait

Narayana R. Bhat
Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait

Abstract

The State of Kuwait has initiated a large-scale greenery program to both beautify and enrich the living environment. The 290 km long coastline, of which approximately 57% is the intertidal zone, offers a good potential for greenery development. Afforestation of intertidal zones with mangrove plants is considered an option to improve coastal environment and enrich marine biodiversity. Past studies have established scientific feasibility for growing mangroves along Kuwait's coastline. The study reported in this paper was conducted to assess the environmental impact for introduction of mangrove *(Avicennia marina)* to Kuwait's coastline. This study was conducted during 2000-2001 using two ten year old and one newly established *Avicennia marina* plantations. Biodiversity and productivity together with water quality and total organic carbon contents of mudflat soils were determined to evaluate the impacts of mangrove plants in the intertidal zone on the environment. The study showed positive impacts of mangrove plants on the environmental parameters studied. This was manifested by the improvement in the water quality and reduction of total organic carbon. Due to this positive impact, an action plan for the establishment of intensive mangrove plantation along Kuwait's coastline has been suggested.

Keywords: *Avicennia marina*, marine biodiversity, marine productivity, intertidal mudflat, coastal greening

Introduction

Marine ecosystems have been an important renewable resource for Kuwait. However, in recent years, increased developmental activities and misuse of native vegetation have greatly degraded the coastal

environment and marine ecosystems. Harsh weather conditions have also accelerated the disappearance of vegetation cover in both coastal and inland areas. Hence, the State of Kuwait has initiated a greenery program to both beautify and enrich the living environment. The 290 km long coastline, of which approximately 57% is the intertidal zone, offers a good potential for greenery development (AbuEl-Nil et al., 2001). Afforestation of intertidal zones with mangrove plants is considered a viable option to improve coastal environment and enrich marine biodiversity. Mangrove plantations also protect the coastline from strong currents and support the accumulation of sediments and organic matter in the intertidal zones. These changes would improve the quality of mudflats and promote the survival and growth of marine fauna (Subandar et al., 2001; Ogino, 1993; Emabi 1993). In view of these benefits, the Kuwait Institute for Scientific Research (KISR) initiated studies in 1991 to naturalize mangrove species and establish technical feasibility for growing mangrove species (*Avicennia marina, Avicennia germinans and Ceriops tagal*) under Kuwait's coastal environmental conditions. For this purpose, three experimental plantations of *Avicennia marina* was established in 1993 (Abu El-Nil et al., 2001) and subsequently, five more have been established during 1999-2000 (Bhat et al., 2002). Periodic observations on growth performance of different mangrove ecotypes suggested good potential for using mangroves in the intertidal mudflats at suitable locations (Bhat et. al., 2002; Bhat et al., 2004). It was observed that the marine fauna flourished in these plantations. Large amounts of leaf debris accumulated in the interdidal zones, crab burrows increased and shells of marine animals deposited onshore. Several birds started to visit and live near mangrove plantations, an indication of increased availability of food.

Avicennia marina is a hardy mangrove species known for its tolerance to environmental stresses, particularly to temperature extremes and high salinity (Clough, 1993), although the growth of trees is influenced by a combination of stress factors (Al-Muharami, 1994). It thrives in a number of soils, often rooting into deep, water-saturated anaerobic layers. In Australia, mangroves grow in soils with a wide range of soil textures, from coarse sand through fine alluvial soils, heavy clays and peats, but most soils have soil salinity near to that of the tidal water (Clough, 1993). Hence, this species has been recommended for establishing large-scale plantations in Kuwait.

When introduction is successful and the plant has been naturalized, it is important to ascertain the potential environmental impacts of its introduction and suggest mitigation measures to overcome any negative impacts that might result from new introductions. Hence, the present study was conducted to asses the impacts of mangrove introduction on Kuwait's marine environment and marine biodiversity.

Materials and Methods

Climate and Soil

Geographically, Kuwait occupies approximately 17,800 km^2 of the northwestern part of the Arabian Gulf, between 28°30' and 30°05'N, and 46°33' and 48°30'E It is bounded on the South by Saudi Arabia, on the North and west by Iraq, and on the East by the Arabian Gulf.(Annual Statistical Abstract, 2006). Kuwait's climate is characterized by harsh summers and mild winters. Temperature extremes are high, with means during the warmest and coolest months ranging between 46.2°C and 6.9°C (Annual Statistical Abstract, 2006). Winter brings occasional frost. Rainfall is minimal, not exceeding 115 $mm.yr^{-1}$, but evaporation is very high, averaging 14.1 $mm.d^{-1}$. The relative humidity is low, and strong, dry and hot, northwesterly winds prevail during summer, particularly in June and July. Kuwait's soils are sandy in texture, alkaline, high in calcareous materials ($CaCO_3$) and low in organic matter and plant nutrients. Underground water resources are limited and brackish in nature with total dissolved solids (TDS) concentrations ranging from 3.0 to 10.0 $g.liter^{-1}$.

Costal Habitat

Coastal habitats in Kuwait range from exposed beaches to rocky highlands. Sand, silt and clay exist on both intertidal and sub-tidal littoral zones. Artificial structures (platform, jetties, etc.) and offshore islands play a considerable role in the variability of resources existing in Kuwait.

Jones (1985) in his study on the coastal and marine habitats in the Arabian Gulf, noted that the interaction of the physical factors produces a severe regime for the marine biota of the region, especially intertidally, so that diversity is lower within the inner part of the area (Strait of Hormuz to north) than in the gulf of Oman and the Indian Ocean in general. Although biological and ecological data on the marine biota of the region is limited, with some coastal areas receiving more attention than others at least four critical marine habitats, coral reefs, intertidal marshes, mangrove and sea grass beds, and kept forest, have been recognized in the region (Price 1993).

Coastal Geomorphology and Environmental Setting

Based on the sediment nature and morphology, the coastal zone of Kuwait was classified into two main provinces: northern muddy (material finer than 62.5 microns) province and southern rocky/sandy (coarser than 62.5 microns) province. These provinces were subdivided into several zones (Abou-Seida and Al-Sarawi, 1990)

The northern coastal area is characterized by the presence of Khor Al-Subiya, which is a long tidal channel at 60 km long and 1.5 km wide, separating Bubiyan and Warba islands from the mainland. The coastal strip of this area has a muddy intertidal flat 300-1300 wide. The intertial zone in this area is bound landward by a wide coastal Sabkha (low land occasionally flooded by water by high tide).

One of the features of the Kuwaiti marine environment is Kuwait bay which is an elliptically shaped bay that protrudes from the Arabian Gulf in westward direction at its northwestern corner. It is of a moderate size (850 km^2) with an average water depth of 5 m and a maximum depth of 20 m at the entrance (Al-Ghadban, 2004). The northern shoreline is a pristine shore and in contrast, the southern part the bay hosts urban activities, major ports such as Shuwaikh and Doha Ports and three major power and desalination plants (Doha East, Doha west and Subiya). Kuwait Bay presents a unique ecosystem and a significant nursery ground for many fishes and shrimp species (Al-Yamani et al., 2004). The bay supports a thriving fishing industry and contains a site of an aquaculture facility of 80 net pen cages with a production of roughly 500 – 600 metric tons of sea bream (*Sparus auratus L.*) per year (Glibert, et al., 2004).

Based on the data by Dames and Moore (1983) and other sources (e.g., Samhan et al. 1986), the water quality in Kuwait Bay and Khor Al-Subiya is acceptable. Dissolved oxygen levels are above minimum accepted limits, biological oxygen demand is low, trace metal concentrations are also low, and pH values are within acceptable limits. Moreover, strong tidal currents provide good flushing of the water of the bay and about 30% of the water of the bay is exchanged in a normal tide cycle (Al-Ghadban and Al-Ajmi, 1993). Other physical and chemical parameters such as alkalinity, phosphorous level, salinity, and oil and grease are within acceptable and normal values for this region of the world.

The situation is somewhat different along the coastal zone. This area is exposed and stressed as a result of the extensive man-made activities, such as dredging, indiscriminate solid and liquid waste disposal and over fishing. In their extensive study for the coastal area of Kuwait, Al-Bakri et al., (1985) have concluded that the alteration of the coastal zone has resulted in more impact to the ecosystem compared to the harsh environmental condition. The environmental condition of the coastal area became more critical as a result of the war-related activities (Al-Ghadban et al., 1992).

Sulaibikhat embayment is located in the southern part of Kuwait Bay. It is a shallow water body with a maximum 4 meter water depth and a muddy bottom. The surface water consistently flows northwest into Kadhma Bay during flood tides, reversing during ebb tides with a current velocity of 1.0

m/sec at the central part of the bay (Dames and Moore 1983). It hosts urban activities and several discharge point sources such as sanitary, wastewater and emergency outlets (Fig. 1).

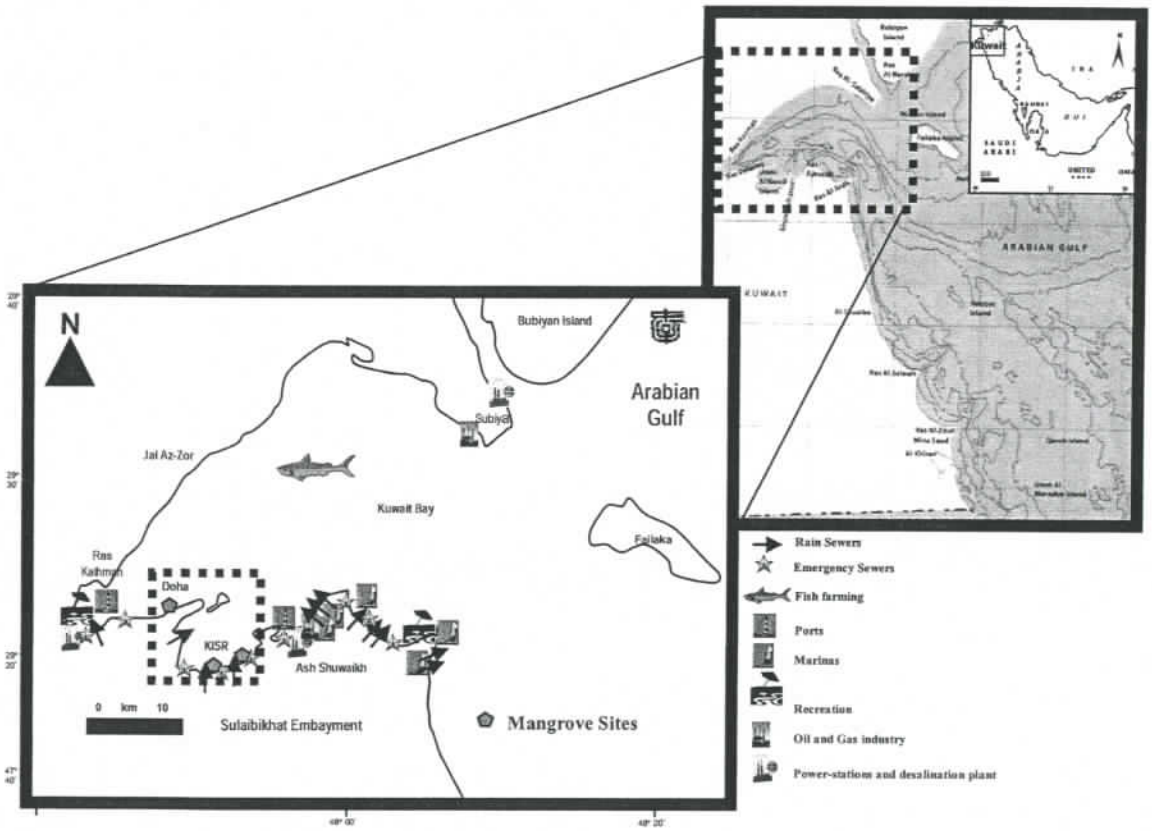
Previous studies on sediments quality of Sulaibikhat embayment reported higher concentrations of total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbon (PAHs) and aliphatic hydrocarbons (Khan et al., 1999). Such contaminants were attributed to the effect of Shuwaikh and Doha ports and the discharge points in the bay (Fig. 1).

In his recent study Al-Sammak et al., (2005) compared the levels of heavy metals in bottom sediments of Kuwait Bay and Sulaibikhat embayment with the reported values of Dubai creek and Canada and highlighted higher values of cadimum and nickel. Al-Majed et al., (2004) identified certain concentration of total and methyl mercury in the embayment and attributed such concentration due to the power plant and also due to the pervious industrial outfall and also due to the shipping activities and the discharged into the area from the emergency outlets.

Higher values of total organic carbon content (more than 3%) were reported in the area (Al-Ghadban et al., 1994). In their study, Al-Sammak et al., (2005) reported that Sulaibikhat embayment is the most vulnerable area with an increase concentration of pollution load, and therefore, recommended a rehabilitation plan for the area.

This paper is an integral part of a major project which was conducted at the Kuwait Institute for Scientific Research for the purpose of introduction of mangrove on the southern part of Kuwait bay (Bhat et al., 2002). This paper discusses the environmental impact assessment approach which was used for such plantation.

Figure 1: Kuwait Bay Including Sulaibikhat Embayment



Establishment of Mangrove Plantations

Selection of Sites. In 1993, mangrove [*Avicennia marina* (Forssk) Vierh] plantations were established on two sites. However, the sites for the recent plantations were selected based on field surveys of the

entire coastline and analysis of soils from all potential sites (Bhat et al., 2002; Bhat and Suleiman, 2004). The five sites that were found most suitable were used for establishing experimental plantations.

Raising and hardening of Seedlings. Propagules of *Avicennia marina* used for raising seedlings were procured from United Arab Emirates. Immediately upon arrival, propagules were unpacked and graded into large (with an average weight of 5.0 g) and small size (average weight of 2.4 – 2.5 g) before placing them in fresh water (total dissolved salts around 500 ppm). Holding water was changed daily and the separated peels were removed to prevent the accumulation of phenolic compounds in the holding water. Out of the various soaking duration treatments (0, 24, 48 or 72 hrs) tested, 24 hr soaking treatment resulted most rapid and greater germination than other treatments. Hence, this treatment was used in subsequent studies. Presoaked propagules were germinated in specially designed galvanized iron (GI) trays or polyethylene-lined benches in an evaporatively cooled greenhouse. For improving survival and growth in the field, seedlings were acclimatized to prevailing salinity levels by gradually raising the salinity levels of the holding water to around 50,000 ppm. The seedlings were maintained at this salinity level until they are transferred to the field.

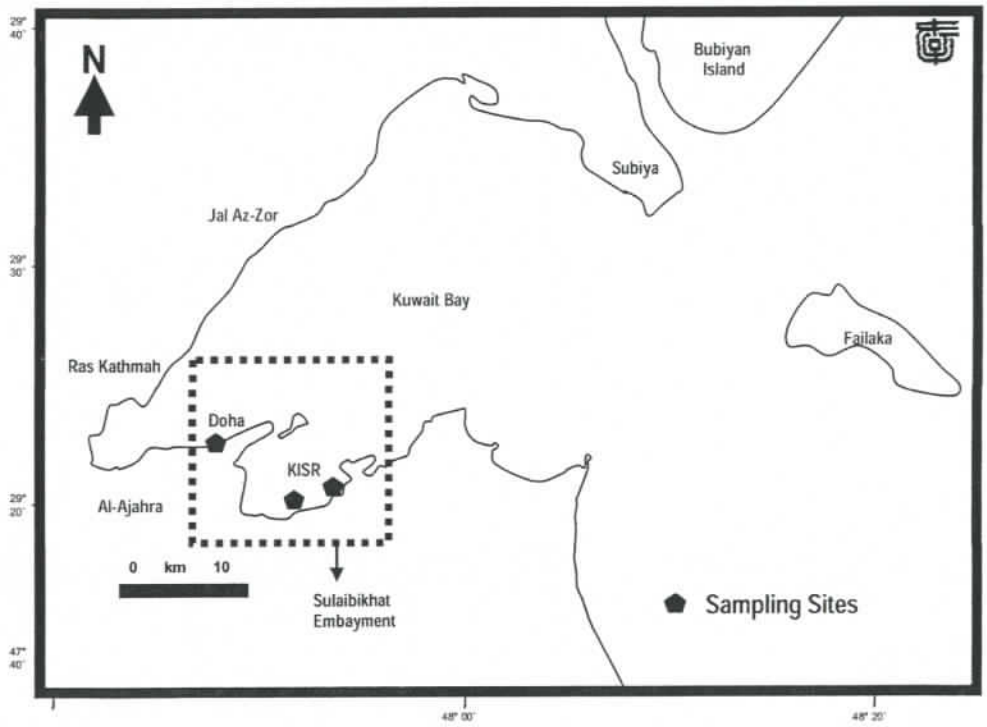
Field Planting. Acclimatized seedlings of *Avicennia marina* with an average height of 25 – 30 cm were planted in five selected sites. Thirty-cm planting holes were prepared in three or more rows (tidal line, one or more lines on either side of the tidal line at 1 X 1 m spacing. The taproot with its root ball intact was inserted into the planting holes and back-filled with the native soil. Survival and growth of seedlings at different locations were monitored periodically.

Mangrove plantations at three sites (two old and one new) were used in the environmental impact assessment (Fig. 2).

Environment Impact Assessment Procedure

This is not a classical Environmental Impact Assessment (EIA) project, so the main method used for implementing an EIA in this study was a comparison between two sites of old mangrove plantations (one on the east planted in 1993 and other one on west (planted in July 1992), and one of the five new plantations (planted in Doha

Figure 2: Mangrove Sampling Sites



in April 2001). A comparison among the 3 areas was done to observe the effect of mangrove plants on the environment. The comparison was based on water quality measurements, total organic carbon content in the soil, and biodiversity of Macroinvertebrates. Measurements were taken for the above parameters, and the final conclusion was derived from the important findings pointing to the potential ecological, physico-chemical and aesthetic effects.

Sampling and Analysis Procedures

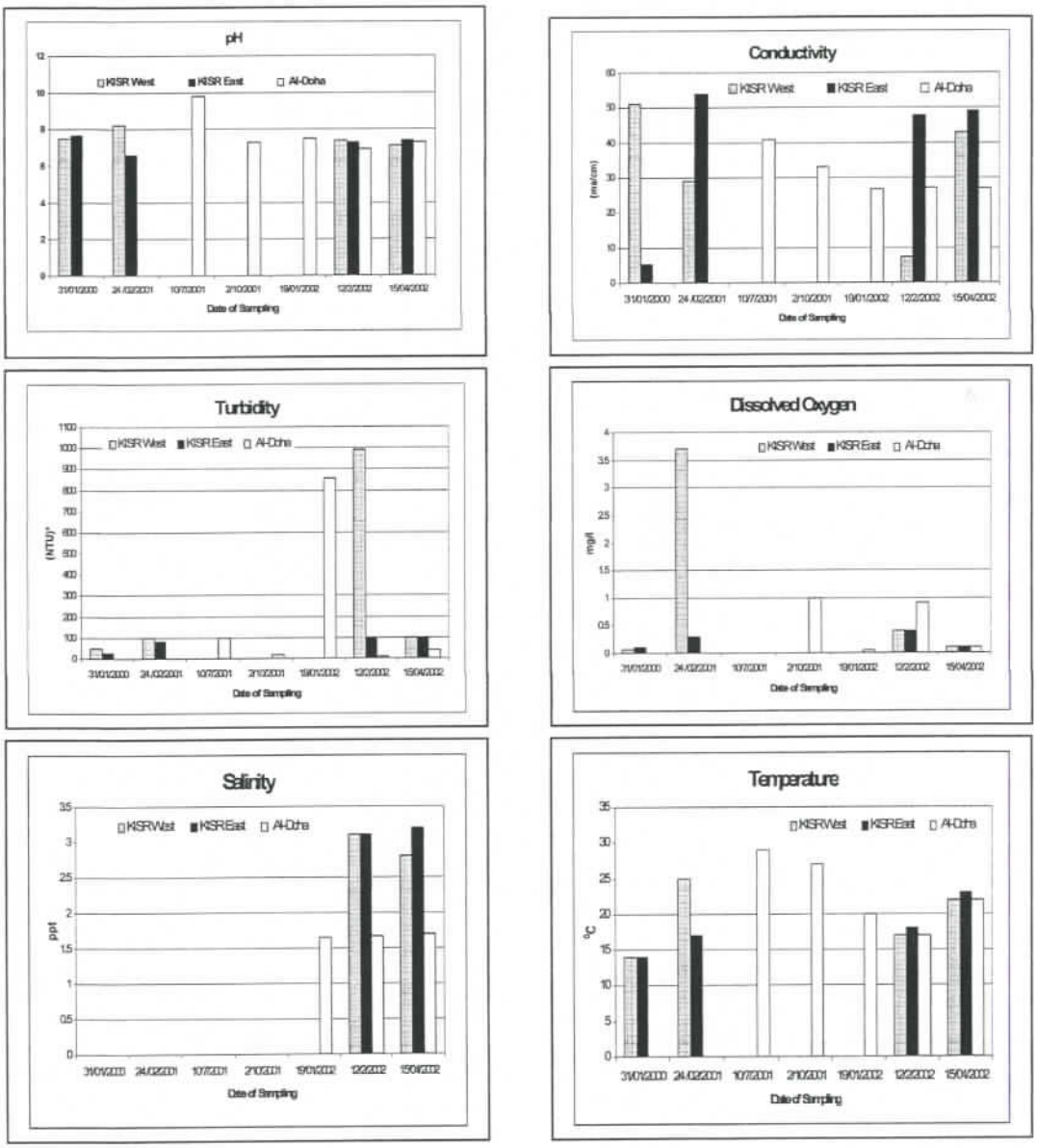
Water quality was assessed using a portable measuring instrument "Horiba" (Water Quality Checker U-10, Kernco Instruments Co., INC). For this purpose, a pit dug was about 1.5 m deep and 1.0 m wide about 5 meters away from the plantations. Measurements were taken by the apparatus. Soil samples were collected from the upper layer of soil profile in the close proximity of mangrove plants. Total organic carbon contents were determined according to the Wakeel and Riley method (Wakeel and Riley, 1957). Soil samples for assessing the marine fauna were collected from three mangrove sites at random using the Quadrant procedure and identified to the species level with the help of Invertebrate Taxonomists from Kuwait University.

Results

Water Quality

The water quality parameters as measured at the three mangrove sites are presented in Fig.3

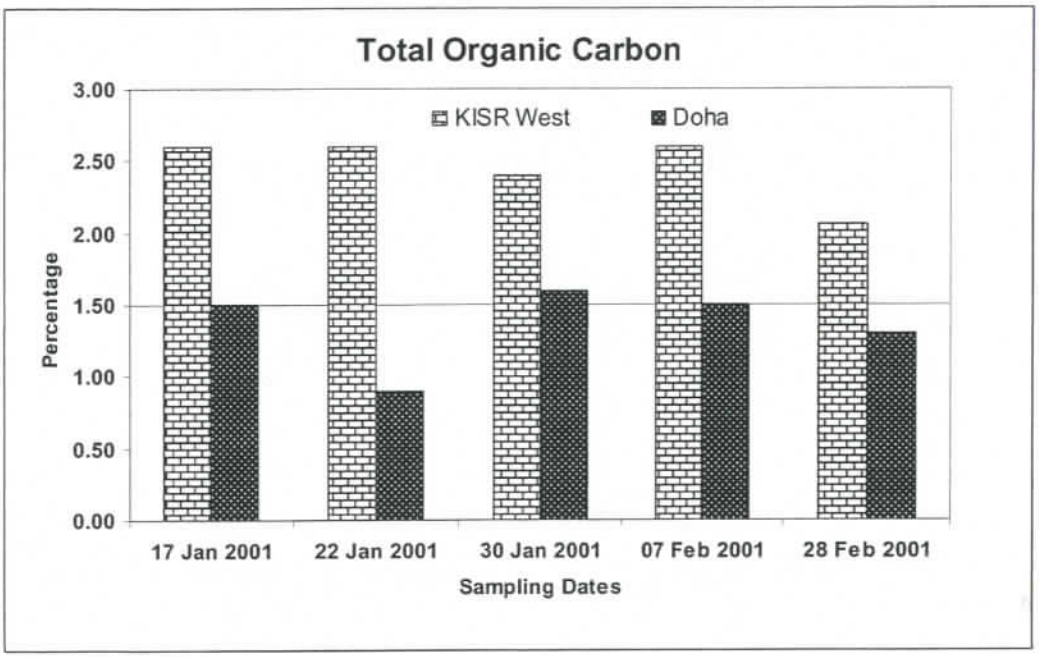
Figure 3: Main Parameters of Water Quality measured at 3 sites (a) KISR WEST (b) KISR EAST (c) Al-Doha



Total Organic Carbon

Figure (4) summarize the findings of the total organic carbon (TOC) analysis in site KISR west and Al-Doha site, the Sheikh Zaid Bin Sultan conservatory, collected over a period of time.

Figure 4: Total Organic Carbon percentage at the sites (a) KISR West (b) Doha



Biological Diversity

Macro-invertebrates in KISR site 1 (east) and 2 (west), and in Doha site are presented in Table 1.

Table 1: Macroinvertebrates in KISR Station 1 and 2 and Al-Doha Station (Mangrove)

Phaylum	Class	Subclass	Order	Family	Species	KISR St. 1 (East)			KISR St. 2 (West)			Al-Doha st		
						Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
Annelida	Polychaeta			Nereidae	Nereis sp.		x				x			
Mollusca	Gastropoda	Prosobranchia	Mesogastropoda	Littorinidae	Nodilittorina (Nodilitorina arabica)		x							
				Planaxidae	Planaxis sulcatus		x							
				Potamididae	Cerithidea cingulata		x	x		x	x	x	x	x
				Cerithiopsidae	Seila sp.		x							
	Bivalvia	Pteriomorpha	Mytiloida	Mytilidae	Brachidontes variabilis							x		
			Ostreeida	Ostreidae	Saccostrea cucullata		x	x		x				
		Heterodonta	Venenoida	Chamidae	Chama asperella									x
				Trapeziidae	Trapezium sublaevigatum							x		
Arthropoda	Crustacea	Cirripedia			Balanus amphitrite		x	x			x	x		
		Malacostraca	Isopoda		Ligia exotica	x								
			Amphipoda	Corophiidae	Unknown Corophium							x		
			Decapoda	Paguridae	Unknown hermit crab sp.	x			x					
				Alpheidae	Alpheus djeddensis									x
				Ocypodidae	Uca sindensis	x	x	x				x		
					Uca lactea	x	x	x	x					
					Nasima dotilliforme		x			x	x			x
					Nasima sp.		x					x	x	x
					Manningis arabicum						x			x
					Ilyoplax stevensi						x		x	
					Macrophthalmus depressus	x	x			x				
				Grapsidae	Nanosesarma minutum					x				
					Sesarma plicatum							x		
				Xanthidae	Eurycarcinus orientalis								x	
Chordata	Osteichthyes				Scartelaos viridis						x			
					Boleophthalmus boddarti						x			

X=Present

Discussion

Important outside factors occurred in Kuwait Bay and impacting Sulaibikhat embayment need to be considered when assessing the water quality. These factors are the discharge of approximately 30,000 cubic meters of untreated sewage water and the shut down of the sea water injection plant north of Kuwait Bay (used to inject treated sea water in oil wells to maximize oil production) that lead to release of highly toxic and biocidal bacteria. Such factors combined with the heat and humidity and low evaporation rate may have lead to the recent fish kill accident that happened in August 2001[5]. This impact also manifested on the death of some Mangrove plants in Al-Doha site in the north and therefore, it is difficult to observe the effect of the Mangrove plants on water quality.

It was noted that the total organic carbon in the upper tidal sediments at KISR stations was about 2% to 2.6% when compared to Doha station (0.9% to 1.5%). It is to be noted that the mangroves at KISR stations are 8 to 9 years old whilst Doha mangroves is less than a one year old. However, the observed higher values of TOC at KISR's site can be attributed to some recent events occurred in the area. Increased input of untreated sewage has lead to eutrophication and eventually had contributed to the increase of the total organic carbon percentage.

As for the biodiversity study increased numbers of animal phyla and species were found at KISR site compared to Doha site. KISR station 1 contained phyla; *Annelida, Mollusca*, and *Arthropoda*. In KISR station 2 similar ones in addition to Phyla chordata. Doha site on the other hand contained phylum *Mollusca* and *Arthropoda* only. Such increase in the biodiversity and population at KISR sites can be attributed to the increased of organic matter due to the existence of mangrove at that area.

It can be concluded that at the long run an increased population and diversity of fauna followed by richness of animal species can be expected in the area. This however, will lead to a better environment and good rehabilitation of this stressed area.

Another observation was noted in the area. Through months of autumn, spring and early summer, migratory birds were observed taking refuge in this area, amongst them are large flocks of flamingo, indicating the availability of sufficient food for these birds.

Based on the above, the cumulative effects points towards having positive impacts due to planting of mangrove in the polluted area it was concluded that the establishment of such mangroves proved to be effective in reducing the environmental stress in the area and improved the aesthetic value and contributed in the implementing the rehabilitation plan of Sulabikhat area.

The study showed the added value (beneficial) of such mangrove plantation in the impacted area and therefore, it was recommended that more plantation be executed in the impacted area for better environmental conditions.

Acknowledgement

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[5] This is the author's view and does not constitute any official records.

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