American-Eurasian J. Agric. & Environ. Sci., 6 (3): 328-340, 2009
ISSN 1818-6769

Present Status and Degradation Trends of Mangrove Forests on the Southern Red Sea Coast of Saudi Arabia

Loutfy I. El-Juhany

Prince Sultan Reseach Centre for Environment, Water and Desert,
King Saud University, P.O. Box 2454 Riyadh 11451, Saudi Arabia

Abstract: Present status of mangrove forests along the southern Red Sea shores in Saudi Arabia were studied in terms of their structure, hazards that threaten them, indications of their degradation and, the required conservation through an elaborated inventory comprises different phases. For the purpose of inventory, from "Al-Moussam" at the southern border point of Saudi Arabia to the Southern Jeddah Cornish north was considered as the southern Red Sea coast. Mangrove forests were inventoried in two large areas, Jazan region and Asir and Makkah Al-Mokrramah regions. Sampling frame was designated depending on stratified random sampling, where 6 and 9 sites were randomly chosen in Jazan and, Asir and Makkah Al-Mokrramah regions, respectively. The inventory showed that these mangrove forests are scattered groups consist mainly of *Avicennia marina* with only few groups of *Rhizophora mucronata*. Tree density was higher in Jazan region than in Asir and Makkah Al-Mokrramah regions but, the size of trees were greater in the former than the later. Although the inventoried area in Asir and Makkah Al-Mokrramah regions was approximately double that in Jazan region, however, the total stem volume in the former was only 57% of that in the later. The growth of the trees is very poor because they have been subjected to many anthropogenic and environmental stresses such as sand drifting, extensive exploitation, discharging wastewaters in the sea, disposing rubbish on the beaches, camel grazing, replacing by other activities such as large scale shrimp farming, die-back of trees and others. Restoration of mangrove forests in Saudi Arabia is essential and should start immediately through strict interferences that stop degradation firstly then through adopting comprehensive and extended national projects including conservation and reforestation measures as appropriate.

Key words: Mangrove · Red Sea coast · Saudi Arabia · Degradation · Restoration

INTRODUCTION

Mangrove forests are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines; they generally are trees and bushes growing below the high-water level of spring tides [1]. There are approximately 70 species of true mangroves of which some 65 contribute significantly to the structure of mangrove forests. The total area of mangroves in the world is 181,399 sq km, with 79 mangrove species are found in the world [2]. Approximately 15 species occur in South-East Asia, approximately 15 species occur in Africa and approximately 10 species occur in the America [3]. Areas of mangrove forests in Asia are found in Pakistan, India, Bangladesh, Myanmar, Thailand, Cambodia, Vietnam, Malaysia, Philippines and Indonesia. In addition, some mangrove forests occur in most other countries located between Arabian Peninsular in the west and Japan in the east. About two fifth of all mangrove forests in the world is in Asia [4].

Mangrove forests in Saudi Arabia are found in the form of fragmented stands in many tidal areas on the Red Sea and the Arabian Gulf coast, south of latitude 26° north. They consist mainly of *Avicennia marina* (Forssk.) Vierh. trees. On the coast of the Red Sea, *Avicenna marina* is accompanied by a few examples of *Rhizophora mucronata* Lam., while on the Saudi Arabian Gulf *Rhizophora mucronata* is very rare [5]. Mangrove forests along the Red Sea coast of Saudi Arabia are scattered groups spread from the southern borders with

Corresponding Author: Dr. Loutfy I. El-Juhany, Professor of Forestry, Prince Sultan Research Centre for Environment, Water and Desert, King Saud University, P. O. Box 2454 Riyadh 11451, Saudi Arabia
Tel: +966508860400

Yemen Republic to "Duhbah" in the north. They do not grow as luxuriously as most other tropical mangroves due to conditions of high salinity, poor soil textures, low precipitations and low nutrient concentrations [6, 7]. Their distribution is not continuous [8] and in general their growth is very poor as compared to deltaic areas in the world [9].

In the past, mangroves along the whole Red Sea coast of Saudi Arabia were dense but nowadays such dense growth occurs only in the southern section [10]. Environmental conditions in the RSGA Region (Red Sea and Gulf of Aden), such as temperature and salinity, are near the upper limits for mangrove existence, which makes them very sensitive to disturbance and can hinder their ability to recover [11].

The present status of mangrove forests in Saudi Arabia suggests that they have been subjected to various sorts of disturbances that affected their growth, distribution and the quality of their trees. Some of these disturbances are classified as physical factors such as sand movement but the most effective factors including extensive exploiting by the locals in the past. In addition, there were destructive practices to both marine and terrestrial environments through the last three decades such as drainage sewage on the sea, throwing away the wastes on the seashores and the misuse of these areas with the absence of any kind of management for these forests. PERSGA [11] asserted that mangroves in Red Sea and Gulf of Aden are prone to degradation and removal from a multitude of developmental and exploitative activities. They are destroyed by land-filling and cleared for the construction of shrimp ponds. They are cut for firewood and for construction. Grazing by camels reduces the height of mangrove trees, their productivity and their reproductive capacity. The report of the latest survey of 79 stands of mangrove in the Red Sea and Gulf of Aden region mentioned that 74% of them are damaged and shrinking rapidly [12]. Indeed, the cumulative effects of natural and anthropogenic pressures make mangrove ecosystem along the Red Sea coast of Saudi Arabia one of the most threatened environmental ecosystems in the country. However, there was no conservation actions have been carried out on the ground. The major efforts to conserve the mangrove areas are contained in national and regional action plans; however, the implementation of these plans is proceeding at very variable rates [11].

The present study aims to clarify the present status of the mangrove forests along the southern part of the Red Sea coast in Saudi Arabia in terms of their structure, hazards that threaten them and indications of their degradation and, the potential conservation. This study was carried out through elaborated inventory and resulted in large data. Hopefully, the information included herewith can assess in preparing conservation programmes toward saving this significant natural resource.

MATERIALS AND METHODS

Study Area: The present inventory focused on the mangrove forests on the Red Sea coast from the southern border of Saudi Arabia in Jazan region to the South Cornish of Jeddah City. This comprises the whole coast of Jazan region (in addition to Farasan archipelago) and the whole coast of Asir region and a part of Makkah Al-Mokrramah region (province) (Fig. 1). The whole inventoried area accounted for 4827.3 km^2 and lies between 16° 25` and 21° 16` North latitude and, between 39° 08` and 42° 09` East longitude. The area in which mangrove forests were studied has 1099.79 km long. The area was divided into two sections from the south to the north comprises Jazan region as the first section with 320.47 km long and, Asir region and the southern part of Makkah Al-Mokrramah region as the second one with 779.33 km long (Fig. 1). The area of mangrove forests inventory in Jazan region starts from "Al-Moussam" at the southern border point of Saudi Arabia (16° 25` N) to the remotest northern point of Jazan Region at "Ras-Massoud" (17° 33` N). The other area of the inventory consists of the coast of Asir region and a part of the coast of Makkah Al-Mokrramah region and

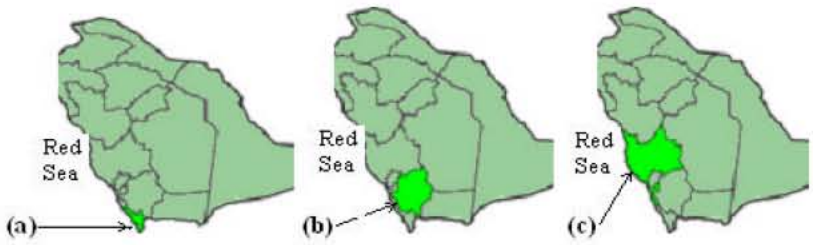

Fig. 1: Locations of Jazan (a), Asir (b) and Makkah Al-Mokrramah (c) regions (province) within the political map of Saudi Arabia (the Kingdom has thirteen provinces)

starts from "Al-Gihmah" at the remotest southern point of Asir region (17° 48` N) to the Southern Jeddah Cornish (21° 16` E). This dividing approach was adopted to meet the hopefully anticipated rehabilitation of the mangrove forests in these regions as it could be carried out according to administrational concept.

Inventory: The inventory of mangrove forests on the southern Red Sea coast of Saudi Arabia was carried out depending on field work (ground survey). It comprises the mangrove communities on the southern Red Sea coast starting from "Al-Moussam" (16° 25` N) at the southern border point of Saudi Arabia with Yemen Republic towards the north to the Southern Cornish of Jeddah city (21° 16` N). The area of each inventoried site and consequently those of the two main sections of the whole area were obtained by the courtesy of The Space Research Institute, King Abdulaziz City for Sciences and Technology, Riyadh, Saudi Arabia. This work was achieved using remote sensing through digital images were obtained from Spot-4 Satellite for 2004 and analyzed using the Normalized Difference vegetation index (NDVI).

Determination of Sampling Units: The number of sampling units needed for carrying out the inventory was determined using the equation that suggested by Shiver and Borders (1996) [13] as the following:

$$n = 4N S^2_y / B^2_M N + 4 S^2_y$$

where:

n = number of needed units, B_M = allowable error,
S_y = standard error of mean, S^2 = variance and,
N = total number of sampling units in the population

Sampling Design: Sampling design depends on stratified random sampling (*i. e.* samples were chosen randomly within each site). Because the inventoried area is large and not homogeneous, it was divided into sites. In each site containing mangroves within the area of inventory, the number of the sampling units (plots) was defining according to the area of the whole site, species existed, tree density, position of the mangrove communities in relation to seawater and, the topography of the seaside.

Field Measurements: Before commencing field measurements, we recorded mangrove species, tree growth characteristics (flowering and fruiting status) and tree destruction patterns. Following the procedures explained in Cintron and Schaeffer-Novelli [14] and Kairo *et al.* [15] coordinates of each plot centre were recorded using GPS device (Global Positioning System). In each plot (10 × 10 m) established perpendicular to the sea shore, the number of trees was counted, tree density was calculated as stem per ha, total main stem height, stem diameter at breast height (1.3 m) of all standing living trees within the plot were measured. Total tree height was measured using a telescopic hypsometer while diameter was measured by a stainless steel tree caliper. The stem volume of each tree was only roughly estimated by multiplying the basal area (cross-sectional area) by the total height, which was then multiplied by 1 to adjust for the error in assuming cylinder geometry [16]. Number of seedlings in each plot was also counted.

Sampling Frame: The present inventory comprises the mangrove forests from the southern far point of Saudi border at "Al-Moussam" by the Red Sea coast to the last point of the northern borders of Jazan region at "Ras-Massaud." As the mangrove forests of Saudi Arabia in general are scattered groups spread on the Red Sea coast, this section was divided into five groups (sites) (in addition to Farasan Island as one site); each included several plots representing the sampling frame with 28 plots (Table 1).

Similarly, the sampling frame of the northern section (comprises Asir and Makkah Al-Mokrramah regions) was divided into nine groups (sites) included 37 plots (Table 2). The sampling frame of the whole inventoried area included 15 sites represented by 65 sampling plots.

Data Treatment: The collected data was analyzed using SAS computer programme [17]. Mean and sum of each variable (number of trees, number of species, stem diameter, stem height and stem volume) in each plot and in each site were calculated.

RESULTS

Results of Mangrove Inventory: The whole area inventoried accounted for 1099.79 km long and covered an area of 4, 827, 3 Km^2. The actual area of mangrove forests covered an area of 36.15 km^2. 35.33% of this area was in Jazan region (12.77 Km^2), while the rest (64.67%) was in Asir and Makkah Al-Mokrramah regions (23.38 Km^2). These figures were calculated from the digital data of Spot-4 Satellite for 2004 using the Normalized Difference vegetation index (NDVI), which was carried out by the Space Research Institute, King Abdulaziz City for Sciences and Technology, Riyadh, Saudi Arabia.

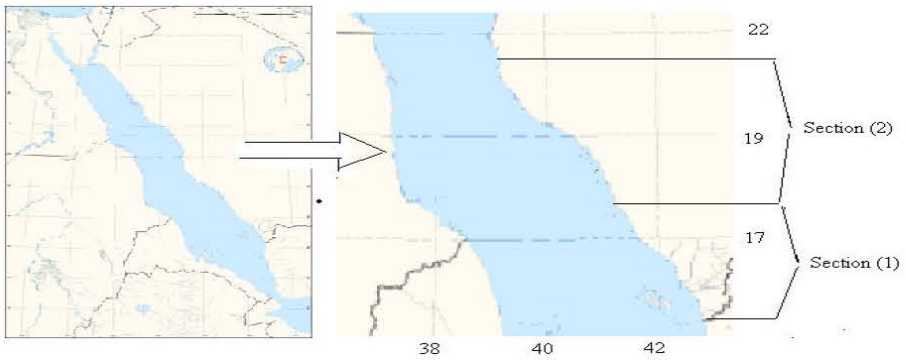

Fig. 2: Mangrove inventory areas on the southern Red Sea coast including Jazan region, section (1), Asir and Makkah Al-Mokrramah regions, section (2), with latitudes and longitudes

Table 1: Location and coordinates of the sampling plots of mangrove inventory in Jazan region

			Coordinates	
Site	Plot no.	Plot location	Latitude (N)	Longitude (E)
Al-Sihaie	1	Al-Sihaie-1	16 25 11	42 46 28
	2	Al-Sihaie-2	16 29 00	42 46 47
	3	Al-Shatamrah	16 34 14	42 47 05
	4	El-hasahees beach	16 35 29	42 43 14
Al-Magaad	1	North Maqaad	16 40 05	42 44 08
	2	Khour Goag	16 41 17	42 43 50
	3	Al-Thahabain	16 41 34	42 43 02
	4	Khour Al-Thahabain	16 42 37	42 42 52
Al-Madhaya	1	Al-Madhaya-1	16 44 07	42 41 35
	2	Al-Madhaya-2	16 45 00	42 41 33
	3	Al-Madhaya-3	16 44 28	42 41 20
	4	Mersa Al-Madhaya	16 43 53	42 42 17
	5	Al-Suez beach	16 47 20	42 40 31
Ra's Al-Tarfah	1	Ras Al-Tarfah-1	17 02 22	42 23 22
	2	Ras Al-Tarfah-2	17 02 26	42 23 15
	3	Ras Al-Tarfah-3	17 02 42	42 23 11
	4	Ras Al-Tarfah-4	17 08 38	42 23 06
	5	Ras Al-Tarfah-5	17 10 18	42 22 25
	6	Al-Gouze	17 09 13	42 26 00
Baish- Al-Semirat	1	Baish-1 (Ashiaeb)	17 21 17	42 19 51
	2	Baish-2	17 20 11	42 19 15
	3	Baish-3 (Al-Humaisah)	17 27 16	42 18 24
	4	Baish-4 (Beer Aukrush)	17 27 15	42 17 39
	5	Al-Semirat-1 (Al-Jarah)	17 32 21	42 12 09
	6	Al-Semirat-2 (Ras Massud)	17 33 43	42 09 30
Farasan Island	1	Al-Gandal	16 47 39	42 06 31
	2	Shoura beach-1	16 48 34	42 04 13
	3	Shoura beach-2	16 49 25	42 04 21

Table 2: Number of sampling units, number of trees and seedlings and their percentage of total Jazan and tree density in the mangrove forests in Jazan Region

	No. and percentage of trees			No. and percentage of seedlings		Area of the site	
Site	No.	%	Tree density (stem ha^{-1})	No.	%	km^2	% of total region area
Al-Sihaie	43	14.43	1075	37	11.67	0.36	2.82
Al-Maga'ad	13	4.36	325	53	16.72	0.54	4.23
Al-Madhaya	61	20.47	1220	87	27.44	2.62	20.50
Ras Al-Tarfah	106	35.57	1767	55	17.35	6.45	50.47
Baish-Al-Semirat	44	14.77	733	84	26.50	2.80	21.90
Farasan Island	31	10.44	1033	1	0.32	Not included	
Total Region	298	100	1025.5	317	100	12.77	100

Table 3: Location and coordinates of the sampling plots of mangrove inventory in Asir and Makkah Al-Mokrramah regions

Site	Plot no.	Plot location	Coordinates	
			Latitude (N)	Longitude (E)
Al-Gihmah	1	Sharm El-Taanah	17 48 34	41 52 27
	2	Jabal El-Ragabah	17 48 41	41 53 27
	3	Meghazzal	17 58 25	41 41 11
	4	Al- Gihmah beach-1	18 00 01	41 40 32
	5	Near Jabal Wasm	18 00 01	41 40 39
	6	Al- Gihmah beach-2	18 01 05	41 40 11
	7	Al-Meshahedeen	18 03 17	41 39 07
Al-Berk	1	Dahban-1	18 04 08	41 36 08
	2	Dahban-2	18 06 14	41 35 01
	3	Dahban-3	18 09 17	41 34 17
	4	Zahran beach	18 17 20	41 31 26
	5	Al-Mahajeen	18 20 31	41 28 11
	6	Suban	18 26 04	41 27 12
	7	Emeg	18 27 15	41 27 01
Al-Gunfuthah South	1	Um El-Houar-1	18 29 18	41 25 26
	2	Um El-Houar-2	18 28 10	41 25 30
	3	Al-Jemiat	18 50 35	41 14 52
	4	Al-Wadih beach-1	19 02 39	41 10 25
	5	Al-Wadih beach-2	19 02 13	41 09 44
Al-Gunfuthah North	1	Hemeg beach-1	19 13 15	41 32 12
	2	Hemeg beach-2	19 14 35	41 03 26
	3	Abulnour	19 18 13	41 01 28
	4	Al-Malawhah-1	19 30 29	40 58 15
	5	Al-Malawhah-2	19 32 30	40 56 16
Ras-Mehesin	1	Al-Thahab-1	19 36 16	40 48 30
	2	Al-Thahab-2	19 44 33	40 48 30
	3	Mersa Al-Masaeed	19 37 05	40 48 43
	4	Salam El-Zawahir	19 47 36	40 45 17
Ras Um-Rubaise	1	Ras Um-Rubase-1	19 47 23	40 38 32
	2	Ras Um-Rubase-2	19 45 37	40 41 08
	3	Ras Um-Rubase-3	19 45 37	40 42 36
	4	Ras Um-Rubase-4	19 46 39	40 38 39
Al-Rakah	1	Al-Rakah-1	20 02 21	40 26 00
	2	Al-Rakah-2	20 03 24	40 25 07
Al-Laith North	1	Khour El-Soudah	20 32 41	39 37 23
	2	Al-Shiabah	20 44 59	39 30 21
Jeddah South Cornish	1	Southern Jeddah Cornish	21 16 16	39 08 11

Jazan Region: According to the sampling frame of the present inventory, Jazan region comprises six sites included 28 sampling plots in which trees were measured. The number of the sampling plots in the region ranged between three in Farasan Island and six in both Ras Al-Tarfah and Baish-Al-Semirat (Table 1). The main mangrove species found in all sites and plots of Jazan region is *Avicennia marina* apart from two community of *Rhizophora mucronata* occurred in two sampling plots in Baish-Al-Semirat and Farasan Island; at a rate of 4.55 and 12.90% of the total number of trees in both sampling plots, respectively. In addition to these there is a small community on the far end of Ras Um Rubaise in Makkah Al-Mokrramah region.

298 trees were measured in all the sampling plots and ranged between 13 trees in Al-Maga'ad and 106 trees in Ras Al-Tarfah. 317 seedlings were found in all the sampling plots and ranged between one and 87 seedlings in Farasan Island and Al-Madhaya, respectively (Table 2). Tree density in the sites ranged between 325 and 1767 trees ha^{-1} in Al-Maga'ad and Ras Al-Tarfah, respectively; with a mean of 1025.5 trees ha^{-1} for the whole Jazan region (Table 2).

The area of mangrove in Jazan region ranged between 0.36 and 6.45 Km^2 in Al-Sihaie and Ras Al-Tarfah, respectively; represented 2.82 and 50.47 per cent of the total mangrove area in Jazan Region.

Table 4: Number of trees, number of seedlings and their percentage of total area and tree density in Asir and Makkah Al-Mokrramah regions

	No. and percentage of trees			No. and percentage of seedlings		Area of the site	
Site	No.	%	Tree density (stem ha^{-1})	No.	%	km^2	% of region area
Al-Gihmah	82.0	6.51	1367.0	82.0	31.78	7.22	31.21
Al-Berk	231.0	18.33	2888.0	47.0	18.22	6.55	28.31
Al-Gunfuthah south	43.0	3.41	1433.0	30.0	11.63	1.40	6.05
Al-Gunfuthah north	287.0	22.78	5740.0	41.0	15.89	1.30	5.62
Ras-Mehesin	95.0	7.54	2375.0	44.0	41.00	1.31	5.66
Ras Um-Rubies	110.0	8.73	2750.0	1.0	0.39	0.35	1.51
Al-Rakah	66.0	5.24	3300.0	13.0	5.04	1.00	4.33
Al-Laith North	39.0	3.10	1950.0	0.0	0.00	4.00	17.29
Jeddah South Cornish	307.0	24.37	30700.0	0.0	0.00	0.25	0.02
Total Regions	1260.0	100.00	5833.7	258.0	100.00	23.38	100.00

Table 5: Mean diameter, height, volume of mangrove trees and total tree volume of trees within in the sampling sites of Jazan region

Site	Mean tree diameter (cm tree^{-1})	Mean tree height (m tree^{-1})	Mean tree volume (m^3 tree^{-1})	Total tree volume (m^3 site^{-1})
Al-Sihaie	6.76	2.24	0.016	0.690
Al-Magaad	14.57	5.12	0.107	1.492
Al-Madhaya	8.79	4.13	0.044	2.681
Ra's Al-Tarfah	7.53	3.70	0.023	2.454
Baish- Al-Semirat	17.62	6.54	0.187	8.248
Farasan Island	9.46	4.85	0.060	1.978
Region	10.79	4.43	0.073	17.543

Table 6: Mean diameter, height, volume of mangrove trees and total tree volume of trees within in the sampling sites of Asir and Makkah Al-Mokrramah regions

Site	Mean tree diameter (cm tree^{-1})	Mean tree height (m tree^{-1})	Mean tree volume (m^3 tree^{-1})	Total tree volume (m^3 site^{-1})
Al-Gihmah	7.82	2.94	0.0206	1.6914
Al-Berk	7.82	2.90	0.0165	3.8000
Al-Gunfuthah south	5.39	1.59	0.0070	0.2991
Al-Gunfuthah north	3.55	1.46	0.0035	1.0082
Ras-Mehesin	6.14	2.28	0.0136	1.2943
Ras Um-Rubaise	5.69	2.78	0.0079	0.8732
Al-Rakah	3.24	1.51	0.0016	0.1041
Al-Laith North	7.76	3.39	0.0245	0.9537
Jeddah South Cornish	2.95	0.50	0.0002	0.0562
Region	5.60	2.15	0.0114	10.0802

Asir and Makkah Al-Mokrramah Regions: Asir and Makkah Al-Mokrramah regions comprise nine sites included 37 sampling plots in which trees were measured. The number of the sampling plots ranged between one in South Jeddah Cornish and seven in both Al-Gihmah and Al-Berk (Table 3).

Avicennia marina was the dominated species in all sites of the region except in Ras Um-Rubaise where a small community of *Rhizophora mucronata* occurred.

1260 trees were measured in all the sampling plots and ranged between 39 trees in Al-Laith North and 307 trees in South Jeddah Cornish.

258 seedlings were found in the sampling plots and ranged between none in both Al-Laith North and South Jeddah Cornish and 82 seedlings in Al-Gihmah, respectively (Table 4). Tree density in the sites ranged between 1367 and 30700 trees ha^{-1} in Al-Gihmah and South Jeddah Cornish, respectively with a mean of 5833.7 trees ha^{-1} for the whole inventoried area in both regions (Table 4).

The area of mangrove in Asir and Makkah Al-Mokrramah regions ranged between 0.25 and 7.22 Km^2 in South Jeddah Cornish and Al-Gunfuthah, respectively; represented 0.02 and 31.21 % of the total mangrove area in these Regions, respectively (Table 4).

Tree Dimensions and Stem Volume: In Jazan Region, the mean diameter of mangrove trees ranged between 6.76 cm in Al-Sihaie and 17.62 cm in Baish-Al-Semirat, with a mean of 10.79 cm for the whole region. While mean tree height ranged between 2.24 m in Al-Sihaie and 6.54 m in Baish-Al-Semirat, with a mean of 4.43 m for the whole region (Table 5).

Rhizophora mucronata trees in Baish-Al-Semirat have stem diameter and height were 7.75 cm tree^{-1} and 6.50 m tree^{-1} as averages, while those in Farasan Island have 5.5 cm tree^{-1} and 4.23 m tree^{-1} as averages, respectively.

Total tree volume in the sites ranged between 0.69 m^3 in Al-Sihaie with a mean of 0.016 m^3 tree^{-1} and 8.248 m^3 in Baish-Al-Semirat, with a mean of 0.187 m^3 tree^{-1}. Total tree volume in the region as a whole accounted for 17.543 m^3, with a mean of 0.073 m^3 tree^{-1} (Table 5).

In Asir and Makkah Al-Mokrramah regions, the mean diameter of mangrove trees ranged between 2.95 cm in Southern Jeddah Cornish and 7.82 cm in both Al-Gihmah and Al-Berk, with a mean of 5.60 cm for the whole region. While mean tree height ranged between 0.50 m in South Jeddah Cornish and 3.39 m in Al-Laith North, with a mean of 2.15 m for the whole region (Table 6). Total tree volume in the sites ranged between 0.0562 m^3 in Southern Jeddah Cornish with a mean of 0.0002 m^3 tree^{-1} and, 3.8000 m^3 in Al-Berk, with a mean of 0.165 m^3 tree^{-1}. However, the maximum mean tree volume was that in Al-Laith North (0.0245 m^3 tree^{-1}) (Table 6). Total tree volume in the region as a whole accounted for 10.0802 m^3, with a mean of 0.0114 m^3 tree^{-1} (Table 6).

DISCUSSION

The present inventory of mangrove forests on the southern Red Sea coast of Saudi Arabia showed that they are valuable natural resource offered many benefits and services to the local and regional environment. This inventory focused on two parts of the southern Red Sea coast of Saudi Arabia. Firstly, the distance from the southern far point of Saudi border at "Al-Moussam" to the last point of the northern borders of Jazan region at "Ras-Massaud", in addition to Farasan Island. Secondly, the distance from Al-Gihmah; the first district belongs to Asir region and adjacent to Jazan region up to South Jeddah Cornish in Makkah Al-Mokarramah region. As the mangrove forests of Saudi Arabia in general are scattered groups spread on the Red Sea coast and differ in their dimensions, each part was divided into groups (sites) in which some sampling plots were randomly chosen.

The main mangrove species found in the whole inventoried area was *Avicennia marina* Forssk. Vierh., with only three small communities of *Rhizophora mucronata* Lam. in Farasan Island and Baish-Al-Semirat (Jazan region) and Ras Um Rubaise (Makkah Al-Mokrramah region). This result concurs with the finding of Price *et al.* [18] that along the Saudi Arabian Red Sea coast significant stands of *Avicennia marina* occur while *Rhizophora mucronata* is much less widespread than *Avicennia marina*. Presidency of Meteorology and Environment [19] stated that *Rhizophora mucronata*, found only at six sites. They are found in such areas as broad coastal plains, protected shores, over shoals and spits and in lagoons. This may be because *Avicennia marina* is a hardy species that grows in extreme climate conditions. It is the only species of mangroves which can tolerate desert climate [20], such as that prevalent in western Saudi Arabia [21]. Rouphael *et al.* [22] mentioned that species of mangrove also have specific environmental requirements that influence their distribution. For example, *Avicennia* is more tolerant of high saline conditions (60- 65‰) than *Rhizophora*. Barratt *et al.* [23] suggested that this is one reason why *Avicennia* dominates the northern Red Sea coast of Yemen where the interface between fresh and salt (sea) water occurs inland of the coast.

In an attempt to find out the causes of the existence of specific species composition in a mangrove stand, Alongi [24] stated that "for mangrove forests, stand composition and structure are the result of a complex interplay of physiological tolerances and competitive interactions leading to a mosaic of interrupted or arrested succession sequences in response to physical/chemical gradients and changes in geomorphology."

The actual area of mangrove forests covered an area of 36.15 km^2 (3615 ha). 35.33% of this area was in Jazan region (12.77 Km^2), while the rest (64.67%) was in Asir and Makkah Al-Mokrramah regions (23.38 Km^2). In this regard, Saenger [5] mentioned that the estimated area of mangroves on the Red Sea shore is about 200-6 000 ha. It seems that he was talking about the whole Red Sea shore in Saudi Arabia. Presidency of Meteorology and Environment [19] reported that Saudi Arabia's Red Sea coast on the west stretches to approximately 1760 kilometers, while its eastern coast on the Gulf covers 650 kilometers, including 35 sq. km of mangroves.

The number of trees measured in Asir and Makkah Al-Mokrramah regions was more than four times as much as that measured in Jazan region. This was a result of the increase in the number of sites in the former comparing with that in the later. The length and area of the inventoried sites in Asir and Makkah Al-Mokrramah were 2.5 and 1.8 times as much as those in Jazan region, respectively. Approximately, fourth of the number of trees measured in Asir and Makkah Al-Mokrramah regions was in South Jeddah Cornish site only. However, the number of seedlings found was higher in Jazan than in Asir and Makkah Al-Mokrramah regions.

Tree density in the inventoried sites ranged between 325 and 1767 trees ha^{-1} and between 1367 and 30700 trees ha^{-1} in Jazan and Makkah Al-Mokrramah regions, respectively. Mandura *et al.* [6] mentioned that the density of trees in Midaya (in Jazan region) was 25 trees per 100 m^2 (=2500 trees ha^{-1}). The density of *Avicennia marina* varied from 11 plants/1000 m^2 (110 trees ha^{-1}) at Jabal Wasm (near Al-Quhma) [18]. This figure seems very low comparing with that obtained in the present study for Al-Gihmah site which was 1367 trees ha^{-1} as an average of the tree density of six sampling plots, ranged between 500 and 3100 trees ha^{-1}. This discrepancy may be a result of the variation in the chosen sites for measurements or the method of carrying out the inventory. In general, the figures show that there is an increase in the density towards the north. This result is in accordance with the finding of PERSGA/GEF [25] that the density of *Avicennia marina* showed a general decrease southward, possibly because the increased plant size and shading towards the south allows growth of fewer plants per unit area.

The size of mangrove trees was larger in Jazan region than that in Asir and Makkah Al-Mokrramah regions. The means of stem diameter and height of the trees were 10.79 cm $tree^{-1}$ and 4.43 m $tree^{-1}$ in Jazan region compared with 5.60 cm $tree^{-1}$ and 2.15 m $tree^{-1}$ in Asir and Makkah Al-Mokrramah regions, respectively. Salinity may also be a factor affecting mangrove height, as suggested by the negative correlation between the two in a previous study [18]. Mandura *et al.* [6] reported that tree height was 1.03-3.31 m for the mangrove community in Midaya (a site in Jazan region) which is much less than the figures we obtained for the same site in the present study and were 8.79 cm $tree^{-1}$ and 4.13 m $tree^{-1}$ for mean stem diameter and height, respectively. *Avicennia marina* trees had an average of 6.9 cm $tree^{-1}$ and Red Sea mangrove do not grow as luxuriously as most other tropical mangroves due to high salinity, poor soil texture, low precipitation and low nutrient concentration [6, 7].

Consequently, the observed variation in the size of trees between Jazan region and Asir and Makkah Al-Mokrramah regions may be a result of the increase in salinity level of the sea water in the later comparing with the former. Unfortunately, there is no even a single river in the entire Saudi Arabian Red Sea coast region. However, instead a number of wadis occur in the area. These are ephemeral rivers which collect water from adjacent mountains during occasional rains and flash-floods and bring it to the plains and eventually to the seashores, along with the alluvium. The southern region is rich in such wadis. All the mangrove stands are located close to the opining of drainage channels of these wadis [6]. PERSGA [26] stated that while mangroves are found scattered along much of the Red Sea coast, the major concentration is in the southern Red Sea where factors such as increased sediment create an environment more conducive to their development. The extent of a particular mangrove stand, in general, is related to the number of wadis feeding it [6]. Por *et al.* [27] suggest that in Sinai (Egypt) salinity is probably the main factor restricting the number of mangrove species.

Wood volume of tree stem ranged between 0.016 and 0.187 m^3 $tree^{-1}$ in Jazan and, between 0.0002 and 0.0206 m^3 $tree^{-1}$ in Asir and Makkah Al-Mokrramah regions. The highest tree volume in Jazan was that in Baish-Al-Semirat with 8.248 m^3 (137.47 m^3 ha^{-1}), representing about half the total volume of the region. In Asir and Makkah Al-Mokrramah regions, Al-Laith North site has the highest tree volume with 0.0245 m^3 $tree^{-1}$; this may due to its larger trees comparing with those in the other sites. The mean stem diameter and height of the trees in this site were 7.76 cm and 3.39 m $tree^{-1}$, respectively. Price *et al.* [18] reported that the largest mangrove stands were observed at five locations included Al-Quhma where plants of 5-7 m high were recorded. Moreover, Saenger [5] mentioned that the tallest mangrove trees (6 m height) are located in Al Qahmah. In the present study, the mangrove trees in Al-Gihmah site had mean stem diameter and height were 7.82 cm $tree^{-1}$ and 2.94 m $tree^{-1}$, respectively. The mean tree volume in this site was 0.0206 m^3 $tree^{-1}$, but the greatest total tree volume in Asir and Makkah Al-Mokrramah regions was that in Al-Berk site which accounted for about 38% of the total tree volume of the regions.

The mean stem volume of the mangrove trees in Jazan sites was more than six times as much as that in Asir and Makkah Al-Mokrramah regions. This is a result of the existence of small size trees in more than one site in Asir and Makkah Al-Mokrramah regions such as those in Al-Gunfidah (south and north), Al-Rakah and Jeddah South Cornish, whose mean tree volumes were 0.007, 0.0035, 0.0016 and 0.0002 m^3 $tree^{-1}$. On the other hand, in Jazan region, although tree density was low, the trees were large, however. For instance, the stem diameter of mangrove trees in Jazan sites ranged between 6.76 and 17.62 cm $tree^{-1}$ in Al-Sihaie and Baish-Al-Semirat, respectively.

Degradation of Mangroves: It was noticed from the present inventory of the mangrove forests on the Red Sea

coast of Saudi Arabia that they are small fragmented communities. They look degraded in most sites, with low tree density in general. The status of trees in terms of growth is poor and the natural regeneration is very weak. The status of the present extent of mangrove communities suggests that they have been subjected to different anthropogenic and environmental stresses. There are many causes for such degradation comprises the increase in human population and negligence. Mangroves were the first to be cleared (because of their uselessness), filled in and used for rubbish dumps. In the past several decades, habitat destruction through human encroachment has been the primary cause of mangrove loss [28]. This puts mangrove forest like all tropical resources under severe pressure [2]. Thus, in the long-term, destruction and degradation of mangroves will seriously affect marine fisheries, increase coastal erosion and the impacts of the sea on the land and lead to degradation of adjacent habitats. Such losses are far greater, in the long run, than any profits to be gained from commercial and industrial projects causing mangrove degradation [25]. Development of coastal recreational facilities and coastal villages and shrimps aquaculture along the southern Red Sea coast have contributed to the decline of Saudi Arabia's Coastal mangroves [19].

Causes and Indications of Degradation: Sand drifting is one of the natural environmental stresses that affect the growth of the mangrove forests on the southern Red Sea coast of Saudi Arabia. This can be seen obviously in Ra's Al-Tarfah and Ras Um-Rubaise in Jazan and Makkah Al-Mokrramah regions, respectively. PERSGA/GEF [25] reported on adverse effects of sand drifting upon mangrove stands in the Red Sea and Gulf of Aden (including Saudi Arabia). They asserted that mass mortality in considerable parts of the mangrove stands appears to be a serious problem along the coasts of the Region. Death to the uppermost and outermost branches ('top dying') is common among trees in many severely disturbed mangrove areas in the Region. The predominant cause of this appears to be localized modifications in the topography of the coastal area. These modifications divert tidal water away from the mangroves, decreasing water levels in the mangrove channels/lagoons and reducing the area of mangroves inundated by tidal water in the upper reaches of the stands. These modifications were attributed to construction activities involving dredging and sediment dumping on the shore and excessive sedimentation by sand dunes that has buried and closed some of the tidal channels through which seawater flows into the mangroves. In many areas, degradation of the mangrove and terrestrial vegetation has lead to reduced trapping capacity, allowing increased movement of sand dunes from land.

The other factors that affecting the growth and survival of the mangrove communities are the extensive exploitation by locals. These include the destructive practices to both the marine and terrestrial environments such as over cutting (in many sites), discharging wastes in the sea (*e. g.* South Jizan city, Farasan Island, Al-Malawhah and Jeddah South Cornish) and disposing rubbish on the beaches, in particular in the fishing Mersas and Fishermen's villages (*e. g.* Al-Madhayah, Baish-Al-Semirat and Jeddah South Cornish). There is no doubt that such practices cause environmental perturbation that may affect many organisms' life. UNEP [29] reported that the discharge of untreated sewage effluents produces long-term adverse impacts on the ecology of critical coastal ecosystems in localized areas due to the contribution of nutrients and other pollutants. The potential effects of toxic substances in the marine and coastal environments include the destruction of fish and other wildlife leading to a loss of biodiversity, decrease in productivity of mangrove [29].

The affected mangrove stands are dominated by stunted, multistemmed trees. Branched, twisting and dead pneumatophores are common (PERSGA/GEF. 2004). These features are obvious in the mangrove of south Jeddah Corniche which is the smallest stand that has so far reported on the red sea. All the plants of the stand are *Avicenna marina* and do not have a clear tree form, but are like bushes with trunks almost covered on all sides by branches and foliages. However, this negative impact on the stand is, at least in part, due to receiving discharges of domestic sewage and industrial wastewater from the nearby large treatment plant [30]. The stand is in an area that has been subject to a high inflow of nutrients from largely untreated sewage effluent for more than 20 years.

Moreover, Lauri and Gibson [31] asserted that over time, environmental stress can kill large numbers of mangrove trees. However, mangroves posse high capacity to retain pollutants which probably attributed to their anaerobic conditions, periodically flooded by tides (which resulted in fluctuation of salinities) and high clay and organic matter content [32]. Therefore, discharging wastewater to the mangrove ecosystem may have a beneficial effect on their productivity, particularly in areas where nutrient status is low [33]. Part of this area has been proposed as a Natural Reserve in NCWCD's System Plan for Protected Areas, however, no conservation measures have been taken [25].

Large areas of mangroves are being cut and replaced by other activities such as large scale shrimp farming (*e. g.* Al-Sehaie and Al-Shuaibah). In the later, there are presently local threats from small-scale cutting of mangrove and grazing by camels, but plans to develop shrimp farms in the future are a critical threat to the mangrove. The area is not proposed for protection in the NCWCD System Plan for Protected Areas [34]. Kairo *et al.* [35] postulated that a major threat to mangrove wetlands is their conversion to areas of aquaculture. Commercial shrimp farms have been reported to cause devastation to the coastal environment, particularly to mangrove habitats that are often favoured for shrimp farms. However, Shrimp farming does not have to pose an environmental threat, provided that environmental precautions are considered [25].

Mangrove communities are threatening by changing the nature of the sea shores through excavating and filling up (*e. g.* Farasn Island, Al-Malawhah and Khor Abu-Doudah). Mandura and Khafaji [36] reported severe effects on the mangrove stand of Khor Farasan during the establishment of a sea port in the Island which included building up pier, mersa, car parks, boat and heavy duty workshop, *etc.* Developments of coastal recreational facilities and coastal villages have contributed to the decline of Saudi Arabia's Coastal mangroves [19].

The worse and dangerous threat is the continuous camel grazing (every day) in all the sites over all the whole mangrove inventory areas. Camel grazing led to destroying the growth of trees. If the browsed tree was large it will loss most of its new growths; leaves and twigs. Thereafter, the form of the tree will change from spreading to umbrageous shape as a result of camel grazing from lower part to the top of tree. If the tree was small or still young it will become dwarf and weak and, both the old and young or the large and small trees will be subjected to pest infestation. Many insects were observed on and around trees during the present inventory. Camel grazing is an addition factor limiting the extend mangrove development in the Red Sea, as it was observed at the majority of the southern region causing large areas have already been destroyed and degraded [37, 38]. Grazing by camels is the primary agent in degradation of accessible mangrove locations [39]. Die-back cases were observed on *Avicennia marina* trees in different sites, while the entire death of trees was more widely spread. Large trees were seen dead in many sites of all the inventory regions (*e. g.* Al-Maga'ad, Baish Al-Semirat, Al-Laith north).

Moreover, environmental factors, including temperature, salinity and rainfall also are important key determinants that have a strong influence over the growth, survival and distribution of mangroves [40].

The conservation and restoration of mangroves have in recent years become a priority of many government and non-government organizations [41, 1, 42, *c.f.* 43). Unfortunately, there is no mangrove conservation programmes or management plan have been lunched so far in Saudi Arabia. However, some efforts are being done through The National Commission for Wildlife Conservation and Development (NCWCD). Their activities include rehabilitation of some degraded mangrove areas via growing seedlings in the nursery, which mostly is located in sea water by the beach. However, seedlings in the nursery are subjected to encroachment by sea water and/or to pollution either from industrial or municipal sources [44].

Restoration Required: The presented status and degradation trends of mangrove forests in the southern Red Sea coast of Saudi Arabia suggests that an immediate restoration action has to be taken over sooner not later. This means returning the former mangrove forests area to their previous status before degradation through planting seeds and producing seedlings (artificial regeneration) or encouraging natural generation. In severely degraded ecosystems, regeneration of mangrove vegetation might not occur without human intervention because natural regeneration replies on naturally occurring propagules of mangroves [28].

Stop mangrove degradation or at least mitigate the adverse effects of the present misuse should be considers a top priority. Therefore, protection of the degraded and not degraded areas may be the first step to be carried out through preventing all the encroachment upon mangrove forests. This should goes along with awareness generation on the causes for the degradation of mangrove forests and the need for its restoration that should be done using the media and other available meanings. Macintosh and Ashton [45] suggested that first priority should be given to conserving the remaining areas of natural mangrove forest, especially areas supporting mature, seedling-bearing trees. In this regard, raising mangrove nurseries for planting in the restoration areas should be included in any restoration project. Sustainable management programme through the approach of silviculture should be implemented. Mangrove restoration will be to preserve, enhance or maintain the original functioning of the system [46] or, at least, its conjectured original functioning [35]. Monitoring of restoration projects is essential and will require to determining the magnitude of recovery of naturally functioning mangrove

ecosystems during and after restoration in terms of species development, seedling growth and growth characteristics. The final stage in examining mangrove restoration is to assess the "success" of a restoration. Success might be judged in terms of cost and speed of recovery of facilitated mangrove systems versus those left to regenerate their own [47]. Therefore, given the present condition of the mangroves sound programmes addressing mangrove rehabilitation and conservation are urgently needed in the Region. These should focus on sustainable use of the resources, protection from impacts and threats that lead to mangrove degradation and rehabilitation of degraded mangrove areas [25].

CONCLUSION

The mangrove forests on the Red Sea coast of Saudi Arabia consist mainly of *Avicennia marina* with small groups of *Rhizophora mucronata* trees. In general, they are scattered groups and their growth is poor, with low capacity of natural generation. They have been subjected to different forms of stresses such as sand drifting, extensive exploitation, discharging wastes in the sea, disposing rubbish on the beaches, camel grazing, replacing by other activities such as large scale shrimp farming, die-back of trees and others. They are neglected, degraded and threatening with more degradation in the future unless they attract deserve and adequate attention as a unique natural resource. Mangrove degradation must be considered a major hotspot issue. The efforts should be directed to stop the factors that cause the degradation and, put the areas under a sustainable forest management authority to takeover works toward restoration, conservation and development of mangrove forests. Thus, establishing a national mangrove management plan is essential.

ACKNOWLEDGMENT

This work was a part of a large elaborated project aims at “inventory of the natural forests in the southwestern region of Saudi Arabia”, funded by the Ministry of Agriculture and, supervised by The Space Research Institute at King Abdulaziz City for Sciences and Technology. I would like to thank the following people for their various contributions to this study: Mr. Y. Al-Dool, Mr. A. Al-Wtaid, Mr. T. Al-Shalhoub and Dr. F. Al-Arifi. Thanks are due to Professor I. M. Aref for continuous encouragement.

REFERENCES

1. FAO., 1994. Mangrove Forest Management Guidelines. FAO Forestry Paper no. 117, 319 p. Food and Agriculture Organization of the United Nations, Rome, Italy.
2. Yahaya J. and S.C.H. Ramu, 2003. Coastal Resource Development in Malaysia: Is there a Need for Sustainable Mangrove Forest Management? The Federal Environmental Agency (FEA) Working Paper No. 2003-2.
3. Bioinformatics Centre, 1998. *What are Mangroves*? National Institute of oceanography, Dona Paula, Goa, India. http://www.nio.org/Biology/mangrove/MANGCD/what.htm
4. Hussain, Z., 1997. The Sundarbans, *In*: Hails, A. (ed.), 1997. Wetlands, Biodiversity and the Ramsar Convention. Ramsar Convention Bureau, Gland, Switzerland.
5. Saenger, P., 1993. *Management of Mangroves in the Kingdom of Saudi Arabia. Riyadh,* Saline Water Conversion Corporation and Ministry for Agriculture and Water.
6. Mandura, A.S., S.M. Saifullah and A.K. Khafaji, 1987. Mangrove ecosystem of southern Red Sea coast of Saudi Arabia. *In*: Proceedings of Saudi Biol. Soc., 10: 165-193.
7. Mandura, A.S., A.K. Khafaji and S.M. Saifullah, 1988. Ecology of a mangrove stand of a central Red Sea coast area: Ras Hatib (Saudi Arabia). *In*: Proceedings of Saudi Biol. Soc., 11: 85-112.
8. Saifullah, S.M., 1996. Mangrove Ecosystem of Saudi Arabian Red Sea. J. KAU: Mar. Sci., 7 (Special Issue): 263-270.
9. Saifullah, S.M., S.S. Shaukat and S. Shams, 1994. Population structure and dispersion pattern in mangrove of Karachi, Pakistan. Aquat. Bot., 47: 329-340.
10. Khafaji, A.K., A.M.N. El-Nakkadi, S.Z. El-Agamy and M. Ilyas, 1993. Studies on the cultivation of *Avicennia marina* mangrove. J. KAU: Mar. Sci., 4: 165-179.
11. PERSGA- The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden, 2005. Mangroves in the RSGA Region. Habitats and Biodiversity, Activities and Programs, Jeddah, Saudi Arabia. http://www.persga.org.

12. Kotb, M.M.A., M.H. Hanafy, H. Rirache, S. Matsumura, A.A. Al-Sofyani, A.G. Ahmed, G. Bawazir and F.A. Al-Horani, 2008. Status of Coral Reefs in the Red Sea and Gulf of Aden Region. International Coral Reef Initiative Forum. http://www.icriforum.org/gcrmn/2008/4.%20Red%20Sea%20PERSGA.pdf
13. Shiver, B.D. and B.E. Borders, 1996. Sampling Techniques for Forest Resource Inventory. John Wiley & Sons, Inc. New York, U.S.A.
14. Cintron, G. and Y.S. Novelli, 1984. Methods for studying mangrove structure: The Mangrove Ecosystem, Research Methods. UNESCO.
15. Kairo, J.G., F. Dahdouh-Guebas, P.O. Gwada, C. Ochieng and N. Koedam, 2002. Regeneration Status of Mangrove Forests in Mida Creek, Kenya: A compromised or Secured Future? Ambio, 31: 562-568.
16. Sathirathai, S., 2003. Economic Valuation of Mangroves and the Roles of Local Communities in the Conservation of Natural Resources: Case Study of Surat Thani, South of Thailand. Research Reports. International Development Research Centre, Ottawa, Canada. http://www.idrc.ca/uploads/user-S/10536137110ACF9E.pdf.
17. SAS Institute, 2001. SAS User's Guide Statistics 21ed. SAS Inst. Cary, NC. USA.
18. Price, A.R.G., P.A.H. Medley, R.J. McDowal, A.R. Dawson-Shepherd, P.J. Hogarth, R.F.G. Ormand, 1987. Aspects of mangal ecology along the Red Sea coast of Saudi Arabia. J. Nat. Hist., 21: 449-464.
19. Presidency of Meteorology and Environment (PME), 2005. First National Communication Kingdom of Saudi Arabia. Submitted to The United Nations Framework Convention on Climate Change (UNFCCC).
20. Macnae, W., 1968. A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific Region. Adv. Mar. Biol., 6: 73-270.
21. Siraj, A., 1984. Climate of Saudi Arabia, climatic features of Saudi Arabia, pp. 32-42. In: Buttiker, W. and Krupp, F. (eds.). Fauna of Saudi Arabia, 6: 32-52.
22. Rouphael, T., E. Turak and J. Brodie, 1998. Seagrasses and Mangroves of Yemen's Red Sea. Chapter 3. In: A. DouAbal *et al.* (eds) Protection of Marine Ecosystems of the Red Sea Coast of Yemen. UN Publication, pp: 41-49. http://www.actfr.jcu.edu.au/idc/groups/public/documents/journal_article/jcudev_015628.pdf
23. Barratt, L., A. Dawson-Shepherd, R. Ormond and R. McDowell, 1987. Yemen Arab Republic Marine Conservation Survey, Volume 1, Distribution of habitats, species along the YAR coastline, unpublished report, International Union for Conservation of Nature and Natural Resources.
24. Alongi, D.M., 2008. Mangrove forests: Resilience, protection from tsunamis and responses to global climate change. Estuarine, Coastal and Shelf Sci., 76: 1-3.
25. PERSGA/GEF. 2004. Status of Mangroves in the Red Sea and Gulf of Aden. PERSGA Technical Series No. 11. PERSGA, Jeddah.
26. PERSGA. 2002. Status of the Living Marine Resources in the Red Sea and Gulf of Aden and Their Management. Strategic Action Programme for the Red Sea and Gulf of Aden (PERSGA). Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden.
27. Por, F.D., I. Dor and A. Amir, 1977. The mangal of Sinai: limits of an ecosystem. Helgoländr Wiss Meer, 30: 295-314.
28. Ren, H., S. Jian, H. Lu, Q. Zhang, W. Shen, W. Han, Z. Yin and Q. Guo, 2008. Restoration of mangrove plantations and colonization by native species in Leizhou bay. South China Ecol. Res., 23: 401-407.
29. United Nations Environment Programme, 2000. An Overview of Land Based Sources of Marine Pollution. Caribbean Regional Co-coordinating Unit, Caribbean Environmental Programme (CAR/RCU, UNDP). http://www.cep.unep.org/issues/lbsp.html#Sewage
30. Mandura, A.S., 1997. A mangrove stand under pollution stress: Red Sea. Mangrove and Salt Marshes, 1: 255-262.
31. Lauri, B. and J. Gibson, 2000. Mangrove Wetlands. A Field Guide. San Diego Natural History Museum (SDNHM), USA.
32. Tam, N.F., 1998. Effect of wastewater discharge on microbial populations and enzyme activities in mangrove soils. Environ. Pollut., 102: 233-242.
33. Wong, Y.S., C.Y. Lan, G.Z. Chen, S.H. Li, Z.P. Liu and N.D.F.Y. Tam, 1995. Effect of wastewater discharge on nutrient contamination of mangrove soils and plants. Hydrobiologia, 295(1,3): 243-254.
34. BirdLife International, 2009. Important Bird Area factsheet: Shuqaiq mangrove, Saudi Arabia. Downloaded from the Data Zone at http://www.birdlife.org on 14/6/2009

35. Kairo, J.G., F. Dahdouh-Guebas, J. Bosire and N. Koedam, 2001. Restoration and management of mangrove systems – a lesson for and from the East African region. S. Afr. J. Bot., 67: 383-389.
36. Mandura, A.S. and A.K. Khafaji, 1993. Human impact on the mangrove of Khor Farasan island, Southern Red Sea coast of Saudi Arabia. M. Lieth and A. Al Massoum (eds): Towards Rational Use of High Salinity. Kluwer Academic Publishers, Netherlands.
37. Price, A.R.G., 1982b. Conservation and Sustainable Use of Marine Resources. Report for IUCN/MEPA for the Expert Meeting of the Gulf Co-coordinating Council to review environmental issues.
38. Vousden, D.H.P. and A.R.G. Price, 1985. Bridge over fragile waters. New Sci., 145: 33-35.
39. Mohamed, B.F., 1984. Ecological observations on mangroves of the Red Sea shores of the Sudan. Hydrobiologia, 110(1): 109-111.
40. Blasco, F., 1984. Taxonomic considerations of the mangrove species. In: S.C. Snedaker and J.C. Snedaker (Eds.). The mangrove ecosystem: Research methods. UNESCO, Paris, pp: 81-89.
41. Baconguis, S.R.., D.M. Cabahug and S.N. Alonzo-Pasicolon, 1990. Identification and inventory of Philippine forested-wetland resource. For. Ecol. Manag., 3/34: 21–44.
42. ITTO, 2002. Report of the ITTO International Mangrove Workshop. Yokohama, Japan: Inter. Trop. Tim. Org.: pp: 103.
43. Walters, B.B., 2003. People and mangroves in the Philippines: fifty years of coastal environmental change. Environ. Conserv. 30(2): 293-303.
44. Aref, I.M., L.I. El-Juhany and M.Y. Khamis, 2006. Effects of different sources of irrigation water and soil types and their interactions on the growth of *Avicennia marina* seedlings. *In*: The Proceedings of The 3rd International Conference for Development and the Environment in the Arab world, March, 21-23, 2006, Assiut University, Center for Environmental Studies, Assiut, Egypt, pp: 123-134.
45. Macintosh, D.J. and E.C. Ashton, 2002. A Review of Mangrove Biodiversity Conservation and Management. Centre for Tropical Ecosystems Research, University of Aarhus, Denmark.
46. Morrison, D., 1990. Landscape restoration in response to previous disturbance. In: Turner MG (ed.) Landscape heterogeneity and disturbance. Springer-Verlag, New York, pp: 159-172.
47. Henry, C.P. and C. Amoros, 1995. Restoration ecology of riverine wetlands: I. A scientific base. Environ. Manag., 19: 891-902.