The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden

(PERSGA)

Status of Mangroves in the Red Sea and Gulf of Aden

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PERSGA is an intergovernmental organisation dedicated to the conservation of the coastal and marine environments in the region and the wise use of their natural resources.

The Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (Jeddah Convention) 1982 provides the legal foundation for PERSGA. The Secretariat of the Organization was formally established in Jeddah following the Cairo Declaration of September 1995. The PERSGA member states are Djibouti, Egypt, Jordan, Saudi Arabia, Somalia, Sudan, and Yemen.

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Table of Contents

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

GBH	Girth at Breast Height
HBC	Habitat and Biodiversity Conservation
IDB	Islamic Development Bank
MPA	Marine Protected Area
NCWCD	National Commission for Wildlife Conservation and Development
NGO	Non Governmental Organisation
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
RSA	Rapid Survey Assessment
SAP	Strategic Action Programme
SSM	Standard Survey Methodology
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WSSV	White Spot Syndrome Virus

Executive Summary

A mangrove survey programme was planned and executed by PERSGA during the months of July and August 2002 in Djibouti, Sudan and Yemen. Regional experts also provided a review of the status of mangrove habitats in Egypt and Saudi Arabia. This document is a synthesis of these reports. It gives an indication of the status of mangroves in the Region[1] and guidelines for mangrove rehabilitation, conservation and management.

Avicennia marina is the most abundant mangrove species; it was reported in all mangrove areas in the Region. Relatively thick and well grown *Rhizophora mucronata* stands coexist in a few areas, particularly in Djibouti, while some other less developed *Rhizophora mucronata* stands occur in Yemen and Saudi Arabia. Previous surveys reported the presence of *Ceriops tagal* and *Bruguiera gymnorrhiza*. Almost all other mangrove forests are mono-specific consisting only of *Avicennia marina* except, occasionally, when a few poorly developed *Rhizophora mucronata* occur (e.g. Halaib area).

Typically, the mangroves grow as thin or, rarely, thick forests along:

- the shore-line
- on near and off-shore islands
- fringing tidal creeks and channels of various size (locally known as khors, sharms or mersas).

Although the mangrove stands are typically thin, ranging between 50 to 300m in width, their length varies considerably from some 100m to well above 20km. The size of the *Avicennia* plants ranges from stunted bushes, usually growing in the outer fringes of the stand to well developed trees reaching up to 4-6m in height. The GBH of mature well developed trees ranges from 10-100cm. In some particular localities e.g. Al-Urj (Yemen), Maskali Island (Djibouti) and Arakiyai (Sudan), the well-oxygenated, relatively sandy substrate and substantial underground freshwater seepage provide favourable conditions for massive growth of the *Avicennia* trees; here they reach up to 8-10m in height and more than 200cm in GBH. The well-grown *Rhizophora* at Khor Angar, Godoria and on Moucha Island in Djibouti reach up to 9-13m height and attain more than 100cm GBH.

Camel grazing was reported as a major problem causing degradation in all mangroves, excluding only a few stands growing in protected islets. The intensity of camel browsing varied from low in some areas to moderate in most mangrove stands and severe in others. This depends on the size of the camel herds present in the area, accessibility of the site and the availability and condition of other pastoral resources in the coastal area. Where heavy grazing occurs, severe impacts on the mangroves include a considerable reduction in the green parts and limiting of the tree growth to stunted multi-stemmed bushes. Destruction of the seedlings and pneumatophores under the feet of camels were recorded. Mature trees with dropped limbs were reported as common in most of the mangrove areas. Although limited mangrove cutting was reported, the impact is severe due to the limited size of the stands. Cutting has lead to a reduction in the

[1] The Region (capital ‘R’) stands for the geographical area within the Red Sea and Gulf of Aden region described in Article II of the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment, 1982.

number of trees, denuded patches within mangrove forests, increased abundance of multi-stemmed trees, barren depressions in which the hydrological regimes were modified and compaction of the surface soil. In addition, cutting has made the inner, dense parts of the stands accessible for grazing by camels. Thus, the combined effects of grazing and cutting have accelerated the degradation of several mangrove areas near major population settlements in the Region.

Mass mortality of mangrove trees appears to be a serious problem along the southern coasts of Yemen and Sudan, and on the Gulf of Aden coast in Djibouti, where mortalities occur in considerable parts of the mangrove stands. In other areas, localized pockets of dead standing trees were reported due to various kinds of known and unknown stresses. 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 the mass mortality and ‘top dying’ of the mangrove trees 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. The modifications were attributed to construction activities involving dredging and sediment dumping on the shore, diversion of tidal water through newly constructed canals to feed salt pans, 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. Decline in rainfall and surface run-off has decreased floodwaters, which has probably increased the sedimentation rate of sand from tidal flows. The Indo-Pacific El-Nino of 1997-1998 might have contributed to the problem by depositing huge quantities of terrestrial sediments in the wetlands.

Pollution in the mangrove areas is largely confined to domestic solid-wastes, e.g. polythene bags and bottles, plastic and metal cans, which are disposed of in large quantities near population centres of the major coastal towns and villages. This may have serious physical impacts by covering the young seedlings and pneumatophores, blocking tidal channels and causing disturbance to the mangrove-associated fauna. Some mangrove areas have been under stress of pollution by sewage water for several years. Stunted, multi-stemmed trees with a high incidence of branched, twisting and dead pneumatophores dominate these stands. Oil pollution or direct chemical and industrial inputs to the mangroves were not reported during the present surveys. However, there are many threats from the expansion of industry and coastal development and the proximity of one of the world's major shipping routes with vessels potentially approaching the coast.

The recently emerging and growing shrimp farming industry in the Region will pose a serious threat to the mangroves. Commercial shrimp farms have been reported causing devastation to the coastal environment in several Asian countries. Based on the preliminary information about the projects and the infrastructure and technical know-how available, small-scale, intensive and highly productive aquaculture systems will apparently be adopted. Such small-scale intensive shrimp farms have been reported as problematic with 5-6 years sustainability because of rapid degradation of water quality and consequent spread of diseases caused by effluents from the shrimp farms themselves. As these changes are usually irreversible, the investors move to new coastal areas causing more and more devastation. Given the growing market demand and the need to raise income from exports, shrimp farming is anticipated to grow rapidly in RSGA region during the coming years. To reduce adverse effects on the coastal environments, the governments need incentive programmes and technical assistance, access to credit etc., which will facilitate the adoption of sustainable, less destructive, though more expensive, shrimp farming systems.

The distribution of mangroves is greatly influenced by the amount of surface run-off and alluvium deposited at river mouths by seasonal floods. Damming of rivers and excessive groundwater pumping are also threats that will lead to degradation of the mangroves for three reasons:

- increased intrusion of saltwater
- decline of the alluvium sediment load deposited at the river mouths
- increased sand infilling and deposition of sand from the sea.

Mangroves in the Region are on government-owned land, under the jurisdiction of various authorities in the different countries. At present, some mangrove areas are afforded legal protection for nature conservation purposes (mainly in Egypt and Saudi Arabia). However, the majority of the mangroves have open access. The vast majority of these mangroves are small, often very narrow, and thus unsuitable for potential harvesting of wood and animal fodder. Their ecological roles are important and include:

- coastal protection from erosion
- trapping of sediments
- consolidation of the shoreline habitats
- providing nursery grounds and shelter for a number of marine organisms
- nesting and roosting sites for several avian fauna
- enriching the marine food web in the surrounding oligotrophic water.

These are far more valuable than their role as a potential source of fodder and timber products. Therefore it is strongly recommended that these mangroves should be used sustainably and protected legally.

Given the present condition of the mangroves, an effective conservation and management policy is needed. The main objectives, management strategies and prescription guidelines for a mangrove rehabilitation and conservation programme are outlined and discussed in the report.

Introduction

Mangroves are a dominant form of vegetation along tropical coasts. Their forests represent one of the major ecosystems of the biosphere, covering about 161,000km² and 60-75% of the shores in the tropics (SPALDING et al. 1997). The occurrence of mangroves along the Red Sea was described by ancient authors such as Theophratus in his "*Historia Plantarum*" (350 BC) and Pliny in his "*Historia Naturalis*" (AD77). The Arabian botanist Abu-el-Abbas en-Nabaty gave an account of a journey through Arabia in 1230 in which he described *Rhizophora* and named it as "Gendela", and *Avicennia* which he named "Quorm". Both names persist in Arabic and Swahili to the present day (MACNAE 1968).

The term 'mangrove' includes about 70 species from 20 families of trees or bushes that grow between high water springs and high water neap tide levels (JONES 2002; RAVEN et al. 1988; MACNAE 1968). Some genera such as *Rhizophora* and *Avicennia* have developed a special root system that supports respiration and stability. Prop roots and pneumatophores reduce current velocities, increasing sedimentation of suspended material. Therefore mangroves can advance seawards to occupy new coastal habitats (WOODROFFE 1992) and they are especially important for protecting coasts from erosion.

Apart from their significance for coastal protection, mangroves play a vital role in marine life and fisheries by providing food and shelter for a large and varied group of marine organisms including fish and shellfish. MATTES and KAPETSKY (1988) listed well over 1000 fish species of commercial importance from mangrove habitats worldwide. Outwelling of nutrients and organic matter in the form of mangrove leaf litter contributes to the enrichment of coastal waters (DITTMAR 1999) and enhances the marine food web in tropical coastal environments.

In spite of the ecological importance of the mangrove ecosystem and its manifold economic benefits (Box 1), the loss and degradation of mangrove areas is enormous. Mangroves are used traditionally and commercially in several activities e.g. as timber and domestic firewood that requires cutting and removal of trees (SAENGER et al. 1996). In many tropical areas large-scale removal of mangrove forests takes place in favour of aquaculture, land reclamation and for other purposes. Coastal development causing pollution, alteration of the substrate and modifying hydrological regimes also exert serious stresses on mangroves. There is growing evidence of continuous deforestation of mangroves all over the world (e.g. SASEKUMAR 1993; MASTALLER 1996, 1997). It was estimated that world's area of mangrove forests has been reduced by about 35% since the 1980s (VALIELA et al. 2001). This has led to recognition that the ecosystem is being adversely impacted and has accelerated efforts by scientists and conservation bodies addressing protection of the mangrove ecosystem.

Although the mangroves of the Red Sea and Gulf of Aden (RSGA) are not as luxuriant as those on other tropical coasts, they play similarly important ecological roles. They are nurseries for several commercial fish species (KHALIL 1994; KHALIL & KRUPP 1994) and they protect coral reefs by trapping sediment loads from the seasonal rainwater influx (WILKEI 1995). As they grow in a very hostile environment, the Red Sea mangroves are very sensitive to over-exploitation (PRICE et al. 1987). Mangrove degradation has been reported in many parts of the Region due to over-cutting, excessive browsing by camels, damming rainwater draining through valleys, pollution and coastal constructions (MOHAMED 1984; MANDURA 1997; MANDURA & KHAFAJA 1993; KHALIL 1994, 2001; KHALIL & KRUPP 1994; WILKEI 1995).

Box 1. Uses and functions of mangrove ecosystems

The uses of mangrove plants are surprisingly varied. Where mangrove forests are extensive the trees are often of considerable economic importance. The wood is widely used as fuel and that of some species makes good quality lumber used in house and boat construction, as fence posts and railroad ties. It is also harvested for the manufacture of rayon. The bark is a source of commercial tannin used in tanning leather and preservation of fishing nets. It is also a source of various dyes and stains. The leaves have been used as livestock feed and as "green manure" in southeast Asian brackish fish ponds. They have also been used for various medicinal purposes for humans and livestock. The fruits of some species are edible and some are sources of fish poisons (MACNAE 1968; ODUM & JOHANNES 1975).

The functions of the mangrove ecosystem are far more important than the uses of the plants and forest products. Mangroves provide a buffer between land and shallow sea communities, such as corals and seagrass beds. Mangrove roots trap sediment and help to protect shores from waves and hurricanes. Mangroves are often planted for erosion control (DAVIS 1940; MACNAE 1968). The removal of mangroves from an area may bring about degradation of adjacent habitats.

The most important functions of the mangroves are those of providing food and shelter for a large group of marine fish and shellfish. MATTES & KAPETSKY (1988) listed well over 1000 species of commercial importance from mangrove areas worldwide. Extensive mangrove forests also support a variety of terrestrial wildlife such as small mammals, reptiles and avian fauna. In the Red Sea, mangroves have been reported as important nesting sites for several birds such as the Goliath heron *Ardea goliath* and the reef heron *Egretta gularis* (ORMOND 1980).

The Habitat and Biodiversity Conservation (HBC) component of the Strategic Action Programme (SAP) executed by PERSGA has taken the regional shortcomings in existing knowledge of the status of mangrove biotopes into account. PERSGA has developed a set of Standard Survey Methods (SSM) and trained regional specialists to conduct mangrove surveys. A programme of regular surveys has been established within the Red Sea and Gulf of Aden.

Aims of the Survey Programme

The aims of the mangrove survey programme are:

1. to use the SSM to collect qualitative and quantitative data on mangroves and their associated biota over an extended period,
2. to use the data to develop country and regional reports that evaluate the status of mangrove habitats, and to provide guidelines for the development of conservation management and rehabilitation plans,
3. to raise public awareness and encourage participation of local communities in those locations where surveys take place.

The baseline data will be used for monitoring the existing pristine mangrove biotopes to:

- establish the degree of naturalness and their potential to act as sources of replenishment,
- identify unknown pollution or disturbance and predict any future threats to assist in prompt implementation of control methods.

The baseline data will also be used to monitor and assess the polluted and disturbed mangrove biotopes in order to:

- identify types and sources of impacts and assess acute, local short-term effects, and
- predict and monitor chronic long-term, broad-scale effects in future surveys.

Methodology

A mangrove survey was carried out in Sudan, Djibouti and Yemen during July and August 2002. The survey area included the majority of mangrove stands in these countries. Information presented on the status of mangroves in Saudi Arabia and Egypt is based on a review of results of similar, previous surveys conducted in these two countries (AL-WETAID 2003; GALAL 2003).

The survey methods were based on the Standard Survey Methods (SSM) and the mangrove monitoring programme developed by PERSGA (JONES 2002; KHALIL 2002). KHALIL (2002) describes statistical methods for the analysis of survey and monitoring data. The physical conditions, stand characteristics, and presence/absence data of Key Species for the biotope were recorded. The source and level of impacts or disturbances and any observed effects on the mangroves were also recorded. Threats from any activities in the surrounding settlements were noted. The data provides information on the condition of the mangroves related to the level of human disturbance and habitat degradation (KHALIL 2003a, b, c).

Methods for quantifying abundance and biomass of mangroves are described in ENGLISH et al. (1997). Most are not applicable in the sparse stands found within the Region. Density, height and girth at breast height (GBH) of the trees, density of seedlings and other parameters and indicators (see below) were used to evaluate the condition of the mangroves. Quadrat methods were used with the following dimensions: 10 x 10m for trees and 0.5 x 0.5m for pneumatophores. The parameters and indicators used in the studies include (SAENGER et al. 1996):

- dead standing trees
- dead felled trees
- grazed trees and shrubs
- mature trees with dropped limbs
- trees with top dying of uppermost and outermost branches
- dead seedlings
- branched pneumatophores
- twisting and curling pneumatophores
- prop roots with dead tips
- deformed propagules and seeds
- leaves with spotty chlorosis or necrosis
- twisting and curling leaves.

For each area surveyed, the survey data were recorded on three sheets (Appendix 1):

- Sheet 1: physical characteristics and general visual assessment data
- Sheet 2: quantitative data and quadrat measurements of stand size, extent and characteristics, and the condition of the mangrove vegetation
- Sheet 3: presence and status of mangrove associated fauna.

Status of Mangroves

2.1 Djibouti - Gulf of Aden Coast

Distribution and extent of the mangrove stands

The mangroves were surveyed at seven localities along the coast and islands of Djibouti (Figure 1). These make up the vast majority of the mangrove wealth in the country and include Ras Siyyan, Khor Angar, Godoria, Obock, Gaan-Maan, and Moucha and Maskali Islands. Other areas reported to have mangrove vegetation and not visited during this survey include small stands growing at Ambado and Domerjog on the southern part of the coast, and two other small stands growing near the western end of the Gulf of Tadjoura.

Avicennia marina is the most abundant mangrove species and it was reported in all mangrove areas in Djibouti. Relatively thick and well grown *Rhizophora mucronata* stands coexist in three areas including Godoria, Khor Angar and Moucha Island. Previous surveys reported the presence of *Ceriops tagal* and *Bruguiera gymnorrhiza*. All other mangrove forests are mono-specific consisting only of *Avicennia marina* except for Ras Siyyan where a few trees of *R. mucronata* were observed. The mangroves are typically found as thin or relatively thick forests along the shore-line, on near and off-shore islands and fringing tidal inlets, which extend landwards along depressed areas forming shallow channels of various size, locally known as khors.

The *Avicennia marina* stands are typically thin, fringing the coastline, 50 to 300m in width. Their length varied considerably from tens of metres to several kilometres. Total length of the areas surveyed was estimated at 27km, concentrated in three areas: Khor Angar, Godoria and Moucha Island. The forests range from monospecific stands of *Avicennia* to dense, multispecific mangrove forests supporting a composite system of mangrove channels, lagoons and associated communities. The mangrove areas of Djibouti may be divided into three categories according to ecological features, diversity and extent of the stands:

- Areas with extensive tidal inlets, numerous channels and lagoons forming an inundated estuary-like system. These areas support dense multispecific forests, dominated by *Avicennia marina* and *Rhizophora mucronata*, and high diversity of mangrove associated fauna. They include Godoria, Khor Angar and Moucha Island.
- Areas with small tidal inlets, which support dense monospecific stands of *Avicennia marina*. Some *Rhizophora mucronata* trees may occur but they are very limited in size and number, e.g. Ras Siyyan.
- Areas with mostly muddy substrate and no inundated channels or creeks. These areas support thin, relatively sparse mono-specific stands of *Avicennia marina*, these include all other mangroves in the country, e.g. Gaan-Maan.

Local characteristics and condition of the mangrove stands

Ras Siyyan (12° 28'N, 43° 18'E)

Ras Siyyan cape is a rocky outcrop on the northern coast facing the straits of Bab al-Mandab. The coastal area is fringed with coral reef, parallel to the cape. On a shallow platform east of Ras Siyyan, the Sept Frères archipelago is also surrounded by coral reefs. To the west, on the leeward side of the cape is a small protected bay, open to the sea at its northern end. This bay is fringed with a dense stand of mangroves. The substrate is sandy, grading to sandy mud in the lower littoral and shallow sublittoral parts of the bay. The area is inhabited by nomads and a small population of fishermen who live in small huts near the mangroves. Subsistence animal breeding, fishing, and collection of lobsters, gastropods (mainly for *zurumbak* and *dufra*), and sea cucumbers are the dominant occupations.

The mangrove forest (Table 1) comprises several adjacent stands of *Avicennia marina*. Two or three *Rhizophora mucronata* trees grow in the west of the stand. The forest fringes the shore for about 2.5km along the bay from the foot of Ras Siyyan hill to the western end of the small bay. The width of the forest varies from a few metres to 400-500m. The outer landward zone of the stand consists of stunted *Avicennia marina* bushes reaching up to 0.5m in height and small to moderate trees of 3-4m height. GBH of the trees in this zone is 17-55cm. The inner seaward zone of the stand consists of relatively well grown *Avicennia marina* up to 7-9m in height. However, some trees are stunted, affected by grazing and cutting.

At Ras Siyyan, the mangroves are seriously affected by camel grazing, cutting and burial by creeping sand dunes. Severe cutting has affected the outer parts of the stand considerably. Approximately 20% of the trees were completely destroyed and removed, and several others had dropped limbs. The growth of the majority of remaining *Avicennia* is stunted as a result of heavy browsing by camels. In some places, where cutting has created denuded patches in the outer belt, camel grazing extends deeper into the stand. This causes considerable damage to these parts as well. Massive sedimentation by sand dunes represents a major problem. It severely affects the mangroves growing on the outer fringes and blocks the regular tidal flow of water to the upper reaches of the stand. Several dead standing trees are found in the outer fringes, while twisting and curling leaves, and death of the uppermost and outermost branches is common. Severe cutting of the trees has created some denuded patches, allowing sand to advance deeper into the forest, covering the aerial roots and lower parts of the trunks of some trees. The number of dry pneumatophores and those with dead tips is relatively high (about 20%). Death of pneumatophores occurs mainly due to destruction by the feet of camels and burial by sand.

Khor Angar

At Khor Angar, a wide, elongated inlet merges with the sea forming a large channel that extends along the shoreline for about 6-7km. The main channel is relatively wide at its connection with the sea, becoming gradually narrower and undulating towards the upper reaches. It extends along the coastline from northeast to southwest, enclosing an extensive coastal area, with the mainland shore to the east, Khor Angar to the north and west, and a saltmarsh and coastal plain in the south. Vegetation in this area consists of few scattered salt-tolerant grasses. Substrate is predominantly sand with some patches of muddy sabkha sediments. Exposed sand flats and elevated sand dunes are common in the shallow water and shore area. Increased sedimentation by sand appears to be a serious environmental problem affecting the mangroves in the area. The banks of Khor Angar are fringed with mangroves, which become especially dense and extensive in the middle and upper reaches, where the main channel splits into several narrow tidal channels forming an estuary-like network. The area is mainly inhabited by nomads and a

small population of fishermen. The main economic activities are subsistence fishing and animal breeding. Besides the few huts, a small military camp is located near the village.

There are two stands of mangroves in the Khor Angar area (Table 1):

a) Khor Angar I (12° 24'N, 43° 20'E) is a relatively small *Avicennia marina* stand, located just north of the junction of Khor Angar and the sea. This stand is separated from the main forest on the khor by about one kilometre. It fringes about 150m of the mainland shore and extends approximately 400m inland along an area which is regularly inundated by tidal water. Mangroves in the landward zone are heavily grazed and cut. Camel grazing extends to middle and inner zones of the belt through denuded patches created by cutting and severe grazing. Although trees grow up to a relatively good height (4-5m), they attain small GBH (10-20cm) because they are almost all multi-stemmed, which indicates that they have been subjected to severe cutting in the past. Estimates from the remains of the destroyed mangroves suggest that about 40% of outer zone and 20% of the middle and inner zone of the belt have been removed. There is a high rate of mortality among mangrove trees in some parts of the middle zone of the forest, in which the dead standing trees represent over 40% of the trees present. Dryness of the uppermost and outermost branches is also common among the trees growing in the outer fringes of the belt. Dead, branched and curling pneumatophores are also very common. All these indicate that the mangrove stand is suffering from severe degradation.

Table 1. Characteristics and condition of mangrove stands at Ras Siyyan and Khor Angar

Variables and characteristics	Site					
	Ras Siyyan (outer zone)	Ras Siyyan (inner zone)	Khor Angar I (outer zone)	Khor Angar I (mid zone)	Khor Angar II (*Avicenna marina*)	Khor Angar II (*Rhizophora mucronata*)
Mangrove trees (quadrat size 10 x 10m):						
Density of trees	23	15	24	30	31	16
Height range (m)	0.5-4.0	0.5-9.0	0.5-4.0	3.0-5.0	0.5-5.5	9-13
GBH range (cm)	17-55	30-80	10-15	10-20	10-30	40-105
Dead standing trees	5	0	0	13	3	3
Dead felled trees	4	0	10	10	2	4
Grazed trees and shrubs	10	15	14	7	26	0
Mature trees with dropped limbs	1	6	4	4	7	7
Trees with top dying uppermost and outermost branches	2	1	6	0	18	7
Multi-stemmed trees	4	6	14	20	29	3
Number of seedlings	0	0	0	0	0	0
Dead seedlings	0	0	0	0	0	0
Deformed propagules and seeds	NR	NR	F	F	NR	F
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	F	NR	NR	NR	M	NR
Pneumatophores (quadrat size 0.5 x 0.5m):						
Density of pneumatophores	25	18	21	24	91	--
Branched pneumatophores	8	2	4	6	10	--
Twisting and curling pneumatophores	3	0	5	6	2	--
Pneumatophores with dead tips	5	5	11	9	38	--

NR: not recorded, F: few, M: many

b) Khor Angar II (12° 23'N, 43° 21'E), is a relatively large multi-specific forest growing on the banks of Khor Angar. This forest extends for about 6km along the khor. It is rather thin (50-200m) at the narrow mouth and in the northern parts of the khor. It becomes relatively wide (up to 800m) and dense in the middle and southern parts where the khor branches into several channels and lagoons that cover a large coastal area. Accordingly, the forest may be divided into two zones:

The northern zone, located in northeastern part of the forest, consists of a dense belt of *Avicennia marina* that fringes the main khor channel. This extends for about 1.5-2.0km along the lower reaches of the channel. The well-grown *Avicennia marina* trees reach up to 5-6m in height and 20-40cm GBH. Heavy grazing and wood cutting occur at several sites in this zone, especially the landward areas, where the majority of the mangroves are stunted to 0.5m *Avicennia* shrubs. All living trees are browsed by camels. About 10% of the trees present in a randomly selected quadrat were dead standing, 6% were felled and removed, while several others had dropped limbs (about 27%) and the majority had 'top dying' of outermost and uppermost branches (about 69%). Degradation is severe and will probably lead to the disappearance of the mangroves from this part of the forest unless protective measures take place immediately.

The middle and southern zone of the forest occupies the upper two-thirds of the khor banks. This zone is dominated by *Rhizophora mucronata*, which forms a thick belt of well-grown trees reaching up to 9-13m in height and more than 100cm GBH. The *Rhizophora mucronata* belt is fringed by a very thin *Avicennia marina* belt which merges with the dense *Avicennia marina* stand to the northern parts of the khor. The thin *Avicennia* belt is severely grazed by camels and affected by cutting at many sites. This has created several denuded patches in the outer belt allowing the advance of moving sand and sand dunes deeper into the forest. Tidal water circulation through the khor and its numerous small branches has been blocked. This has led to a severe mass mortality among *Rhizophora mucronata*. This represents the most serious problem facing the mangroves of Khor Angar. The mass mortality is estimated as 35-40% of the total *Rhizophora mucronata* stand. The dead trees are infested by insect pests and microbial organisms that may spread to the dry limbs of living trees causing additional stress. Many dead, dry trunks have been blown down by the wind. The massive accumulation of dead wood and leaves in the tidal channels blocks tidal water circulation and provides an ideal situation for microbial decomposition. Anaerobic water conditions and sediment deposition prevails. In addition to the stagnation, the massive accumulation of dry wood deprives the young seedlings of ground space and increased exposure to sunlight provides unfavourable conditions for their growth. Seedlings are nearly absent from the area affected by the mass mortality; those present are apparently not sufficient for natural regeneration of the mangroves.

Godoria (12° 09'N, 43° 24'E)

At Godoria the shore line is undulating and includes a large inlet and a wide coastal area with several lagoons and channels forming a semi-estuary. This site supports the most extensive, dense and diverse mangroves in Djibouti. The thick forest forms a circular belt around the bay, which connects to the open sea through a narrow channel at the eastern end. A small tourist camp is found near the southern end. This consists of a few huts and 2-3 small boats that are used for tourists to sail round the swamp. The camp was not in use during the recent survey. There is no other significant human activity in the vicinity and most of the mangrove area is remote and not easily accessible. However, the coastal plains in the neighbourhood are inhabited by sparse populations of nomads who bring their camels to graze on the *Avicennia* mangroves in the accessible, outer parts of the forest.

The mangrove forest at Godoria (Table 2) is in a relatively good state. The thick mangrove belt extends approximately 10km, fringing the shores of a large inlet and mangrove channels which contain standing water at low tide. The good condition of the mangroves could be attributed to the remoteness of the area and low levels of human disturbance. *Rhizophora mucronata* and *Avicennia marina* are the dominant species. Previous surveys reported the presence of some *Ceriops tagal* and *Bruguiera gymnorrhiza*. The *Avicennia* form a thick belt fringing most of the peripheral channels and landward fringes of the mangrove. Their height ranges from 1.5-3.5m in the stunted outer fringes of the belt to 2.0-7.0m in the well-grown inner parts of the stand. The Rhizophora, which is more dominant in terms of biomass, forms a dense well-grown stand of massive trees that occupies most of the inner parts of the forest.

Table 2. Characteristics and condition of mangrove stands at Godoria, and Moucha and Maskali Islands

Variables and characteristics	Site					
	Godoria (Tourist camp, *Avicennia*)	Godoria (Inner zone, *Avicennia*)	Moucha Island (*Avicennia*)	Moucha Island (*Rhizophora*)	Maskali Island (Outer zone)	Maskali Island (Inner zone)
Mangrove trees (quadrat size 10 x 10m):						
Density of trees (/10m²)	25	36	9	26	18	9
Height range (m)	1.5-3.5	2-7	3-4	10-13	5-8	8-11
GBH range (cm)	10-25	15-30	15-95	25-70	45-160	40-246
Dead standing trees	4	4	0	2	0	0
Dead felled trees	0	1	1	1	2	2
Grazed trees and shrubs	21	5	0	0	0	0
Mature trees with dropped limbs	5	3	8	6	13	7
Trees with top dying uppermost and outermost branches	7	0	0	5	10	4
Multi-stemmed trees	25	30	0	0	6	2
Number of seedlings	0	0	0	32	8	21
Dead seedlings	0	0	0	3	0	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	NR	NR	NR	NR	F	F
Pneumatophores (quadrat size 0.5 x 0.5m):						
Density of pneumatophores	22	54	8	--	61	59
Branched pneumatophores	4	12	0	--	7	2
Twisting and curling pneumatophores	2	0	0	--	0	0
Pneumatophores with dead tips	0	4	3	--	4	0

NR: not recorded, F: few, M: many

Most of the mangroves at Godoria are undisturbed. However some parts of the landward western fringes of the *Avicennia* stand are significantly affected by camel grazing, cutting and localized mortality of mangrove trees. In these parts around 20% of the *Avicennia* are dead standing and almost all of the remaining living trees are browsed by camels. The percentage of trees with 'top dying' uppermost and outermost branches is also relatively high (around 30%). This suggests that these parts of the stand might suffer mass mortality in the future. Penetration of sand dunes from the west and southwest is a serious concern. Outer fringes of the stand are

buried by sand, which contributes to the localized mortality of some mangrove trees. The increasing stress from heavy grazing and cutting has caused several denuded patches in the outer zone of the belt, allowing increased erosion and sand movement. Sand may advance deeper into the stand, burying the mangrove channels and blocking water circulation. This may lead to mass death of mangrove trees similar to that encountered in the Khor Angar mangroves.

Obock (11° 55'N, 43° 19'E)

Obock village is the capital of Obock district. It is the largest population settlement on the northern coast of Djibouti. The village is located on a narrow stretch of coast backed by rocky hills. Major economic activities are fishing and animal breeding. Limited subsistence agriculture and horticulture is practiced by a few inhabitants. Land resources are poor and the ferry connecting the small town to the capital is the major public transport and lifeline. There are also several boats that import goods from Yemen and Djibouti town.

A very small and thin aggregation of stunted *Avicennia marina* mangroves extends for about 50m along the shore, near the fish landing mersa located in the vicinity of the ferry quayside. The mangrove stand has been severely destroyed by cutting and camel grazing. What is left is scanty mangrove vegetation consisting of few stunted shrubs and trees, which is now under severe stress, threatening their overall existence.

Moucha and Maskali Islands

Moucha Island (11° 43'N, 43° 12'E) is located at the entrance of the Gulf of Tadjoura, north of Djibouti city. Moucha and Maskali Island (11° 43'N, 43° 10'E), are based on a vast reef plateau surrounded by extensive coral reefs. The two islands represent popular night and weekend recreational centres for national and foreign tourists. Other human activities include occasional fishing by fishermen from Djibouti city. There are several camps that host tourists, occasional visitors and military forces. The shores of the islands are steep, rocky cliffs intersected by sandy beaches. The topography varies between rocky and sandy substrates. Terrestrial vegetation comprises salt-tolerant grasses. Both islands support well-grown mangroves, which are especially extensive on Moucha Island.

Moucha Island supports an extensive multi-specific mangrove forest dominated by *Rhizophora mucronata* and *Avicennia marina*. The well developed and dense stand of *Rhizophora* grows in standing water in a network of channels that flow to the upper part of the island. The *Avicennia* form a thin belt (10-40m wide) that fringes the outer part of the forest. The belt is relatively wide where flatter ground allows tidal water to flow through the channels at high tide. The *Avicennia* trees reach up to 3-4m in height and are mostly single-stemmed with the GBH of well-developed trees reaching 90cm. The *Rhizophora* trees attain 9-13m height and 25-70cm GBH. Pneumatophores are sparse and short because of the relatively sandy well-oxygenated substrate. The *Rhizophora* prop roots are well-developed and dense (Table 2).

However, a considerable area of the *Rhizophora* stand has undergone mass mortality with the loss of around a thousand trees. The major cause of the mass mortality is sand infilling that has blocked the water flow through the mangrove channels depriving some parts of the stand of seawater. The increased sand sedimentation has probably resulted from the removal of some parts of the thin outer belt of *Avicennia*. The mass mortality of *Rhizophora mucronata* trees is the most serious problem threatening mangroves on Moucha Island.

The dead *Rhizophora mucronata* trees are infested by pests. Many tree trunks have been blown down by wind. The accumulation of the dry wood in tidal channels blocks water

circulation and deprives the young seedlings of ground space. The stagnant water conditions and increased exposure to sunlight provide unfavourable conditions for the growth of seedlings. However the situation is rather better than at Khor Angar, as a large number of seedlings were observed growing near the mass mortality area. It is doubtful, however, whether this indicates good regeneration because the seedlings are growing on the outer edge of the stand that may dry up at extreme low tide or due to the increase in sand filling the channels. The situation is aggravated by wood cutting on the outer *Avicennia* belt by visitors to the island.

Maskali Island supports a much smaller mangrove stand than that found on Moucha Island. It is a mono-specific stand of *Avicennia marina* 200-300m long and 50-100m wide. It contains the most massive and ancient *Avicennia* trees in Djibouti. Some trees have reached 2.5m GBH and more than 10m in height. Like Moucha Island, the adjacent Maskali Island is critically disturbed by tourist activities on and around the island. The mangroves are heavily polluted by domestic solid waste (glass and plastic bottles, empty bags etc.) which accumulates among the pneumatophores and tree trunks. The stand is seriously affected by cutting. Approximately 10-20% of the *Avicennia* trees were felled and the majority of living trees had dropped major or minor limbs. Besides its ecological importance the *Avicennia* stand at Maskali has a cultural value as it contains the oldest and largest *Avicennia* trees in Djibouti. Conservation plans should give particular consideration to protect this mangrove stand from the impact of pollution and cutting (Table 2).

Gaan-Maan (11° 33'N, 43° 08'E)

This mangrove area is located near Djibouti town and consists of three, small, adjacent stands of sparse *Avicennia marina*. The development of the capital has modified the coastal area extensively. It was originally rich with an extensive saltmarsh and mangroves at the seaward end of a large valley. Remnants of the saltmarsh are found in some places on the seaward side of the coastal road. The mouth of the wadi is fringed with rocky boulders. The bottom is sandy grading to muddy sand and muddy silt in the lower reaches. Landward, the terrestrial vegetation consists of a dense belt of the introduced *Prosopis* sp. The mangroves are severely affected by the vicinity of Djibouti town, the capital, which is inhabited by about 75% of the total population of the country. The fishing harbour and Djibouti port and container harbours are located close to the mangroves. The activities of the fishing boats and maritime transport create risks for the mangroves and the surrounding habitats.

The first mangrove stand is located on the north eastern outskirts of Djibouti town near Gaan village, and consists of a thin belt of *Avicennia marina* trees, 10-30m wide and 300-400m long. The stand, which fringes the shoreline is being destroyed by camel grazing and cutting. The remains of the mangrove vegetation suggest that at least 50% of the original mangrove stand has been removed. The remaining mangroves are stunted *Avicennia* shrubs in the outer stand with some trees growing up to 3-4m at the seaward stand. The latter are protected from local inhabitants and their camels by the stickiness of the muddy silt sediment that increases in depth seawards. The stand is under severe stress, which seriously threatens its existence.

The second mangrove stand grows on a small tidal inlet some 800-1000m to the west. It consists of stunted *Avicennia marina* trees, 2-4m high and covering 100 x 200m. This stand is under severe stress from sewage pollution. The sewage flows directly to the mangroves through a short stream that originates from Djibouti town and crosses to the sea via a tunnel under the coastal road. However, the deep muddy substratum and unpleasant polluted ambiance make the mangrove stand rather inaccessible, hence the impacts from cutting and grazing are insignificant.

The third mangrove stand in the area comprises an aggregation of *Avicennia marina* growing on a mud flat close to the presidential palace on the landward side of the asphalt road. Tidal water reaches the mud flat through small tunnels beneath the road and regularly floods the stand at high tide. The stand covers an area 100m x 100m and consists of low growing, dense, young trees indicating that this area has been recently colonized by the mangroves. The substrate is very deep inaccessible mud and the area is protected for security purposes. The mangrove stand is therefore secure from any grazing or cutting disturbance.

2.2 Western Red Sea Coast (Egypt and Sudan)

EGYPT

The mangroves of Sinai were first mentioned by Ascherson in 1887 (POR et al. 1977). Several studies have concentrated on these mangroves in the past, e.g. POR et al. (1977), POR & DOR (1975), DOR & LEVY (1984) and recently GAZZAR (1995) and GALAL (1999) both cited in GALAL (2003). These publications provide information on the location, extent, productivity, composition and zonation of mangroves and their associated floral and faunal communities. Some other studies have concentrated on the mangroves of the Egyptian-African Red Sea coast (e.g. KASSAS & ZAHRAN 1967). A number of studies and surveys have been carried out documenting impacts on mangroves in Egypt. These are cited and reviewed by GALAL (2003). The following information is extracted from his review except, where another reference is indicated in the text.

Distribution and extent of the mangrove stands

Mangrove stands in Egypt are, in general, relatively small (Figure 1). They are dispersed along the Egyptian Red Sea coastline in sheltered bays and lagoons protected behind coral reefs. The mangrove stands along the Gulf of Aqaba and the Egyptian Red Sea coastlines cover a total area exceeding 550 hectares. They are predominantly mono-specific, consisting only of *Avicennia marina*, except for a few stands in the southern Sudanese border area where *Rhizophora mucronata* coexists along with *Avicennia marina*. From a geographical point of view, the Egyptian mangroves may be divided into the Sinai mangroves, and mangroves growing on the Egyptian-African Red Sea coast.

Local characteristics and condition of the mangrove stands

SINAI MANGROVES

The Sinai mangrove thickets are found only on the south-eastern tip of the Sinai Peninsula. They consist of five stands. One of these includes a small group of *Avicennia* trees growing along a channel that cuts across Ras Mohammed at the southern extension of the peninsula. The other four stands are denser and are found along a 20km stretch of coast on the alluvial fan of Wadi Kid, to the north of Nabq Oasis. They are, from north to south, Shura Al-Manquata, Shura Al-Rowaisseya, Mersa Abu Zabad and Shura Al-Gharqana (Shura is local name for *Avicennia* stand). All mangrove stands in Sinai are monospecific - *Avicennia marina*. Except for the sparse mangrove of Ras Mohammed the stands are characterized by tree growths developing in the shelter of a broad subfossil-reef flat. At low tide the reef flat is only covered by a few centimetres of water or is dry. The holes in the landward side of the reef flat become true lagoons around which the mangrove stands develop (POR et al. 1977).

The Sinai mangroves have suffered through cutting and by pollution from the accumulation of domestic solid waste. Mangroves near Ras Mohammed were reported as being stressed by a build up of oil pollution from past spills (BALDWIN & FERGUSON 1988). Recent surveys detected several small tar mats beneath the soft substrate in the area. However, since all the Sinai mangroves were included within the territories of Nabq Protected Area and Ras Mohammed National Park (established since 1983), wood cutting has been banned and plastics cleared from the mangroves on a regular basis. The following gives some details on the characteristics of the stands.

Shura Al-Manquata (28° 12.5'N, 34° 25'E)

The mangrove stand at this site is considered as the northerly limit of the Western Indian Ocean Region. The total area of the stand was estimated as 7.1ha in 1998 (GALAL 2003). *Avicennia marina* trees are relatively well-developed and especially dense towards the protected western edge of a sandy lagoon, separated from the sea by a strip of fossilized reef. Mean tree height is 2.6m, while some trees attain up to 5.6m in height.

Shura Al-Rowaisseya (28° 11'N, 34° 27'E)

This is the largest stand in the group, extending for more than 3km along the shoreline and covering around 27.6ha. The outer zone is occupied by stunted trees not exceeding 1.5m in height. Fully-grown trees up to 5-6m height grow in the middle and inner zone, especially around a large lagoon and some other subtidal pools. These are fully connected to the sea only at high tide. POR et al. (1977) however, suggested that they might have some permanent connection to sea from underground seepage.

Mersa Abu Zabad (28° 09'N, 34° 27'E)

The mangrove stand at this site extends approximately 1.2km and covers 14.4ha. Due to highly saline substrate beneath, the stand consists of mostly low growing shrubs; however some trees in the seaward fringe are up to 5m in height.

Shura Al-Gharqana (28° 07'N, 34° 26.5'E)

The Gharqana lagoon is a small embayment 1.4-4.0m deep, which is partly separated from the sea by a wide fringing reef. Some *Avicennia marina* trees grow at the north-eastern end of the lagoon. Another patch of sparse shrubs grows along the shoreline to the south of the lagoon. The total area covers 3.4 ha.

Ras Mohammed (27° 44'N, 34° 15'E)

The relatively small stand at Ras Mohammed grows along both banks of a shallow channel 500m in length. The sandy sediments of the mangrove channel are typically exposed at low tide. Mean tree height was 2.6m, maximum height was 4.5m.

MANGROVES ALONG THE EGYPTIAN-AFRICAN RED SEA COAST

GALAL (2003) reported mangroves at 23 localities between latitudes 27° 40'N and 22° 33'N, most of which are only small patches or aggregations of stunted *Avicennia marina*, as described below. The mangroves located at Halaib are dealt with in a separate section of this report.

Geisum Island (27° 40'N, 33° 42'E)

Scattered *Avicennia marina* trees grow along the western shoreline of Geisum Island. The mangroves are stunted and grow up to 2m high. This stand is disturbed by solid waste

accumulation mainly in the form of plastics. Small tar mats beneath the soft sediment in some parts of the stand are signs of previous oil pollution.

Al-Gonah (27° 24'N, 33° 41'E)

This is also a stunted, sparse stand of *Avicennia marina* growing along the coast and on some lagoonal islets. The locality has been impacted by extensive development of hotels and marinas, and the modification of the hydrological regime as a result of construction of artificial lagoons and channels in the area.

Abu Minkar Island (27° 13'N, 33° 52'E)

A relatively dense *Avicennia marina* stand grows in the centre of the island and along a shallow channel, covering an area of approximately 60ha. A small area has been affected by oil pollution, while large areas of the stand suffer from solid waste accumulation, predominantly plastics. The mangrove thickets support a number of osprey nests, and numerous juvenile fish were recorded in the creeks.

Safaga Island (26° 45'N, 33° 59'E)

The western shoreline of the island supports a relatively well grown *Avicennia marina* stand, with trees up to 4.8m high. The stand suffers from accumulation of solid wastes, mainly in the form of plastics.

South Safaga (26° 38'N, 33° 59'E)

A small *Avicennia marina* stand grows in a sheltered area interspersed with mud flats. The stand also suffers from accumulation of solid wastes, mainly in the form of plastics.

Wadi Abu Hamra (26° 21'N, 34° 09'E)

The stand of *Avicennia marina* grows around a small embayment that leads to a small creek. The mean tree height was 2.8m, while maximum height was 4.2m.

Sharm El-Bahari (25° 52'N, 34° 24'E)

The stand at this site grows along both sides of the wadi mouth. Trees growing along the northern side are more protected and attain larger crowns. The southern section is occupied by dwarf trees not exceeding 2m in height. Construction of coastal road and tourist development in the area could have impacts on groundwater seepage. The stand also suffers from accumulation of solid waste, mainly in the form of plastics.

Sharm El-Qebli (25° 50'N, 34° 26'E)

This *Avicennia marina* stand grows along the shoreline in the shelter of a fringing reef. Mean tree height was 3m, while maximum height was 4.5m. Heavy grazing by camels was reported at this stand, especially at its southern edge. Mangrove trees along the northern edge attain larger crowns and grow higher than those at the grazed southern edge.

Mersa Shagara (25° 40'N, 34° 35'E)

The coastline is characterized by sabkha flats where several mangrove thickets grow. The stand is now separated from the sea by a newly formed sandy beach which has cut off tidal flow. The beach has been stabilized by an ecotourism diving resort. No regeneration of mangrove trees in the area was reported.

Wadi El-Gimal (24° 40'N, 35° 05'E), W. El-Gimal Island (24° 40'N, 35° 10'E), Ras Baghdadi (24° 49'N, 35° 06'E)

These are three mono-specific stands of stunted *Avicennia marina*. They have been included within the territories of Wadi El Gimal Protected Area, which was declared in 2003.

Hamata mangroves

These are four, relatively large stands growing at the mouths of Wadi Mastura (24° 23'N, 35° 16'E), Wadi Al-Qulaan (24° 21'N, 35° 19'E), Wadi Rawada Al-Edaiah (24° 20'N, 35° 20'E) and Wadi Harbiyyah (24° 19'N, 35° 20'E), where silt and sand loads are deposited in the coastal zone by occasional flooding of the wadis. Mean tree height was 2.8m, while maximum height was 5.5m. The landward fringes of the stands are impacted by camel grazing.

Shawareet Island (24° 21'N, 35° 26'E)

A small *Avicennia marina* stand is located at the southern end of this island. This stand also suffers from the accumulation of solid waste, mainly in the form of plastics.

Wadi Lahmy(24° 13'N, 35° 26'E)

A small *Avicennia marina* stand grows on a sandy substrate at the mouth of Wadi Lahmi, surrounding a shallow lagoon. Mean tree height was 2.8m and maximum height was 5.6m. The landward fringe of the stand is being impacted by camel grazing. There is an ecotourism camp very close to the stand.

Quoraat Hartawy (24° 06'N, 35° 30'E)

Several small stands of stunted *Avicennia marina* at the fringes of a tidal inlet; the trees grow up to 1.5m in height, a few reach 3.4m. The stand is severely impacted by camel browsing.

Mersa El-Hamira mangrove (23° 29'N, 35° 29'E)

This mangrove stand extends for 2000m along the shore of a large bay. Mean tree height was 3m, while older trees have larger crowns and grow up to 5.8m in height. The construction of a causeway at the south-eastern end of the lagoon has resulted in reduced water exchange. The landward parts of the stand are heavily impacted by camel grazing.

Shalateen Island (23° 08'N, 35° 41'E)

The stand occurs along the south-eastern shoreline of the island. It is disturbed by abundant solid waste accumulation, mainly in the form of plastics.

MANGROVES LOCATED IN THE EGYPTIAN-SUDANESE BORDER AREA

Sharm- El-Madfaa (22° 57'N, 35° 40'E)

The shoreline at this locality comprises sabkha flats that are periodically flooded by tides through a shallow inlet. Dense growth of *Avicennia marina* fringes the shoreline around the inlet. Mean tree height was 2m, while some trees with larger crowns reach up to 6m in height.

Mersa Shaab (22° 50'N, 35° 45'E)

This large stand grows for 6km along mouth of the alluvial fans of Wadi Shaab and Wadi Abib. The northern parts are dominated by *Avicennia marina*. Seaward, a mixed zone of *Avicennia marina* and *Rhizophora mucronata* occurs. The former reaches up to 4.8m and the latter up to around 6m in height. Several turtle nests were reported in the area, while pollution by domestic solid waste was minimal.

Mersa Abu Fassi (22° 41'N, 36° 00'E)

The mangrove stand at this site extends 2.5km along the shoreline. Minimal impacts of grazing were reported due to the remoteness of the stand.

Wadi Al-Hoor (22° 38'N, 36° 13'E)

Both *Avicennia marina* and *Rhizophora mucronata* occur in this area. The northern and southern sectors of the stand are dominated by *Avicennia marina*, while *Rhizophora mucronata* forms dense thickets at the seaward margin of the central sector of the stand. The *Avicennia marina* reaches up to 5.8m in height, while *Rhizophora mucronata* attains higher crowns reaching 7m at some localities. The landward fringes of the stand are affected by grazing.

Adaldeep (22° 33'N, 36° 17'E)

The mangrove stand at this locality extends for 2000m along the shoreline. Mean tree height was 4.5m, maximum height was 7m. The landward parts of the stand are impacted by wood cutting and grazing.

SUDAN

Distribution and extent of the mangrove stands

Mangrove stands were surveyed at 14 localities along the Sudanese Red Sea coast. These include, from north to south, Mohammed Qol, Arakiyai, Halut, Kilo Tammania, Klanieb, Mersa Atta, Adofab, Lagagengeeb, Fagum, Haydob, Sheikh Ibrahim, Tekranyai, Sheikh Saad and Ashat (Figure 1, Table 3). These are the vast majority of the mangrove areas in the country. Other localities reported to have mangrove vegetation and not visited during this survey include three areas: Halaib, Mukawwar Island (Magarsam) and Agig.

Avicennia marina was the only mangrove species found in the country during this survey. Older reports have recorded that other species were present in the past. ANDREWS (1950) reported both *Rhizophora mucronata* and *Bruguiera gymnorrhiza* as occurring south of Suakin. KASSAS & ZAHRAN (1967) reported *R. mucronata* in mangrove stands north of Halaib, near the Egyptian border. None of the surveys carried out in the past two decades have reported the existence of these species.

The *Avicennia marina* stands are typically thin, mostly ranging between 15 to 300m in width. They grow along the shore-line, on near-shore islets and fringing tidal inlets or creeks, which extend landwards along depressed areas of various sizes, locally known as mersas. The majority of the stands are typically small, rarely exceeding 1-2km in length. The density and size of the stands increases towards the southern coast, which supports muddier substrates and receives more freshwater influx from surface run-off. However, at some localities in the northern parts, the better oxygenated, sandier substrate and considerable underground freshwater seepage may favour growth of *Avicennia* trees to a greater height and GBH (e.g. Arakiyai). Based on ecological features and the extent and distribution of mangrove stands, the coastal area may be divided into three stretches:

1. The coastal area from the Egyptian border in the north to Port Sudan in the south. This area represents a long coastal stretch comprising about two-thirds of the Sudanese Red Sea coast. It is characterized by extensive sandy beaches e.g. Arus, protected bays e.g. Dungonab bay, tidal inlets, saltmarshes, rocky shores, and rich coral reef growth fringing most of the coastline and islands. The southern half of this coastal stretch, between Port

Sudan and Dungonab, supports sparsely distributed *Avicennia* stands growing at some localities. The northern half extending north of Dungonab to Halaib is relatively rich in tidal inlets and has more dense mangroves.

2. The coastal area from Port Sudan in the north to Suakin town in the south. The shoreline of this 60km stretch of coast is rich in tidal inlets, mud and sand flats and has extensive saltmarshes in the lower reaches of valleys. Mangroves grow in relatively dense stands, in which the trees are close to each other.

3. The coastal area between Suakin to the Eritrean borders in the South. This area is characterized by relatively wide coastal plains intersected by massive valleys. The shoreline is rather undulating with numerous tidal inlets that support dense mangroves. The stands are adjacent to each other on most of the shoreline forming a thin, semi-continuous belt of *Avicennia marina* interrupted only by a few gaps of bare shore areas.

Table 3. Location and extent of mangrove stands surveyed, Red Sea coast of Sudan, July 2002

Stand Code	Stand site	Position	Approximate Length (km)
RSS1	Mohammed Qol	20° 47'N, 37° 10'E	1.3
RSS2	Arakiyai	20° 18'N, 37° 11'E	0.9
RSS3	Halut	19° 48'N, 37° 15'E	1.1
RSS4	Kilo Tammania	19° 35'N, 37° 15'E	0.8
RSS5	Klanieb	19° 30'N, 37° 16'E	2.0
RSS6	Mersa Atta	19° 18'N, 37° 18'E	3.5
RSS7	Fagum-Lagagengeeb	19° 01'N, 37° 23'E	3.9
RSS8	Haydob	18° 57'N, 37° 23'E	1.6
RSS9	Sheikh Ibrahim	18° 56'N, 37° 24'E	0.4
RSS9	Sheikh Saad	18° 50'N, 37° 26'E	1.4
RSS10	Shabarango-Gofud	18° 46'N, 37° 29'E	3.5
RSS11	Ashat	18° 45'N, 37° 30'E	7.0
Total length			27.5

Local characteristics and condition of the mangrove stands

MANGROVE AREAS OF NORTH SUDAN, FROM THE EGYPTIAN BORDER TO PORT SUDAN

This area comprises about 400km of Red Sea coast with a variety of habitats including intertidal flats, tidal inlets, bays, saltmarsh, mangroves, seagrass beds, rocky shores and coral reefs. Mangrove growths are generally less common and sparse compared to the coastal area south of Port Sudan to Agig. The southern part of the area comprises a flat stretch of Red Sea coast between Mohammed Qol and Port Sudan. The coast is exposed, with sandy beaches e.g. Arus area, large areas of sabkha, patches of intertidal mud flats in the more sheltered mersas e.g. Halut, Arakiyai, rocky shore with seaweeds and seagrass beds e.g. near Mohammed Qol. The middle of the area is occupied by Dungonab Bay, which is one of the largest bays of the Red Sea. The bay has a wide entrance at its southern end, which is almost blocked with coral reefs, with only a few passages navigable for small vessels.

Terrestrial vegetation consists mainly of halophytes, bushes such as *Suaeda* sp. and *Zygophyllum* sp. that grow in sandy areas and sabkhas above the high water mark. Towards the plains, the vegetation is dominated by *Acacia tortilis* desert scrub. North of Port Sudan the lower reaches of khor Arbaat is densely covered with the introduced *Prosopis* sp. Fin and shell-fisheries are the main activities in the coastal villages of Halaib, Dungonab and Mohammed Qol. Oyster

culture has been traditionally practiced for many years in Dungonab and Mohammed Qol and represents a major source of income for local inhabitants. The tourist village at Arus, which had been planned for 3000 to 4000 persons per year, is not operational at present. The planned shrimp farms at Halut, north of Port Sudan is anticipated to create environmental problems in the future. Shrimp farms may result in irreversible conversion of coastal habitats. The mass discharge of effluent and nutrients will have serious impacts on mangroves and fringing reefs. The construction of channels to divert seasonal freshwater run-off from the mountains to protect the ponds will change the hydrological regimes in the area and adversely impact the coastal habitats. Although mangroves are sparse compared to the southern parts of the coast (Port Sudan to Agig), relatively good stands were identified south of Mohammed Qol and at Mersa Arakiyai and Mersa Halut (Table 4).

Table 4. Characteristics and condition of mangrove stands north of Port Sudan

Variables and characteristics	Site					
	Moh. Qol (outer zone)	Moh. Qol (inner zone)	Arakiyai (outer zone)	Arakiyai (inner zone)	Halut (outer zone)	Halut (inner zone
Mangrove trees (quadrat size 10 x 10m):						
Density of trees	15	20	13	17	99	13
Height range (m)	0.75-1.95	0.6-4.1	6-9	7-10	40-85	6-9
GBH range (cm)	--	15-35	95-185	100-195	--	5-80
Dead standing trees	0	1	1	0	21	4
Dead felled trees	0	0	1	2	4	1
Grazed trees and shrubs	10	7	11	13	74	8
Mature trees with dropped limbs	0	1	11	9	9	6
Trees with top dying uppermost and outermost branches	5	1	7	9	74	6
Multi-stemmed trees	14	20	13	15	60	5
Number of seedlings	6	7	3	10	5	56
Dead seedlings	0	1	0	0	1	4
Deformed propagules and seeds	NR	NR	NR	NR	NR	F
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	NR	NR	NR	NR	NR	NR
Pneumatophores (quadrat size 0.5 x 0.5m):						
Density of pneumatophores	26	46	43	37	16	61
Branched pneumatophores	5	4	8	10	1	4
Twisting and curling pneumatophores	1	6	3	0	1	0
Pneumatophores with dead tips	12	11	16	9	13	46

NR: not recorded, F: few, M: many

Mohammed Qol

This mangrove area is located at 20° 47’N, 37° 10’E, a few kilometres south of Mohammed Qol village. According to fisheries statistics, the village is inhabited by a small population of approximately 290 full-time and part-time artisanal fishermen. Other activities include animal breeding and small scale trading. A small market in the village is busy with visiting merchants bringing Egyptian goods from Shalatin and Halaib at the border. They stop there for a short rest or overnight stop before continuing their trip to Port Sudan in the south or Shalatin in the north.

The mangrove area consists of a thin belt of *Avicennia marina* growing on a sandy mud and sandy substratum. In the landward outer zone of the belt the substratum is sandy mud with a compact top layer that becomes rather loose towards the lower eulittoral. In the inner and deeper parts of the forest, the substratum is dark consisting of loose sandy mud and muddy sediments. The small lagoons among the mangroves have a deep colloidal muddy substratum.

The mangroves are distributed in three separate stands, the greatest width of each is 200-250m. The southern stand extends 900m in a U shaped forest connecting in the north to enclose a shallow lagoon. The second stand is 500m north and extends 180m along the shore. The third is located another 1000m to the north. It is denser as it extends along a 200m elevated islet separated from the main shore by a mud flat covered with shallow water.

The southern stand is severely affected by camel grazing as it is the most easily accessible from land. In the outer stand, where outermost and uppermost branches of almost all mangrove trees are browsed, the *Avicennia marina* trees are stunted forming 0.7-2.0m high bushes. Those in the inner stand are in a better condition, where camel browsing has only affected outer and uppermost parts of 20-30% of the trees present. The mangrove trees are 3-5m in height and 12-30cm GBH. 'Top dying' of mangroves is common among the trees affected by camel browsing. Some felling and limb cutting were reported. The vast majority of fully grown trees are multi-stemmed indicating that they have been subjected to severe cutting in the past. Natural regeneration is apparently good; a number of healthy seedlings were reported in the stand. However, several seedlings and pneumatophores were destroyed by camels' feet. The *Avicennia* trees were flowering at the time of the survey.

The shoreline north of the present mangrove stands, towards Mohammed Qol village, is characterized by sparse *Avicennia* shrubs and the remains of felled tree trunks. This suggests that the stand extended further north, covering at least three-times the present area and has been greatly diminished through cutting. Several huts in Mohammed Qol market are constructed with *Avicennia* wood.

Arakiyai

The mangrove stand at mersa Arakiyai extends 0.9km along the shore. Although the stand is very thin, consisting of only 1-2 rows of trees for most of its length, the *Avicennia* trees grow to a relatively massive size - up to 7-10m in height and 100-240cm GBH. These are by far the biggest and oldest *Avicennia* trees recorded from mangrove areas in the country. The relatively sandy substrate and considerable underground freshwater seepage in the area probably provide favourable conditions for the massive growth of *Avicennia*. Camel grazing is heavy over the entire stand. The affected parts include the outermost and uppermost branches of the young growing trees and the lower branches of the well-grown tall trees. Significant destruction of aerial roots and seedlings by camels' feet was noted; however a good number of healthy seedlings were recorded indicating that natural regeneration may occur if suitable protection measures are put into force. The stand has apparently been subjected to extensive cutting and the original area occupied by mangroves is greatly reduced. Recovery of the lost cover by planting will significantly extend the present area occupied by the stand. Felled trees and mature trees with dropped limbs are common among the stand. The area is easily accessible from land and is apparently used as a recreational site for weekend visitors. The remains of burnt charcoal and firewood from cooking sites were observed at several sites. This represents a serious threat to the mangrove stand.

Halut

The mangrove stand at Halut grows on the tidal inlet of a relatively wide, depressed shore area where a part of Khor Arbaat reaches the sea. The substratum is loose muddy sand and mud. Landward, sharp, raised fossil coral rocks enclose the inlet. An elevated rocky plate, which is sharply cut at the inner edge facing the stand, is grooved at the southern side by runoff and flood waters from Khor Arbaat. Salinity is relatively low as some terrestrial halophytes (*Aeloropus* sp. and *Zygophyllum* sp.) overlap with *Avicennia* shrubs on the landward side of the stand. This may suggest the presence of considerable freshwater seepage. Further west the terrestrial vegetation consists mainly of a thick belt of the introduced *Prosopis* sp.

The mangroves form two adjacent stands 500-700m long; the greatest width of each is 250-300m. The outer zone of the stands consists of extremely stunted *Avicennia* bushes 0.4-0.85m tall. Uppermost and outermost branches of all mangroves in this zone are heavily browsed by camels. Dryness of these parts is very common among the grazed mangroves. The *Avicennia* forms a dense canopy in the inner zone, where tall trees reach up to 7-9m in height and 80cm GBH. However, these are also affected by camel browsing and by cutting. Mortality of mangrove trees is frequent; in some parts up to 20% of the trees were ‘dead standing’. It may be of concern that many other trees have dead top and outer branches.

The proposed shrimp farm in the area will have a serious impact and may lead to the disappearance of the mangrove stand. The construction of several ponds is planned, in addition to camping villages for the labourers, a power station and a paved road to link the farm with Port Sudan. In addition to the effects of such large scale construction activities, commercial shrimp farms have been reported to cause much devastation to the coastal environment, which is evident especially in several Asian countries (BARBIER & COX 2002; see section 6). Based on the preliminary information about the project, the infrastructure and technical know-how available, small-scale, intensive and highly productive aquaculture systems, with ponds averaging up to 1ha will probably be adopted.

MANGROVE AREAS BETWEEN PORT SUDAN AND SUAKIN

The coastal area between Port Sudan and Suakin is flat for 60km. It is rich in tidal inlets especially at the seaward end of drowned valleys. These support extensive saltmarsh vegetation at their wide lower reaches and sparse to dense mangrove growths at their mouths (mersas) such as mersa Klanieb and Atta. Seaward, the mersas are faced by extensive muddy lagoons, shallow flats often carpeted with dense algal growths, fringing reefs and then deep coastal water. Landward, the area is bordered by the coastal plains, dominated with *Prosopis* sp. and *Acacia* sp. scrub. The highway connecting Port Sudan with Khartoum runs parallel to the coastline.

Due to its location between the country's two major ports and close to major coastal settlements, industries, the new oil terminal at Bashair harbour, the emerging Duty Free Zone, coastal highway and airport, the area is considered as a ‘hotspot’ area. There are serious threats from industrial pollution, oil spills and considerable devastation of the coastal area associated with the growing maritime transport, industry and trade that will have impacts on the mangroves, coral reefs and other coastal environments. Mangrove areas were identified and visited at three localities in the area: Kilo Tammania, Klanieb and Mersa Atta (Table 5).

Kilo Tammania

This mangrove area is located on the southern outskirts of Port Sudan city, facing the oil refinery and close to a camping beach area used as a recreation site for night and weekend visitors from the city. The mangroves grow in two adjacent stands 500-600m long; the widest part

of each is 200-250m. They grow on a sandy mud and muddy substratum. The outer zone is muddy with a very compact top layer, merging to softer mud towards the lower eulittoral and an enclosed lagoon. This grades into a sandy seagrass bed bordered by fringing reefs.

Table 5. Characteristics and condition of mangrove stands between Port Sudan and Suakin

Variables and characteristics	Site					
	Kilo Tammania (outer zone)	Kilo Tammania (inner zone)	Klanieb (outer zone)	Klanieb (inner zone)	Mersa Atta (outer zone)	Mersa Atta (inner zone
Mangrove trees (quadrat size 10 x 10m):						
Density of trees (/10m²)	12	21	39	18	27	32
Height range (m)	0.35-1.0	1.0-4.5	0.5-1.2	3.0-5.0	0.5-1.5	0.5-7.0
GBH range (cm)	--	5-20	--	--	15-30*	45-80*
Dead standing trees	2	0	24	2	6	7
Dead felled trees	1	0	0	0	2	6
Grazed trees and shrubs	8	3	15	12	13	4
Mature trees with dropped limbs	1	3	0	1	2	4
Trees with top dying uppermost and outermost branches	6	0	15	4	5	3
Multi-stemmed trees	11	18	39	18	24	23
Number of seedlings	1	8	0	23	2	5
Dead seedlings	0	0	0	4	0	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	M	F	NR	NR	NR	NR
Pneumatophores (quadrat size 0.5 x 0.5m):						
Density of pneumatophores	25	24	35	41	51	53
Branched pneumatophores	13	6	7	1	14	21
Twisting and curling pneumatophores	1	0	0	0	2	2
Pneumatophores with dead tips	8	1	33	8	18	10

NR: not recorded, F: few, M: many. (*): For mature trees only

Camel grazing is severe especially on the outer parts of the stands. These consist of stunted, heavily browsed trees with mostly dry top and outermost branches. Heavy camel footprints were observed among mangrove trees and bushes with several aerial roots and possibly seedlings destroyed. The stand has also suffered from cutting especially at the accessible landward parts. This may account for the dominance of multi-stemmed trees. The inner parts of the stand consist of well grown *Avicennia* trees 4-5m in height and 20cm GBH The trees were flowering at the time of the survey. A rich seedling population was found on a narrow flat seaward of the stand, which indicates that the mangrove is advancing seaward into the shallow muddy lagoon. A small fishing camp is found near the recreation beach. A small saltpan is also operating about 500m landward. At present, because the saltpan is relatively small, no mortality of trees was observed linked with deviation of tidal water. Disturbance by the visitors from the adjacent beach may be of concern. In addition to some physical destruction, solid domestic waste including empty glass and plastic bottles, plastic bags, and rubber were frequently observed in different parts of the stand. There are threats of serious chemical pollution and oil leakage or spills due to the close

proximity of the oil refinery. These could result in severe impacts on the mangroves. Oil sheens and some leakages have been reported in the past.

Klanieb

The mangrove stand at Klanieb extends along the shore, fringing part of a small round tidal inlet. Landward, the mangroves are bordered by a flat coastal area occupied by the large ponds of a government owned salt plant. This is associated with the Police Force and has been operating for several years. The main part of the stand is a 1.5km long belt along the shore in the mid and lower eulittoral. It consists of low-growing *Avicennia* trees. Most are multi-stemmed and 3-5m in height. Trees on the outer margin are affected by camel browsing. A considerable number of the trees in the stand have dry tops and outer branches, several are 'dead standing'. 'Top dying' and tree mortality may be attributed to diverting the tidal flow through constructed channels to feed the ponds of the saltpan. The northern parts of the stand are more easily accessible; they are severely browsed by camels stunting the growth of 50% of the mangroves to low-growing bushes.

The constructed channel and salt production ponds have obviously created some changes in the tidal flow and hydrological regimes, affecting the distribution of mangroves in the area. A small patch of *Avicennia* bushes growing in the higher parts of the stand, near the entrance of the channel, has suffered mortality. A new aggregation of well-grown *Avicennia* has spread on the seaward side of the channel facing the dead patch. This side is protected from camels by the presence of the constructed channel.

Mersa Atta

The mangroves at Mersa Atta are the most dense and extensive on the coast between Port Sudan and Suakin. They grow along the mainland shore and on several small islets enclosing a shallow, wide, muddy lagoon. There are two stands of mangroves on the mainland shore with a small, denuded square in the middle. The northern stand is 2km long and the southern one is 1.5km long. Both stands extend as a narrow strip fringing the shore. The inner stands on the facing islets are dense and are made up of five patches which are separated from each other by narrow shallow channels and from the shoreline mangroves by the deep and wide lagoon.

The outer zone of the shoreline stands is occupied by stunted, heavily browsed, *Avicennia* bushes 0.5-1.5m in height. A significant number (up to 20%) are dead standing trees, or have dry tops and outermost branches (15%). Although felling in this zone was not evident, some trees have dropped major limbs. The inner zone of the stands has both low-growing and relatively tall trees 6-7m high and 45-80cm GBH. Dead standing trees, felling and cutting are common. Although a rich population of seedlings was found among the trees and at the stand fringes, several were dead or destroyed.

The overall existence of the mangrove area is threatened by the proposed Red Sea Free Zone. The RSFZ was set up and its location defined in 1994 to include 26 million square metres. It is planned to encourage investments in intensive industrial, commercial and related services (Box 2). This will potentially cause massive devastation to all the coastal habitats.

Box 2: The Red Sea Free Zone (RSFZ)

The RSFZ was announced and the location described by the 1994 Act of the Sudanese Free Zones (SFZ). Accordingly, 26 million square metres of coast, 38km south of Port Sudan, were designed and master-planned to encourage investment and to be utilized as a multi-purpose free zone hosting industrial, commercial and related services.

RSFZ was officially declared in February 2000. A starting phase of 1 square kilometre is operational and is scheduled to be fully invested in February 2004. Major infrastructures accomplished for this phase include road network, power generation, water plant, telecommunication, residential centres, administration offices, banks and storage services.

Since February 2000, 193 licenses have been granted, of which 145 are commercial, 10 are industrial 38 are investments into related service industries. The origin of the investments includes 80% from domestic sources , 19% from overseas and 1% from joint ventures. Foreign investments originate from U.K., Japan, Australia, Jordan, Saudi Arabia, Qatar, UAE, Yemen, Chad and Ethiopia.

Major commercial investments include transit trade, export-import, warehouses, banking and insurance. The industrial investments are in the field of petrochemicals, food, plastic and assembling industries.

This huge project is anticipated to cause immense, irreversible devastation of the coastal environment and resources, unless a sound environmental protection strategy is adopted, with emphasis on environmental legal framework, enforcement of regulation, technical know-how, capacity building and efficient management.

MANGROVE AREAS SOUTH OF SUAKIN

The area south of Suakin to the Eritrean border consists of more than 200km of coastal flats, with numerous tidal inlets and flooded depressions, rich in alluvium. The alluvium, originating from the Red Sea hills is transported by flash floods across the relatively wide coastal plains to be deposited at the seaward end of extensive basins (khors) that support *Avicennia* mangroves at their mouths. The wide deltas of the two major basins, Quawb and Ashat, support the most extensive and dense mangrove stands in the country. The stands grow very close to each other in a thin belt. From north to south these are: Fagum-Lagagengeeb, Haydob, Sheikh Ibrahim, Sheikh Saad, Shabarango-Gafud and Ashat (Table 6).

The distribution of the mangroves in the area is probably greatly influenced by the amount of surface run-off and alluvium reaching the sea. This depends on the geological characteristics of the Quwab and Ashat basins. Recent investigations using satellite imagery (KOCH & EL-BAZ 1992) revealed that the status of the two basins as hard rock aquifers is quite different. The northern part of Khor Ashat is underlain by a granitic batholith, which is bounded to the south by a volcano-sedimentary complex. This occupies the whole central part, including the mouth of the drainage basin. Volcano-sedimentary rocks have (as opposed to fracture granitic rocks) a retarding effect on groundwater flow. Thus most of the water coming via Khor Ashat fractures from the upland will flow down as surface run-off. In Khor Quwab the lithology is mostly granite, making this basin more favourable for groundwater flow. This explains the occurrence of more extensive mangroves towards Mersa Ashat.

Lagagengeeb-Fagum

This consists of adjacent stands of well-developed *Avicennia* extending along approximately 4km of shoreline. The outer mangrove belt fringing the shore bends at the northern end to enclose a relatively wide lagoon, bordered seaward by another dense stand growing on a small semi-islet. This is only connected to the mainland through a narrow entrance at the southern end of the stand. The inner stand runs parallel to the outer belt and becomes fully inundated by shallow water at high tide. Landward most of the forest is backed by dense growth of terrestrial halophytes.

Table 6. Characteristics and condition of mangrove stands south of Suakin to the Eritrean border

Variables and characteristics	Site									
	Lagagengeeb-Fagum		Haydob		Sheikh Saad		Shabarango-Gafud		Ashat	
	Outer zone	Inner zone	Outer zone	Inner zone	Outer zone	Inner zone	Outer zone	Inner zone	Outer zone	Inner zone
Mangrove trees (quadrat size 10x10m):										
Density of trees (/10m²)	21	26	35	26	19	22	14	7	22	17
Height range (m)	3.0-5.0	3.0-8.0	4.0-5.0	5.0-7.0	4.0-5.5	5.5-8.0	2.0-4.0	4.8-5.0	3.0-5.0	3.0-5.5
GBH range (cm)	15-70	20-120	30-50	35-70	37-85	65-125	10-55	50-65	15-60	30-75
Dead standing trees	1	3	0	5	0	0	1	0	3	2
Dead felled trees	8	11	28	14	15	13	5	3	4	11
Grazed trees and shrubs	9	7	6	7	4	7	8	7	15	4
Mature trees with dropped limbs	5	6	5	6	4	5	4	4	7	4
Trees with top dying uppermost and outermost branches	4	4	2	4	2	5	5	4	15	4
Multi-stemmed trees	5	5	4	5	0	3	8	0	8	6
Number of seedlings	11	5	14	16	0	2	29	0	6	2
Dead seedlings	2	0	0	0	0	1	2	0	2	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	NR	NR	NR	NR	NR	NR	NR	NR	M	F
Pneumatophores (quadrats 0.5 x 0.5m):										
Density of pneumatophores	27	20	37	27	35	47	37	16	41	36
Branched pneumatophores	7	6	13	9	12	15	20	6	9	6
Twisting and curling pneumatophores	0	3	2	2	2	1	0	0	2	1
Pneumatophores with dead tips	16	1	23	16	29	33	19	12	16	10

NR: not recorded, F: few, M: many. (*): For mature trees only

The tree cover at the more accessible southern end of the stand has been significantly reduced by camel browsing and felling. The number of felled trees (estimated from the remains of the removed trunks) was approximately 40% of the total in the survey quadrats. Cutting of the outer stand has allowed camel browsing further into the inner stand. Some standing trees also suffered mortality and 'top dying' because of excessive browsing by camels. Severe destruction of pneumatophores and young seedlings by camels' feet was reported from the outer belt. Good regeneration occurs in the inner stand where relatively rich seedling growth occurs. However, their chances of becoming fully mature trees are slim due to the chronic risk of trampling. The success of natural regeneration and recovery will largely depend on controlling camel access.

Haydob

The mangrove area at Haydob represents a good example of formerly healthy mangroves that have been severely damaged by cutting and grazing. From the remains of the destroyed vegetation, the original stand extended at least 7-8km. It fringes the shore of an elongated inlet, which intrudes from the southern side of the mersa and runs parallel to the shoreline. The inlet is permanently inundated by deep water. The mangroves growing on the inner bank are accessible through a narrow shallow channel at the northern end of the inlet. At high tide, this area becomes fully inundated by shallow water and mangroves on the inner bank of the inlet are isolated on a small islet surrounded by shallow water.

The part of the forest that covered the outer (landward) bank of the inlet has been almost completely removed. The few remaining trees left standing indicate that the belt used to consist of well-grown *Avicennia* trees up to 5-7m in height and 50-80cm GBH. The stand on the inner bank suffers from severe cutting and grazing that threatens its overall existence. Approximately 80% of the total number of trees estimated in a quadrat in the outer zone, and 35% in the inner zone of this stand have been felled and removed. The remaining living part of the stand suffers from excessive browsing, limb cutting, 'top dying', and destruction of pneumatophores. There is some mortality among the standing trees. This indicates severe degradation of what is left of the mangrove cover at the site. Although the stand supports some seedlings, successful regeneration will require replanting of the removed outer belt and the large denuded patches among the inner parts of the stand. The present open-access for camels and wood harvesters should be controlled to protect the mangroves and any replanted seedlings from further damage caused by browsing and cutting.

Sheikh Ibrahim

The mangrove stand at Mersa Sheikh Ibrahim consists of a narrow belt of *Avicennia marina* along 300-400m of the shoreline. Outer fringes of the stand consist of stunted *Avicennia* bushes badly affected by camel browsing. These grade into low-growing trees of 3-5m in height and 15-50cm GBH. The inner zones consist of well-grown trees reaching up to 6-8m in height and 35-70cm GBH. The stand is also severely affected by limb cutting and felling.

Sheikh Saad

The mangrove stands at Mersa Sheikh Saad are relatively small. Each consists of a narrow belt of *Avicennia marina* extending along 300-400m of the shoreline. Outer fringes of the stands consist of stunted *Avicennia* bushes badly affected by camel browsing. These grade into low-growing trees of 3-5m in height and 37-85cm GBH. The inner zones consist of well-grown trees up to 6-8m in height and 65-125cm GBH. The stands are severely affected by felling, especially at Sheikh Saad, where 50-70% of the trees in quadrats have been felled and the remaining ones had dropped limbs. Branched and dead pneumatophores are common and seedling populations are very sparse. The area is important for fishing, sea cucumber and shell collection.

Shabarango-Gafud

The mangroves at this site form a dense belt approximately 3.5km long, fringing the shore of a round, submerged inlet. The northern stand bends around the northern edge to enclose the inlet from the north and extends forming an inner belt parallel to the outer one. The southern stand bends around the southern end of the inlet forming (with the northern stand) a semi-circular belt surrounding the inlet. The southern stand is however much smaller and supports only a sparse growth of *Avicennia*.

The stands consist of low-growing trees 2-5m in height, with a few taller trees, GBH is10-65cm. Felling is severe in all parts of the stand. Felled trees were estimated as 30-40% of the total. The remaining living trees suffer greatly from camel browsing, 'top dying' and limb cutting. Significant numbers of pneumatophores (up to 90% in some parts of the stand) have dead tips. Good seedling growth occurs on some fringes and denuded patches, indicating a good potential for natural regeneration provided that suitable protective measures are put in place.

Ashat

The mangrove stands at Ashat are evidently the most extensive and dense in the country. This may be attributed to the relatively high drainage of Khor Ashat as mentioned before in this section. However, this mangrove area has suffered from extensive mass mortality during the last decade, resulting in a significant loss in the mangrove cover. The area has three stands. The northern and southern stands bend round the northern edge to enclose a large inlet. A third stand is located seaward on an elongated islet, forming the inner bank of the inlet. The northern stand is narrow and about 2.5km long. The southern stand is relatively broad and long, extending along 4km of the inlet bank. The inner stand is the smallest, forming a 500m belt. Compared to other mangrove areas in the country, the forests cover a wider area, well above 500m width in parts. The vegetation is of dense low-growing trees, which rarely exceed 5-6m in height. The GBH ranges between 15-75cm.

The southern stand is dominated by dead, standing trees. The mass mortality covered a wide area of the stand (1.5km long by 500m wide). Collection of the dry limbs and tree trunks for fuel and timber has cleared a considerable area affected by the mass mortality. Recent felling of living trees was also reported, in spite of the presence of ample amounts of dry wood. The quality of the wood from the dead trees is low because heavy infestation by wood boring insects. 'Top dying' of uppermost and outermost branches and curling leaves is common among other stands in the area. This indicates that the stand is still under stress. The cause of the mortality is uncertain. However, it could be attributed to localized changes in tidal flow regimes. This might have been caused by excessive sediment loads in the entrance and channels of the inlet. Similar situations were reported in some stands in Djibouti and along the southern Red Sea coast of Yemen during the recent regional survey.

Natural regeneration is taking place. Many seedlings were observed growing in the inner fringes and some denuded patches. However, owing to the large size of the area affected by mass mortality and excessive damage by destructive cutting and grazing, regeneration should be enhanced by planting and controlling access of camels and wood cutters.

2.3 Eastern Red Sea Coast (Saudi Arabia and Yemen)

SAUDI ARABIA

Distribution and extent of the mangrove stands

The Red Sea mangroves of Saudi Arabia have been the subject of several studies (e.g. PRICE et al. 1987; MANDURA et al. 1987, 1988; MANDURA & KHAFAJI 1993), ranging from ecological surveys to impact assessments. The most comprehensive survey was carried out by PRICE et al. (1987) and covered the whole of the Saudi Arabian Red Sea coast and many offshore islands.

Both *Avicennia marina* and *Rhizophora mucronata* are found, although the occurrence of the latter is restricted to a few localities. The northerly limit for distribution of the *Avicennia marina* is Sharm Zubeir (Lat. 27° 25'N). It extends south beyond Jizan and into Yemen. Based on the distribution and density of the *Avicennia* mangroves along the shore, the Red Sea coast may be broadly divided into two areas:

1. The area north of Al-Lith where mangrove distribution is sparse. However, moderate to well developed stands are found in certain places. These include: Sharm Zubeir, the shoreline between Al-Wajh and Umm-Lajh, Al-Wajh Bank, near Yanbu, between Rayyis and Mastura, Rabigh area south of Jeddah, and Qishran Bay north of Al-Lith.
2. The area south of Al-Lith where the mangroves are relatively dense, fringing most of the shoreline e.g. Khor Amiq, Shuqaiq and Jizan mangroves and some offshore islands. The distribution of mangroves increases towards the south, coinciding with the gradual disappearance of stony corals and increased availability of muddier substrate and rainwater. The mean mangrove height was reported as increasing southward and correlated negatively with latitude and salinity ($P<0.05$). The density of *Avicennia marina* showed however, a general decrease southward, possibly because the increased plant size and shading towards the south allows growth of fewer plants per unit area. The largest stands were recorded at Al-Quham, Khor Itwad, Shi'b-al-Kabir and Khor Al-Ja'afirah, where trees are up to 5-7m in height. Camel browsing impacts the majority of the stands in the south. It was reported to be particularly intense at Khor Itwad. In general, grazing appears to be most prevalent on the landward (i.e. most accessible) sides of the stands.

Rhizophora mucronata, which is much less widespread, was only recorded in five areas by PRICE et al. (1987): Al-Wajh Bank, Umm al Qandal Island, Gharaniq Island, Zifaf Island and Shi'b Abu Al-Liqa. This list was extended by AL-WETAID (2003) to include 11 areas (Table 7).

Local characteristics and condition of the mangrove stands

Sharm Zubeir

Small stands of *Avicennia marina* were reported near Sharm Zubeir. This represents the northerly limit (Latitude 27° 25'N) for distribution of the *Avicennia marina* along the Saudi Arabian Red Sea coast.

Al-Wajh to Umm Lajh

This is a large area comprising mainland coast, shallow water and reef systems and a plethora of Red Sea islands (Al-Wajh Bank) lying offshore between Al-Wajh and Umm Lajh. Al-Wajh Bank (25 35'N, 36 45'E) is located about 120km south of Al-Wajh. The archipelago has approximately 50 islands, ranging in size from 1ha to 1,100ha. Some are sandy whereas others

are rocky with low cliffs, usually of less than 5m in height. The islands are not inhabited on a permanent basis, although they support seasonal fishing camps. The area is important to the local artisanal fishery.

Some islands support vegetation, with mangrove and salt-tolerant bushes, but elsewhere they are barren. PRICE et al. (1987) reported *Avicennia marina* stands along the coast south to Al-Wajh, and both *Avicennia marina* and *Rhizophora mucronata* growing on some islands of the Bank. The location and extent of the *Rhizophora mucronata* stands in the area (three stands at Umm Ruma Island and one stand on the mainland shore at Dugm Sabq) are described by AL-WETAID (2003) (Table 7).

The area has been proposed as a Resource Use Reserve in NCWCD's System Plan for Protected Areas (CHILD & GRAINGER 1990), however, no conservation measures have been put in place.

Table 7. Distribution of *Rhizophora mucronata* along the Saudi Arabian Red Sea Coast
Source: AL-WETAID (2003)

Site	Position	Approximate length (size)
Al-Wajh Bank: Umm Ruma Island: Stand 1 Umm Ruma Island: Stand 2 Umm Ruma Island: Stand 3	 25° 42' 54"N, 36° 34' 21"E 25° 42' 48"N, 36° 34' 44"E	 1200m (6.5ha) 1500m (6.5ha) 500m (3.0ha)
Dugm Sabq	25° 36' 12"N, 36° 58' 05"E	150m
Gama'an Island: Stand 1 Stand 2	25° 32' 25"N, 36° 51' 09"E 25° 32' 43"N, 36° 50' 39"E	} 1100m
Shibara Island	25° 25' 05"N, 36° 52' 45"E	Mixed with *Avicennia*
Umm Al-Qandal Island	19° 45' 32"N, 40° 41' 22"E	700m
Ras Umm Al-Rubais	19° 45' 12"N, 40° 41' 05"E	150m
Umm Al-Rubais Island	19° 40' 10"N, 40° 45' 52"E	200m
Al-Gahaf: Stand 1 Stand 2	17° 27' 11"N, 42° 17' 20"E 17° 27' 45"N, 42° 17' 01"E	800m (destroyed) 500m
Farasan Kebir Island: Stand 1 Stand 2 Stand 3	 16° 47' 30"N, 42° 06' 00"E 16° 47' 30"N, 42° 06' 10"E 16° 47' 00"N, 42° 06' 10"E	 900m (15ha) 200m 400m
Solain Island	16° 45' 05"N, 42° 12' 55"E	400m
Zifaf Island	16° 43’N, 41° 47 'E	

North of Jeddah to Yanbu

The shoreline along this coastal stretch supports mangroves at several localities. PRICE et al. (1987) and SAP (2001) map mangrove stands near Yanbu, between Rayyis and Mastura, and south to Rabigh.

The mangrove areas along the delta of Wadi Farrah support dense stands of *Avicennia marina* that extend along 11km of Red Sea coastline from 23° 56'N, 38° 14'E. The site is adjacent to the new industrial city of Yanbu (Yanbu-al-Sinaiyah), which is 25km south of Yanbu al-Bahr. The area also includes coral reefs, sandy beaches, saltmarshes and sabkha.

As the area is surrounded by the largest oil terminal on the Saudi Arabian Red Sea. Oil pollution poses the main threat to the area, though oil spill contingency planning is well advanced and good clean-up and containment facilities are available. Plans exist to build a new marine laboratory and a centre to promote public awareness in environmental issues. The site was

proposed as a Biological Reserve in NCWCD's System Plan for Protected Areas. The mangroves have been identified as an "Important Bird Area" by BirdLife International (EVANS 1994).

Jeddah South Corniche

A small mangrove stand is found on Jeddah's South Corniche at 21° 23'N, 39° 07'E. 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. Along the South Corniche roads have been constructed and much of the area has been in-filled for potential industrial expansion. There is some livestock grazing and a small fishing village in the area.

The impact of sewage pollution on the mangrove stand was studied by MANDURA (1997). A high proportion of the pneumatophores were reported to be dead and/or aberrant. Decreased aerial root capacity has affected the respiration rate of the root system, nutrient uptake and plant development leading to retarded growth of the mangroves (MANDURA 1997).

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. Although a restricted military area reduces disturbance, it does not curtail the pollution.

North of Al-Lith

Avicennia marina mangroves were reported to occur near Qishran Bay, north of Al-Lith. Qishran Bay (20° 15'N, 40° 10'E), is one of the largest lagoon systems on the Red Sea coast, with considerable tracts of mangroves on islands. The bay is isolated from the open sea by a long narrow barrier island and a smaller island at its mouth. Inside the shallow bay there are eight other islands. These are covered with dense vegetation, mostly the salt-tolerant succulent *Salicornia* sp, and surrounded by *Avicennia marina* mangroves.

Artisanal fisheries, livestock breeding (camels) and falcon trapping are the main activities. Increasing recreational pursuits are a potential problem. The area has been proposed as a Special Nature Reserve in the NCWCD System Plan for Protected Areas.

Between Al-Lith and Khor 'Amiq

Well-developed *Avicennia marina* mangroves are found along this coastal stretch fringing the shoreline. The islands of Umm al Qandal and Gharaniq also support *Rhizophora mucronata*.

Aquaculture of shrimps in Saudi Arabia started at Al-Lith when a private company developed a 20ha pilot farm in 1983. In the mid-1990s that the company expanded its operation to 100ha. Now it is developing 1,000ha. The farm suffered a huge production failure in late 1998. Diseases had been detected in the farm previously but this time the animals tested positive for White Spot Syndrome Virus (WSSV). The farm and three hatcheries were subjected to an extended dry out in an attempt to break the disease cycle. No information is available about the impacts of shrimp culture on mangroves in this area.

Khor 'Amiq to Al-Qahmah

Khor 'Amiq (18° 26'N, 41° 26'E) is 30km north-west of al-Birk. The Khor, also known as Amq or Omq, is situated at the northern end of a predominantly mangrove-fringed coastline backed by a black lava plain (harrat) with extinct volcanic cones, extending south for 60km to Al Qahmah. The site also includes a complex of shallow, muddy and sandy saline lagoons and channels. Large mangrove stands of *Avicennia marina* surround the bay. The sub-tidal zone is characterized by extensive seagrass beds.

The area supports a local artisanal fishery and represents a characteristic example of a relatively undisturbed, mangrove-fringed lagoon on the southern Red Sea coast. However, camel grazing is causing damage in the mangrove stands. Small-scale cutting is also practiced which threatens the mangroves growing there. The site has been proposed as a Resource Use Reserve in the NCWCD System Plan for Protected Areas.

Shuqaiq Mangrove (17° 48'N, 41° 52'E)

Shuqaiq mangroves are located on the southern Red Sea coast. The area comprises a fairly small embayment at a point where basaltic harrat comes down to the waterline. The mangrove stands that line the coast are separated by inter-tidal mudflats. There are extensive seagrass beds offshore. The area supports a local fishery based in a small fishing village and is a very popular recreational area. According to PRICE et al. (1987), this area supports the largest mangrove trees in the country, at Al-Quham, Khor Itwad, Shi'b-al-Kabir and Khor Al-Ja'afirah, where *Avicennia* reaches up to 5-7m in height.

There is some impact from small-scale cutting of mangroves, camel grazing and recreational visitors - especially fishermen at week-ends. However, the mangroves are seriously threatened by recent changes in land use. The Ministry of Agriculture has fenced much of the area off and is developing it as a shrimp farm. The mudflats and sabkha inland of the mangroves have been partitioned by causeways. Aquaculture of shrimps is often reported as one of the major causes of serious damage to mangrove (Box 3). No information is available about the impacts and anticipated adverse effects of aquaculture in the area.

Khor Wahlan (16° 45'N, 42° 40'E)

Khor Wahlan is located on the southern Red Sea coast, approximately 35km south of Jizan. The site comprises a representative stretch of southern Red Sea coastline with a wide diversity of marine habitats (lagoon, mudflats, sabkha, mangroves) and a unique fresh to brackish water wetland, known locally as 'Sawarma Marsh'.

The coastal zone is composed of two inlets and a small island. The island is connected to the mainland by a causeway across the sabkha. At low tide, rich mudflats are exposed. The marsh is inland of the southern inlet (Khor Wahlan), either where springs seep laterally from an adjacent dune plateau aquifer or artesian leakage from a buried geological fault line. Stands of *Avicennia marina* occur on the inland sides of both inlets and seagrass beds are present close to the shoreline.

Khor Wahlan is used as an anchorage by local fishermen and a small harbour has been constructed. The whole area is grazed heavily by camels and goats. Camels regularly bathe and wallow in the wet area, causing extensive damage to the marshland vegetation. A fairly large garbage dump is present on the northern edge of the marsh. The coastal part of the site is proposed as a Special Nature Reserve in NCWCD's System Plan for Protected Areas.

Farasan Islands (16 20'-17 20'N, 41 24'-42 26'E)

The Farasan Island group is a large archipelago of Red Sea coral islands lying 40km offshore from Jizan. The islands are situated on a broad, shallow shelf 125km wide. They were formed by uplift from a rising salt dome beneath the area. The main archipelago lies within an area of 75km by 50km. The site includes approximately 70,000ha of land with 605km of coastline; the proposed Marine Protected Area covers 331,000ha. The archipelago includes two large islands connected by a bridge, Farasan Kebir and Segid, the former being over 50km in length.

Sheltered coastal areas of Farasan support extensive stands of *Avicennia marina*, and north-east Farasan Kebir supports the largest patch of *Rhizophora mucronata* on the Saudi Red Sea. Above the inter-tidal zone, beaches usually have a wide or narrow band of *Suaeda monoica, Halopeplis perfoliata, Limonium axillare* and several species of *Zygophyllum*. Inland, vegetation cover is sparse except in gullies between fossil coral outcrops. It supports a *Commiphora-Acacia-Salvadora* scrub community with occasional thickets of *Euphorbia fractiflexa*. Other marine biotopes include coral-dominated fringing and patch reefs, algae-dominated fringing and patch reefs, coral-algal fringing reefs, platform reefs, pavement, shoals, mudflats and sub-tidal sand flats. The Farasan Islands are a large Red Sea archipelago with a high diversity of marine biotopes and many internationally important vertebrate groups including breeding turtles and seabirds and wintering shorebirds.

The human population in the area is 5,000, mostly restricted to one large town on Farasan Kebir and several villages Farasan Kebir and Segid. Only one smaller island is inhabited permanently (Qummah). The main occupation is fishing, though herds of goats and camels are grazed in the vicinity of villages. Several small areas are cultivated with date palm plantations or sorghum. On many of the smaller islands, small fishing camps are occupied intermittently. Continuously manned coastguard stations occur on the main island and several smaller ones, such as Zifaf and Rumain.

The terrestrial area is an established NCWCD Reserve, including a no-hunting zone, and several Special Nature Reserves and Natural Reserves. A ranger force is employed to prevent poaching of gazelles. A large part of the archipelago has been proposed as a Saudi Arabian Red Sea marine protected area. The proposed marine protected area includes 128 islands, one coral cay and 18 shoal areas. Ratification is expected in the near future, and marine rangers will be recruited to supervise controlled zones of fishing activity and control other activities such as the collection of seabird eggs.

The industrial/commercial and artisanal fisheries sectors are likely to increase. Few changes are expected on land, although a large part of south-east Farasan Kebir has been earmarked for a naval base. Development of the naval base could have an impact on terrestrial and marine wildlife in the area. Construction of a new soil dam has led to dry-up and significant mortality of one of the mangrove stands on Farasan Kebir. Some effort has been undertaken to rehabilitate the area affected by mortality (AL-WETAID 2003).

YEMEN

Distribution and extent of the mangrove stands

Mangroves were surveyed at 29 localities along the Red Sea coast and the near and offshore islands of Yemen (Figure 1, Table 8). This represents well above 95% of the mangrove areas in the country. Two areas reported to have mangroves were not visited during this survey. The first includes the islands off the north-east coast, particularly Tikfash and Humar that support small stands of *Avicennia marina*, and the second area is a crater lake, Kharif Shaaran, fringed by *Avicennia marina*. It is the only mangrove stand on the 1400km Gulf of Aden coast of Yemen.

All surveyed mangrove forests, except for two, are mono-specific stands of *Avicennia marina*. The exceptions include Kamaran Island and two stands near Al-Hudaydah, where stands of *Rhizophora mucronata* coexist with *Avicennia marina*. Typically, the mangroves grow as thin forests along the shoreline, on near- and offshore islands, and fringing tidal inlets and channels

locally known as khors. These extend landwards along depressed areas forming shallow inundated areas of various lengths. They are more common on the north than the central and south coast. In some areas like Al-Luhayah and Midi, the khors are particularly extensive with permanently flooded inlets often used as landing sites for fishing boats.

Table 8. Location and extent of mangrove stands surveyed in Yemen, July and August 2002

Stand code	Stand site	Position	Approximate length (km)
RSY1	Midi	16° 21'N, 42° 47'E	0.8
RSY2	Between Midi and Al-Habl (1)	16° 20'N, 42° 47'E	0.2
RSY3	Between Midi and Al-Habl (2)	16° 16'N, 42° 48'E	0.4
RSY4	Between Midi and Al-Habl (3)	16° 15'N, 42° 48'E	0.35
RSY5	Between Midi and Al-Habl (4)	16° 13'N, 42° 48'E	1.5
RSY6	Between Midi and Al-Habl (5)	16° 11'N, 42° 50'E	3.5
RSY7	Al-Habl	16° 09'N, 42° 49'E	7.0
RSY8	Al-Buhays	15° 59'N, 42° 49'E	29.0
RSY9	Between Al-Buhays and Al-Luhayah	15° 49'N, 42° 46'E	22.0
RSY10	Al-Luhayah North	15° 43'N, 42° 42'E	2.0
RSY11	Al-Luhayah	15° 42'N, 42° 41'E	3.0
RSY12	2km south of Al-Luhayah	15° 41 N', 42° 42'E	0.8
RSY13	6km south of Al-Luhayah	15° 39'N, 42° 43'E	1.5
RSY14	5km south of Al-Khawbah	15° 29'N, 42° 46'E	0.9
RSY15	12km south of Al-Khawbah	15° 27'N, 42° 46'E	3.5
RSY16	Ibn Abbas	15° 29'N, 42° 46'E	6.5
RSY17	Al-Harounia mersa	15° 18'N, 42° 48'E	7.0
RSY18	Between Al-Harounia and Al-Salif	15° 13'N, 42° 46'E	3.5
RSY19	Kamaran Island	15° 22'N, 42° 35'E	7.0
RSY20	Al-Urj	15° 06'N, 42° 52'E	0.8
RSY21	North of Al-Hudaydah	14° 52'N, 42° 57'E	0.95
RSY22	Hudaydah islets 1 (Am-Shura Islet)	14° 50'N, 42° 55'E	0.3
RSY23	Hudaydah islets 2 (Gandal islet)	14° 53'N, 42° 56'E	0.15
RSY24	Hudaydah islets 3 (Mugamalah islet)	14° 51'N, 42° 56'E	Few trees
RSY25	Hudaydah islets 4	14° 54'N, 42° 56'E	0.7
RSY26	Between El-Rowais and Yakhtul	13° 32'N, 43 16'E	7.0
RSY27	5km south of El-Makha	13° 16'N, 43° 15'E	0.15
RSY28	Between Al-Kadaha and Al-Ubaidah	13° 08'N, 43° 18'E	16.0
RSY29	El-Ghurairah at Bab al-Mandab	12° 44'N, 43° 28'E	1.5
Total			128.0

Although the mangrove stands are typically thin, ranging from 50 to 300m in width, their length varies considerably from 100m to over 20km (Table 8). The total length of the mangrove forests surveyed along the Red Sea shore and near shore islands was estimated at 128km. More than half of these (55%) are concentrated along the north coast between Midi and Al-Luhayah. The mangrove stands are especially extensive at Al-Buhays (15° 59'N, 42° 49'E) and Al-Habl (16° 09'N, 42° 49'E). Distribution and density of the mangroves on the Red Sea coast may be classified into four areas according to ecological features:

1. Midi to Al-Luhayah area: mangroves stands are most dense and extensive in this area forming a semi-continuous belt along the shore;

2. Al-Khawbah to Ras Isa: mangrove stands are less dense than the coastal area to the north, interrupted by relatively large patches of bare shore;
3. Al-Urj to Al-Hudaydah: mangrove stands are limited in size and confined to a few tidal inlets and small islets.
4. South of Al-Hudaydah to Bab al-Mandab: mangrove stands are relatively thin and widely separated from each other, influenced by the topography of the shoreline and the higher aridity of the area. However, extensive stands are found where considerable fresh water seepage exists.

Local characteristics and condition of the mangrove stands

Midi to Al-Luhayah

This is a 90km stretch of Yemen's northern Red Sea coast near the Saudi Arabian border. It consists of a very flat 'sabkha coastline' with several narrow inlets. The coastal area receives seasonal freshwater drainage through Wadi Mawr. There are extensive intertidal mudflats at Al-Luhayah in the south, sandy beaches at Midi in the north, and occasional sand dunes and cliffs, especially in the north. There is a small rocky hill at Al-Luhayah (Jebel al-Humarah). Terrestrial vegetation along the coast is sparse, consisting mainly of salt-tolerant spiny grasses. Fishing is the main economic activity based around the major population centres of Midi, Al-Habl, Al-Buhays and Al-Luhayah. Al-Luhayah is a classic Red Sea port of great cultural, archaeological and historical interest.

A well developed, semi-continuous belt of *Avicennia marina* covers most of the coastline in the area. Mangrove stands were identified at 13 sites including: a small stand near the Midi landing site, five small to moderate stands between Midi and Al-Habl, one moderate stand at Al-Habl, two large stands in the Al-Buhays area, and four small to moderate stands at Al-Luhayah (Table 8, Table 9 & Figure 1).

Midi fish landing site

This stand, located north of Midi village, consists of a dense belt of *Avicennia marina* fringing both sides of a khor that extends a kilometre inland. A fishing village inhabited by 80-100 people is located near the forest. The lower reach of the khor is used as a landing site. The width of the mangrove stand is 100-300m. Heavy grazing and woodcutting occur in the stand.

The worst affected part of the stand is the part neighbouring the village and the fish-landing site. An area of about 200x100m has been removed and completely destroyed; only the remains of the cut and uprooted stems are present. The outer zone of the stand bordering the destroyed area is heavily grazed by camels and is dominated by stunted *Avicennia* shrubs and trees less than one metre high. A few trees are more than 2m in height. The inner zone is slightly affected by grazing and trees are up to 3m tall. The GBH of the well-grown trees in this zone is 13-40cm.

Dredging and land filling to construct a new fish-landing jetty 0.5-1.0km south of the old mersa are impacting the site. These activities are diverting some of the tidal water flow from the khor. Twisting and curling leaves are common among the trees in the stand. Some mangroves fringing the upper reaches are dead and several others have 'top dying' uppermost and outermost branches, probably as a result of changes to tidal water flow. Large quantities of domestic solid waste, mainly plastic bottles and sacs have been dumped directly on to the mangroves or have drifted with the tide and are trapped there amongst the trees and their aerial roots.

Table 9. Characteristics and condition of some *Avicennia marina* stands located at Midi and Al-Luhayah (Yemen)

Variables and characteristics	Site						
	Midi Khor (outer zone)	Midi Khor (inner zone)	8km south of Midi	Al-Luhayah North (grazed)	Al-Luhayah khor area (sparse)	Al-Luhayah khor area (dense)	Al-Luhayah khor area grazed
Mangrove trees (quadrat size 10 x 10m):							
Density of trees	26	17	18	21	11	21	14
Height range (m)	0.2-2.5	1.5-3.0	2.0-5.0	0.5-1.2	0.2-1.5	2.0-2.5	1.0-1.5
GBH range (cm)	-	13-40	20-110	-	-	15-20	-
Dead standing trees	1	0	1	0	1	0	0
Dead felled trees	2	0	0	1	0	0	0
Grazed trees and shrubs	23	1	1	20	2	0	14
Mature trees with dropped limbs	6	4	4	7	0	0	0
Trees with top dying uppermost and outermost branches	11	1	0	0	0	0	0
Multi-stemmed trees	24	17	5	21	9	21	14
Number of seedlings	0	2	29	0	11	0	0
Dead seedlings	0	0	0	0	3	0	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	M	M	NR	NR	NR	F	NR
Pneumatophores (quadrat size 0.5 x 0.5m):							
Density of pneumatophores	21	36	72	26	46	22	16
Branched pneumatophores	0	4	3	0	3	2	2
Twisting and curling pneumatophores	0	2	0	0	0	6	0
Pneumatophores with dead tips	9	0	14	7	9	2	7

NR: not recorded, F: few, M: many

Between Midi and Al-Habl I

A narrow mangrove stand is found at this site, 2km south of Midi. The stand extends 200m along the shore. It is easily accessible from land and is heavily browsed by camels. It is dominated by stunted, multi-stemmed *Avicennia marina* bushes and trees, which are severely affected by camel grazing and cutting.

Between Midi and Al-Habl II

This is a relatively well-developed *Avicennia marina* stand 6km south of Midi. The mangroves grow on both sides of a 400m long, narrow channel which protrudes perpendicular to the shoreline. Camels graze some of the accessible and outer areas of the stand.

Between Midi and Al-Habl III

This mangrove stand is located about 8km south of Midi. It consists of a dense belt of well-developed *Avicennia marina,* 350m in length. The stand is dominated by well-developed trees up to 5m tall and is fringed by dwarf trees up to 2m in height. The GBH ranges between 20cm for small and 110cm for well-grown trees. Except for the grazed outer fringes of the belt, the stand is relatively undisturbed.

Between Midi and Al-Habl IV

The site is located 16km south of Midi. A well-developed *Avicennia marina* stand extends 1.5km on both sides of an elongated khor, with small branches in the middle and upper reaches. The main channel of the khor is 1-4m deep and 10-50m wide. The mangroves grow 4-5m in height with GBH 30-100cm. Trees growing in the outer zone are slightly affected by grazing. The site is being converted into a shrimp farm. The aquaculture project will have an impact on the mangrove stand. This may include physical destruction and modification of the tidal water regimes at the site. This may reduce tidal water outflow through the khor.

Between Midi and Al-Habl V

This stand is 21km south of Midi, it is 3.5km long, ending just north of Al-Habl village. It consists of a narrow belt of well-developed *Avicennia marina*, up to 4-6m in height. GBH is up to 120cm for well-grown, old trees. Outer parts of the stand are heavily grazed and stunted forming bushes less than one metre high.

Al-Habl

A narrow (50-200m wide) stand of *Avicennia marina,* 7km along the shore north and south of Al-Habl. Outer parts of the belt are heavily grazed and stunted, inner areas have well-developed trees reaching up to 7-8m in height.

Al-Buhays

This is the longest mangrove stand in Yemen. It is a continuous narrow belt of *Avicennia marina* (50-300m wide) extending 29km along the shore from 16° 04´N, 42° 50´E to 15° 50’N, 42° 47’E, north and south of Al-Buhays village. Mangroves in the outer fringes are affected by camel grazing, while those in the inner parts of the stand are relatively undisturbed and grow 4-6m high with a GBH of up to 100cm.

Between Al-Buhays and Al-Luhayah

This is another long stand of *Avicennia marina* extending 22km along the coastline between Al-Buhays and Al-Luhayah. Unlike the extensive stand located to the north, this one is extremely badly damaged by camel grazing and cutting, resulting in several bare patches and gaps among the mangroves. This is probably because the stand is easily accessible to the relatively large population in Al-Luhayah and the adjacent areas.

North of Al-Luhayah

A very thin stand of *Avicennia marina* grows just to the north of Al-Luhayah, extending 2km along the shore and fringing a small tidal channel. The stand is severely impacted by camel grazing, especially the outer parts, where *Avicennia marina* trees are stunted, only reaching 0.5-1.0m in height. Mangrove trees in the inner parts of the stand are also moderately stunted growing 2.0-2.5m in height.

Al-Luhayah

At Al-Luhayah, a wide elongated khor emerges from a large bay forming a channel that extends for about 2-3km inland. The main channel bends and winds almost enclosing a small semi-island (about 3 x 1.5km) south of the mainland coast of the bay. The semi-island is separated from Al-Luhayah town by the main khor channel. Several narrow tidal channels across the semi-island connect the main khor channel with the bay. The main khor channel and its branches are densely fringed with *Avicennia marina*, which also covers a small islet (100 x 30m) in the centre of the main channel.

Al-Luhayah town is an active fishing settlement inhabited by 3000 people. The middle section of the main khor channel is used as landing site for fishing boats. Mangroves were probably removed from this site in the past. This is indicated by the presence of small patches of stunted *Avicennia marina* bushes and the remains of felled trunks. The other side of the khor supports vigorous growth of mangroves, enclosing the semi-island, with the exception of areas affected by camel grazing, wood collection and felling. The shore of the khor is muddy and the *Avicennia* trees grow densely but are relatively short (up to 3-4m tall and 15-20cm GBH). The shore of the semi-island facing the open bay is sandy and muddy-sand. It supports less dense stands of taller *Avicennia marina* trees up to 5-6m in height.

South of Al-Luhayah

Two mangrove stands are located just south of Al-Luhayah. The first is a narrow 0.8km long belt of *Avicennia marina* located about 2km south of the town. The mangrove trees in this stand are well developed and dense reaching up to 5-6m in height. The stand fringes a small bay and a small khor which emerges from the bay. The second stand, located 6km south of Al-Luhayah, is 1.5km long. A shrimp farm with four or five ponds is being constructed near the mangrove stand. A canal will pump seawater to them from the khor. A car track connecting the farm to the inland highway is also under construction. The mangrove stand is seriously threatened by modification of the tidal flow, physical destruction and pollution.

The coast between Al-Luhayah and Al-Khawbah is devoid of mangroves except for these two stands. This is probably because the stress on the area from the two large settlements is very high. Al-Khawbah is particularly densely populated. The town is an important fishing centre on the north coast. It is inhabited by 15,000 people and has an ice plant. The market near the ice plant is crowded with fishermen and petty-sellers of food and other goods. More than 40 big boats (sambouks) and 200 small boats (Huries) are operating in the fishery. Most of the huts and small houses in the town are fenced with wood. Most of the wood is *Avicennia*, the rest is from terrestrial woody plants found in the area. This may explain the remarkable disappearance and degradation of the *Avicennia marina* cover north and south of Al-Khawbah. There is also heavy camel grazing and a massive domestic waste disposal problem; plastic sacs, bottles and empty food cans were observed accumulating everywhere in the town and on the surrounding shore.

Al-Khawbah to Ras Isa

This coastal stretch extends from Al-Khawbah in the north to Ras Isa, a headland on the mainland coast, to the south-east. The site includes the large shallow sheltered bay, Bahr Ibn Abbas and the large island of Kamaran. As mentioned before, Al-Khawbah is a major fishing port and town with an ice plant providing services for fishermen in the area. Al-Salif is a modern container port and is the Red Sea terminus for a major oil-pipeline. Ibn Abbas is a major fishing village. Al-Harounia is a smaller landing site for fishermen inhabiting the nearby inland villages. The north coast of Ras Isa and the coast of Bahr Ibn Abbas are very flat and dominated by bare sabkha, broken only by a coral outcrop at the port of Al-Salif and occasional areas of sand dunes. An appreciable freshwater seepage north and south of Ibn Abbas supports some inland groves of *Phoenix* and *Hyphaene* palms.

Mangrove stands were identified at six sites including two stands south of Al-Khawbah and stands at Ibn Abbas, Al-Harounia mersa, between Al-Harounia and Al-Salif, and Kamaran Island (Table 8, Table 10 & Figure 1). The first five stands are predominantly *Avicennia marina*. Both *Avicennia marina* and *Rhizophora mucronata* grow on Kamaran Island.

Table 10. Characteristics and condition of *Avicennia marina* stands between Al-Khawbah and Ras Isa

Variables and characteristics	Site							
	South of Al-Khawbah (Outer zone)	South of Al-Khawbah (Inner zone)	Al-Harounia (Outer zone)	Al-Harounia (Inner zone)	Al-Harounia (Cutting site)	Between Al-Harounia and Al-Salif (Outer zone)	Between Al-Harounia and Al-Salif (Middle zone)	Between Al-Harounia and Al-Salif (Inner zone)
Mangrove trees (quadrat size 10 x 10m):								
Density of trees (/10m²)	12	8	32	16	22	27	21	28
Height range (m)	5.0 -6.5	6.0-7.0	0.3-1.8	1.0-2.0	0.5-2.0	0.5-1.9	0.7-2.3	2.0-4.0
GBH range (cm)	45- 95	50-110	--	10-15	--	--	--	20-40
Dead standing trees	0	0	0	2	1	3	0	5
Dead felled trees	7	4	1	2	13	3	0	6
Grazed trees and shrubs	5	4	31	0	9	21	21	1
Mature trees with dropped limbs	5	4	0	0	1	3	1	5
Trees with 'top dying' uppermost and outermost branches	0	0	15	14	9	21	15	6
Multi-stemmed trees	1	2	31	16	20	21	21	14
Number of seedlings	6	0	0	0	0	3	9	15
Dead seedlings	1	0	0	0	0	0	1	0
Deformed propagules and seeds	NR	NR	NR	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR	NR	NR	NR	NR	NR
Twisting and curling leaves	F	F	NR	NR	NR	F	M	F
Pneumatophores (quadrat size 0.5 x 0.5m):								
Density of pneumatophores	47	89	18	24	11	18	30	26
Branched pneumatophores	5	6	3	4	2	2	1	1
Twisting and curling pneumatophores	0	4	0	0	2	1	1	1
Pneumatophores with dead tips	4	3	3	2	5	2	5	4

NR: not recorded, F: few, M: many

South of Al-Khawbah

Two narrow (50-200m wide) mangrove stands were identified south of Al-Khawbah. The first stand (RSY14), located 5km south to the town, extends for 0.9km along the shore. It consists of well-grown, old *Avicennia marina* trees up to 6-8m in height, with relatively thick trunks exceeding 100cm GBH. Unlike other mangrove stands in the area, the trunks are not branched. The lower green parts of the trees are heavily browsed by camels, which were observed stretching their necks to reach the higher leaves.

The second stand located 12km south of Al-Khawbah is longer, extending 3.5km along the shore. However, the mangroves are sparse, very overgrazed and destroyed by cutting in several areas, creating many bare patches. The remaining vegetation consists of very stunted shrubs and dwarf multi-stemmed trees up to 1.5-2.0m in height.

Ibn Abbas

The mangrove forest at this site extends 6.5km along the shore north and south of Ibn Abbas village (15° 22'N, 42° 48'E). Trees growing on the outer fringes of the stand are very severely grazed by camels, especially to the south of Ibn Abbas, where only sparse and stunted trees grow. Mangroves on the coast up to Al-Harounia in the south are the most damaged by cutting and camel browsing. Several relatively large herds (more than 50 camels per herd) were observed.

Al-Harounia

The mangrove stand at this site extends approximately 7km along the shore north and south of Al-Harounia mersa. The area is badly impacted by heavy grazing. Mangroves occur as very sparse stunted shrubs. The pneumatophores have been trampled by camels in several areas of the stand. There is a small mersa for the huries of fishermen who live at Al-Harounia village nearby (4km inland). In the area surrounding the mersa the trees have been cut severely and many have been removed creating a large denuded patch in the middle of the stand.

Between Al-Harounia and Al-Salif

This dense *Avicennia marina* stand fringes both banks of a 3.8km long inlet. The stand is the seaward end of a large sabkha (about 4-5km wide and 5km long) It extends from the littoral area and is bounded landwards by the highway connecting Al-Hudaydah with Al-Salif. The thick forest fringes the main channel of the inlet and several branches on both sides of the inlet, forming a relatively large stand with several other associated patches of mangroves. Trees and bushes in the outer patches are stunted due to high salinity and grazing. Those on the main inlet and its entrance to the sea are well-grown, up to 4-6m high and 40-50cm GBH. They are protected from camels and people by the muddy and slippery substrate of the sabkha. The site contains many seedlings, especially in undisturbed areas of the stand. Mature trees carry fruits and many seeds were observed on the ground among the trees.

Kamaran Island

Kamaran island (15° 22'N, 42° 35'E) is 20km long and 8km wide. It is separated from the mainland by a channel 2.5km wide. Mangroves cover the undulating eastern shore of the island, which includes several lagoons and inlets forming an extensive mangrove swamp. Two species, *Rhizophora mucronata* and *Avicennia marina* are found. The *Avicennia* forms a thick belt fringing most of the peripheral channels and the main channel, surrounding a well-grown stand of *Rhizophora* trees. The *Rhizophora* reach up to 7-9m in height and the *Avicennia* up to 4-5m. Camel grazing is not significant in most parts of the stand, except the outer landward areas, which are damaged. There is limited cutting of the *Rhizophora* roots around the main lagoon. Mangroves of Kamaran are the most dense and diverse in Yemen and are in a good condition.

Al-Urj to Al-Hudaydah

This is a 40km stretch of the Red Sea coast extending from the fishing village of Al-Urj in the north to Al-Hudaydah in the south. It includes a large shallow bay protected from the open sea by Ras Al-Kathib, a 15km long sandy peninsula protruding north-westerly from the mainland coast about 5km north of Al-Hudaydah. Towards Al-Urj, much of the coastline is a steep sandy beach backed by sand dunes and areas of bare salt flats (sabkha). South of Al-Urj, the beach is split by a tidal inlet one kilometre long at the mouth of a dry wadi. Substantial seepage of fresh groundwater from the tidal inlet feeds several brackish wells and small ponds. It supports an extensive coastal fringe of doum palms *Hyphaene* sp. and groves of date palms *Phoenix* sp. Towards the shore, the extensive intertidal mud and sand flats support well-developed mangroves. At the southern end, the area includes Al-Hudaydah sewage lagoons, a complex of small lagoons and marshes created by the overflow from a sewage treatment plant near Al-Hudaydah.

Small mangrove stands were identified at six localities in the area including Al-Urj, Al-Hudaydah Islets (4 islets) and near the sewage lagoons, 7km north of Al-Hudaydah (Table 11, Figure 1).

Table 11. Characteristics and condition of *Avicennia marina* stands north of Al-Hudaydah to Al-Urj

Variables and characteristics	Site		
	North of Al-Hudaydah Outer part	North of Al-Hudaydah Inner part	Am-Shura Islet
Mangrove trees (quadrat size 10 x 10m):			
Density of trees	132	19	14
Height range (m)	0.3-2.2	2.0-5.0	1.0-5.0
GBH range (cm)	0	15-20	10-30
Dead standing trees	14	1	0
Dead felled trees	32	0	0
Grazed trees and shrubs	9	5	0
Mature trees with dropped limbs	100	2	0
Trees with top dying uppermost and outermost branches	100	4	0
Multi-stemmed trees	96	19	7
Number of seedlings	0	0	10
Dead seedlings	0	0	0
Deformed propagules and seeds	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	NR
Twisting and curling leaves	M	NR	F
Pneumatophores (quadrat size 0.5 x 0.5m):			
Density of pneumatophores	32	29	81
Branched pneumatophores	3	4	4
Twisting and curling pneumatophores	3	5	0
Pneumatophores with dead tips	5	7	4

NR: not recorded, F: few, M: many

Al-Urj

The mangrove stand at Al-Urj contains the biggest and oldest *Avicennia marina* trees in Yemen. The stand grows on a narrow shore, fringed by palm trees inland and protected seaward by a barrier-beach of shell-sand. The *Avicennia* trees attain up to 9-11m height and 200-240cm GBH. Salinity is low to moderate (around 17ppm), perhaps favouring the massive growth of the mangrove trees. Although rich populations of terrestrial woody plants (palms and scattered Acacia trees) are present, (which may provide a source of firewood for local inhabitants), cutting is still very severe in some parts of the stand. Many *Avicennia marina* trees have been felled and removed.

North of Al-Hudaydah

This site is near a complex of lagoons and marshes created by an overflow from the Al-Hudaydah sewage treatment plant; it is between sandy desert and coastal sabkha on the northern outskirts of Al-Hudaydah. The mangroves grow along the shore forming three small, adjacent stands. The northern stand is 200m long and 50m wide. It is separated from the middle stand by 300m. The middle stand is 600m long and 50-100m wide, separated from the smaller, relatively dense southern stand by 200m. The southern stand is 150m long and 50m wide. The mangroves

are predominantly *Avicennia marina*, except for a few *Rhizophora mucronata* trees (4 trees, one dead) that grow at the southern end of the middle stand. The *Avicennia* grow up to 2-5m in height and 15-20cm GBH in the inner, less disturbed parts of the stands, while the outer grazed parts are dominated by stunted bushes less than half a metre tall, with a few trees up to 2m in height. The mangrove belt is fringed landwards by terrestrial halophytes and a *Prosopis* sp. belt.

The outer, landward parts of the northern and middle stands are severely damaged by camel grazing and cutting that has created bare patches. Some of these gaps show the remains of removed trunks and uprooted trees. There are also several dead, standing trees at this site. Dense seedlings grow seawards between the middle and southern stands, indicating that the mangroves are advancing into the fringing shallow tidal flat, out towards the nearby Gandal islet. The stand is heavily disturbed by solid waste and sewage pollution. The solid wastes (mainly polythene bags, cans and other domestic wastes) blow into the mangrove from the nearby rubbish dump of Al-Hudaydah city. The sewage water flows over the mangroves and the shore area from a stream in the vicinity. The stream takes water from the marshes across a narrow strip of sabkha into the adjacent shallow bay.

Al-Hudaydah islets

There are four small islets close to the shore of a large bay at the entrance of Al-Hudaydah port. They include:

1. Am-Shura islet: (Shura is the Arabic name for *Avicennia.*) This islet is small, 400m long and 50-100m wide. Most of the islet is covered by a dense stand of *Avicennia marina*. The mangroves range from stunted bushes to well-grown trees reaching 3-5m in height. The GBH of the well-developed trees is up to 30cm. Dense seedlings and saplings grow on the narrow strip of shore and in open patches amongst the trees. Pneumatophores are densely infested by barnacles. There is severe erosion of the shore sediments on the windward side of the stand facing the deep narrow ship channel leading into Al-Hudaydah harbour.

2. Gandal islet: (Gandal is the Arabic name of *Rhizophora.*) This islet is small (30x130m) and is separated from the mainland shore by a one kilometre wide shallow lagoon, and from Am-Shura islet by the deep ship channel leading to the port at Al- Hudaydah. Gandal islet is densely covered with *Rhizophora mucronata,* with a few well developed *Avicennia marina* growing in the middle of the stand and at the side of the islet facing the port. The pneumatophores and prop roots are densely covered by barnacles. *Rhizophora* trees are up to 3-6m tall, while *Avicennia marina* trees reach 3-4m in height. GBH for *Rhizophora* reaches 15-30cm. The islet is a raised reef with rocky edges, covered by a layer of sand and muddy sand in the middle. The sediment is not very deep, which limits the growth of both *Rhizophora* and *Avicennia* trees. *Rhizophora* trees were flowering and some were fruiting at the time of the survey.

3. Mugamala islet: This islet is located between Gandal and Am-Shura islets. It is closer to the mainland shore than the other two islets and separated from it by a shallow submerged flat that is exposed at extreme low tide. The islet is accessible to people and camels from the mainland. The sparse stand of *Avicennia marina* is severely affected by grazing and cutting.

4. Al-Hudaydah islet 4 is larger than the rest in the group. It is 2km north of Gandal islet and is 800m long. The islet has a dense stand of *Avicennia marina* trees up to 5-6m in height.

South of Al-Hudaydah to Al-Ghurairah (Bab al-Mandab)

This is a 200km stretch of Red Sea coast with a variety of habitats including intertidal flats, tidal inlets, coastal lagoons, sabkhas, mangroves, seagrass beds and coral reefs. Sites with

mangrove growth are less frequent and they are more sparse compared to the area north of Al-Hudaydah.

A flat stretch of Red Sea coast extends about 90km from the southern outskirts of Al-Hudaydah to the lower section of Wadi Zabid. Wadi Zabid reaches the sea at Al-Fazzah village (14° 07´N, 43° 06´E) a few kilometres north of Al-Khawkhah. The coast is exposed, with sandy beaches, large areas of sabkha, and patches of intertidal mud flats in the more sheltered areas, as north of Al-Nukhailah. Substantial seepage of freshwater occurs at many places along the coast, supporting extensive grassy pasture, *Typha* beds, with *Juncus* sp., *Pandanus* thickets and open, shallow, brackish water pools on the coastal flat. There are dense doum palms (*Hyphaene* sp.) and extensive plantations of date palms (*Phoenix*) at Al-Nukhailah, Al-Ghulaifiqah, Al-Mujailis and Ras-el-Buqa. Coastal sand dunes are common. Terrestrial halophytes such as *Suaeda* sp. and *Zygophyllum* sp. grow above the high water mark in sandy areas.

The middle section consists of about 60km of coastline stretching between the towns of Al-Khawkhah (13° 48´N, 43° 14´E) and Al-Makha (13° 19´N, 43° 18´E). It includes the fishing villages of Mawshij, Al-Ruays and Yakhtul. The northern sites are dominated by narrow sandy beaches, the southern sites by large areas of bare salt flats (sabkha) with several saltpans. Considerable underground freshwater supports dense growth of palms (*Hyphaene* sp. and *Phoenix* sp.) at Al-Ruays and north of Yakhtul. Halophytes (*Suaeda* sp. and *Zygophyllum* sp.) are very common along most of the coast, especially on low dunes and fringes of sabkha. *Salvadora* sp. bushes are locally common inland.

The southern part of the area, south of Al-Makha to Bab al-Mandab, is more arid with less groundwater which limits the growth of palm trees. The coastal area is characterised by lagoons and saline flats fringed by sparse terrestrial halophytic vegetation. The coastal plain supports a semi-natural vegetation of dwarf shrubland, grassland and *Acacia-Commiphora* bushland. It is relatively undisturbed in the Dhubab area due to military security.

Although mangroves are sparse compared to the northern parts of the coast (Midi to Al-Hudaydah), relatively good stands were identified between Al-Ruays and Yakhtul, south of Al-Makha, between Al-Kadaha and Al-Ubaidah, and at Al-Ghurairah near Bab al-Mandab (Table 12, Figure 1).

Between Al-Ruays and Yakhtul

A thin but relatively long (7km) stand of *Avicennia marina* grows between the villages of Al-Ruays and Yakhtul. The mangroves form a narrow belt (50-100m wide) becoming wider in parts, where tidal water regularly covers several depressions and small channels across the soft sabkha. Grazing by camels and goats is severe in many outer parts of the stand, inhibiting growth. Mangrove trees are well developed in the inner parts of the stand, up to 7m in height and 90cm GBH. Some sites are affected by mass mortality and felling e.g. a considerable mass mortality occurs 1.5km south of El-Ruays where large patches include only dead standing trees. Mass mortality occurs partly because of the excessive burial by moving sand dunes. This represents a major problem in the area. However, the major cause appears to be the diversion of tidal water into saltpans, which are common in the area. Limited pollution by solid waste was recorded in parts of the mangrove stand. Considerable underground seepage of freshwater supports several supratidal brackish water pools and wells in the area. Landwards, the mangroves are fringed by groves of palm trees.

Table 12. Characteristics and condition of *Avicennia marina* stands south of Al-Hudaydah to Bab al-Mandab

Variables and characteristics	Site				
	Between Al-Ruays and Yakhtul Outer zone	Between Al-Ruays and Yakhtul Inner zone	Al-Ubaidah	Al-Ghurairah Outer zone	Al-Ghurairah Inner zone
Mangrove trees (quadrat size 10 x 10m):					
Density of trees	13	49	16	35	15
Height range (m)	2.0-2.5	6.0-7.0	1.0-3.0m	0.5-1.5m	1.0-4.0
GBH range (cm)	10-40	30-90	30-40(1)	0	20.30(1)
Dead standing trees	0	2	1	8	0
Dead felled trees	0	39	5	15	0
Grazed trees and shrubs	5	0	10	20	0
Mature trees with dropped limbs	4	2	4	5	3
Trees with top dying uppermost and outermost branches	0	9	0	3	0
Multi-stemmed trees	10	22	4	20	12
Number of seedlings	9	7	1	0	0
Dead seedlings	0	3	0	0	0
Deformed propagules and seeds	NR	NR	NR	NR	NR
Leaves with spotty chlorosis and necrosis	NR	NR	F	NR	NR
Twisting and curling leaves	NR	NR	M	F	NR
Pneumatophores (quadrat size 0.5 x 0.5m):					
Density of pneumatophores	34	4	9	20	90
Branched pneumatophores	2	0	8	10	4
Twisting and curling pneumatophores	2	0	0	0	5
Pneumatophores with dead tips	8	3	2	4	7

NR: not recorded, F: few, M: many. (1) For some old mature trees only

South of Al-Makha

Five kilometres south of Al-Makha, a very thin belt of stunted *Avicennia marina* extends for 150m along the shore. This stand has been severely damaged by camel grazing.

Between Al-Kadaha and Al-Ubaidah

A long stand of *Avicennia marina* extends for 16km from El-Kadaha (7km south of El-Makha) in the north to Al-Ubaidah in the south. This stand is very narrow (mostly 20-50m wide but up to 100m wide at a few sites) and severely impacted. It is being buried by sand in some areas and grazed along its outer margins. Most of the mangroves in this stand appear to receive seawater frequently through tidal channels. Excessive sedimentation by sand is severely impacting tidal water flow in some of the channels.

Al-Ghurairah

Al-Ghurairah village near Bab al-Mandab is the most southerly fishing settlement on the Red Sea coast of Yemen. A relatively long narrow inlet emerges from a bay in the village and extends north-east for 3km. In the upper 1.5km of the channel, both banks are fringed by a dense stand of *Avicennia marina*. Tree height reaches 0.5-1.5m in the outer stand and 1.0-4.0m in the inner stand. Over the past few years, sand dunes have increasingly buried the narrow entrance of the

khor, significantly reducing the flow of tidal water and the water level in the inlet. This has caused mass mortality of mangroves in the upper reaches. The mass mortality area was 100 x 500m, with well above 2500 dead trees. Cutting of the living trees is very limited; local inhabitants collect dead trunks and dry wood. The living part of the mangrove stand also suffers from camel grazing on the outer fringes and limited pollution from domestic solid wastes.

Mangrove Fauna

Regional studies on Red Sea mangrove faunal communities have been conducted in Sinai (POR & DOR 1984; POR et al. 1977), Saudi Arabia (PRICE et al. 1987) and Sudan (KHALIL 1994, 2002; KHALIL & KRUPP 1994). Observations during the present survey indicate that similar communities are present in all the mangroves along the Red Sea. However, richer assemblages are found in the more extensive mangroves of the south coast. The dense multispecific mangrove forests of Godoria and Moucha Island in Djibouti support particularly rich assemblages. The assemblages are characterised by typical Indo-Pacific mangrove macrofaunal species such as the mudskipper *Periopthalmus koelreuteri*, the mangrove snail and the mangrove isopod borer *Sphaeroma* sp. In 1987, PRICE et al. reported that *P. koelreuteri* had only been recorded south of latitude 16° 44' 25"N on the Saudi Red Sea coast.

There are various habitats within the mangrove vegetation and adjacent biotopes, inhabited by biota typical for each. These biotopes include the landward mud and sand flats, the mangrove vegetation including the trunk, aerial roots, leaves and the ample shade of the trees, the mangrove associated lagoons and channels and the adjacent seaward shallow subtidal sand and mud flats, seagrass beds and fringing reefs. Degradation of the mangrove cover will obviously affect all these habitats and disrupt their faunal communities.

The outer landward mud and sand flats, where only isolated and dwarfed *Avicennia marina* shrubs are found, are exposed and dry at low tide and partially submerged at high tide. The most conspicuous macrofauna are *Uca* sp., *Dotilla* sp., *Ocypode* sp. and the terrestrial hermit crab *Coenobita* sp. These species are not specific to mangrove areas and can be found elsewhere along the Red Sea shoreline. As this zone is situated landwards, it is subjected to physical stress from camels crossing the zone to graze on the mangroves. It is also impacted by severe pollution from domestic solid wastes at several sites near population centres. These impacts probably cause considerable disturbance to the faunal species. A marked lower abundance and richness of macrofaunal species and burrows was observed at mangrove areas severely affected by camel grazing.

The mangrove vegetation supports a quantitatively rich community of algal, mobile and sessile macrofaunal species. Among the macrofauna the most conspicuous is the graspid crab *Metopograpsus* sp. Other common species include the scyphozoan jellyfish *Cassiopeia* sp. and sea spiders. The trunk and pneumatophores provide habitats for intertidal fauna e.g. *Littorina* sp. and barnacles. Poor animal communities were observed in mangroves degraded by heavy camel grazing and woodcutting compared to relatively undisturbed mangroves. The abundance of the

graspid crab *Metopograpsus* sp. appears to be largely influenced by the density and condition of the mangroves. Well-developed and relatively undisturbed mangroves support dense populations of *Metopograpsus* sp. Lower numbers were observed in mangroves suffering from degradation and disturbance. The species was represented by very few individuals or was nearly absent from sites suffering from mass mortalities of the trees or with extensive denuded areas.

The mangrove lagoons and associated channels are inhabited by a number of fish species. Most are not true residents but utilise the mangroves as nursery grounds. Studies in the Sudanese Red Sea (KHALIL 1994; KHALIL & KRUPP 1994) have reported that the juveniles of several commercially important fish species, which are caught as adults in areas adjacent to the mangroves, are dependent upon the mangroves as feeding grounds. These studies reported significantly higher abundance and diversity of fish species from mangrove areas and associated lagoons compared to the open shore, and significantly higher abundance and diversity in the more extensive and dense mangrove stands.

KHALIL (1994) described the relationships between fish species and mangroves in the Red Sea and identified three main categories:

1. True residents: fish species that may spend their entire life cycle in the mangroves such as *Aphanius dispar*, *Gerres oyena* and some gobiids.
2. Closely associated species: fish species that are found in the mangroves as juveniles, or juveniles and subadults. These species utilise the mangroves as nursery and feeding grounds e.g. *Acanthopagrus berda, Chanos chanos, Crenidens crenidens, Hypoatherina temminckii, Leiognathus equulus, Terapon jarbua, Pomadasys commersonni* and some Mugilid species.
3. Loosely associated species: those which enter the mangroves as occasional visitors searching for food or protection e.g. *Sillago sihama, Thryssa baelama*.

The extensive shallow flats seaward of the mangroves are also protected from erosion, excessive sedimentation and turbidity. This provides favourable habitats for growth of algae e.g. *Digenea* sp. and *Cystoseira* sp. These flats also support rich populations of commercially important gastropods *Strombus* sp. and *Lambis* sp., which are collected for their meat and *dufra* (local perfumes extracted from the operculum of the animal). Sea cucumbers are also collected from shallow waters around mangrove areas. The impact of mangrove degradation on fisheries and the protection of adjacent habitats, should be investigated through long-term studies and monitoring programmes.

A variety of bird fauna was observed during the present mangrove survey. These areas form important resting and wintering sites for migratory birds, both shorebirds and seabirds. They are used as breeding and nesting sites by several species. The very common Pink-backed pelican (*Pelecanus rufescens*) and the Goliath heron (*Ardea goliath*) probably breed in the mangroves. The mangroves, coastal palms and other woody vegetation support an interesting assemblage of breeding avifauna e.g. Black kite (*Milvus migrans*) and several other species.

Impact Assessment and Potential Threats

4.1 Camel grazing and cutting

Camel grazing was reported in almost all the mangrove areas surveyed in Djibouti, Sudan and Yemen, excluding stands growing on inaccessible islands. In Saudi Arabia several previous surveys have reported excessive camel grazing as a major factor causing mangrove degradation along the Red Sea coast, particularly in the south (e.g. PRICE 1987; MANDURA et al. 1987, 1988; MANDURA & KHAFAJI 1993). This is also the case for Egyptian mangroves (GALAL 2003).

Within the Region the intensity of camel browsing varied from low in some areas, to moderate in most of the mangrove stands, and severe in others. This depends on the size of the camel herds present in the area, accessibility of the site and the availability and condition of other pastoral resources. In areas where heavy grazing occurs, severe impacts on the mangroves include:

- considerable reduction in the green parts of the trees,
- dryness of the uppermost and outermost parts of the grazed branches,
- limiting of the mangrove growth to stunted multi-stemmed bushes,
- destruction of the seedlings and pneumatophores under the feet of camels.

Cutting and removal of the mangroves is more destructive than camel grazing. Unplanned mangrove cutting was reported in several mangrove stands. The impact is severe due to the limited size of most stands. Cutting was also reported within the boundaries of established reserves and protected areas e.g. Moucha Island mangrove in Djibouti, indicating poor enforcement and inadequate management. Mature trees with dropped limbs were reported as common in most of the mangrove areas. Cutting of living trees is largely concentrated on the limbs, whereas felling is less common. In some areas, where dead standing trees are common, wood collection and felling is largely confined to the dry parts of the stand. Many accessible stands are dominated by multi-stemmed trees, indicating that they have been used extensively for coppicing and allowed to regenerate later.

In areas affected by severe mangrove cutting, significant reduction in the number of trees, denuded patches, barren depressions with modified hydrological regimes, and compaction of the surface soil were observed. These observations are similar to those reported as short-term effects of mangrove cutting elsewhere (SAENGER et al. 1996). Besides reducing tree cover, it has been observed that cutting provides passage to the dense inner parts of the stands for camels to graze. The combined stresses of grazing and cutting have accelerated degradation of several mangrove areas near major population settlements along the coast. Assessment of the status of mangrove areas in relation to the impact of camel grazing and cutting is summarised in Table 13.

4.2 Mangrove mortality

Mass mortality of mangrove trees appears to be a serious problem in several mangrove areas, particularly in Djibouti (Khor Angar and Moucha mangroves), the southern parts of the Red Sea coast in Yemen (mangrove areas between Al-Ruays and Yakhtul and near Al-Ghuraira), Sudan (Ashat mangrove), and some mangroves of Saudi Arabia. In several other areas localised pockets of dead standing trees were reported; for example, at Ras Siyyan in Djibouti, Klanieb in Sudan, Midi and some parts of Bahr Ibn Abbas in Yemen. 'Top dying' of the uppermost and outermost branches is widespread among trees in many other disturbed mangrove areas in the Region.

Table 13. Assessment of the status of mangrove stands in Yemen related to the impact of camel grazing and woodcutting

Status	Assessment of the impact of camel grazing
Not affected	Mangrove stands that are not accessible to camels or protected by natural barriers e.g. islands.
Slightly affected	Only some accessible trees at the outer fringes of the stands are browsed; stands are accessible with difficulty e.g. reserves, protected areas, military areas. Grazing or cutting currently has a limited or insignificant impact on the mangroves.
Moderately affected	Mangrove trees growing in the outer fringes of stands are partly or severely grazed and/or cut, while those growing at the inaccessible middle and seaward areas of the stand remain undisturbed. (Most of the mangrove stands in the Region fall within this category.) The impacts include stunted growth of the grazed trees and physical destruction of pneumatophores and seedlings in the grazed outer fringes. Disturbance to the outer belt of the stands may mean that inner parts are indirectly affected by increased erosion or sand infilling from land. Increased sand infilling may block tidal water flow through channels and inlets, leading to mass mortality of mangroves, e.g. Khor Angar mangrove in Djibouti, and Ashat mangrove in Sudan.
Severely affected	Usually where heavy grazing by big herds of camels is combined with mangrove cutting e.g. Al-Harounia and Ibn Abbas areas in Yemen, Haydob in Sudan, and Khor Angar in Djibouti. Outer fringes are severely grazed and/or cut. Many trees in the middle and seaward areas of the stand are also affected by browsing. They became accessible to camels through several passages and bare patches created by cutting and removal of the trees from the belt. Impacts include stunted growth of the grazed trees to multi-stemmed bushes at the outer fringes and destruction of branches, seedlings and pneumatophores. When degradation is severe mangroves may become very sparse or disappear from the site. Denuded patches of modified substrate and modified hydrological regimes also result. Examples include several coastal areas in the Region that supported dense stands in the past, but presently support sparse or no mangroves.

The major cause of the mangrove mortality in the Region appears to be localised modifications to the topography of the coastal area. This leads to diversion or blocking of tidal water flow and drying up of the mangrove stands. This may be attributed to:

- construction activities involving dredging and infilling on the shore e.g. for new harbours, jetties, dams, bridges, and ponds for aquaculture of shrimps;
- diverting tidal water to feed salt pans through canals, e.g. the shore between Al-Ruays and Yakhtul in Yemen, and Port Sudan and Suakin in Sudan;

- excessive sediment loads or infilling b sand that has buried tidal inlets and channels preventing flooding of the mangroves by seawater.

In many coastal areas, human-induced degradation of the mangrove and terrestrial vegetation has lead to reduced soil stability, loss of sediment trapping capacity and excessive movement of sand dunes from land. In some areas sand is transported by wind through denuded patches created by grazing and cutting. The sediment is deposited in the lower reaches of the tidal inlets and channels. This modification of tidal regimes threatens the existence of the affected forests even where cutting or camel grazing does not significantly impact the inner stand.

Prolonged periods of decline in annual rainfall and the effects of the 1997/98 El-Nino have perhaps played a major role in mangrove mass mortality. Decline in rainfall has decreased erosion of the shore area by surface run-off, promoting the accumulation of sediment loads during tidal floods. It has also been reported in recent studies that an increase in terrigenous sediments during the Indo-Pacific El-Nino of 1997-1998 led to huge deposition of sediments in wetlands. This caused massive destruction to the upper reaches of mangroves in some forests in Kenya (KITHEKA et al. 2002). The El-Nino apparently had similar effects on mangroves in the Red Sea and Gulf of Aden. In the present surveys, mass mortalities of mangroves were more common in southern Sudan (Ashat area) and Yemen (Ghurairah, Bab al-Mandab). On the Djiboutian Gulf of Aden coast mass mortalities were more pronounced than along the Red Sea. It has been reported by local inhabitants that significant mass mortalities have occurred since 1998 in Khor Angar and Moucha Island. Recent surveys in Djibouti also reported widespread coral bleaching, which has been attributed to the 1998 El-Nino (OBURA 1998). This suggests that the 1997-1998 El-Nino played a significant role in the degradation of mangroves in the Region.

4.3 Shrimp farming

There are many reasons for the destruction of mangroves around the world. The most important factor in recent years however, has been expansion of shrimp ponds into mangrove forests. Mangrove swamps are considered very suitable for shrimp farming because the areas are flooded with brackish, stagnant water that is ideal for aquaculture. Commercial shrimp farms have been reported causing devastation to the coastal environment, especially in Asian countries (BARBIER & COX 2002).

World-wide, the six billion dollar shrimp farming industry has produced approximately one million metric tonnes a year since 1995. The RSGA and Middle East are striving to become a shrimp producing region. Serious, large-scale development has been taking place in Saudi Arabia and is proposed in Sudan and Yemen. It is necessary to take measures to control the effects of the expanding shrimp farming industry in the Region so that it does not pose a threat to the mangroves. Shrimp farming does not have to pose an environmental threat, provided that environmental precautions are considered (Box 3).

4.4 Freshwater damming

Due to the lack of perennial rivers and the aridity of the Red Sea coastal area, the main source of freshwater, beside desalination plants, is rain water harvested from the lower reaches of major valleys. The population of the coastal area is increasing rapidly. Industrial development and the urbanisation of rural areas has increased the demand for freshwater. Soil dams are being

constructed to harvest water from the lower reaches of major valleys (e.g. Khor Arbaat and Guwab in Sudan and Wadi Mawr in Yemen). This considerably reduces the amount of freshwater reaching the sea from surface run-off.

Box. 3 Shrimp farming and mangrove conservation in the RSGA region

Recently, large-scale development of the shrimp farming industry has been taking place, or has been proposed, in several RSGA countries including Saudi Arabia, Yemen and Sudan. Commercial shrimp farms have been reported to cause devastation to the coastal environment, particularly to mangrove habitats that are often favoured for shrimp farms. Substantial environmental protection measures are needed to safeguard mangroves from degradation caused by shrimp farming. Shrimp farming does not necessarily have to pose an environmental threat provided that:

- aquaculture systems are not designed to involve removal of vegetation and areas naturally fed by tidal water,
- wastewater from farms is sufficiently treated before being released,
- Sufficient technical know-how and assistance is provided to ensure sustainable production methods are used.

Unsustainable production has led to unproductive farms being abandoned and rapid expansion into new areas to replace them.

However, the establishment of sustainable farming systems is more expensive. Most of the investment in the shrimp farm industry in the Region is from private investors and business enterprises. Given the growing market demand and the need to raise income from exports, shrimp farming is anticipated to grow rapidly in the RSGA region during the coming years. To reduce adverse effects on the coastal environment, the governments should have incentive programmes that include technical assistance, access to credit etc., to facilitate the adoption of sustainable and less destructive shrimp farming systems.

The distribution of mangroves is greatly influenced by the amount of surface water run-off and alluvium deposited at valley mouths by seasonal floods. Therefore damming of freshwater will lead to degradation of the mangroves growing close to the valley mouths because of:

- increased intrusion of saltwater leading to hypersaline habitats unfavourable for mangrove growth;
- decline in the alluvium and sediment load deposited at the river mouths, leading to shrinkage of the "deltas" occupied by mangroves;
- increased sand infilling and deposition of sand from the sea obstructing tidal inlets and channels through which tidal flow regularly floods the mangrove forests.

4.5 Pollution

Solid-wastes and garbage

Domestic solid-waste e.g. polythene bags and bottles, rubber, plastic and metal cans etc. are disposed of in large quantities near population centres. Several mangroves, e.g. Al-Khawbah and Al-Hudaydah in Yemen, Djibouti-Ville in Djibouti, Safaga, Sharm-el-Bahari and several stands in Egypt suffer from large accumulations of such waste material. It is often dumped directly into the mangrove stands or near them and is transferred by wind and tidal water becoming trapped among the trees and their aerial roots. This has serious physical impacts, particularly on young

seedlings and pneumatophores and may interfere with water circulation by blocking tidal channels. It may also disturb other mangrove-associated flora and fauna.

Organic pollution

Some mangrove areas in the Region, particularly near Jeddah (Saudi Arabia), Al-Hudaydah (Yemen) and Djibouti-ville (Djibouti) have been under stress from sewage pollution for several years. Untreated or poorly treated sewage flows directly into the mangroves or shore areas in vicinity of the mangroves. The affected mangrove stands are dominated by stunted, multi-stemmed trees. Branched, twisting and dead pneumatophores are common. However, it is difficult to attribute the effects to sewage pollution alone. Some of these stands also suffer stress from other sources such as camel grazing and cutting.

A study was carried out to assess the impacts of sewage effluents on a mangrove stand near Jeddah (MANDURA 1997). The study indicated retarded growth of the mangroves. This was attributed to the high incidence of dead and aberrant pneumatophores. No information is currently available on the impacts of sewage pollution on mangrove faunal and floral assemblages in the Region. Studies elsewhere have reported that the high level of organic carbon found in sewage may lead to reduction of soil redox potential, and place additional stress on mangroves and their fauna (CLOUGH et al. 1983). In the long-term, deleterious effects on mangrove fauna are likely to occur (SAENGER et al. 1995). As some mangroves in the Region have been subjected to long-term pollution by sewage effluent, urgent studies are needed to investigate the impacts of this pollution on the mangrove associated biota.

Oil and industrial pollution

Oil pollution or direct chemical and industrial inputs to the mangroves were not reported in Djibouti, Sudan or Yemen during the present survey. A large oil spill has not occurred on the Red Sea coast. In Egypt, oil pollution represents a significant threat to coral reefs, commercial fisheries, birds, mangroves and other coastal resources. From Suez to Hurghada, coastal areas were reported to be affected by petroleum residue from ships, offshore oil facilities and pipelines. Mangrove forests near Ras Mohammed are stressed from chronic oil pollution (BALDWIN & FERGUSON 1988). At present, however, oil and chemical pollution were reported as minimal in mangrove stands along the Egyptian Red Sea coast; it is confined to tar balls and mats resulting from previous oil spills in the area (GALAL 2003).

Although the impacts of industrial and oil pollution are currently reported as minimal on the Red Sea mangroves, there are serious threats from the following:

- Recent expansion and development of huge industrial areas close to mangroves along the coast. Examples include the industrial city of Yanbu in Saudi Arabia and the Red Sea Free Zone in Sudan (Box 2).
- The coastal region embraces major sites for oil exploration, oil related industries and export terminals (e.g. Yanbu in Saudi Arabia, Ras Isa in Yemen, Gulf of Suez in Egypt, and recently Bashair terminal in Sudan). The potential for oil spills and leakages from these sites into the mangroves in surrounding areas is high.
- The Red Sea is one of the world's major shipping routes with vessels approaching close to the coast e.g. Suez Canal, Miyurn in Yemen. Navigation errors pose serious threats to the coastal marine environment.

Catchment pollution

Due to lack of perennial rivers flowing into the Red Sea, pollution from inland sources might be considered to be negligible. However, parts of the coastal plain and the higher and middle reaches of the seasonal valleys are cultivated (e.g. Yemen and Sudan) and receive herbicides, pesticides and fertilisers. The central eastern Red Sea coastal plains are a desert locust breeding and swarming area. These plains have been subjected to annual insecticide sprays for several years carried out by the Locust Control Program (e.g. Sudan).

The vulnerability of the coastal area (especially mangroves that grow where wadis meet the sea) to catchment pollution from agricultural inputs and pesticides is uncertain. A study is currently being conducted in Sudan to assess the impact of pesticide pollution on non-target mangrove communities.

4.6 Coastal construction and changes in land use

Recently, the Red Sea Region has witnessed several construction activities such as roads, harbours, industrial sites, commercial areas, tourist hotels, airports, bridges, channels, aquaculture ponds, saltpans, etc. Mangroves on the Red Sea appear to be less affected by coastal infilling than those on the Arabian Gulf. Saudi Arabia has infilled a considerable percentage of its coastline, wiping out half of its native mangroves.

Although construction activities have not usually involved the direct removal of mangroves or vegetation on the Red Sea, they have indirectly imposed severe impacts on the mangroves in several localities. Coastal road construction may reduce seasonal freshwater supply. For example, in Egypt signs of mangrove mortality were observed in stands growing at Al-Gonah, Mersa El-Hamira and Mersa Shagara after construction of a coastal road and tourist camps landward of the stands (GALAL 2003). In Saudi Arabia, construction of a new soil dam on Farasan Island has led to drying up and mass mortality in a mangrove stand (AL-WETAID 2003). Similar impacts were caused by channels and ponds constructed for saltpans in Sudan (Klanieb) and Yemen (Yakhtul). Generally construction, dredging and infilling activities indirectly affect mangroves by altering hydrological regimes, either by reducing normal freshwater supply or modifying the tidal flow and seawater supply to the mangroves.

In several places, changes in land use in the surrounding coastal area could have adverse effects on the mangroves. Human interference, which was once restricted to artisanal fishing, fodder and wood collection, is now rapidly growing to include tourist camps, hotels, aquaculture ponds, industrial and commercial zones. Such interference will ultimately create changes in the coastal environment that will affect mangroves and other natural coastal habitats. This necessitates sound environmental management that adopts serious measures and policies to conserve mangroves and other living marine resources.

Recommendations and Guidelines for Mangrove Conservation, Rehabilitation and Management in the Region

5.1 Importance of resource conservation

The mangrove stands along the Red Sea are predominantly small, thin, and thus unsuitable for harvesting of wood and animal fodder. Their ecological roles include protecting the coast from erosion and trapping sediments. As a result they also protect coral reefs, consolidate shore habitats, provide nursery and shelter for a number of marine organisms, provide nesting, roosting and breeding sites for several birds, and enrich the marine food web in the surrounding oligotrophic water. These roles are far more important than their role as a potential source of fodder and wood products. 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 (coral reefs, seagrass beds) upon which many of the living marine resources depend. Such losses are far greater, in the long run, than any profits to be gained from commercial and industrial projects causing mangrove degradation. 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.

5.2 Objectives of mangrove management

The immediate objectives of mangrove ecosystem management in the Region should include:

- Controlling the present impacts and stresses that are directly or indirectly causing adverse effects on the mangroves. These include the unsustainable use of the resources by allowing open access for people and camels and other impacts.
- Protection of mangroves against further degradation from potential threats in the near future.
- Extending the present mangrove areas by securing natural regeneration and mangrove plantation.

The long-term objectives of mangrove ecosystem management should include the development and implementation of an integrated management approach based on scientific research and long-term monitoring to ensure sustainable use and conservation of the resources.

5.3 Management strategies and prescriptive guidelines

Strategies to be adopted for establishing a proper mangrove conservation and management system may include:

- providing finance and long-term funding commitments for conservation and monitoring programmes,
- establishing legislative and institutional frameworks,
- reviewing available databases and the establishment of scientific research and equipment for long-term monitoring programmes to provide guidelines for management,
- capacity building and training of local technical staff to implement the management policies,
- ensuring public awareness and local community participation in conservation and rehabilitation activities,
- providing suitable mechanisms and equipment required for implementation of the adopted management policies,
- efficient implementation of management policies, based on sufficient technical know-how and periodic evaluation of the programmes.

The following paragraphs give some recommendations and discuss the justification for these management strategies:

Finance for regional mangrove management programmes

The complexity and importance of the regional and global problems associated with mangrove degradation justify the allocation of sufficient finances and long-term funding. The governments and NGOs concerned need to make a commitment to mangrove conservation and rehabilitation programmes. The UN Conference on Environment and Development recommended that research efforts should be stepped up to improve prediction of natural and man-made changes in marine and coastal environments. The success of mangrove conservation programmes in the Region will depend on the allocation of sufficient finance to fund basic inventory research, preventive problem-oriented research and conservation-rehabilitation activities.

Legal and institutional framework

Although mangrove areas in the RSGA countries are situated on government-owned land, their jurisdiction falls under different government authorities. Given the absence of clear coastal zone management plans, the presence of numerous stakeholders, and growing coastal developments in the Region, mangroves may be subjected to various impacts resulting from changes in land use. This makes the task of mangrove conservation management difficult. Efficient coordination and genuine cooperation is needed between the different authorities and stakeholders concerned.

Some countries have included some of their mangroves within established marine protected areas or reserves (mainly Djibouti, Saudi Arabia and Egypt). However the vast majority of the mangrove areas in these countries and in other parts of the Region (including all mangrove areas in Sudan and Yemen) lack any legal protection for conservation purposes. For management

purposes, the present report suggests classifying the mangrove areas according to their present legal situation and land use as follows:

1. Mangrove areas located within existing MPAs and reserves (see PERSGA/GEF 2001): priorities should include development of management plans to enforce regulations, efficient monitoring, public awareness and participation in monitoring and conservation activities. This will overcome the present situation where illegal destructive activities take place in protected mangrove areas e.g. wood cutting and pollution at Moucha and Maskali Islands in Djibouti.
2. Mangrove areas within proposed MPAs and reserves (see PERSGA/GEF 2001): priorities should include urgent implementation of feasibility studies, and development of management plans similar to that mentioned in 1 above.
3. Mangrove areas outside existing or proposed MPAs and reserves: for proper resource management and conservation reasons, it is strongly recommended that all these mangroves should be brought under control of some sort of legal protection (i.e. as MPAs, Marine Reserves or Forest Reserves).

Present knowledge and outlines for management plans

Classification of mangrove areas according to their level of degradation, future threats and prioritisation of actions, will assist in the adoption of suitable and successful management plans. Based on present knowledge of status and degradation level, the mangrove areas in the Region could be classified into the following categories:

1. areas with dense, well-developed trees, undisturbed or insignificantly disturbed by browsing and/or cutting,
2. areas with naturally low-growing mangrove shrubs, undisturbed or insignificantly disturbed by browsing and/or cutting,
3. areas partially affected by browsing and/or cutting in the more accessible outer and landward parts,
4. areas severely affected by camel grazing and cutting in all or most of the stand, with denuded areas where mangroves have been completely destroyed or removed,
5. areas suffering from mass mortality due to known or unknown causes,
6. areas under prolonged stress from organic pollution by sewage effluent,
7. areas that have been subjected to oil pollution in the past, which may still be suffering from long-term effects that need to be assessed,
8. areas threatened by anticipated changes in land use or development projects in the near future.

It is clear that some mangrove areas may be categorised under more than one of the above, for example, an area may subjected to organic pollution and cutting at the same time. In this case management plans to control both impacts should be applied.

At present, due to increasing human and natural stresses, areas covered by undisturbed mangroves (categories 1 & 2) are rapidly shrinking, while degraded and threatened areas (categories 3, 4, 5 and 6) are expanding rapidly over the entire coastal area. Actions should aim to

reverse the present situation i.e. keeping and increasing the areas classified under categories 1 & 2 and improving the status of other areas. Such priority actions should therefore integrate both protection and rehabilitation remedies. The protection remedies may include:

- establishing an institutional and legislative framework, using environmental laws and efficient management to implement protective measures and enforce regulations,
- prohibition and restriction of present activities causing mangrove degradation including uncontrolled camel browsing and wood cutting,
- control of mangrove pollution and elimination of pollutants and their potential threats,
- raising institutional awareness of the need for mangrove protection and conservation,
- feasibility studies and management of industrial and coastal development projects and institutional participation in mangrove conservation programmes,
- public and private sector awareness and participation in protection plans,
- establishing long-term mangrove monitoring programmes to monitor natural and human-induced changes and follow up for rehabilitation and restoration programmes.

Mangrove rehabilitation and restoration programmes may include securing natural regeneration where possible by:

- restricting activities which disturb the growth of seedlings and young plants,
- moderating human-induced changes and modification of the habitat, which reduce the potential of mangroves to regenerate naturally. e.g. constructed channels, which deviate tidal flow, freshwater damming, pollution.

Selection of sites suitable for mangrove restoration (replanting) programmes should be based on feasibility studies. These need to consider both physical criteria such as substrate, hydrological characteristics, slope, tidal movement etc., and social criteria such as public participation, distance workers have to travel, distance to a source of propagules, accessibility, land claims etc. (see SAENGER et al. 1996). Replanting areas may include:

- denuded patches among stands severely degraded by cutting and grazing,
- coastal areas where mangrove cover has been removed or lost through mass mortality; (the cause of any mass mortality through pollution, diverting or obstruction of water supply etc. should be identified and eliminated before replanting),
- coastal areas with the potential to support mangroves, or that have been colonised recently by pioneer seedlings,
- rehabilitation of vegetation cover in the adjacent coastal plain and saltmarsh.

A general decline in rainfall over the last few decades has, perhaps, contributed to the degradation of mangroves in the Region. The effects of this have been combined with and accelerated by human induced stresses on the mangroves. Degradation of pasture has forced the local inhabitants to shift to mangroves as an alternative supply of wood for fuel and fodder for their camels. Conservation plans need to provide alternatives for these people to attain their objectives. The rehabilitation of the mangroves needs to be considered as a part of an integrated environmental management programme which includes rehabilitation of the pasture and

vegetation of the coastal plains (KHALIL 2001). In this context the recent activities of UNESCO to initiate halophyte farms are noted.

Research needs and monitoring programmes

There are major gaps in our knowledge about the physical environment of mangroves, floral and faunal communities and the short and long-term effects of natural and human induced impacts. Both basic research and problem-oriented research efforts are needed to provide guidelines and principles for appropriate management.

Basic research and problem-oriented research are closely linked in the analysis of ecosystems. Basic research studies the life strategies of species on the basis of their genetic properties and adaptations to animate and inanimate conditions. In order to understand community structure and functions, it is necessary to conduct studies on the nutrition and reproductive biology of specific species, their physiological efficiency and inter- or intra-specific interactions at all ontogenetic levels. In this context it will be necessary to pay more attention to pathological and epidemiological changes. Application and problem-oriented research deal with the effects of human induced alterations to the ecosystem and develops concepts for sustainable utilisation and protection of the resource. However, this is only possible if the organisms and their diversity are known from basic research.

Basic research on mangroves and associated communities in the Region should be promoted to provide knowledge about:

- reproduction, growth and nutritional biology of the species,
- adaptive physiology, biochemical and genetic characteristics,
- parasites, pests and diseases of mangroves and economically important species,
- intra- and inter-specific relationships and interactions,
- community structure and function,
- ecosystem dynamics, trophic relationships, materials and energy flow,
- temporal and spatial variations and natural cycles of the species.

Application and problem-oriented research should concentrate on:

- short and long-term effects of pollution and human impacts on the species and their environments,
- resource assessment and development of concepts for sustainable use,
- development of concepts and measures to protect and conserve the resource,
- development and promotion of efficient and cost-effective long-term monitoring systems,
- socio-economic aspects of the mangrove resource.

References

AL-WETAID, A. 2003. Status of Red Sea mangrove in Kingdom of Saudi Arabia. (Draft Report. PERSGA, Jeddah (In Arabic).

ANDREWS, F.W. 1950. The flowering plants of Anglo-Egyptian Sudan. Sudan Government.

BALDWIN, M.F. & FERGUSON, D. 1988. World Directory of Country Environmental Studies: Biodiversity Assessments, Strategies, and Action Plans (Africa). U.S. Agency for International Development, Bureau for Asia and Near East, Egypt.

BARBIER, E. & COX, M. 2002. Economic and demographic factors affecting mangrove loss in the coastal provinces of Thailand, 1979-1996. *Ambio* **31(4)**: 351-357.

CHILD, G. & GRAINGER, J. 1990. A System Plan for Protected Areas for Wildlife Conservation and Sustainable Rural Development in Saudi Arabia. National Commission for Wildlife Conservation and Development, Riyadh. 335 pp.

CLOUGH ET AL 1983. CITED IN TEXT PAGE 48

DAVIS, J.H. 1940. The ecological and geologic role of mangroves in Florida. *Carnegie Institute* **22**: 303-412; also published in *The Bulletin of the American Association of Petroleum Geologists* **26**: 307-425.

DITTMAR, T. 1999. Outwelling of organic matter and nutrients from a mangrove in North Brazil: evidence from organic tracers and flux measurements (PhD thesis). ZMT Contributions 5. Centre for Tropical Marine Ecology, Bremen, Germany.

DOR & LEVY 1984. CITED IN TEXT PAGE 11

ENGLISH, S., WILKINSON, C. & BAKER, V. 1997. Survey Manual for Tropical Marine Resources (2nd edition). Townsville, Australian Institute for Marine Science. 390 pp.

EVANS, M.I. (ed.) 1994. Important Bird Areas in the Middle East. *Birdlife Conservation Series* No. 2. Birdlife International, Cambridge, U.K.

GALAL, N.S. 1999 IN TEXT PAGE 11

GALAL, N.S. 2003. Status of Mangroves in the Arab Republic of Egypt (Draft Report). PERSGA, Jeddah.

GAZZAR, 1995. CITED IN TEXT PAGE 11

JONES, D.A. 2002. Standard Survey Methods for Intertidal and Mangrove Biotopes. PERSGA Training Workshop Report 2002, No.1. PERSGA, Jeddah.

KASSAS, M. & ZAHRAN, M.A. 1967. On the ecology of the Red Sea salt marshes, Egypt. *Ecological Monographs* **37(4)**: 297-315.

KHALIL, A.S.M. 1994. An Ecological Study on Fishes of the Mangrove Ecosystems of the Sudanese Red Sea. MSc. Thesis, Department of Zoology, University of Khartoum, Sudan.

KHALIL, A.S.M. 2001 CITED IN TEXT PAGE 54

KHALIL, A.S.M. 2002. Monitoring Program for Mangrove and Intertidal Biotopes in the Red Sea and Gulf of Aden. PERSGA, Jeddah.

KHALIL, A.S.M. 2003a. Status of Mangroves in the Republic of Djibouti (Draft Report). PERSGA, Jeddah.

KHALIL, A.S.M. 2003b. Status of Mangroves in the Republic of Yemen (Draft Report). PERSGA, Jeddah.

KHALIL, A.S.M. 2003c. Status of Mangroves in the Republic of Sudan (Draft Report). PERSGA, Jeddah.

KHALIL, A.S.M. & KRUPP, F. 1994. Fishes of the mangrove ecosystem. In: *Comparative ecological analysis of biota and habitats in littoral and shallow sublittoral waters of the Sudanese Red Sea*. Report for the period of April 1991 to December 1993. Faculty of Marine Science and Fisheries, Port Sudan & Forschungsinstitut Senckenberg, Frankfurt.

KITHEKA, J.U., ONGWENYI, G.S. & MAVUTI, K.M. 2002. Dynamics of suspended sediment exchange and transport in degraded mangroves in Kenya. *Ambio* **31(7-8)**: 580-587.

KOCH & EL BAZ 1992. CITED IN TEXT PAGE 22

MACNAE, W. 1968. A general account of the fauna and flora of the mangrove swamps and forests in the Indo-West-Pacific Region. *Advances in Marine Biology* **6**: 73-270.

MANDURA, A.S. 1997. A mangrove stand under sewage pollution stress. *Mangroves and Salt Marshes* **1**: 255-262.

MANDURA, A.S. & KHAFAJI, A.K. 1993. Human impact on mangrove of Khor Farasan Island, Southern Red Sea Coast of Saudi Arabia. In: *Towards the rational use of high salinity tolerant plants* Vol. 1. **(**Leith, H. & Al Masoom, H. eds): 353-261. Kluwer Academic Publishers, Dordrecht.

MANDURA et al. cited in text 1987 & 1988? Pages 26 and 44

MASTALLER, M. 1996. Destruction of mangrove wetlands – causes and consequences. *Natural Resource Development* **43/44**: 37-57.

MASTALLER, M. 1997. *Mangroves: The Forgotten Forest between Land and Sea*. Tropical Press Sdn. Bhd., Kuala Lumpur, Malaysia.

MATTES, H. & KAPETSKY, J.M. 1988. Worldwide compendium of mangrove-associated aquatic species of economic importance. *FAO Fisheries Circular* **814**: 236 pp.

MOHAMED, B.F. 1984. Ecological observations on the mangroves of the Red Sea shores of the Sudan. *Hydrobiologia* **110**: 109-111.

OBURA, D.O. 1998. Project: Marine and Coastal Assessment, Djibouti (Draft Report). EARO/75545/389.

ODUM & JOHANNES 1975. cited in text - Box 1, page 2

ORMOND, R.F.G. 1980. Management and Conservation of Red Sea Habitats. In: *Proceedings of the Symposium on the coastal and marine environment of the Red Sea, Gulf of Aden and Western Indian Ocean*, 9-14 Jan 1980, Khartoum, ALESCO/UNESCO/The Saudi-Sudanese Red Sea Commission, Vol. 2**:** 135-162.

PERSGA/GEF. 2001. Strategic Action Programme for the Red Sea and Gulf of Aden. Volume 2. *Country Reports*. The International Bank for Reconstruction and Development. Washington D.C. and PERSGA, Jeddah.

POR, F.D. & DOR, I. 1975. cited in text page 11

POR, F.D. & DOR, I. (eds) 1984. *Hydrobiology of the Mangal*. Dr. W. Junk, The Hague.

SAENGER, P. ET AL 1995. CITED IN TEXT PAGE 48 (? THIS SHOULD ALSO BE 1996)

SAENGER, P., SANKARE, Y. & PERRY, T. 1996. Effects of Pollution and Over-cutting on Mangroves. GEF Large Marine Ecosystem Project for the Gulf of Guinea. UNDP Report.

SASEKUMAR, A. 1993. Asian-Australian marine science projects: Living Coastal Resources. *Proceedings of a workshop on mangrove fisheries and connection*. Australian International Development Assistance Bureau (AIDAB), Brisbane.

SPALDING, M., BLASCO, F. & FIELD, S.D. 1997. *World Mangrove Atlas*. The International Society for Mangrove Ecosystems, Okinawa, Japan.

PRICE, A.R.G., MEDLEY, P.A.H., MCDOWALL, R.J., DAWSON-SHEPPARD, A.R., HOGARTH, P.J., ORMOND, R.F.G. 1987. Aspects of mangal ecology along the Red Sea coast of Saudi Arabia. *Journal of Natural History* **21**: 449-464.

RAVEN, P.H., EVERT, R.F. & CURTIS, H. 1988. *Biologie der Pflanzen*. Walter de Guyter Verlag, Berlin.

VALIELA, I., BOWEN, L.J. & YORK, J.K. 2001. Mangrove forests: One of the world's threatened major tropical environments. *BioScience* **51 (10)**: 807-815.

WILKEI, M.L. 1995. Mangrove Conservation and Management in the Sudan. FAO Report. Ministry of Environment and Tourism, Khartoum & FAO, Rome.

WOODROFFE, C. 1992. Mangrove sediments and geomorphology. In: *Tropical Mangrove Ecosystems*. (Robertson, A.I. & Alongi, D.M. eds). American Geophysical Union, Washington D.C.

APPENDIX 1

Survey sheets

Survey sheet I
Physical data and general visual assessment

Site: Date: Location:

A) Physical readings:

Variable	Station											
	Littoral fringe			Upper Eulittoral			Lower Eulittoral			Sublittoral		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Air Temp. (°C)												
Surface sediment Temp. (°C)												
Interstitial Salinity ppm												
Interstitial pH												
Eh (mv)												
Oxygen conc. (Mg/l)												

Comments on sediment characteristics:

B) Standardised visual assessment of human impacts:
Is there any evidence for: (if 'yes' give some details on source and intensity of the impact)
Camel grazing:
Wood cutting:
Diverting or damming freshwater or seawater supply:
Oil residues or oil sheen:
Garbage or other refuse:
Inputs of industrial waste from factories:
Inputs from aquaculture/agriculture:
Sewage disposal from village or town:
Other human activities (e.g. fishing, saltpans etc.):

C) Other notes:

Survey sheet II
Mangrove vegetation

Site: Date: Location:

Quadrat data

Variables and characteristics	Quadrat position			
I) Mangrove trees and seedlings (Quadrat size 10 x 10m):				
Total number of trees				
Height range (m)				
GBH range (cm)				
Dead standing trees				
Dead felled trees				
Grazed trees and shrubs				
Mature trees with dropped limbs				
Trees with top dying uppermost and outermost branches				
Multi-stemmed trees				
Number of seedlings				
Dead seedlings				
Deformed propagules and seeds (1)				
Leaves with spotty chlorosis and necrosis (1)				
Twisting and curling leaves (1)				
II) Pneumatophores (Quadrat size 0.5 x 0.5m):				
Density of pneumatophores				
Branched pneumatophores				
Twisting and curling pneumatophores				
Pneumatophores with dead tips				

(1) Describe as NR= not recorded, F= few or M= many within the quadrat

B) Comments on stand size and density:

C) Other notes:

Survey sheet III
Key floral and faunal species

Site: Date: Location:

Species	Abundance (1)				Comments
	Upper fringe	Upper Eulittoral	Lower Eulittoral	Sub-littoral	

(1) Describe as R=rare, O=Occasional, C=Common, A=Abundant or D=Dominant

Other notes: