

REVIEW ARTICLE

MANGROVE ECOSYSTEM OF RED SEA COAST (SAUDI ARABIA)

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ABSTRACT: The present paper reviews critically the existing information on mangrove ecosystem of Saudi Arabian Red Sea coast and identifies problems and shortcomings that should be removed or remedied. Mangrove structure and composition seems to have been substantially studied along with salient environmental features, and these are thoroughly summarized herewith. However, the functional aspects, especially energy flow through the ecosystem, remain totally neglected. Both the flora and fauna indicate severe environmental conditions, such as very low nutrient levels, very high salinity values and hard bottom, which are unique to the area. Mangrove growth and diversity is very poor, although conditions in the southern part are relatively favourable. The extreme poverty of the ecosystem is supported by exports of organic matter from adjacent seaweed and seagrass ecosystems and also Sabakhas. Preponderance of epiphytic and benthic algae within the mangrove ecosystem is another source of nutrient replenishment in the otherwise oligotrophic habitat of Red Sea. Finally, a hypothetical model of energy flow in the ecosystem is proposed.

KEY WORDS: Red Sea, mangroves, desert climate, hard bottom.

INTRODUCTION

Information on the mangroves of Saudi Arabian Red Sea coast is poor. The history of mangrove studies is very recent and spreads over only a few decades. Vessey-Fitzgerald (1955, 1957) and Migahid (1978) mentioned their occurrence while Zahran *et al.* (1983) and Frey *et al.* (1984) offered some ecological notes. Mandura *et al.* (1987, 1988) studied the mangroves of the area with an ecosystem approach for the first time. They described the structure of the mangrove ecosystem in terms of phytosociology, physiology and zonation of mangroves and also the nature and composition of related plant and animal communities. Saifullah *et al.* (1989) estimated annual litter production in mangroves, which is the most important functional aspect of this ecosystem. It is not only considered to be an index of net primary production (Bunt *et al.*, 1979) but also as a source of energy to animals residing in the area (Lugo and Snedaker, 1971). It is also believed that the food chain in the system is based mainly on detritus (Odum, 1971). Khafaji *et al.* (1988) made estimates of protein, carbohydrate and lipid contents of mangroves of the area to determine their nutritive value.

The present study critically reviews all the existing information on the subject and points out the shortcomings and gaps that should be removed and fulfilled for a better understanding of the ecosystem, and eventually its conservation.

DESCRIPTION OF THE AREA

The Red Sea coast of Saudi Arabia extends in NNW-SSE direction to a distance of 1,700 km, covering about 4/5th of the entire length of the sea, between the Yemeni and Jordanian borders (Fig. 1). It resides in both tropical and sub-tropical belts, as the line of

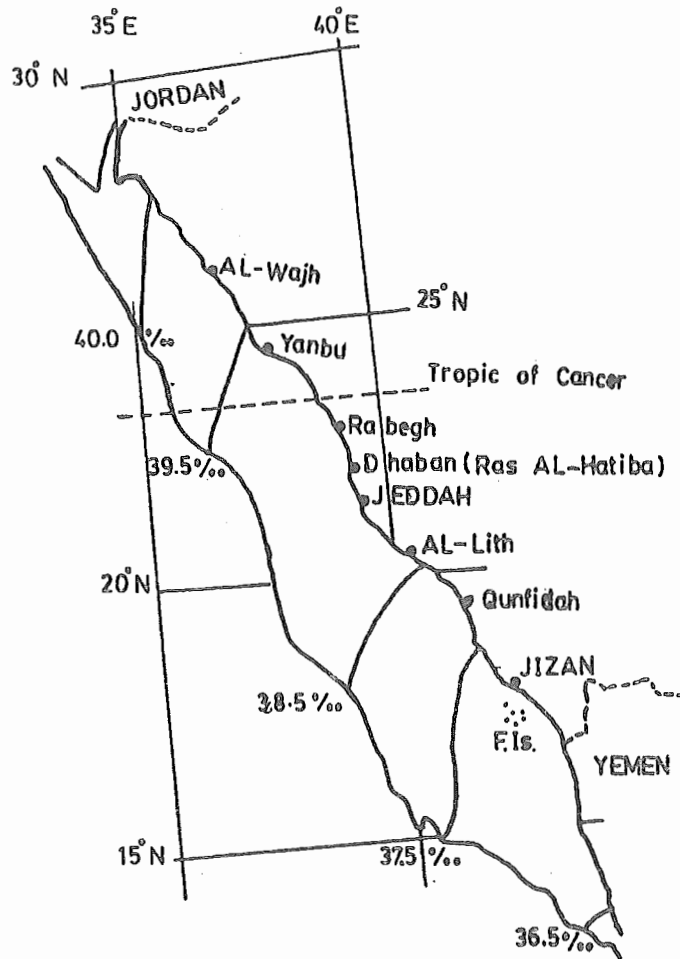


Fig.1. Map showing Saudi Arabian Red Sea coastline (with salinity profiles after Robinson, 1979).

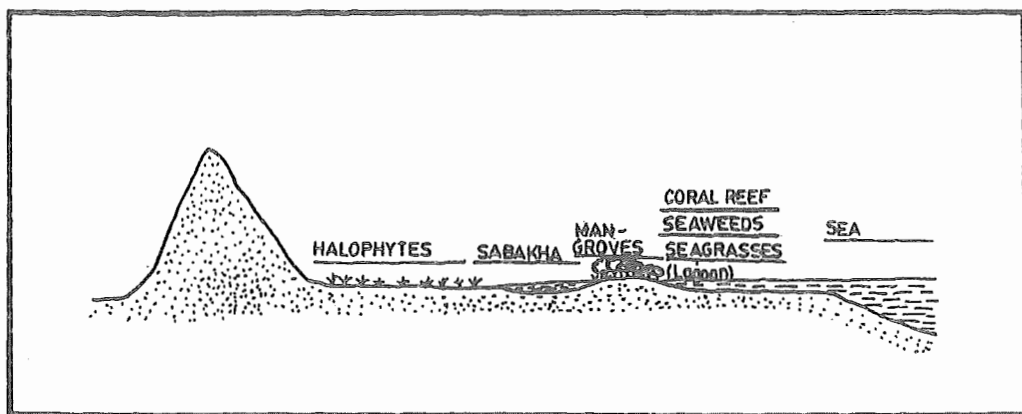


Fig.2. Schematic topography of Saudi Arabian Red Sea coast (not to scale).

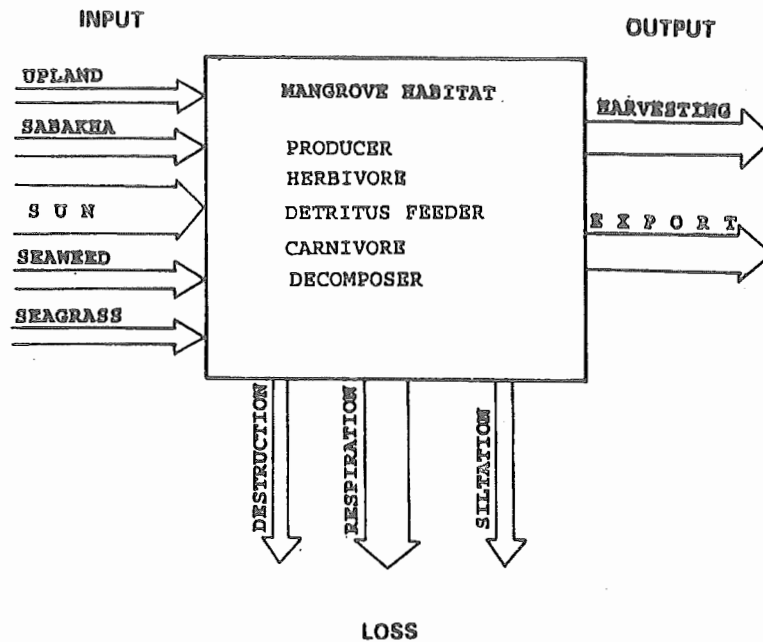


Fig.3. Schematic energy flow model of the mangrove ecosystem.

the Tropic of Cancer passes between Rabegh and Yanbu. The topography of the entire coastal belt remains almost the same throughout its entire length (Fig. 2). In general, the sea shore is flanked landward by shallow lagoons which have been given several local names such as Khawr, Mersa and Sharm. These have originated as a result of erosion by wadis and may total seventy in number. They provide a depositional environment and are, therefore, often favourable sites of mangrove growth in the otherwise barren coastline of the Red Sea.

The mangrove belt forms the landward limit of lagoons, beyond which lies about a 30 km wide flat desert plain called Tihama (Vessey-Fitzgerald, 1955). In most cases its part adjacent to the mangrove belt is low lying and forms a special kind of landform called Sabakha, where a moist sandy-muddy substrate is superimposed by a layer of sun-dried salt impregnated sand and silt. Here, the tidal water inundation occurs only a few times during a year, and in winter when the mean sea level is high. When wet, it allows a very thick growth of filamentous Cyanobacteria, but when dry, as is the case during most of the year, the alga die out leaving their black sheaths persisting in the area and giving it an appearance of beached dark oil from a distance.

The Tihama plain is bordered on its western side by the Hijaz mountains in the north and by Assir mountains in the south (Vessey-Fitzgerald, 1957). Both the plain and the mountains are traversed by a number of wadis which form a network of shallow drainage channels that collect rain water along with alluvium which drain in to lagoons or directly into the sea (Morley, 1975).

CLIMATE AND OCEANOGRAPHY

The arid climate of Saudi Arabia is very severe with very high temperatures and minimum rainfall (Siraj, 1984). The wind pattern is northerly in winter, pushing the Red

Sea water out in the Indian Ocean, and southerly in summer allowing water movement in the reverse direction (Morley, 1975). The oceanographic conditions are also extreme in the Red Sea (Edwards, 1987) with very high seawater temperatures (32°C) and salinity (40 parts per thousand). Surface temperatures increases southward as a function of latitude, whereas salinity increases northward indicating the intrusion of low salinity water from the Gulf of Aden into the Red Sea (Edwards, 1987). This water is also rich in nutrients and, therefore, higher values of nutrient are recorded in the southern than in the northern part (Weickert, 1987).

The tidal amplitude in the area is very small (Edwards, 1987). It is about 50 cm in the northern and southernmost parts but gradually decreases towards the centre, until it reaches a nodal point value of zero near Jeddah. It is, however, compensated by mean sea level, which is usually a meter high during the winter season, and also by high wind speed. This extends the limits of the intertidal zone which would be very narrow if controlled only by the tidal amplitude.

MANGROVES

Mangroves have been reported to occur all along the Red Sea coast of Saudi Arabia, but their distribution is not continuous. Earlier, it was thought that they grew only in the southern and central parts, and not in north (Vessey-Fitzgerald, 1955, 1957; Migahid, 1978), but the later studies of Zahran *et al.* (1983), Frey *et al.* (1984) and Aleem (1978) noted their occurrence as far as the Jordanian border. In general, mangrove growth is very poor as compared to deltaic areas in the world (Lugo and Snedaker, 1971; Saifullah *et al.*, 1994). The mangroves of the southern coast, however, show better growth than in north (Table I) and are comparable with other environmentally favourable areas of the world on a unit area basis. In lagoons they form a fringe type of forest (Snedaker, 1989), that is several kilometers long and as wide as 500 meters (Mandura *et al.*,

Table I. Comparison between mangroves of northern and southern areas of Saudi Arabian Red Sea coast.

	NORTH	SOUTH
1.	Sub-tropical and tropical	Tropical only
2.	Rocky substrate	Muddy substrate
3.	Fewer Wadis	Many Wadis
4.	Less rainfall	More rainfall
5.	Low nutrients	High nutrients
6.	More saline	Less saline
7.	One species of mangroves	Two species of mangroves
8.	Poor growth of mangroves	Dense growth of mangroves
9.	Dwarf forest	Fringe forest
10.	Flowering and fruiting October-April	Flowering and fruiting March-August
11.	Litter fall 2.16 gm m ⁻² day ⁻¹	3 gm m ⁻² day ⁻¹
12.	<i>Bostrychia tenella</i> absent	Present
13.	Mudskippers absent	Present

1987). In the north, however, the mangrove belt is very narrow reaching a maximum width of around 50 meters (Mandura *et al.*, 1988), and in some cases may even form a single row of trees. These may be classified as a dwarf forest (Snedaker, 1989) because of a narrow tidal zone, oligotrophic waters, high salinity values and small size of plants.

Only two species of mangroves are known to occur in the area. *Avicennia marina* Forssk. is the most dominant and, in fact, the only species on the mainland. The other species *Rhizophora mucronata* Lam. is found only along the Farasan Archipelago (Mandura *et al.*, 1987; Khafaji *et al.*, 1989). Migahid (1978) reported it from the Jizan area, which may be a mistake, as no other worker has ever found a single tree of this species there (Zahran, 1983; Mandura *et al.*, 1987).

Flowering and fruiting seasons also vary among the localities (Table I). Thus trees flower earlier (March-August) in south (Mandura *et al.*, 1987) than in north (October-April; Mandura *et al.*, 1988). The situation in Farasan is, however, rather different from the southern and is surprisingly similar to the northern area.

ALGAE AND SEAGRASSES

As many as 76 species of marine algae have been so far reported to occur in the mangrove areas of the Saudi coastline (Mandura *et al.*, 1987, 1988). Fifteen of them belonged to Cyanobacteria, twenty four to Chlorophyta, twenty two to Phaeophyta, and fifteen to Rhodophyta. *Avrainvillea amadelpa*, *Caulerpa racemosa* and *Cladophora* occur in lagoons close to mangrove stands. *Sargassum dentifolium* and *Turbinaria triquetra* formed dense stands in lagoons and when detached drift in to mangrove areas and contribute significantly to the organic biomass. Pith species are were also very tall, especially *S. dentifolium* reached a height of more than three meters.

Most red algae, especially the filamentous forms, occur preferentially as epiphytes on submerged mangrove parts and on other algae. The most common and abundant form is *Bostrychia tenella*, which occur profusely on pneumatophores giving them a spongy appearance in the Farasan Archipelago. It is a first record from the Saudi Arabian Red Sea coast (Papenfuss, 1968). *Spyridia filamentosa* and *Laurencia papillosa* are the common attached forms in shallow mangrove pools in Ras Hatiba (Mandura *et al.*, 1988), a situation similar to the Sinai Peninsula (Por and Dor, 1975).

The blue green algae are all microscopic and less diverse than any other group, nevertheless, they are the most widespread and important group of them all in the mangrove habitat. They grow both as benthic and epiphytic forms. *Nodularia spumigena*, well known to host a variety of epiphytes (Bursa, 1968), forms a mat in Ras Hatiba (Mandura *et al.*, 1988). *Anacystis aeruginosa* forms a thin slimy film on sand in Al-Gabr in Farasans (Khafaji *et al.*, 1989). The latter species is also a new record from the area (Papenfuss, 1968). Other species such as *Microcoleus cthonoplastes* and *Oscillatoria nigroviridis*, also formed extensive mats in Al-Quz in the south (Mandura *et al.*, 1987). *Lyngbya majuscula* occurs attached to the substrate in shallow pools but later drifts in to mangrove areas where they become entangled with pneumatophores and seedlings. In Khor Zifaf of Farasan Islands, they are as long as half a meter and their dried sheath is used as nesting material by local birds. The author has seen such nests there. Among the epiphytes *Lyngbya confervoides*, *Dicothrix penicillatus* and *Brachytrichia quoyi* occur attached to the pneumatophores and mangrove seedlings. *B. quoyi* is recorded for the first time from Red Sea area (Papenfuss, 1968) and it forms a

profuse spongy growth on pneumatophores of *A. marina* in Getlah, Farasan Archipelago (Khafaji *et al.*, 1989).

The sabakhas, large low lying areas, adjacent to mangrove habitat are also sites of exclusive and intensive growth of Cyanobacteria, which forms a several centimeters thick covering at the surface. *Microcoleus cthonoplastes* and *Oscillatoria nigroviridis* are the dominant forms in the south (Mandura *et al.*, 1987) and *Lyngbya estuarii* in the north (Mandura *et al.*, 1988).

Seagrass beds occur in shallow pools with clear water having sandy-rocky bottom. All of the ten species of seagrasses found in the Red Sea have also been reported to occur along the Saudi Arabian Sea coast (Baeshin and Aleem, 1978; Aleem, 1979). *Syringodium isoetifolium*, *Cymodocea serrulata* and *Thalassodendron ciliatum* are known to occur exclusively in the northern part (den Hertog, 1970; Aleem, 1979). Recently, the author has collected specimens of the last mentioned species from the south in Frasan; these are preserved in the Faculty of Marine Science, King Abdul Aziz University, Jeddah.

ANIMALS

As for resident animals in the mangrove area, they are numerous and belong to different groups and phyla. In this paper only those animals are mentioned that are characteristic of the mangrove habitat. The reader may refer to the papers of Mandura *et al.* (1987, 1988) for details on the other animals.

Cerithium nodulosum, *Pirinella conica*, *Strombus fasciatus*, *S. tricornis* and *Tibia insulaeacarb* are very common forms in the area. *Crassostrea cucullata* occurs exclusively attached to pneumatophores. The former species was recorded in the southern part (Mandura *et al.*, 1987) and also in the Sinai Peninsula (Por and Dor, 1975) which indicates its wide occurrence.

The most prominent crab is *Uca inversa inversa*, which occurs in such abundance in Midaya that the muddy flat appears pink in colour (Mandura *et al.*, 1987). It has also been reported from north (Por *et al.*, 1977; Jones *et al.*, 1987) but not from Ras Hatiba (Mandura *et al.*, 1988). Other crabs are *Metapograpsus messor*, *Portunus pelagicus*, *Ocypode saraten* and *Macrophthalmus telescopius*. The Crustacean *Balanus amphitrite* was observed on pneumatophores only in the north (Por *et al.*, 1977; Mandura *et al.*, 1988). Among the coelenterates *Aurelia aurita* and *Cassiopea andromeda* are found in greatest abundance during months of April and May in Ras Hatiba (Mandura *et al.*, 1988), with the former species appearing earlier than the latter. Por and Dor (1975) also recorded the latter species in the Sinai area.

The most characteristic animal of the Asian mangrove habitat is mudskipper, but surprisingly it has never been reported from the eastern coast of Red Sea. Fishelson (1971) reported only *Periopthalmus* sp. from the Dhalak Archipelago on the western side. Recently, Mandura *et al.* (1988) reported *Periopthalmus koelreuteri* and *Boleophthalmus* sp. from the southern part of the Saudi Arabian Red Sea coast (Table I). Their absence from the northern part (Por and Dor, 1975; Mandura *et al.*, 1988) may be attributed to high salinity and low winter temperatures.

GENERAL DISCUSSION

Mangroves are known to occur preferentially in deltaic regions of the tropical and

sub-tropical belt, but may also be found in unfavourable areas within the same belt so long as the habitat is sheltered and depositional. The mangroves of Saudi Arabian Red Sea coast are unique in the sense that they thrive in the most unfavourable conditions. Here the salinity is very high, rivers non-existent, rainfall minimum, bottom hard and the sea very oligotrophic. If lagoons were absent, perhaps there would be no mangroves in the area. They offer a depositional environment which creates a relatively soft bottom and some nutrient enrichment due to decomposition of organic matter, both of which are essential for growth of mangroves. Nature has also compensated for the extreme poverty of the habitat by providing extra source of energy and nutrients. The sabakhas, with profuse cyanobacterial growth and dense stands of large seaweeds in pools, are such additional reservoirs of organic matters which replenish the nutrient demands of the ecosystem. The Cyanobacteria fix elemental nitrogen (Mann and Steinke, 1989) and contribute significantly to overall nitrogen input of the ecosystem. It has been shown by Potts (1979) that both heterocystous and non-heterocystous Cyanobacteria fix nitrogen in the mangrove forest of Sinai peninsula. Although the overall growth of seaweeds is poor in the area (Walker, 1987), some seaweeds like *Sargassum dentifolium* and *Turbinaria triquetra* form very dense stands in lagoons and pools. During winter season, when the mean sea level is high, these algae are detached and transported to the mangrove sites, where they contribute significantly to the organic biomass. Seagrass beds also grow in immediate vicinity and likewise contribute to the energy budget of the mangrove ecosystem.

In addition to the above-mentioned sources of energy and nutrient replenishment, the mangroves of Saudi Arabian Red Sea coast harbour luxuriant growth of Cyanobacteria both as epiphytes and benthic forms, which also compensates for oligotrophy of seawater by fixation of nitrogen.

Figure 1 depicts a hypothetical model of the mangrove ecosystem of the area, which is based on the facts mentioned above. There are four energy sources to the system, i.e., sun, sabakhas, seagrass beds and seaweed stands. The energy output includes harvesting of mangrove parts not exceeding the sustained yield and export of organic matter downstream, where it is used by marine organisms of the shelf area. Finally, a significant part of the energy may be lost from the ecosystem without any subsequent utilization, like respiration, siltation, and destruction. The last two mentioned may also be considered as stressors of the ecosystem. In Khor Farasans, a large area of mangroves was totally destroyed for the construction of the port (Mandura and Khafaji, 1993). It is, unfortunate that energy flow through the ecosystem has not yet been worked out quantitatively. Saifullah *et al.* (1989) has recently estimated the litter fall production in the area, which is a significant step in this direction, as the food chain in mangrove system is supposedly mainly detritus based (Odum, 1971).

The total area of mangrove cover is also not yet estimated, although there have been some localized attempts. Thus, Mandura *et al.* (1987) gave a figure of 25 km² for mangroves of the Jizan area between Al-Quz and Al-Schi, and Jaubert (pers. comm.) gave a figure of 1.01 km² for mangroves of Ras Hatiba. Mufti (1990) provided only the dimensions of the mangrove stand of Shoaiba. He reported a length of 3 km and a width of 38 m, which equals an area of 0.1 km². Information from a large number of mangrove localities in the area thus remains wanting. It is, therefore, advised that estimation of total mangrove cover on Saudi Arabian Red Sea coast also be carried out on a priority basis.

This is important for comparisons with other areas in the world, and also for long-term conservation and management planning.

Although, in general, it can be said that mangrove growth in the area is very poor, the southern area is more favourable for their growth than the northern area, and is comparable to mangrove stands of other favourable areas of the world (Saifullah *et al.*, 1994). The difference between the two areas are listed in Table I. As stated earlier the substrate is hard, salinity values very high, rainfall and nutrients are low in the northern area. The temperature is also relatively low because a significant part of the area is included in the sub-tropical belt (Fig. 1). On the other hand the reverse is true in the southern part. Here, the dead coral reef rocks are superimposed with a thick layer of soft mud and the rainfall and runoff conditions are better as is evident from the large number of wadis. Temperatures are always favourable as they are with in the tropical belt. The environmental conditions are also reflected in the flora and fauna. Thus, the mangroves show better growth in terms of size, density and width of the belt in south than in the north. The typical mangrove animal, mudskipper, and the alga *Bostrychia tenella* are only present in the southern part (Mandura *et al.*, 1987, 1988). Here also two species of mangroves are present as compared to one in south, and litter production is likewise higher (Saifullah *et al.*, 1989; Khafaji *et al.*, 1991).

A. marina is the most dominant species in the area. As a matter of fact, it is the only species on the mainland, which shows tolerance to extreme environmental conditions (MacNae, 1968). The other species *R. mucronata* occurs only in Farasan Archipelago (Khafaji *et al.*, 1989; Mandura and Khafaji, 1993), which seems rather unusual as it is absent from the nearby favourable southern Jizan area (Mandura *et al.*, 1987). However, it has been also recorded from nearby Dhalak Archipelago on the western side (Fishelson, 1971) which indicates the possibility that these islands were once interconnected or were in very close proximity.

Another interesting point is that the growth of benthic and epiphytic algae is very abundant in the mangrove areas which implies optimum utilization of space for photosynthetic purpose. These microscopic organisms increase the photosynthetic area, thereby allowing maximum fixation of solar energy in a limited space. There has been a tacit assumption by ecologists that primary production of mangrove ecosystem is mainly due to mangrove plants and that its food chain is mainly detritus based (Odum, 1971). But, in fact, this may not be the case in all areas. Algae possess very high turnover rates and, therefore, may fix more solar energy than the mangrove plants (Rodriguez and Stoner, 1990). They are also consumed by a number of animals residing in the area and, as such, the concept of a predominantly detritus based chain in the ecosystem needs reconsideration particularly in arid environments. The preponderance of algae also suggests nutrient replenishment in the otherwise very oligotrophic environment.

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