Mangrove Ecosystem of Saudi Arabian Red Sea Coast – An Overview

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ABSTRACT. The present paper reviews critically already existing information on mangrove ecosystem of Saudi Arabian Red Sea coast and sorts out problems and shortcomings that have to be removed or remedied. Its 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 like very low nutrient levels, very high salinity values and hard bottom, which are unique to the area. Mangrove growth and diversity were very poor, although conditions in the southern part are relatively favourable. The extreme poverty of the ecosystem is substantiated 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 yet 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.

Introduction

Information on the mangroves of Saudi Arabian Red Sea coast is as poor as their growth. The history of their studies is very recent and spreads over a few decades only. Vessey-Fitzgerald (1955, 1957) and Migahid (1978) mentioned only their occurrence while Zahran *et al.* (1983) and Frey *et al.* (1984) gave some ecological notes about them. 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 no doubt the most important functional aspect of any such ecosystem. It is not only considered as an index of net primary production (Bunt *et al.*, 1979) but also a source of energy to animals residing in the area (Lugo and Snedaker, 1974). 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, carbohydrates 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 have to be removed and fulfilled respectively, 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 Yemeni and Jordanian borders (Fig. 1). It is included in both tropical and sub-tropical belts, as the line of 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 like Khawr, Mersa and Sharm. These have originated as a result of erosion by wadis and may be as many as 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, after which lies about 30 km wide flat desert
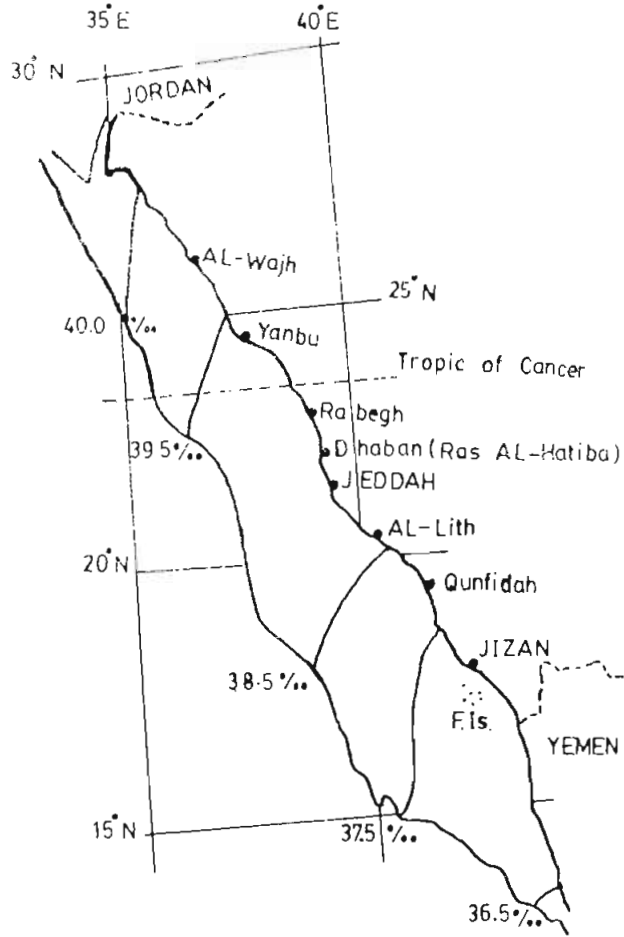
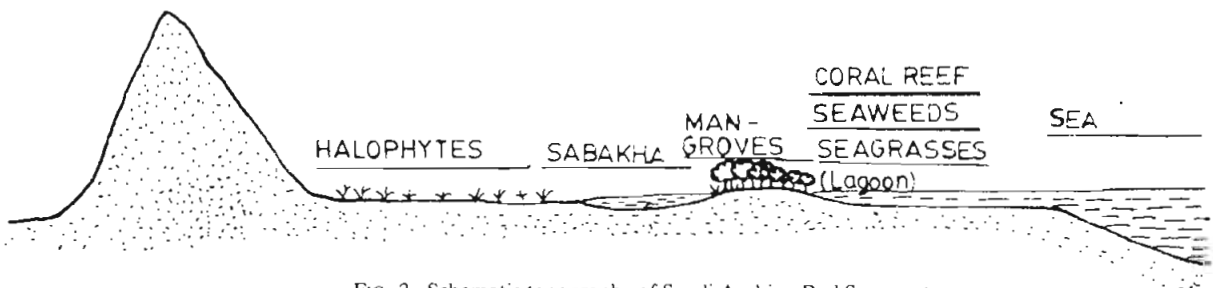FIG. 1. Map showing Saudi Arabian Red Sea coast, with salinity profiles.

FIG. 2. Schematic topography of Saudi Arabian Red Sea coast.

plane 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 reaches only a few times during a year, and that too 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, they die out leaving their black sheaths persisting in the area and giving

it an appearance of beached dark oil from a distance.

The Tihama plane is bordered on its western side by Hijaz mountains in the north and by Asir mountains in the south (Vessey-Fitzgerald, 1957). Both the plane 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 and drain them to lagoons or directly into the sea (Morley, 1975).

Climate and Oceanography

The 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 the water movement in reverse direction (Morley, 1975). The oceanographic conditions are also extreme in Red Sea (Edwards, 1987) with very high seawater temperatures (32°C) and salinity values (40 parts per thousands). Surface temperatures increases southward merely as a function of latitude, whereas the salinity values increase northward indicating the intrusion of low salinity water of Gulf of Aden into the Red Sea (Edwards, 1987). This water is also rich in nutrients and, therefore, a concomitant northward decrease in their values (Weickert, 1987).

The tidal amplitude in the area is very low (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 of zero value near Jeddah. It is, however, compensated with mean sea level, which is usually a meter high during the winter season and also high wind speed. All this extends the limits of the intertidal zone which would have been very narrow if it had been only for 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 and Migahid, 1978), but later studies of Zahran *et al.* (1983), Frey *et al.* (1984) and Aleem (1978) revealed them also to occur as far as Jordanian border. In general, their growth is very poor as compared to deltaic areas in the

world (Lugo and Snedaker, 1974; Saifullah *et al.*, 1994). The mangroves of the southern coast, however, show better growth than in north (Table 1) and are comparable with other favourable areas of the world on a unit area basis. In lagoons they form a fringe type of forest (Snedaker, 1989), several kilometers long and as wide as 500 meters (Mandura *et al.*, 1987). In the north, however, the mangrove belt is very narrow reaching a maximum width of 50 meters or so (Mandura *et al.*, 1988) and in some cases may even form a single row of trees. These may be classified as 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 in Farasan Archipelago (Mandura *et al.*, 1987). Migahid (1978) reported it from Jizan area, which may be a mistake, as no other worker has ever found a single tree of this species there (Zahran, 1983 and Mandura *et al.*, 1987).

Flowering and fruiting seasons also varied with the localities (Table 1). Thus trees flowered earlier (March-August) in south (Mandura *et al.*, 1987) than in north (October-April; Mandura *et al.*, 1988). The situation in Farasan was, however, rather different from south and surprisingly similar to north.

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 amadelpha, Caulerpa*

TABLE 1. Differences 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	March-August
11. Litter fall 2.16 gm m^{-2} day^{-1}	3 gm m^{-2} day^{-1}
12. *Bostrychia tenella* absent	Present
13. Mudskippers absent	Present

racemosa and Cladophora occurred in lagoons close to mangrove stands. Sargassum dentifolium and Turbinaria triquetra formed dense stands in lagoons and when detached drifted to mangrove areas and contributed significantly to their organic biomass. They were also very tall, especially the former species reached a height of more than three meters.

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

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

The sabakhas adjacent to mangrove habitat were also sites of exclusive and intensive growth of Cyanobacteria, which formed a several centimeters thick covering at the surface. Microcoleus cthnoplastes and Oscillatoria nigroviridis were the dominant forms in south (Mandura et al., 1987) and Lyngbia estuarii in north (Mandura et al., 1988).

Seagrass beds occurred in shallow pools with clear water having sandy-rocky bottom. All the ten species of seagrasses found in Red Sea have also been reported to occur along the Saudi Arabian Sea coast (Baeshin and Aleem, 1978 and Aleem, 1979). Syringodinium isoetifolium, Cymodocea serrulara and Thalassodendron ciliatum are known to occur exclusively in the northern part (den Hertog, 1970 and Aleem, 1979). But, recently the author has collected specimens of last mentioned species from south in Frasans, which are preserved in the Faculty of Marine Science, K.A.A. University, Jeddah.

Animals

As for the animals residing in the mangrove area, they were many and belonged to different groups and phyla. In this paper only those animals are mentioned which are characteristic of the mangrove habitat. The readers may refer to the papers of Mandura et al. (1987, 1988) for details of all other animals.

Cerithium nodolosum, Pirinella conica, Strombus fasciatus, S. tricornis and Tibia insulaecarb were very common forms in the area. Crassostrea cucculata occurred exclusively attached to the pneumatophores. The former species was recorded in southern part (Mandura et al., 1987) and also in the wide apart Sinai Peninsula (Por and Dor, 1975), which indicates its wide occurrence.

The most prominent among crabs were Uca inversa inversa, which occurred in such abundance in Midaya, that the muddy flat appeared pink in colour (Mandura et al., 1987). It has also been reported from north (Por et al., 1977 and Jones et al. 1987) but not from Ras Hatiba (Mandura et al., 1988). Other crabs were Metapograpsus messor, Portunus pelagicus, Ocypode saraten and Macropthalmus telescopius. The crustacea Balanus amphitrite was observed on pneumatophores only in the north (Por et al., 1977 and Mandura et al., 1988). Among Coelenterates Aurelia aurita and Cassiopea andromeda were found in great 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 any mangrove habitat is mudskipper, but surprisingly it has never been reported from the eastern coast of the Red Sea. Fishelson (1971) reported only Periopthalmus sp. from Dhalak Archipelago on the western side. But recently Mandura et al. (1988) reported Periopthalmus koelreuteri and Beleopthalmus sp. from the southern part of the Saudi Arabian Red Sea coast (Table 1). Their absence from the northern part (Por and Dor, 1975 and Mandura et al., 1988) may be attributed to
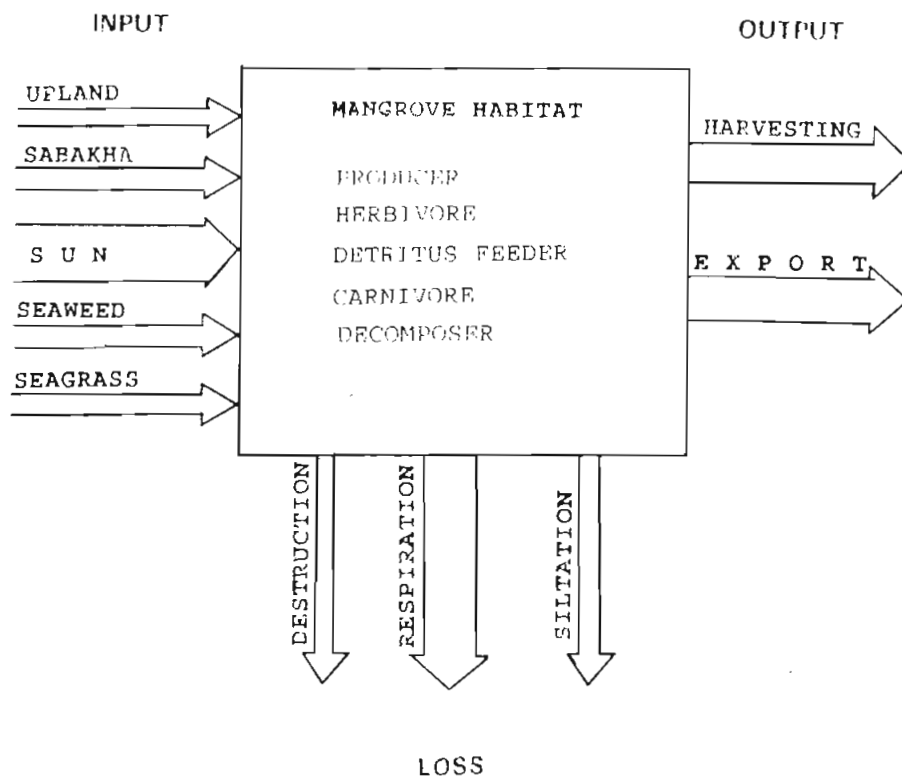
INPUT   OUTPUT

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UPLAND  ──────▶  ┌─────────────────────────┐   HARVESTING ▶
                 │  MANGROVE HABITAT        │  ───────────────▶
SABAKHA ──────▶  │                          │
                 │   PRODUCER               │
                 │   HERBIVORE              │  E X P O R T ▶
S U N   ──────▶  │   DETRITUS FEEDER        │  ───────────────▶
                 │   CARNIVORE              │
SEAWEED ──────▶  │   DECOMPOSER             │
                 │                          │
SEAGRASS ─────▶  └──────┬──────┬──────┬─────┘
                        │      │      │
                   DESTRUCTION RESPIRATION SILTATION
                        ▼      ▼      ▼
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LOSS

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

high salinity values and low winter temperatures.

General Discussion

Mangroves are known to occur preferably in deltaic regions of tropical and sub-tropical belt, but may also be found in unfavourable areas within the same belt as 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 values are very high, rivers non-existent, rainfall minimum, bottom hard and sea very oligotrophic. If the lagoons were absent, perhaps there would not have been a single tree in the area. They offer a depositional environment which allows a relatively soft bottom and some nutrient enrichment due to decomposition of organic matter, 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 that are not found anywhere else in the world. The sabakhas with profuse cyanobacterial growth and dense stands of large seedweeds in pools are such additional reservoirs 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 fixed nitrogen significantly in the mangrove forest of Sinai peninsula. Although the overall growth seaweeds is poor in the area (Walker, 1987), some seaweeds like *Sargassum dentifolim* and *Turbinaria triquetra* formed 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 *in situ* fixation of nitrogen.

Figure 1 depicts a hypothetical model of 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 ex-

port 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 utilization, like respiration, siltation and destruction. The last two mentioned may also be considered as stresses to the ecosystem. In Khor Farasans a large area of mangroves was totally destroyed for the construction of the port (Mandura and Khafaji, 1993). The width of the bars indicate the magnitude of the energy content which in the present case is only assumption as no empirical estimation has been made. It is, therefore, urged that energy flow through the ecosystem be worked out quantitatively on a priority basis, as this is the only effective way of managing and conserving it. Saifullah *et al.* (1989) has recently estimated the litter fall production in the area, which is certainly a significant step in this direction, as the food chain in mangrove system is supposedly based mainly on detritus (Odum, 1971).

It is unfortunate that nobody has as yet estimated the total area covered by mangroves in the area, although there have been localized attempts. Thus, Mandura *et al.* (1987) gave a figure of 25 km² for mangroves of the Jizan area between Al-Quz and Al-Sehi and Jaubert (pers. comm.) gave a figure of 1.01 km² for mangroves of Ras Hatiba. Mufti (1990) gave only dimensions of the mangrove stand of Shoaiba, that is a length of 3 km and a width of 38 m, which equals to 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 be carried out also on a priority basis. This is important for comparisons with other areas in the world and also for long-term planning for their conservation and management.

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 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 1. As stated earlier the substrate is hard, salinity values very high, rainfall and nutrients minimum 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 larger number of wadis. Temperature levels are always favourable at it is included in the tropical belt. The environmental conditions are also reflected

in the flora and fauna. Thus, the mangroves showed better growth in terms of size, density and width of the belt in south than in north. The typical mangrove animal, mudskipper, and the alga *Bostrychia tenella* were also present in the southern part only (Mandura *et al.*, 1987, 1988). Here also two species of mangroves were present as compared to one in south, and litter production was likewise higher (Saifullah *et al.*, 1989 and Khafaji *et al.*, 1991).

Avicennia marina was the most dominant species in the area. As a matter of fact it was the only species on the mainland, which shows its tolerance to extreme environmental conditions (MacNae, 1968). The other species *Rhizophora mucronata* occurred only in Farasan Archipelago (Mandura and Khafaji, 1993), which seems rather strange as it was absent from 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 very close to each other.

Another interesting point to note is that the growth of benthic and epiphytic algae was very abundant in the mangrove areas which implies maximum 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. Algae possess very high turnover rate and, therefore, may fix more solar energy than the mangrove plants (Rodriguez and Stoner, 1990). They are also eaten 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. The preponderance of algae also suggests nutrient replenishment in the otherwise very oligotrophic environment.

Acknowledgements

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النظام البيئي لمنجروف الساحل السعودي للبحر الأحمر
«استقصاء»

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قسم النبات – جامعة كراتشى – كراتشى ٧٥٢٧٠ – باكستان

المستخلص : تستعرض هذه الدراسة المعلومات التي سبق نشرها عن النظام البيئي لمنجروف الساحل السعودي للبحر الأحمر وما أبرزته من سلبيات وإيجابيات هذا النظام . كما توضح أن تركيب النظام البيئي للمنجروف الذي قد درس بشكل مفصل مع التركيز على بعض الصفات والخصائص المناخية المؤثرة في هذا النظام . ويستنتج من هذه الدراسة أن بعض الجوانب الوظيفية وبخاصة انسياب الطاقة من خلال النظام البيئي لازالت مهملة . كما أوضحت الدراسة أن الفلورا والفونا المصاحبة للنظام البيئي للمنجروف في هذه المنطقة يتعرض لظروف مناخية قاسية كالمستوى المنخفض من الغذاء ، والقيم العالية من الملوحة وكذلك القاع الصلب الذي تنمو عليه أشجار المنجروف وهذه جميعها من سمات هذه المنطقة .

كما أظهرت هذه الدراسة أن نمو المنجروف والتنوع النوعي له في المنطقة الشمالية للساحل السعودي ضعيف جداً وأن ظروف النمو في الجزء الجنوبي من المملكة أفضل نسبياً .

ومن مظاهر الجذب في النظام البيئي ما يكون مصحوباً بتصريف المواد العضوية من الأنظمة البيئية المجاورة خاصة الأعشاب البحرية والحشائش البحرية وأيضاً السبخات .

ويستفاد من هذه الدراسة أن النباتات العالقة أو الملتصقة بنباتات المنجروف وكذلك الطحالب القاعية المصاحبة للنظام البيئي للمنجروف تعتبر مصدراً آخر لتعويض نقص الغذاء في بيئة البحر الأحمر حيث أن هذه الكائنات تقوم بالتمثيل الضوئي بصورة إجبارية فيستفيد منها المنجروف .

وتقترح الدراسة نموذجا لانسياب الطاقة في النظام البيئي .