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Zonation and distribution of creek and fringe mangroves in the semi-arid Kenyan coast

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Abstract

Patterns of zonation and distribution of mangroves in relation to climate, hydrology and hydrographic factors are described. There are eight species of mangroves found along the semi-arid Kenyan coast where they may occur as creek or fringe mangroves. The climate along the Kenyan coastal belt is under the influence of two seasonal monsoonal winds, namely the South East Monsoon (SEM), which begins from April to October, and the North East Monsoon (NEM) from November to March. The rains are bimodal, the heaviest rainfall occurring in SEM (range 55 to 272 mm) and the second peak may appear in NEM (range 8 to 84 mm). The ranges of temperatures in SEM and NEM are 20–31°C and 23–32°C, respectively. There are only two permanent rivers and a few seasonal rivers. However, there is considerable discharge of underground water to the sea floor which creates the brackish water conditions required by mangroves. Geographically the bulk of the mangrove forest cover is found far away from the permanent rivers and in some cases at places without any surface flow. The latter areas, however, correspond to the areas receiving heavy discharges of underground water. The range at the Kenyan coast is wide (4 m), and it is therefore common to find zonation in creek mangrove. Based on the principal species, the mangrove zonation observed in an upward shore direction was as follows: *Sonneratia alba* J.Sm., *Rhizophora mucronata* Lam., *Ceriops tagal* (perr) C.B. Robinson, *Avicennia marina* (Forks.) Vierche and *Lumnitzera racemosa* Willd. However, *Avicennia marina* has the widest vertical distribution and almost exclusively occupies the salty flats.

Introduction

There are generally two types of mangrove formations along the Kenyan coast that are easily distinguishable. To use the terminology of Macnae (1968), these are creek and fringe mangroves. The creek mangroves are composed of mangrove trees that grow in low gradient shores in creeks and bays and are well developed forests that may show zonation of mangrove species. In Kenya it is common to see bare or barren areas surrounded by mangrove trees which are also called 'inversa' flats. These 'inversa' flats are common occurrence not only in Kenya but also in other places along the semi-arid East African coast (see Macnae 1968). Fringe mangroves, on the other hand, are solitary or a few clusters of trees which may be composed of a single or mixed species of mangroves growing in front or at the bases of rocky cliffs.

The semi-arid Kenyan coastline has a total of about 530 km^2 of mangrove forests (Doute *et al.* 1981). The mangrove forests along the Kenyan coast are faced with various types of anthropological impacts. The major villages at the Kenyan coast are found along the coastline in the vicinity of mangrove forests and this has been explained by the fact that the ready availability of freshwater from shallow water wells dug near the mangroves in this semi-arid zone tended to 'beckon' human settlements near these biotopes. In the hinterland the settlements were mostly along rivers or in low lying lands where the water table was high enough to allow the digging of wells, but this historical pattern of human settlements dictated by the availability of freshwater has recently changed due to the government's effort to provide piped water from major rivers and underground aquifers to the hinterland and along the entire coastline.

Although there is a change in the human settlement patterns along the Kenyan coast, the major villages have remained the nuclei of development of urban centres and municipalities. Thus, besides the continued exploitation of the mangroves for wood for building and fuel, uncontrolled disposal of sewage and solid wastes from the urban centres and industries also contribute to the degradation of mangrove ecosystems. Some areas of mangrove forest at some localities have been cleared for the construction of salt ponds and mariculture ponds for prawns. Due to increased human pressure, overcutting of mangroves for wood for fuel and building has caused depletion of the forests in some areas.

In appreciation of the roles of mangroves in nutrient cycles and giving shelter and food to various life stages of marine organisms (e.g. Field & Dartnall 1987) studies have been undertaken in Kenya on life stages of prawns by Brusher (1974), Grove *et al.* (1986), and Wakwabi (1988); and on young stages of fish by Grove *et al.* (1986). Some studies on macrofauna in mangroves have been undertaken by Icely & Jones (1978) and Ruwa (1990) and on macroalgae in mangroves by Coppejans & Gallin (1989). Kokwaro (1985) described the geographical distribution of mangroves and their economic importance, whereas Ruwa & Polk (1986) described their distribution in relation to salinity gradients caused by submarine groundwater discharges. Isaac & Isaac (1968) wrote taxonomic notes on the various mangrove species they found in Kenya. This paper presents and reviews some information on the zonation and distribution of creek and fringe mangroves along the Kenyan coast.

The Kenyan coast

The Kenyan coast (Fig. 1) has various protected creeks and bays but in some parts it is straight and exposed. Almost bare rocky shores exist but most of the coastline has abundant sediment deposits (sandy shores and even sand dunes) which are products of both marine and continental sediments since the Permo-Triassic to the present day. The reef is basically a Pleistocene fossil coral reef with partly fossil coralline algae (Hamilton & Brakel 1984) and the rocky shores and cliffs are fossilized raised reefs (Crame 1980, 1981).

Except for two permanent rivers, called R. Tana and R. Sabaki (Fig. 1), the rest are seasonal but the coastline has abundant underground water, which is mostly fresh water and which is frequently discharged into the sea from the aquifers (Ituli 1984). These create the brackish water conditions required by the mangroves. In Kenya the bulk of mangrove forest cover occurs in areas which have submarine underground water discharges rather than in estuaries (Ruwa & Polk 1986). Submarine groundwater discharges with low salinities, which may be as low as 6 ppt, have been encountered and after admixture with seawater (salinity 35–36 ppt) pools of low salinities ranging from 24 to 30 ppt are not uncommon during low tide in the lower intertidal zone (Ruwa & Polk 1986).

The major sea circulation patterns (Fig. 1) are determined by the northward flowing branch of the South Equatorial current (SEC) called the East African coastal current (EACC) (e.g. Newell 1957; Johnson *et al.* 1982). The latter is also known as the Somali current in Somalia. The Northward extent of the EACC is influenced by monsoonal winds, which are the South East monsoon (SEM), beginning from April to October, and the North East monsoon, beginning from November to March. During the NEM the EACC meets with the North Equatorial current (NEC), which is also called the reversed Somali current, to form the Equatorial counter current (ECC) around Lamu, the flow being seaward.

The Kenyan coast has a wide tidal range of about 4 m (Brakel 1982) and its climate is again influenced by the monsoonal winds. The rains are relatively heavier during the SEM and mostly fall around May/June whereas the lighter rains occur in NEM mostly around October/November but may sometimes fail. The mean ranges from 55 to 272 mm in SEM and from 8 to 84 mm in NEM. The SEM season tends to be cooler than the NEM season. The temperature ranges in SEM and NEM are 20–31° C and 23–32° C, respectively.

Materials and methods

Transect studies to describe the distribution and zonation of mangroves across the shores were undertaken at

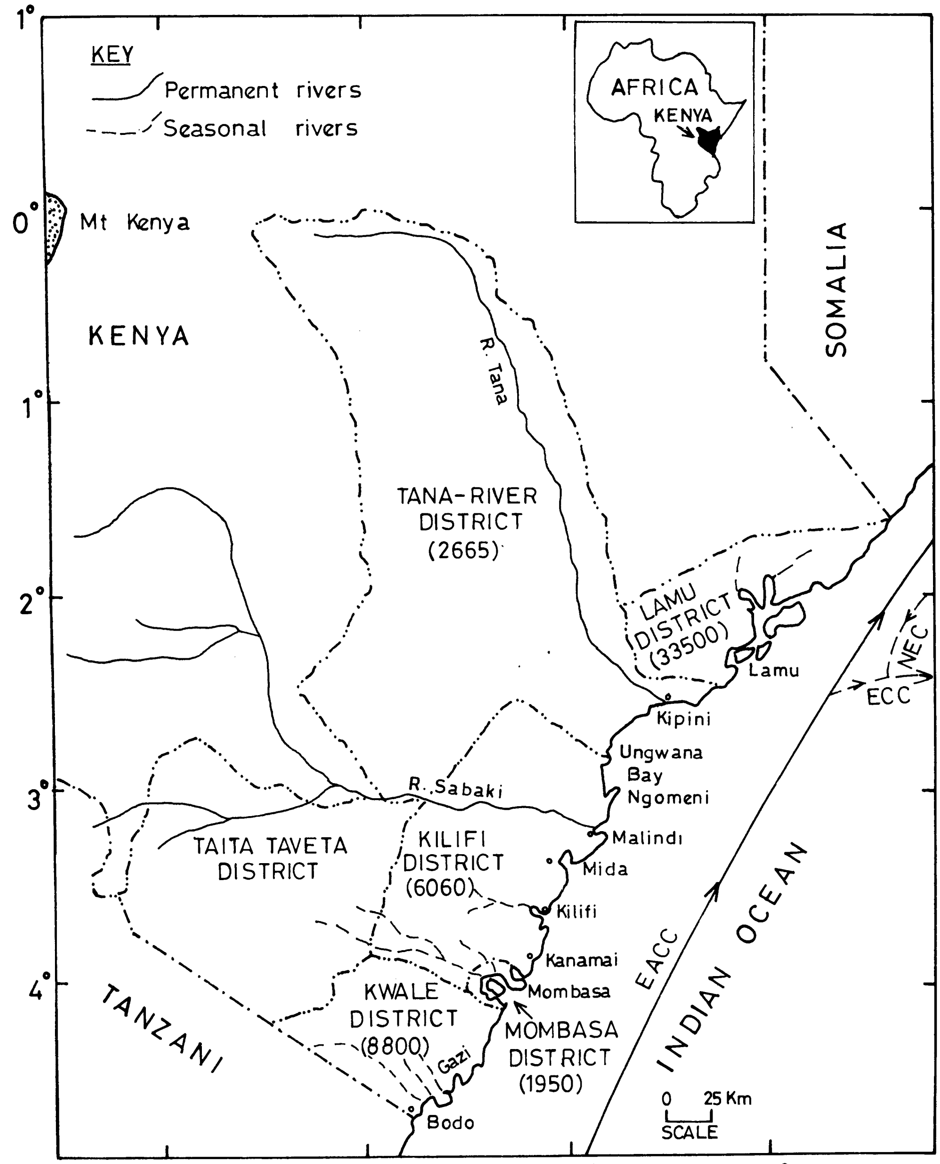

Fig. 1 Kenya coastline. The numbers in parentheses indicate the area of mangrove cover in hectares in each district.

Ngomeni, Mombasa (Mkomani) and Gazi (Fig. 1) between May and November 1989. Belt transects, 5 m wide, were sampled across the creek mangroves at Ngomeni and Gazi and in fringe mangroves at Mombasa (Mkomani) in contiguous 5 × 5 m blocks along the transect. Counts of the living mature mangrove trees of the

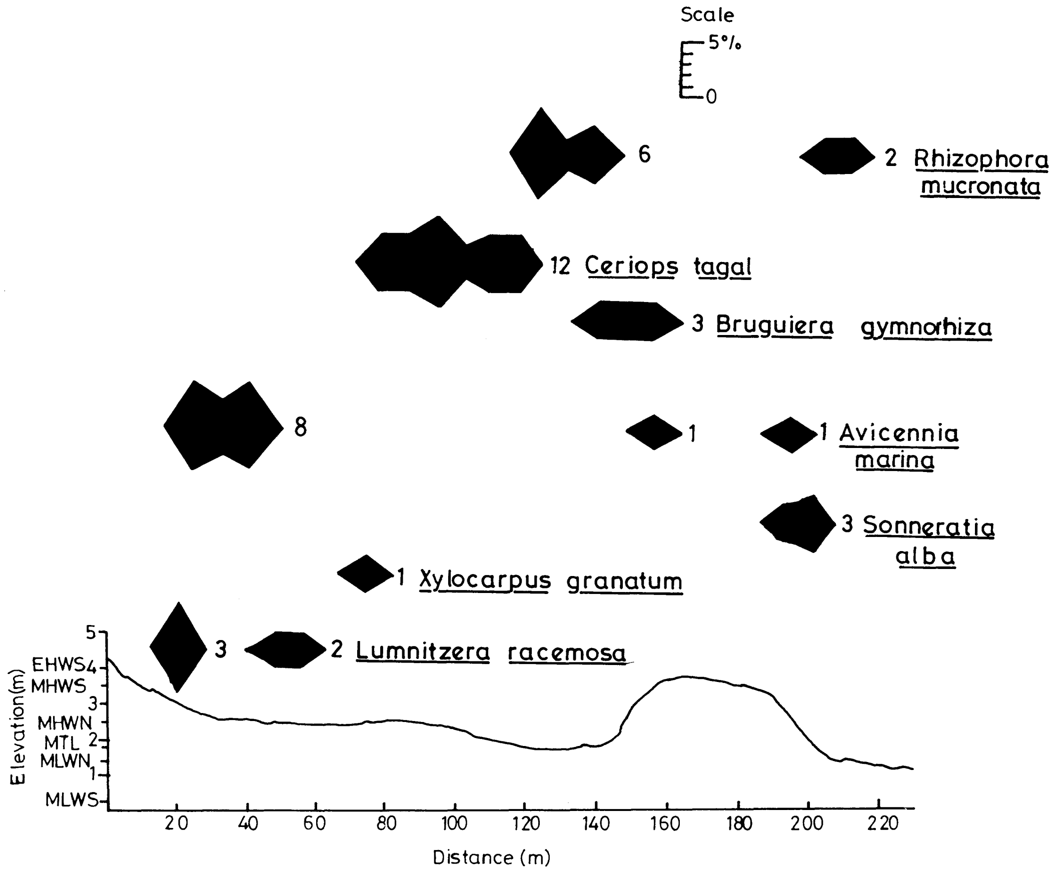

Fig. 2. Transect across a creek mangrove forest at Gazi.

various species encountered in each 5× 5 m block were made.

The profiles across the mangrove forest were described using the method described by Southwood (1965) and Day (1974) and the shore levels were calibrated in relation to the tide datum of Kilindini (Mombasa Port) by calculating the tide levels reached at reference marks along the transects during calm water, using the Kenya Ports Authority (1989) tide tables.

Results

From the transects studies (Figs 2, 3 and 4) the distribution of the various species may be zoned in creek mangrove formations. As deduced from the transect studies at Gazi and Ngomeni, more species of mangroves were rooted in lower shore levels than at higher shore levels. Except for *Avicennia marina,* which rooted both at lower and higher shore levels, the others were confined either to the lower or the higher levels. It was noted that even in gentle sloping swampy shores, the mangroves do not occupy the entire intertidal zone, but the lower limit was around the mean low water neap (MLWN) tide level, making a clear-cut demarcation of their seaward limit. Bare areas occurred in the higher shore levels, in the *Avicennia marina* zone. These areas were devoid of pneumatophores and were characteristically

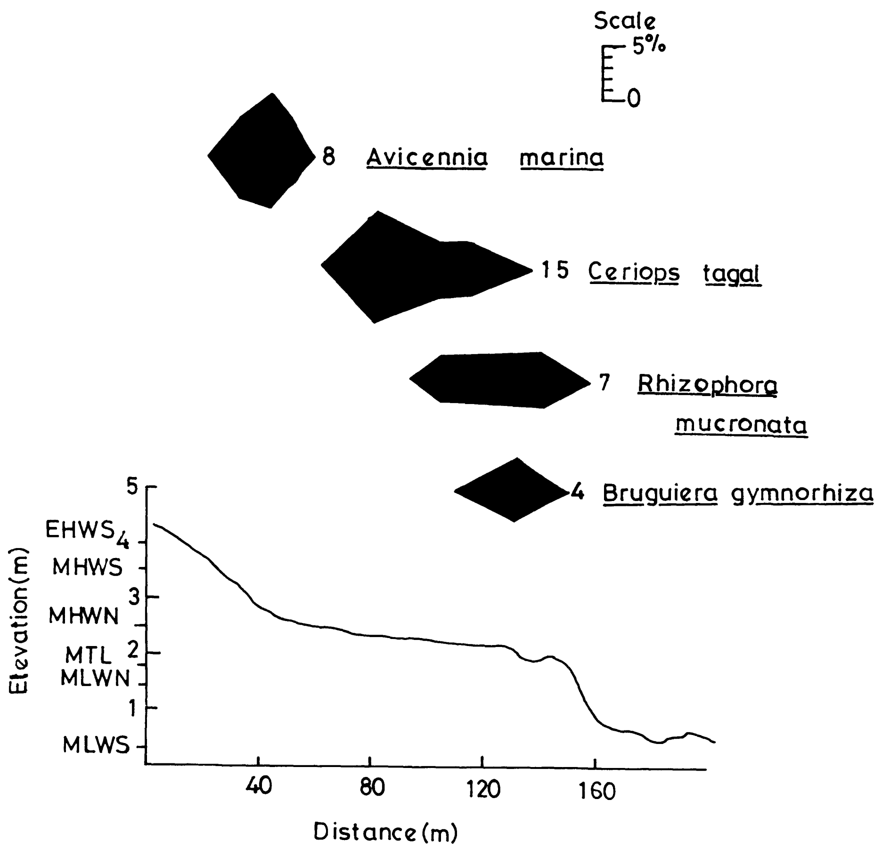

Fig. 3. Transect across a creek mangrove forest at Gazi.

covered with salty crusts around neap tide days when the high tides cannot reach the higher shore levels. The zonation in an upward shore direction based on the prominent species was as follows: either *Rhizophora mucronata* or *Sonneratia alba* was the outermost species, followed by *Ceriops tagal* in the intermediate shore levels, and then *Avicennia marina.* On the outermost landward parts of the *Avicennia marina* zone at higher shore levels conspicuous fringes of *Lumnitzera racemosa* may be encountered. The lower shore level *Avicennia marina* are more robust than the higher level ones, which are stunted.

In the fringe mangrove formation, the mangroves are rooted in coral substrate with only superficial sediments which can hardly cover the root system. At the Mombasa (Mkomani) site, which faces the open sea, the fringe mangrove had two species only, *Sonneratia alba* and *Avicennia marina*, the former being the most predominant species. The *Avicennia marina* grew in the landward zone of the *Sonneratia alba* (Fig. 5). At Mombasa (Bamburi) the fringe mangrove was partially sheltered from the open sea by an arch-shaped protruding cliff, and the species of mangroves that grew behind this cliff were: *Rhizophora mucronata, Avicennia marina, Sonneratia alba, Bruguiera gymnorrhiza* and *Ceriops tagal;* but these were haphazardly intermingled. No transect study was undertaken because the mangroves were clearly intermingled. At Mkomani, the mangroves at Bamburi rooted themselves in a coral substrate with superficial deposits of sediments.

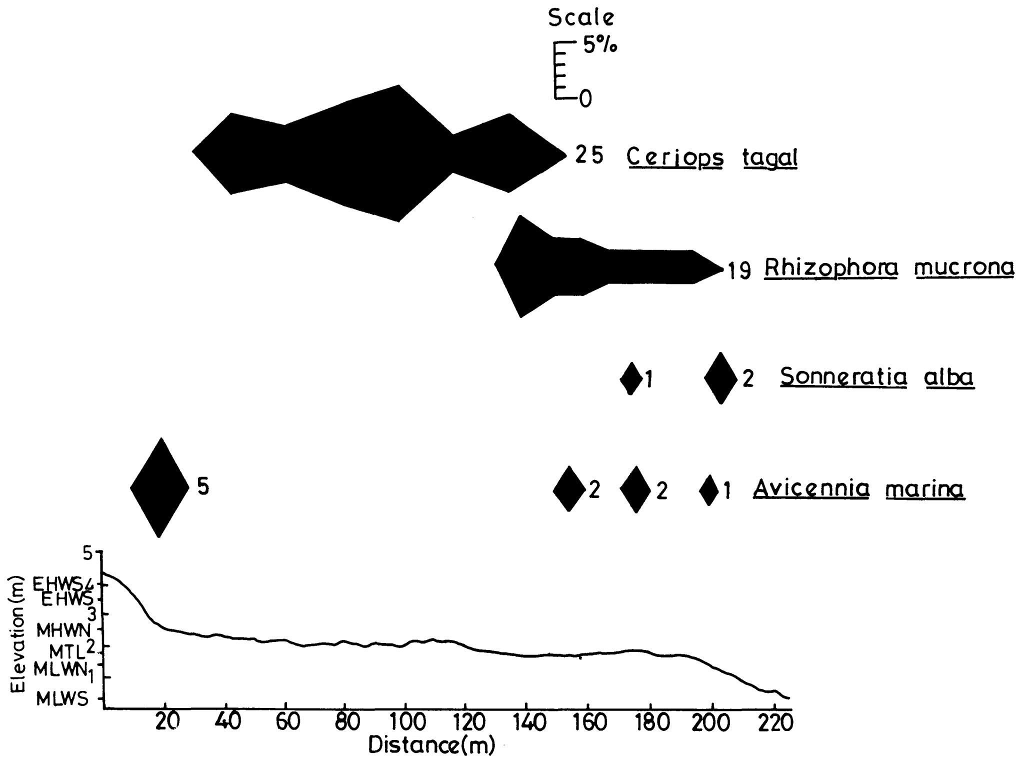

Fig. 4. Transect across a creek mangrove forest at Ngomeni.

Discussion

The distribution and zonation of any organism is dictated by various biotic and abiotic factors and their complex interactions (Odum 1971). For mangroves, the abiotic factors, such as temperature, coastal geomorphology, currents, salinity and substrate, are the important factors that profoundly influence the distribution and occurrence of mangroves (e.g. Chapman 1977). The impact of these factors, however, are different at different stages of the mangrove life cycles: i.e., embryos, seed, seedlings, young plants and adult seed or embryo-producing plants. It is thus inadequate to describe the environment required by mangroves on the basis of mature mangrove tree stands only because they cannot accurately define the past environment which suited the setting and subsequent growth of the seeds or embryos which gave rise to them. It is known that adult mangrove trees may change the microenvironment and make it either unsuitable for setting seeds or embryos of its own species comprising the mangrove stand, or make it suitable for setting of seeds or embryos of other species, different from those of the mangrove stand. Mangrove trees encourage the build up of sediment and these raise the shore levels, which consequently changes the salinity regimes. The work presented here was based on studies on mature mangrove trees and therefore the following discussion should be read bearing in mind what has been stated above.

The coastal geomorphology influences the nature of the mangrove formation. The creek and fringe mangrove formations are due to differences in geomorphological features of the coastline. It was observed that the creek mangroves which grow in environments sheltered from heavy wave action and in low gradient shores exhibited zonation. Going in an upward shore direction

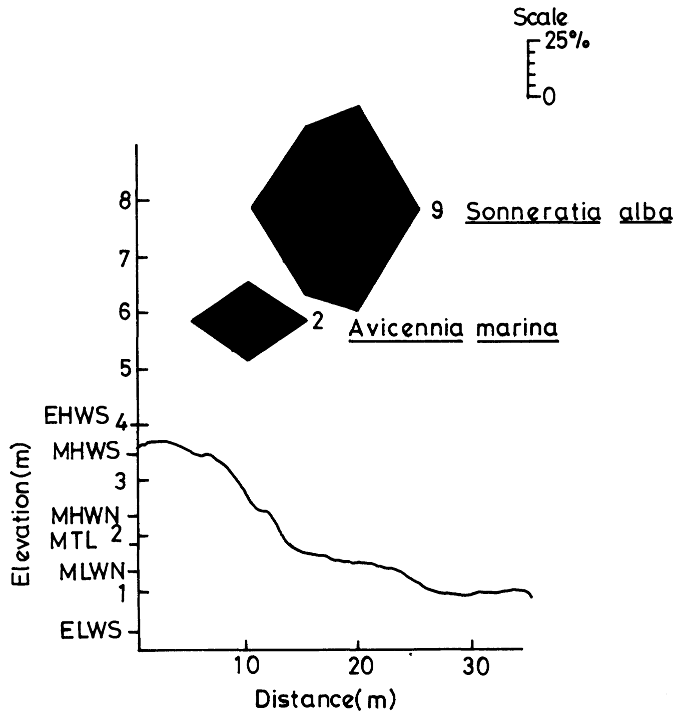

Fig. 5. Transect across a fringe mangrove formation at Mkomani (Mombasa).

the zonation is as follows: *Sonneratia alba, Rhizophora mucronata* or *Avicennia marina* may be the outermost seaward zone, followed by a *Ceriops tagal* zone in the intermediate levels, then by an *Avicennia marina* zone at the higher shore levels, and lastly *Lumnitzera racemosa,* which usually occurs as a small fringe after the *Avicennia marina* zone, may form the outermost landward zone. But in most cases the major outermost seaward zone is of *Rhizophora mucronata;* at the intermediate levels, *Ceriops tagal* forms a zone, whereas the major landward shore one is of *Avicennia marina.* The pattern of mangrove zonation in creek mangrove formation in the Western Indian Ocean is *Sonneratia alba, Rhizophora mucronata, Ceriops tagal, Avicennia marina* in an upward shore direction, but since *Sonneratia alba* is uncommon in some shores it follows that the zonation often starts with *Rhizophora mucronata* as the outermost seaward zone (Macnae & Kalk 1962; Macnae 1968, 1971; Hartnoll 1975).

The major species in the Kenyan coastline show a similarity to the zonation pattern described earlier for the Western Indian Ocean region where the tidal range is similar.

The other species of mangrove occur in the major zones. *Bruguiera gymnorrhiza* occurs frequently in the *Rhizophora* zone, whereas *Xylocarpus granatum* frequently occurs in the intermediate zone of *Ceriops tagal. Lumnitzera racemosa* is frequently encountered in the higher *Avicennia marina* zone. This is again in general agreement with other observations done in the Western Indian Ocean, where the tidal range is almost similar to that of Kenya (see Macnae 1968, 1971). A further species of mangrove, *Heritiera littoralis,* is very localized in its distribution and is found as a pure small stand at the estuary of R. Tana near Kipini.

The most common genera in the mangrove world are *Rhizophora* and *Avicennia* (Chapman 1977). According to Macnae (1968, 1971) the same two genera are most common in the Western Indian Ocean and are represented by the species *Rhizophora mucronata* and *Avicennia marina*, which is similar to the Kenyan case. *Rhizophora mucronata* is a non-salt secreting plant although it is known that its roots exclude much salt from entering the plant; however, their poor efficiency may be the reason that excludes it from occuppying the higher shores where the salinities are higher. In Kenya, the lower shore levels preferred by *Rhizophora mucronata* receive considerable discharges of fresh water from the underground aquifers which therefore help to maintain the low salinity brackish water conditions required by the mangroves where there are no rivers or in dry seasons when the seasonal rivers are dry (Ruwa & Polk 1986). On the other hand *Avicennia marina* is a salt secreting plant which is therefore more tolerant to highly salt water, allowing it to occupy almost the entire shore levels where mangroves can grow, but it is a poor competitor on the lower shore levels. The stress factor caused by salt gradients across the shore may be appreciated from the evidence of stunting of *Avicennia marina* at higher shore levels but individuals of the same species being robust and taller at the lower levels. Where conditions are too salty, e.g. on the salty flats at the high shores, such areas lack mangrove trees (Macnae 1968). It has been observed (pers. obs.) that during the long rains in the SEM several seedlings of *Avicennia marina* grow on the bare flats when salinities are low, but when the drought conditions set in during the hot dry season in NEM, the young mangroves die, leaving the flats devoid of mangroves.

Fringe mangrove formations are a common feature on high wave energy coastlines and high gradient shores in the Western Indian Ocean, both around the islands and the coasts of the African mainland (Macnae 1968, 1971). They do not show zonation, although they may be composed of various species of scattered individuals or lines along the bases of cliffs where submarine ground water discharges occur to cause the brackish water conditions. In some cases, they form almost a pure stand of one species: e.g. the Mkomani (Mombasa) Kenyan site is almost a pure stand of *Sonneratia alba.*

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