The Effects of Habitat Complexities Created by Mangroves on Macrofaunal Composition in Brackishwater Intertidal Zones at the Kenyan Coast

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Introduction

The semi-arid Kenyan coastline has a total of about 52,980 hectares of mangrove forests (Doute *et al.*, 1981). The bulk of these forests occur in intertidal areas where submarine groundwater discharge (SGD) or seepage occurs rather than in estuaries (Ruwa and Polk, 1986). Mangrove forests in Kenya are currently being heavily exploited (Kokwaro, 1986) especially in urban areas where they are under environmental stress due to uncontrolled disposal of domestic and industrial wastes in the vicinity of the forests. Unfortunately, as these activities continue, there is still scanty published ecological information on macrofaunal composition in mangrove ecosystems in Kenya which could be used to initiate conservation strategies. The only published study on macrofauna in mangrove ecosystems in Kenya is by Icely and Jones (1978) based on the ecology of crab species of genus *Uca*. The present study evaluates the role of mangroves in influencing macrofaunal composition, by considering the variety of littoral biotopes (Fig. 1)

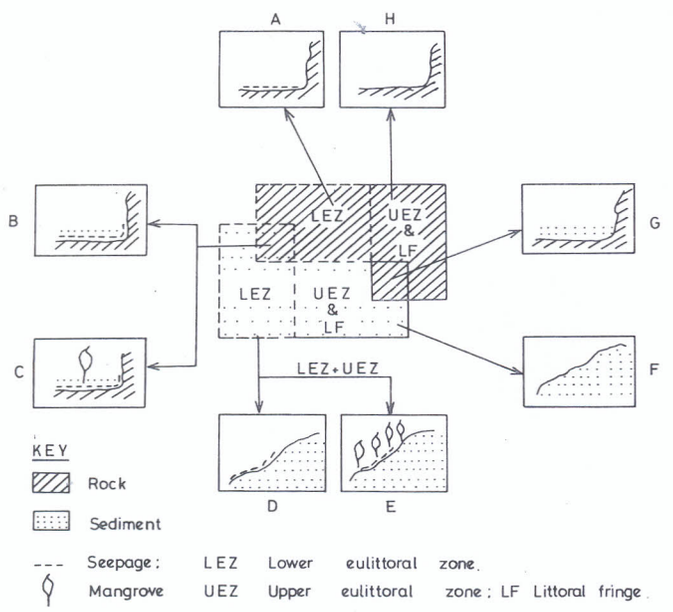

Figure 1. Types of littoral biotopes at the Kenyan coast; terminology as in Lewis (1964) and Hartnoll (1976). A, B, C, D and E are brackishwater biotopes which receive submarine groundwater discharges but the types F,G, and H do not. A, B, C, G, and H are rocky shores whereas D, E, and F are sandy shores.

found along the Kenya Coast.

The presence or absence of an organism in a biotope is dictated by various biotic and abiotic factors acting on an organism (Odum, 1971). In the littoral zone, the prominent abiotic factors are tidal fluctuations, currents, wave action, temperature, salinity, aeration, underground water table fluctuation, sediments and drainage (Clarke and Hannon, 1969). The prominent biotic factors are predation, interspecific and intraspecific competition (e.g. Connel, 1972). All of these interact in a complex way and determine the species composition in the littoral biotopes, i.e., rocky shores, sandy beaches and mangrove swamps. Indeed, the differences in intensities and magnitude of the abiotic factors, especially wave action and currents, make these littoral biotopes distinctly different as have been historically treated (Lewis, 1964; Southwood, 1965; Chapman, 1977; Field and Dartnall, 1987). The role of mangroves can be summarized as follows:

1. Their wood should be considered as a hard substrate like rocks where organisms specialized to inhabit hard substrates can occupy.

2. The type of environment in which the mangroves grow, establish and develop, i.e., littoral estuarine or brackishwater, like any other estuarine or brackishwater biota, depends on the estuarine or brackishwater conditions.

The brackishwater biotope may either be swampy, if there are sediment deposits, or bare rocky surfaces, where SGD or seepage occur (Fig. 1). There are brackishwater beaches without mangroves, plus a variety of mangrove associations ranging from solitary trees to forests in Kenya (Ruwa and Polk, 1986). Other beaches have been left bare after total clearing of the mangroves and what remains in the sediments is the mangrove peat. This has created a heterogenous environment which could strongly influence species composition and offers opportunities to describe the role of mangroves in species composition.

Materials and methods

A total of 8 transects were sampled. The profiles of the transects are shown in Fig. 3. The studies were carried out at Ngomeni, Malindi, Kanamai, Mombasa (Bamburi and Mkomani) and Gazi (Fig. 2) between

April 1986 and February 1987. The Ngomeni mangrove forest has been partly cleared for salt farming and prawn cultivation while the Gazi mangroves are being exploited for wood both for building and fuel. These forests are the types referred to as creek mangroves (Macnae, 1968). They are well developed and show zonation of mangrove species. The mangroves at Mkomani, Bamburi and the lone mangrove at Kanamai are fringe mangroves, the latter being isolated on rocky cliffs.

Malindi and Kanamai provided the isolated brackishwater beaches without mangrove trees since the closest mangrove forests were several kilometers away from these study sites. Studies on beaches with mangrove peat were undertaken at Gazi and Ngomeni. The distribution of the benthic macrofauna was studied by sampling in 5x5m consecutive blocks in 5m wide transects across the beaches and mangrove forests. The profiles were described according to Southwood (1965) and Day (1974). The shore levels were calibrated in relation to tide levels (Kenya Ports Authority, 1986;1987), tide tables. The tide levels reached at reference marks along each transect were calculated. The calculated conventional tide marks according to Brakel (1982) were the mean high water spring (MHWS) 3.5m; mean high water neap (MHWN) 2.4m; mean tide level (MTL) 1.9m; mean low water neap (MLWN) 1.4m; and mean low water spring (MLWS) 0.3m. Where necessary, the sediment was passed through a sieve of 1mm mesh and the macrofauna removed.

The arboreal macrofauna were also caught and recorded. The relevant identification guides for the macrofauna in this region (Barnard, 1960; Crosnier, 1962; 1965; Spry, 1964; 1968; Barnes, 1970; Serene, 1973; Oliver, 1981; Richards, 1984) were used in addition to help from experts who have worked in this region, especially J.D. Taylor (British Museum) on molluscs and P. Siegel (University of Dar es Salaam) on crabs. The identification of the mangroves was according to Isaac and Isaac (1968), who also worked in this region.

Results

Seepage or SGD into the intertidal zone occurred at all the six localities. The creek mangroves and the beach with mangrove peat had the highest numbers of species of benthic macrofauna (Table 1). The sediments under the fringe mangroves had the least number of species. Eight species occurred only in the creek mangrove forests (Fig. 4a). These were *Uca gaimardi, Sesarma meinerti, S. ortmanni, S. eulimene, Sarmatium crassum, Cardisoma carnifex, Cassidula labrella* and *Cerithedia decollata*. The beach with mangrove peat had the highest number of species in common with creek mangroves (Fig. 4a). These species

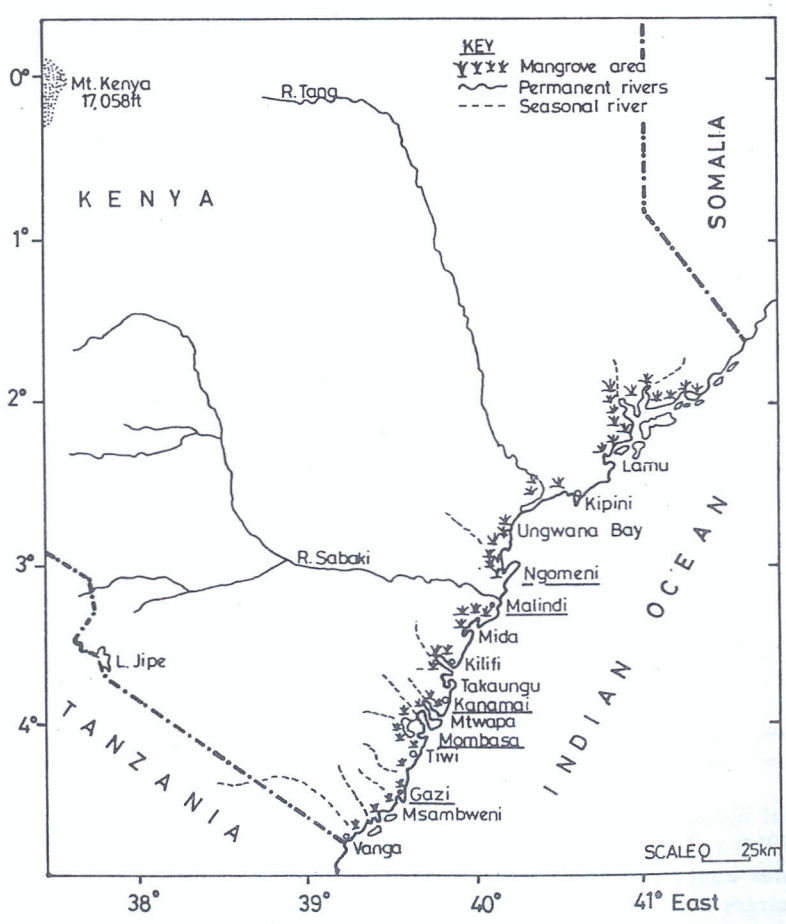

Figure 2. Map of the Kenyan coast showing the study areas underlined: Ngomeni, Malindi, Kanamai, Mombasa and Gazi.

were: *Uca lactea, U. inversa, U. urvillei, U. vocans, Macrophthalmus depressus, Sesarma guttatum, Eurycarcinus natalensis, Epixanthus dentatus, Terebralia palustris, Thalamita crenata, Scylla serrata* and *Ilyograpsus paludicola.*

The species which occurred in both the beaches with mangrove peat and those without peat were: *Uca vocans, Macrophthalmus parvimanus, M. milloti, M. grandidieri, Nassarius fenwecki, Natica qualtierana, Thalamita crenata* and *Scylla serrata* (Fig. 4b). Five species were seen only in the biotope with mangrove peat. These were, *Nassarius coronatus, Polinices mamilla, Thalamita gatavakensis, Nerita polita* and *Strombus mutabilis* (Fig. 4b). Five other species seen only in the beach without peat were *Macrophthalmus bosci, Nassarius arcularius, N. margaritifera, Strombus gibberulus* and *Dotilla fenestrata.* None of the species encountered was found only in the fringe mangroves (Fig. 4c). The fringe mangroves had the highest number of arboreal species most of which were also found on rocky cliffs. Two species, *Branchiodontes variabilis* and *Cerithedia decollata,* were only found on creek mangroves (Table 2; Fig. 5). The range of the vertical distribution of the various benthic macrofauna are diagrammatically presented in Fig. 6.

Discussion

There have been various attempts to find out whether there is a distinct and characteristic mangrove macrofauna caused by the presence of the trees that is not just dependent on the brackishwater environment upon which trees also depend (Macnae, 1968; Warner, 1969; Frith *et al.*, 1979). Macnae (1968) found no distinct and characteristic mangrove macrofauna. However, Warner (1969) stated that a distinct and characteristic mangrove macrofauna existed. Other subsequent studies (Frith *et al.*, 1979) supported Warner's view. The views of Macnae (1968) seemed to have been affected by lack of enough supportive evidence.

Comparisons of the faunal composition in the various biotopes (Fig. 1) have shown that a distinct and characteristic mangrove macrofauna existed only in the creek mangroves. The creek mangrove forests and the beaches with mangrove peat offer habitats to the highest numbers of benthic species. For some species, the creek mangrove forests may be considered as habitat refuge, however, others, like *Uca gaimardi, Sesarma meinerti, S. ortmanni, S. eulimene, Sarmatium crassum, Cardisoma carnifex, Cassidula labrella* and *Cerithedia decollata,* were confined to creek mangroves. These could be termed as creek

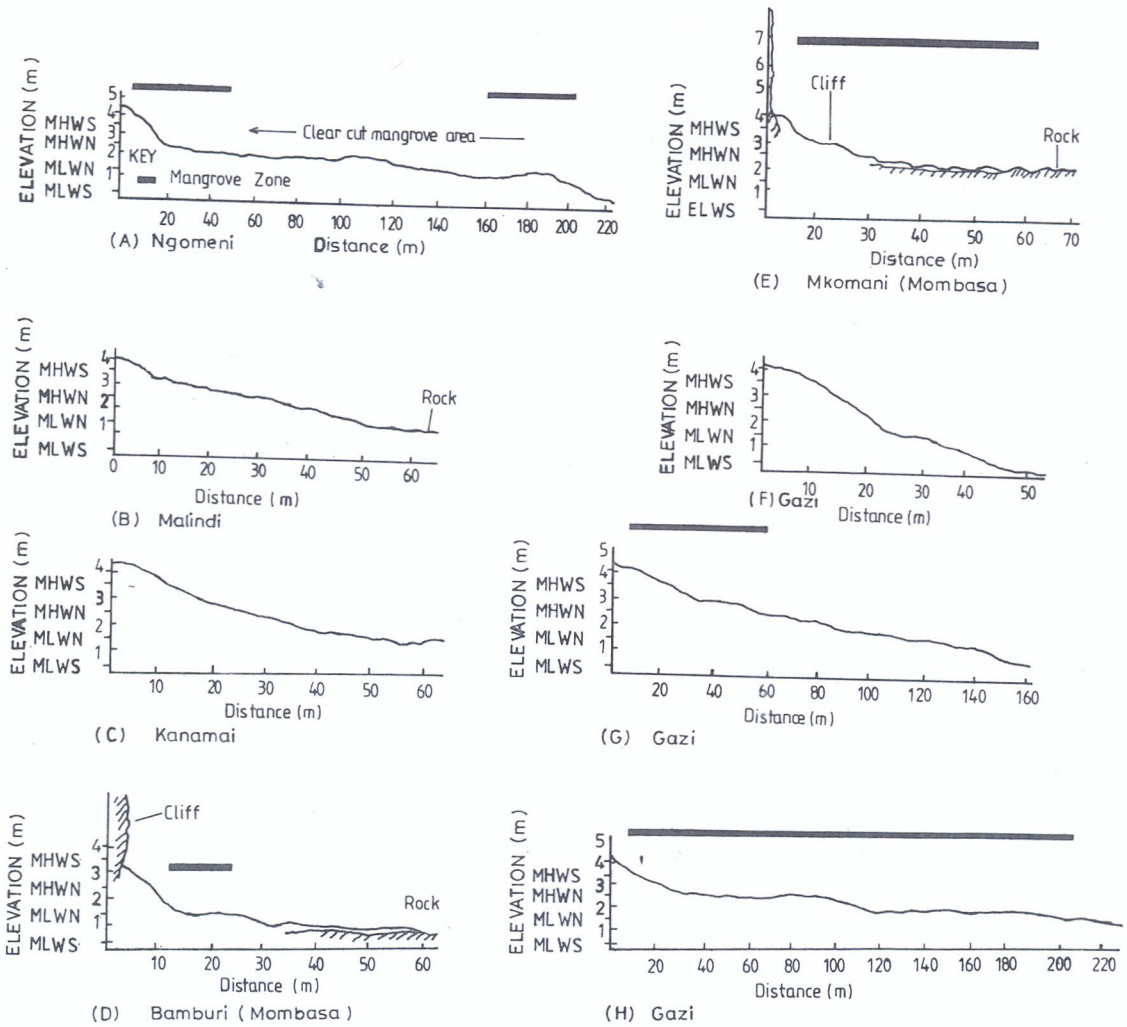

Figure 3. Profiles of the transects studied across the mangrove forests and beaches.

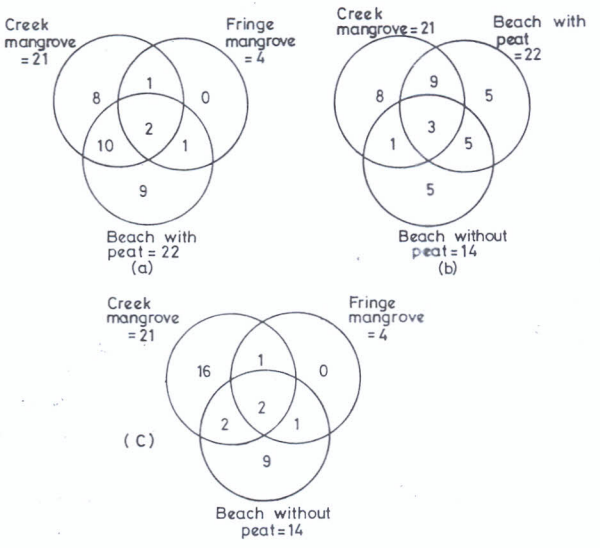

Figure 4. Comparison of benthic species distribution by number in creek mangroves, fringe mangroves, beaches with and without mangrove peat

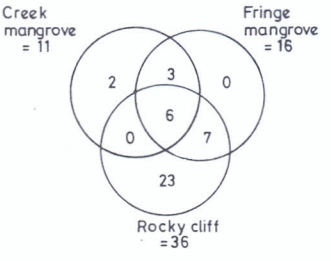

Figure 5. Comparison of arboreal species distribution by numbers on creek mangroves, fringe mangroves and rocky cliffs.

mangrove forest species since their presence depends on mangroves. At Inhaca (Mozambique), *Sesarma meinerti, S. quttatum, S. eulimene, Cerithedia decollata* and *Cassidula labrella* occurred in mangrove forests (Macnae and Kalk, 1962a). Taylor (1968) found *Cardisoma carnifex* burrows within mangroves at Mahe, Seychelles. Creek mangroves have to be carefully exploited to avoid loss of habitat to species that are restricted to these types of mangroves.

The species which commonly occur in the creek mangroves and beach with mangrove peat can be considered as mangrove related species. Their presence depends indirectly on the occurrence of mangroves. These were *Uca lactea, U. inversa, U. urvillei, Macrophthalmus depressus, Eurycarcinus natalensis, Epixanthus dentatus, Terebralia palustris* and *Illyograpsus paludicola*. At Mahe, Seychelles, Taylor (1968) also observed that the distribution of

() = Total number of organisms caught for each species
*** = Organisms occurring only in creek mangroves.
** = Organisms encountered both in open shores and mangrove forests.

Figure 6. Disgrammatic presentation of the range of vertical distribution of benthic macrofauna in brackishwater biotopes.

Uca lactea and *Terebralia palustris* extended from the mangroves to the beaches where the mangroves had been clear cut. Taylor (1971) recorded *Terebralia palustris* occurring outside the mangrove cover at Aldabra, but its distribution extended into the mangroves. At Inhaca (Mozambique) Macnae and Kalk (1962a) found *Uca lactea, U. inversa, U. urvillei, Macrophthalmus depressus, Eurycarcinus natalensis* and *Terebralia palustris*, both in shaded and unshaded areas of the mangrove forests.

The species which occurred in beaches with mangrove peat, whose distribution did not extend to the mangrove forest, were not directly or indirectly mangrove related species; in fact, their distribution extended in a seaward direction, away from the mangroves. They were, therefore, grouped with the species found in beaches without peat. This group was comprised of *Nassarius coronatus, N. arcularius, N.*

Table 1. List of species of benthic macrofauna in creek mangroves, fringe mangroves, beach with mangrove peat and beach without mangrove peat.

Species (Family: Ocypodidae)	Creek Mangrove	Fringe mangrove	Beach with peat	Beach without peat
Uca lactea de Haan	+	+	+	–
U. vocans Linnaeus	+	+	+	+
U. tetragonon (Herbst)	+	+	–	+
U. inversa (Hoffmann)	+	–	+	–
U. gaimardi (Milne Edwards)	+	–	–	–
U. urvillei (H. Milne Edwards)	+	–	+	–
Dotilla fenestrata Hilgendorf	–	–	–	+
Macrophthalmus parvimanus Guerin	–	+	+	+
M. milloti Crosnier	–	–	+	+
M. bosci Audouin & Savigny	–	–	–	+
M. depressus Ruppel	+	–	+	–
M. grandidieri A. Milne Edwards (Family: Grapsidae)	–	–	+	+
Sesarma meinerti De man	+	–	–	–
S. ortmanni Crosnier	+	–	–	–
S. eulimene De man	+	–	–	–
S. guttatum A. Milne Edwards	+	–	+	–
Ilyograpsus paludicola (Rathbun)	+	–	+	–
Sarmatium crassum Dana (Family: Gecarcinidae)	+	–	–	–
Cardisoma carnifex (Herbst) (Family: Portunidae)	+	–	–	–
Thalamita crenata (Latreille)	+	–	+	+
T. gatavakensis Nobili	–	–	+	–
Scylla serrata (Forskal) (Family: Xanthidae)	+	–	+	+
Episanthus dentatus White	+	–	+	–
Eurycarcinus natalensis (Krauss) (Family: Potamididae)	+	–	+	–
Certhedia decollata Linnaeus	+	–	–	–
Terebralia palustris (Linnaeus) (Family: Ellobidae)	+	–	+	–
Cassidula labrella Desh. (Family: Nassaridae)	+	–	–	–
Nassarius fenwecki Kilburn	–	–	+	+
N. arcularius (Linnaeus)	–	–	–	+
N. coronatud (Bruguire)	–	–	+	–
N. margaritifera (Dunker) (Family: Strombidae)	–	–	–	+
Strombus gibberulus Linnaeus	–	–	–	+
S. mutabilis Swainson (Family: Naticidae)	–	–	+	+
Natica gualtierana (Petit)	–	–	+	–
Polinices mamilla (Linnaeus) (Family Neritidae)	–	–	+	–
Nerita polita Linnaeus	–	–	+	–
TOTAL	21	4	22	14

Note: + indicates where the organism was seen.

margaritifera, N. fenwecki, Polinices mamilla, Nerita polita, Strombus mutabilis, Natica qualtierana, Macrophthalmus bosci, M. grandidieri, M. milloti, M. parvimanus, Dotilla fenestrata, swimming crabs *Thalamita crenata, T. gatavakensis* and juveniles of *Scylla serrata.* The adults of the *Scylla serrata* were most frequently encountered in burrows in the creek mangrove forests. Elsewhere some of these species have also been recorded in open shores outside mangroves. At Inhaca, Mozambique *Dotilla fenestrata, Macrophthalmus grandidieri, M. bosci, Uca vocans* and *Polinices mamilla* were recorded on open sand beaches (Macnae and Kalk 1962b). Taylor (1968) similarly found

Table 2. List of species of arboreal macrofauna on creek and fringe mangrove trees.

Species (Family: Littorinidae)	Creek Mangrove	Fringe Mangrove
Littorina scabra (Linnaeus)* (Family: Potamididae)	+	+
Cerithedia decollata (Linnaeus) (Family: Neritidae)	+	–
Nerita textilis Dillwyn*	–	+
Nerita albicilla Linnaeus* (Family: Thaisidae)	+	+
Thais aculeata Deshayes*	–	+
Morula fenestra (Blainville)*	+	–
Thais savignyi Deshayes* (Family: Ostreidae)	–	+
Crassostrea cucullata Born* (Family: Mytilidae)	+	+
Branchiodontes variabilis Krauss (Family: Isognomidae)	+	–
Isognomon dentifer Krauss* (Family: Chthamalidae)	–	+
Euraphia withersi Pilsbry* (Family: Balanidae)	+	+
Balanus amphitrite Darwin (Family: Grapsidae)	+	+
Metopograpsus messor (Forskal)	+	+
Geograpsus stormi de Man*	–	+
Sesarma elongatum (H. Milne Edwards)*	+	+
Sesarma impressum (H. Milne Edwards) (Family: Xanthidae)	+	+
Eriphia laevimanus Guerin*	–	+
Eriphia smithi Mcleay*	–	+
TOTAL	11	16

Note: + indicates where the organism was seen.
* indicates species which also occur on rocky cliffs (Ruwa, 1984)

Macrophthalmus parvimanus and *Nassarius arcularius* on open beaches at Mahe, Seychelles. The latter species also occurred on a beach where the mangrove had been cleared. At Aldabra, Taylor (1971) recorded *Macrophthalmus parvimanus* on sand beaches away from mangroves. Chelazzi and Vannini (1980) found *Strombus gibberulus, Nassarius arcularius, N. coronatus, N. margaritifera, Polinices mamilla* and *Natica qualtierana* in open muddy sand shores at Bender Mtoni, Somalia.

The paucity of benthic species under the fringe mangrove may have been due to the unstable nature of the thin layers of sediments which were under constant erosion and deposition, depending on the strength of the wave action. The benthic macrofaunal composition was transitional. It was composed of both mangrove related species, for example, *Uca lactea*, and non-mangrove related species, for example, *Uca vocans, U. tetragonon* and *Macrophthalmus parvimanus*.

The fringe mangroves had more arboreal species than creek mangroves because the former grow in the vicinity of rocky shores and therefore rocky shores fauna fortuitously obtained surfaces on which to attach or cling. *Branchiodontes variabilis* can be found on rocky shores (Taylor, 1971). The arboreal fauna in creek mangroves was found mostly on trees at the seaward edges. The trees, which commonly occurred around the seaward edges, were *Sonneratia alba* J. Smith and *Rhizophora mucronata* Lamk. These types of mangroves supported the highest densities of the edible oyster *Crassostrea cucullata* and other arboreal fauna. The edible oyster *Crassostrea cucullata* formed an important shell-fishery.

Unfortunately, due to the fact that the two species of mangroves provided better wood for building and fuel, they are heavily exploited, thereby destroying the oyster fishery as well. For the continuity of this fishery and preservation of arboreal species, it is important that the cutting is controlled and mangroves at the seaweed edges of the creek, especially *Rhizophora mucronata* and *Sonneratia alba*, are not destroyed. The surfaces or barks of the two species of mangroves are firm and do not fall off easily for years, therefore, not only do they allow theoysters to grow large sizes, but also allow other arboreal fauna to live long enough to breed.

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