ZONATION OF SPECIES AND MICROHABITATS IN MANGROVES OF NEGOMBO LAGOON

BY

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Affectionately Dedicated

To

My ever loving Parents

And teachers

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ABSTRACT

Mangroves are an extremely important coastal resource both economically and environmentally. In most of natural mangrove areas (large and undisturbed mangrove areas) it is observed that there is distribution pattern. The zonation pattern affects for generate the microhabitats within the mangroves such as fungi, algae, epifauna in root system, as well as macro benthos, soil macro fauna and etc.

Objectives of this project were to identify the major factors that affect of zonation pattern in mangroves and study the functional inhabition in microhabitats in various zones of Kadokele mangrove reservoir of Negombo lagoon.

Physical and chemical factors affecting for the zonation was studied in three major zones such as *Avicennia*, *Lumnitzera* and *Rhizophora*.Microhabitats for infauna (macro benthos) and epifauna (crabs) were studied in all three zones and attempts were made to get a relationship between diversity of microhabitats and faunal density.

Minimum pH was 4.54 – 4.77 which was observed in the water front zone of the *Avicennia* zone. Maximum pH was observed in the inland location of the *Lumnitzera* zone (6.56 – 7.00). Minimum salinity was observed *Lumnitzera* zone while maximum salinity was observed in *Avicennia* zone. Maximum carbon content was observed in the location II of the *Avicennia* zone and minimum carbon content was observed in the location I of the *Lumnitzera* zone more tidal inundation was experienced in *Avicennia* zone. Most diverse microhabitats were recorded in the water front zone of *Avicennia* for both epi fauna and infauna.

Major factors affecting zonation of mangroves of Kadolkele mangrove reservoir of Negombo lagoon are soil salinity, soil pH, soil texture and tidal influence. Water front location of *Avicennia* zone provides more microhabitats for macro benthos while epifauna such as crabs were much prominent in both *Avicennia* and *Lumnitzera* zones. Microhabitats for such epifuanal species have being created according to the behavioral patterns of the same animals.

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ABBREVIATION

AIMS - Australian Institute of Mangrove Science
CCD - Coast Conservation Department
Spp - Species
Ppt - Part Per Thousands
Q - Quadrate

CHAPTER 01

01 Introduction

1.1 General Introduction

The mangrove ecosystem is defined as the inter tidal zone of muddy shores in bays, lagoons and estuaries dominated by highly adapted woody halophytes, associated with continuous water courses, swamps and backwaters, together with their populations of plants and animals (Pinto, 1986). Sri Lanka contains a mangrove covering in an area of over 10,000 hectares. The total number of mangrove species in Sri Lanka is 20 (Jayatissa *et al.,* 2002). Twenty-one true mangrove species and sixteen mangrove-associated species have been recorded from Sri Lanka by Abeywicrama (1964). De Bruin (1965) has documented the faunal distribution of mangroves.

Mangroves are an extremely important coastal resource both economically and environmentally. People use mangroves as food and beverages, fire wood and timber, for brush pile fishery, making of mats and baskets, agriculture, aquaculture, animal feed, corks and floats, medicine, baits, fish food, extraction of tannin and lime. In environmental, mangroves act as the sediment trapper as well as wind barrier and mangroves protect the shores of estuaries and lagoons from erosion.

Although mangroves are important economically and environmentally, the vast tracks of mangroves have been destroyed in last period of time. Mangrove habitats of Sri Lanka are being destroyed for various purposes and are being converted to other land uses such as shrimp farming, agriculture and human settlements (Liyanage, 2000).

In most of natural mangrove areas it is observed that there is a distribution pattern. The zonation is a remarkable feature in mangrove habitats, which is influenced by the site factors such as topography, tidal influence, climate, run-off, sediment deposition, inclusion of seawater and stability (Liyanage, 2000). Soil redox state, sulphide concentration, salinity or combinations of these factors are probable reason for zonation of the mangroves.

The zonation pattern affect to generate the microhabitats within the mangroves for organisms such as fungi, algae, epifauna in root system, as well as macro benthos, soil macro fauna and etc.

1.2 Negombo lagoon

Negombo lagoon (location 7^0 06'-7^0 12,N, 79^0 49'-79^0 53'E) is relatively a large brackish water body located in the western coast of Sri Lanka (Pahalawattaarachchi, 1996).It has been estimated that the mangroves cover 350 ha and they occur mostly in a narrow intertidal belt along the bank of Negombo lagoon(Samarakon and Van zon,1991).

Negombo lagoon is situated in the wet zone of the Sri Lanka.The mean annual rainfall in the Negombo area is 2000-2500 mm and highest rainfall is received during October to November. The mean annual temperature is 27.8^0 C and its seasonal variation is only about 2^0C to 3^0C (Pahalawattaarachchi, 1996). Salinity in Negombo lagoon varies between 5 and 30 ppt. pH and dissolved Oxygen is 7.5-8.3 and 4.6-8.7 respectively.

Most widely distributed mangrove species are *Rhizorphra* species, *Avicennia marina, Lumnitzera racemosa, Excoecoria agallocha* and *Acanthus ilicifolius* has been reported to be the dominant and some times the pioneer species are found in the mangals of Negombo lagoon (Pinto, 1978).

Present studies on mangroves comprised of surveys of mangroves, determination of functional and structural parameters of mangroves such as floral distribution of unmanaged mangrove islets in Negombo lagoon has been studied by Pinto (1978). Litter production and decomposition in the mangrove ecosystem in Negombo lagoon has been studied by Pahalawattaarachchi (1996). Survival of seedlings of *Rhizophora mucronata* Lam. And *Ceriops tagal* (Perr.) C.B. Rob. Under different environmental conditions in Negombo lagoon has been studied by Palihawadana and Pinto (1989).

1.3 Objectives

01. Study of the major factors that affect the zonation pattern of mangroves.

02. Study of the functional inhabitation in microhabitats in various zones.

Specific objectives

Creating a basal data bank for mangrove area management.

CHAPTER 02

02 Literature review

2.1 The mangroves

Mangroves are among the most important and productive ecosystems in the tropical region of the world and are the found along the inter-tidal zones of coastal areas and offshore islands (Liyanage, 2000). The compositions of mangroves are varies including trees, shrubs, epiphytes, licans, ferns and algae. As well as the diversity of the fauna of mangrove ecosystem is varies including fishes, birds, reptiles and microscopic mangrove animals. (Pinto, 1986). The mangrove ecosystem is a complex physio-chemical system. In the mangrove ecosystem two types of floral associations can be observed. The plant species, which occur only with in the mangrove habitats, are called as "true mangrove" (Lugo and Snedakar, 1974) and some plant species occur in the mangrove habitat as well as other habitat (non saline condition) are called as "mangrove associates"(Pinto, 1986).

Some species of mangroves are rare and threaten, as well as some species are most common. The rare species are *Avicennia alba, Pemphis acidula, Sonneratia alba, Xylocarpus rumpii* and *Xylocarpus grantum* have isolated narrow distribution range *Rhizophora* spp *Bruguiera* species, *Exeocaria agallocha, Lumnitzera racemosa* are the most common species in any of mangrove habitat in the country (Liyanage, 2000).

Floristic composition of the dry zone mangrove forest is different from the wet zone mangrove forest. Because seasonal rainfall and lower fresh water discharge in the dry zone. *Nypa fruticance* is found in the wet zone. Its range extends from the estuary of Ranna Oya to the Gin Oya estuary (De silva and De silva, 1998). The two species of *Rhizophora* generally distribute in two different climatic zones. *Rhizophora epiculata* found in habitats south of Negombo to Dikwella while *Rhizophora mucronata* found in habitats north of Negombo and south of Dikwella (Liyanage, 2000).

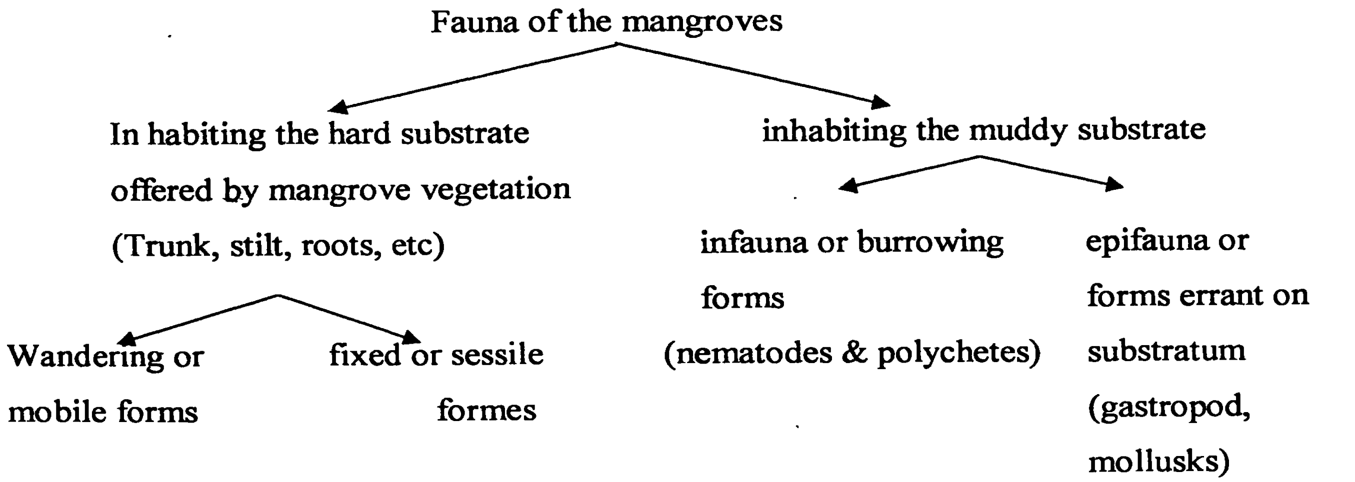
Mangrove fauna diversity is high including fish, birds, reptiles, crustaceans as well as micro fauna. The animals living in the mangrove area have invaded from land, sea or fresh water (Pinto, 1986).

The mangrove soils have relatively small soil particle size less than that of fine sand (less than 0.25 mm) (Pinto, 1986). Particle size increases from the shoreline to the land. In mangrove soil sulfur bacteria is high. Therefore mangrove soil is generally acidic. This soil is rich Sodium, Calcium and Magnesium content is generally higher than that of Potassium. (Pinto, 1986).

In order to compensate for the massive destruction, here as elsewhere, it is necessary to replant mangroves in the form of a green belt around the lagoons, to ensure a constant supply of organic matter to brackish water bodies (Soerianegara, 1986). Reforestation in fact, is one of the main approaches to the rehabilitation of degraded mangrove forests (Zamora, 1987).

2.2 Mangrove fauna

Mangrove forest is situated the interface between marine and terrestrial environment. Therefore animals of both these environments can be found in the mangroves. As an example, estuarine crocodiles, Sea snakes. Mudskippers *(Perioptthylmus* species) are one of the few animals, which are restricted to mangrove environment (de Bruin, 1965: Pinto and wijayarajah, 1980). As well as crustaceans, many species of birds and fish also depend seasonally on mangrove environments for food and shelter (De silva and de silva, 1986). In addition, invertebrate species, like prawns and crabs are seen.



Quantitative and qualitative distribution of the mangrove fauna is governed by tidal amplitude, light penetration, nature of the substratum and distance from the sea.

In mangroves, small fauna species numbers and diversity were higher in the mudflat than at the mangrove sites. The taxonomic composition changed between the mangrove forest and the mudflat. Oligochaeta were more abundant in the mangrove sediment where Polychaets dominated the mudflat (Dittmann, 2000).

Traditionally, the fauna of marine sediments are classified into meio – and macro fauna by the use of defined sieve sizes, whereby organisms retained on a 0.5 or 1 mm mesh sieve are referred to as macro fauna (Schlacher and Woolridge, 1996).

2.3 The mangrove environment and adaptations

The mangrove ecosystem is very unique due to its location, which is saline water, oxygen deficiency, or anaerobic condition, sandy soil but rich in organic matter and sun light temperature and wind is high relatively.

The soil salinity is high in the mangrove eco system but nil more than seawater (De silva and De silva, 1998). Soil is water logged and poor in oxygen (Pinto, 1986).

The mangrove forest is most productive ecosystems. Live and decaying mangrove leaves and roots provide carbon and nutrients that are used by other organism in the mangrove ecosystem (Lugo *et al.*, 1976).

Mangrove ecosystem is rich in organic matter. Bacteria, fungi and some macro organisms break down the nutrient rich litters. Decaying organic matter breaks down to the detritus and these detritus is the food source for most of organisms like molluscus, crustaceans, fish and other large animals (Odum and Heald, 1975).Although mangrove environment has harsh conditions, mangrove biota survives because they contain unique adaptation to the environment (Pinto, 1986). The floral adaptations are given below in table 2.1

Table: 2.1 Floral adaptations of the mangroves.

Problem	Adaptations	Examples
Difficulty of ordinary plant to establish on soil	Containing of stilt roots and prop roots	*Rhizophora* species
High salinity of the soil	Containing the salt secreting glands	*Avicennia* species *Acanthus* species *Aegiceras* species
High evaporation	Sunk stomata Thick / waxy cuticle Sub stomatal chambers	Most of mangroves Most of mangroves *Avicennia, Ceriops, Rhizophora*
Difficulty of the respiration (Poor soil oxygen)	Respiratory roots Pneumatophores Buttress roots, aerial roots Knee roots, shallow roots	*Avicennia* *Sonneratia* *Bruguiera*
Propagation	Viviparity Production of large number of fruits / seeds.	*Rhizophora, Ceriops* *Bruguiera* Most of mangroves
Difficulty of water absorption	Selective absorption Presence of a well developed large celled water-storing hypodermics.	*Rhizophora* Most of mangroves
Damage of wind	Little or no wind throws and rapidly developed new crown.	Most of the mangroves
Ultra violet radiation	Tannin in leaves	*Rhizophora, Ceriops*

Sourse: Pinto, L. (1986)

The faunal adaptations are given below in table 2.2

Table 2.2 The faunal adaptations of mangrove ecosystem.

Problem	Adaptations	Examples
Water level fluctuation	Adaptation on the land and water • Well developed eye • Skin is used respiratory surface Burrowing habitats Burrows between mangrove root or small water hales Single burrow Complex burrow Live attached to mangrove roots	 Mudskipper Most of mangrove animals Common grapsid crabs Fiddler crabs Grapsid crabs Bivalves, crabs
Respiration	Dermal	Mudskipper

Source: Pinto.L (1986).

2.4 Zonation of mangroves

Two types of zonation are identified in the mangroves

01. Horizontal zonation.

Which is further divided in to the zonation of the,

(i) Trees

(ii) Associated animals

02. Vertical zonation.

2.4.1 Zonation of mangrove flora

In most of natural mangrove areas (large and undisturbed areas) it is observed that there is a species distribution pattern. Patterns of species distribution are known as zonation (Lugo and Snedakar, 1974).

The cause of mangrove zonation is still subject to debate but it is probably determined by the topography, tidal inundations of seawater and stability, soil redox state, sulphide concentration, salinity site of propagules (Kennelly, 1982) or combination of these factors.

Generally, zones of dominant mangrove species distribute parallel to the shoreline or to banks of tidal creek system within the mangrove formation; the different species occupy different zones (Kennally, 1982). In larger mangrove forest, there is a zone of *Rhizophora, Bruguiera* and *Sonneratia* at the waterfront, with *Rhizophora* species occupying the nearest water, and toward the inland margin other species like *Bruguiera, Avicennia, Ceriopes, Execoecaria, Lumnitzera* and *Agiceras* are distributed. All these species are often found intermixed with each other. But in some localities some species are dominant (Jayewardene, 1985).

Zonation was described in several ways.
Macnae (1965) Introduced salinity of the soil water, and integrated tidal flow as a subsidiary factor, and divided the zonation into two main areas.
A=Brackish to salt water salinity at high tide, salinity 10 to 30 ppt.
B=Fresh to brackish water, salinity 0 to 10 ppt.
Each is further subdivided in to 3 based on degree of flooding.

Macnae (1968a) used the dominant species of tree or tree assemblage to relate to the zones, from the seaward fringe to the more inland.

In control of zonation, Macnae (1968 a) ascribed control of distribution of mangrove trees and hence their zonation to the interaction of (1) Frequency of tidal flooding, (2) Salinity of the soil water, (3) water logging of the soil. The latter 2 factors rely on rainfall / fresh water supply, evaporation, transpiration and the nature and quality of the soil. Only in areas with annual rainfall above 2000 mm is a complete mangrove succession found. *Avicennia marina* appears to have the widest range of salinity tolerance of all mangroves. *Sonneratia* prefer normal; sea salinity, *Brugeria* prefer < 25 ppt salinity (Macnae, 1968 a)

Overall complete zonation occurs only in areas with: considerable inter-tidal range, high rainfall in all seasons, and silt in suspension available which ensures deposition of mud on soil surface so that it is always raising the soil level enabling mangrove to penetrate further seaward (Macnae, 1968 a)

In some countries such as Indonesia, Malaysia, Thailand, the mangrove zonation is well marked than Sri Lanka.Because of narrowness and the human interferences (De silva and De silva, 1998)

2.4.2 Zonation of the mangrove fauna

01. Horizontal zonation

The main differences are due to the 'wetness' (SE Asia is very wet) and substratum type (sand / mud). Crabs dominate in all zones; they dominate in numbers and importance to the ecosystem. There are about 60 genera of crabs within the mangrove ecosystems. Fiddler crabs (ocyponidae) such as *Uca* spp.live on the mud flats, *Cardisoma* (in the new world replaced by *Ucides*) are at the high shore. There are lots of *Grapsid*crabs (which in the new world are replaced by *Aratus* and Goniopsis) (Macnae, 1968 a).

Zonation in the Indo-Pacific land ward fringe-from high water to ordinary spring tide level upwards there are a number of crabs and hermit crabs which are generally secretive in habitat. There are usually large populations of *Uca* spp. Examples of typical species: *Coenobita* (a hermit crab), *Cardisoma* (a burrowing land crab) this is found in sand. *Thallassina* spp (the mud lobster burrow). In the new world (Neotropics) there is a different species of *Cardisoma* (*cardisoma guanhumi*) and crabs of the genus *Ucides* (Macnae,1968 a).

Macnae (1968 a) observed zonation pattern in fauna of Australian mangroves such as *Sesamid* crabs and different *Uca* species, gastropods and *Goniopsis* crabs in the mid forest, mud skippers (*Macrophthalamus*), Snapping prawns in the lower fringe and *Portunid* crabs in lower shore.

There is generally unclear zonation due to the unclear topography there are many niches, gullies and pools; hence it is always difficult to interpret horizontal zonation. The best method is though to use the amount of time in seawater rather than the pattern across the shore due to then three-dimensional and often much varied terrain of such areas (Macnae, 1968a).

02. Vertical zonation

The zonation in the mangal canopy. Canopy fauna in a mangal are essentially terrestrial, there are some marine intertidal species, mainly *Littorinid* snails that are found above the high water mark, and for these there is usually quite clear zonation (in the Indo-Pacific). Above high water there is *Littorina melanstoma*, high water, *Littorina scabra*, below or at low water, *Littorina undulata.* (Macane, 1968a)

On the leaves of the mangroves is a bivalve called *Enigmonia, which* gets into the leaf joints within the tidal range and it filter feeds when covered by the tide. (Macane, 1968a)

Lower down the canopy; typically find hermit crabs claiming the trees (*Clibinarius longitarsus*). The on the tree trunk it self, there are gastropods of the genus *Cerithidea* these migrate up and down, going down to the mud at low tide to scavenge on the mud. *Nerita* spp are also found lower down. (Macane, 1968a)

On the mangrove roots, there are hand substrata organisms, such as barnacles, oysters and limpets. Typically, *Sesarmids* and *Metograpssus*crabs climb cover and into the trees. There is even small-scale zonation observed on pneumatophores.
Vertical zonations of new world mangroves are,
Highest up- gets Aratus (a true tree dwelling crab found only in the new world).

Further down, get Goniopsis and lower down from this, near the roots get barnacles and mollusks again.

There are Terebrid gastropods on the mudflat, and predatory whelks. Also Nerita snails. Bivalves are found within the mud (as infauna) e.g. *Anadara granosa.*

2.5 Distribution of mangroves

Mangroves have maximum development and luxuriance in parts of SE Asia, Sumatra and Malaya. Distribution is limited by temperature, ocean currents, shoreline topography, tidal range salinity and substrate. All these contribute to the often-unique composition and zonation of the mangroves and their associated fauna at a particular shore, such that generalizations of zonation are very difficult and only very general patterns can be observed. The total area of mangrove forests in the world is estimated as over 150,000 Km^2, of which over 62,000 Km^2 are in tropical Asia (Aksornkoae, 1985).

2.5.1 Global distribution

The largest areas of mangroves occur between the latitudes 0^0 to 10^0 with a total extent of $10.07 * 10^4$ ha, in comparison to $0.25 * 10^6$ ha that occur between the latitudes 30^0 and 40^0 (Twilley et al., 1992). World wide there are 69 recognized mangrove species belongs to 20 families (AIMS, 2000)

Before 1975, the world's largest mangal resources were found in Indonesia. In Kalimantan alone, nearly half of 1.8 million hectares of mangal were cleared between 1975 and 1994 .In Sulawesi, 110,000 hectares in 1965 were reduced to 30,000 hectares by 1994.In the Philippines, mangal areas were reduced from 400,000 hectares in 1920 to 140,000 hectares by 1994.And finally from 1950 to 1983 400,000 hectares of mangroves on the Vietnams coast was reduced to 250,000 (Viles and Spencer, 1995). The extents of mangroves in some Asian countries are given table 2.3.

Table 2.3 The extent of mangroves in some Asian countries.

Country	Mangrove area (ha)	Percentage of mangrove area.
Indonesia	$3.6*10^6$	1.9
Malaysia	$6.5*10^5$	2.0
Bangladesh	$6.3*10^5$	4.4
Burma	$5.2*10^5$	0.76
Pakistan	$2.5*10^5$	0.11
Sri Lanka	$6.3*10^3$	0.16

Source: Pinto, L (1986)

2.5.2 Mangroves of Sri Lanka

Mangrove habitats occur only in the shore of lagoons, estuaries and in the mouths of several streams (Nissanka, 1997).

The largest mangrove patch which is 3385 ha is said to occur in puttlam lagoon, Dutch bay, Portugal bay complex, second one is 1520 ha in Batticallo and third largest is 1020 ha in Trincomalee (Kanakarathne *et al.*, 1983).

The major mangroves are distributed along the east west coast and in Jaffna peninsula as well as southern coast. The largest mangrove forest which is in the Kala oya estuary is not more than 0.5 Km in width and extends upstream about 2 Km from the river mouth (De silva and De silva, 1998). The extent of mangrove in Sri Lanka has been estimate by the CCD (1986) as 12189 ha. (Table 2.4)

Twenty one mangrove species of true mangroves and 16 associated mangrove species have being recorded in Sri Lanka (Abeywikrama, 1964). Jayatissa et al (2000) has revised the number of true mangrove species recorded in Sri Lanka to be 20 and mangrove associated species to be at least 18.

The common species of mangroves are *Rhizophora mucronata, Avicennia marina, Exocecaria agaloca, Acanthus ilicifolis, Lumnitzera racemosa, Sonneratia caseolaris, Bruguiera gymnorhiza* and *Agiceras corniculatum.* Rare species are *Ceriops decandra, Sonneratia apetala, Lumnitzera littoria, Scyphiphora hydrophyllacea* and *Cynometra iripa.* From them, first three are endangered species in Sri Lanka (de silva and de silva, 1998). *Nypa fruticans* is the only palm grooving naturally in the mangroves (Pinto.1986). *Acrosticum aureum* is the only fern grooving in our mangroves (Pinto, 1986).

Table 2.4 Distribution of mangrove in Sri Lanka.

District	Extent (ha)
Colombo	39
Gampaha	313
Puttlam	3210
Mannar	874
Kilinochchi	770
Jaffna	2276
Mulathevu	428
Trincomalee	2043
Batticalo	1303
Ampara	100
Hambantota	576
Matara	7
Galle	238
Kluthara	12

Source: CCD, 1986.

2.5.3 Negombo lagoon

Negombo lagoon is situated in the western coast of Sri Lanka. It is classified as a basin estuary and has been formed by the water body having been cut off from the sea by spit growth (Swan, 1983). The lagoon is connected to sea at its northern end. The southern end of the lagoon is geographically and hydro logically associated with the Muturajawella swamp (Pahalawattaarachchi, 1996).

Negombo lagoon is an estuarine ecosystem with an extent of 3502 ha under water located in Attanagalu basin, which covers an area of 932.4 Sq Km. Most of the lagoon is very shallow. The mean depth of the lagoon at mean sea level is about 1m (Pahalawttaarachchi, 1996).

Dandugam oya and Ja Ela supply the water to the lagoon. The retention time influenced both by fresh water supply and tides is approximately one week (Wickbon, 1992). The annual load of sediment trapped by the Negombo lagoon is estimated to be 50,000 tons. (Samarakon and Van zon, 1991).

The salinity in the lagoon varies between 5 and 30 ppt. Salinity depend on the fresh water supply and evaporation. During the period of high supply, the residence time for the lagoon water is 2-5 days only, while during minimum discharge (5-15m^3 S^{-1}) periods, the residence time increases to about two weeks (Rajapakse *et al.*, 1995).

The human communities around the lagoon exploit the mangrove ecosystems of the Negombo lagoon in numerous ways, Such as brush park fishery, capture fisheries, firewood, light timber and tannin, land reclamation, garbage disposal, discharging factory effluents, land based aquaculture, mangrove shore protection and etc (Pinto, 1986).

Pinto (1986) has reported that the mangrove soils in Negombo lagoon are acidic and has attributed it to be a result of the activity of Sulfur bacteria in the soil.

Studies of mangroves in Negombo lagoon have been carried out by Pinto L. 1978, 1980,1982. Pinto and Wijyarajah S 1980, Swarnamali and Pinto (1988), Pahalawattaarachchi V, (1996).

Kadolkele is the largest area of mangroves remaining in the land of Negombo lagoon. Exploitation was occurred largely due to the human activities, but after acquisition of NARA in 1994 the area has been preserved (Pahalawattaarachchi, 1996). Aluwihare, 1999 revealed that there was a remarkable structural development after 5 years of management.

2.5.3.1 Mangroves of Negombo lagoon

It has been estimated that the mangroves cover 350 ha and they occur mostly in a narrow intertidal belt along the banks of Negombo lagoon (Samarakoon and Van Zon, 1991). The mangals are distributed as narrow belts around the lagoon (Pahalawattaarachchi, 1996).
The best-developed and least disturbed mangroves have being at the mouth of Dandugam oya and most of the mangrove islands located at the sea mouth of the lagoon. Among the mangals around Negombo lagoon, Kadolkele is the largest single island, which covers nearly 13 ha of the intertidal land (Pahalawattaarachchi, 1996).

The most striking feature, with regard to the distribution of mangrove species in the northern part of Negombo lagoon is that the wild stands are mostly composed of *Avicennia marina* and *Rhizophora apiculata* while the cultivated areas are composed mainly of *Rizophora mucronata* (Pahalawattaarachchi, 1996).

Thirteen true mangrove species and mangrove-associated species were encountered around Negombo lagoon (Pahalawattaarachchi, 1996).

The dominant true mangrove species recorded in Negombo lagoon was *Rhizophora* species, Avicennia species, Acanthus species, Sonneratia species etc while the dominant mangrove associates were *Calamus rotang* (wewell), *Hibiscus tiliaceus* (wal beli), *Derris scandens* (kala wel) etc (Pahalawattaarachi, 1996).

2.5.3.2 Faunal diversity in Negombo lagoon

Mangrove ecosystem is located between land and sea environment. Mangroves provide shelter to young and juvenile forms of aquatic animals as well as food via litter fall to a large number of juveniles of aquatic organisms, which are commercially important to man (Odam and Heald, 1975).

In the lagoon, Annelids, arthropods, crustaceans, mollusks and chordates are most common. Among them fish, shrimps, mangrove crabs, gastropods, annelids and barnades are predominant (Pahalawattaarachchi, 1996).

A descriptive study of mangrove fauna has been carried out by Pinto (1978) in Negombo lagoon and according to him; the predominant polychaete that occurs in the lagoon is *Branchiocapitella singularis.* The grapsid are mangrove areas and ocypoid are on mud flats. The most dominant species of grapsid crabs were *C. bidens, C. indiaram*, and *C. darwinensis* (Pahalawattaarachchi, 1996). Soil properties like temperature, salinity, pH, and organic matter, particle distribution in soil and depth of the water table were affecting the distribution of the crabs in that environment. Twenty four species of aquatic organisms associated with oysters, have been recorded. It also been revealed that a vertical zonation of oysters as well as sessile fauna associated with the oysters exists on the mangrove roots (Pahalawattaarachchi, 1996). Xanthid crabs, especially *Baruna socialis* and *Pseidognathus dearira* observed to occur in association with the oysters (Pinto and wignarajah, 1980).

The other fauna of the Negombo lagoon are hermit crabs (*Eupagurus* species, *Paqurus* species). Fiddler crabs (*Uca* species), gastropods (*Faunus ater*), jelly fish (*Scyphozoans*), finfish (*Etroplus suratensis, Oreochromis mossambicus*) and water snakes (*Cerberus rhyhochops*) (Pahalawattaarachchi, 1996).

Resident birds such as comorants, Indian darters, pond herons, gray herons, night herons, white breasted and common kingfishers, white-breasted water hens, black winged stilts, terns, gulls as well as the migrant birds such as sandpipers and plovers are found in the Negombo lagoon (De silva and de silva, 1986).

2.5.3.3 Zonation of mangroves in Negombo lagoon

Kadolkele is situated in Northern part of Negombo lagoon. The distribution of species at Kadolkele exhibited a clear zonation from waterfront to inland (Pahalawattaarachchi, 1996). *Rhizophora* dominated the waterfront of Kadolkele mangrove area while. *Avicennia, Lumnitzera* and *Excoecaria* species occur in the back mangrove zone of Kadolkele (Pahalawattaarachchi, 1996).

2.6 Microhabitats

Faunal and floral diversity is different within the microenvironment of mangroves. These habitats are known as microhabitats. These habitat changes according topography, soil conditions, accumulation of organic substances and anaerobic gas production within the mangrove, There are records that varying groups of fauna inhabit in various microhabitats sush as gullies, channels, water holes and pneumataphorus within the mangroves (Schlacher and Woolridge, 1996).

CHAPTER 03

03. Methodology

3.1 Study area

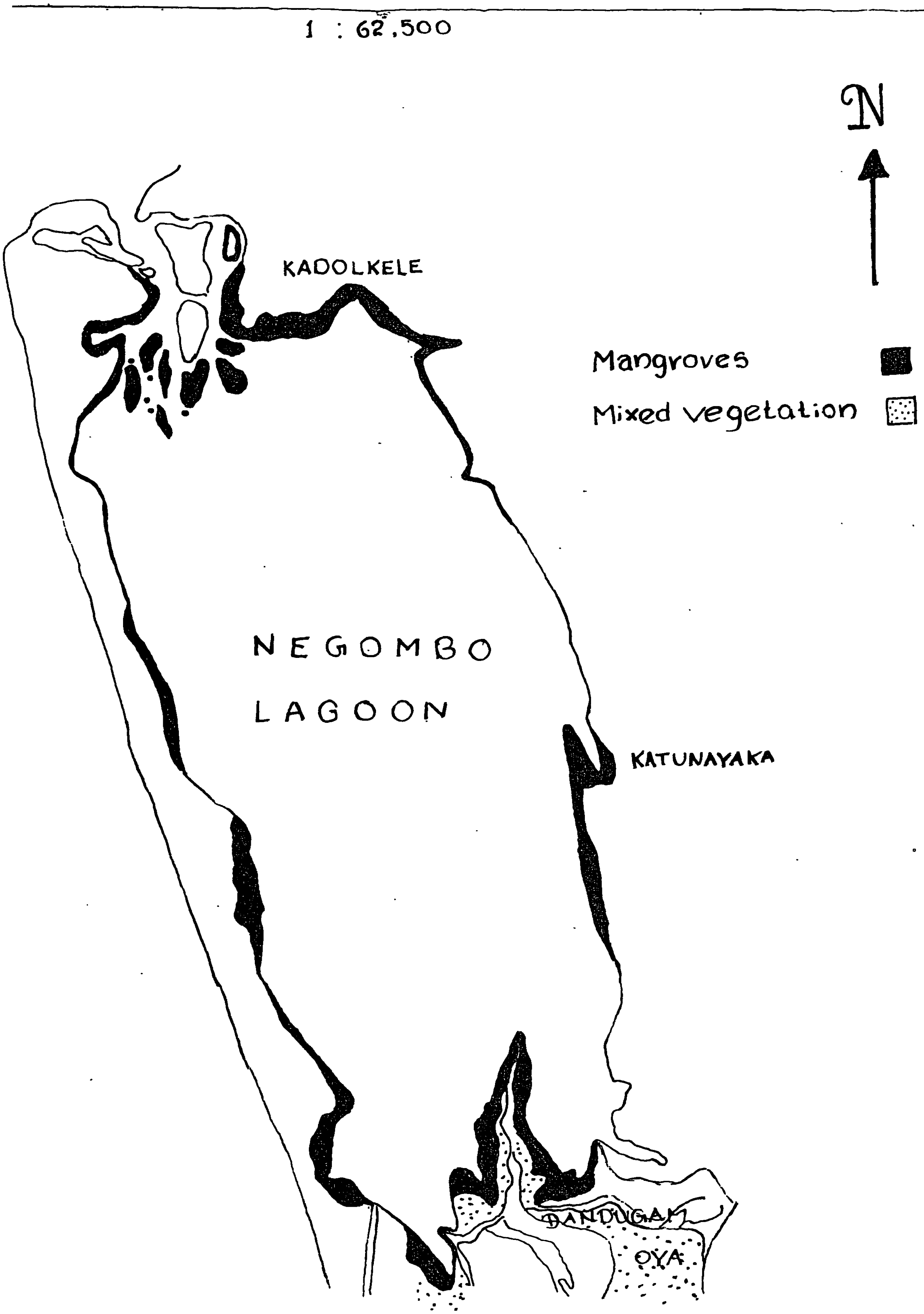
Negombo lagoon was selected as the study area. The lagoon is located 7^0 06'-7^0 12' N, 79^0 49'-79^0 53' E and it covers approximately 3502 ha (Pahalawattaarachchi, 1996). It is connected to the sea at its northern end.

3.1.1 Study location

Kadolkele was selected as the study location in the Negombo lagoon. Mangrove area of Kadolkele is the largest single stand among the mangals around Negombo lagoon, which covers nearly 13 ha (Pahalawattaarachchi, 1996).

Three distinguished zones such as *Avicennia marina* (Plate 1), *Lumnitzera racemosa* (Plate 2) and *Rhizophora mucronata* (Plate3) were selected as study locations within Kadolkele mangrove stand.

Two plots of 10 m x10 m were selected in each zone of *Lumnitzera and Avicennia.* The criteria used for the selection of study plots were distance from the lagoon, changes in the topography, and level of inundation. Only one plot of 7.5 m x 7.5 m was selected in *Rhizophora* zone, as the *Rhizhopora* belt is narrower than 10m and only found in the lagoon front.



3.1 Study area and study sites.

Source: Pahalawattaarachchi, V. (1996).

Study locations are described as follows

Study locations	Remarks
Location I of the *Lumnitzera* zone	Inland (75 m away from the lagoon)
Location II of the *Lumnitzera* zone	Closed to the lagoon (55m away from the lagoon)
Location I of the *Avicenna* zone	Inland (30m away from the lagoon)
Location II of the *Avicenna* zone	In the lagoon front
Rhizophora	In the lagoon front

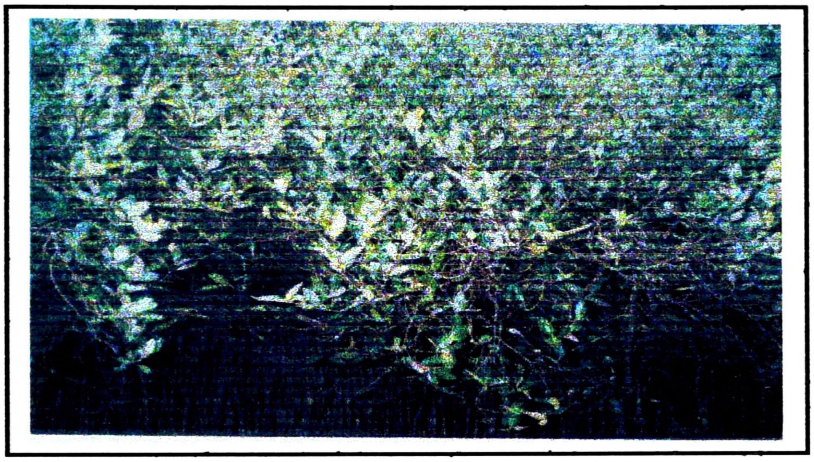


Plate 3.1 Study location *Avinicennia*

Plate 3.2 Study location *Lumnitzera*

Plate 3.3 Study location *Rhizophora*

3.2 Structural parameters

3.2.1 Tree height

Tree height was measured using a graduated pole within the plot.

3.2.2 Tree density

Tree density was calculated using the number of trees (diameter greater than 2.5 cm) of each species.

3.2.3 Canopy width

Canopy width was measured by using a graduated pole.

3.2.4 Root density

Root density was calculated using the number of roots within the 50 cm x 50 cm quadrant.

3.2.5 Seedlings density

Seedlings density was calculated using the number of seedlings of each species within the 10m x 10m plot.

3.3 Factors affecting zonation

3.3.1 Soil parameters

3.3.1.1 Soil pH

Three plots of 50 cm x 50 cm were selected each 10 m x 10m plots. But in the *Rhizophora* zone, one plot of 50cm x 50cm was selected. Because *Rhizophora* zone belt is very narrow in the study area.

Representative samples were taken from each plot in three zones. Three representative samples are measured each one plot.

The active and potential soil pH was determined in water and KCl extracts respectively.10g of air-dried soil (from the sample) was taken in a 50 ml beaker and mixed it with 25 ml of distilled water until a suspension was formed. The suspension was stirred at regular interval for 30 minits before the pH was measured using pH meter and pH was measured after 18 hrs. Potential soil pH was determined following the same procedure using 25 ml of KCl and pH measured after 10 minutes.

3.3.1.2 Soil salinity

Salinity of the soil was measured by taking out of intestrial water from the soil by using a 60 ml syringe and measuring by a refractometer.

3.3.1.3 Soil organic matter/carbon

The crucibles were selected and weighed to the nearest 0.0001 g to determine tare weight. Soil samples were dried in a 100^{0}C oven for 24 hrs. 2.5 g of these oven dry soils were added to each crucible and weighed it. These crucibles were placed in muffle furnace and those were heated at 360^{0}C for 2 hours. Crucibles were cooled completely before removing from furnace. After that calculated the percentage of organic matters as follows.

$$\% \text{ Of organic matters} = \frac{\text{Weight of oven dry soil} - \text{Weight of soil after ignition}}{\text{Weight of oven dry soil}} * 100$$

3.3.1.4 Soil texture

Particle sizes of the soil samples were determined by mechanical analysis through pipette method (Klute, 1986). 10 grams of soil was taken in a beaker and 50 ml of 3% H_2O_2 was added and the mixtures were heated on a water bath while stirring, until the dark color of organic matter disapeared. After that, the mixture was diluted to about 600-700 ml and a solution of 1N NaOH was added gradually, until the pH of the solution was 10.After that these mixtures were placed in a mechanical shaker for 24 hours and subsequently were washed out to a 1000 ml measuring cylinder. The contents were mixed thoroughly and kept undisturbed aside. The silt + clay fractionation was carried out after 4 min 48 sec (at 20 ^{0} C by withdrawing 25 ml of the suspension with a pipette from a depth of 10 cm. After the shaking clay fractination was carried out after 8 hrs in the same manner. These were than transferred to an evaporating basin, dried at 105^{0}C in an oven, cooled in a desicator and weights were obtained. Sand content was determind by subtracting (clay + silt) from the original weight of soil. Using these data, percentages of sand, silt and clay were calculated.

3.4 Tidal inundation

Tidal inundation was observed after every one hour within one day and measured according to the distance of the water level from the lagoon in and the depth of water accumulation in each zone.

3.5 Micro habitats for epi fauna and infauna

Microhabitats for epi fauna and infauna were studied in each zone. A quadrate of 50 cm x 50cm divided into 10cmX10cm squares was used to study the microhabitats. Three random quadrate samplings were done in *Lumnitzera* (Plate4) and *Avicennia* (Plate5) zones while one quadrate sampling was done in *Rhizophora* zone.

Plate 3.4 A zone including microhabitats.

Plate 3.5 A zone including micro habitats

3.5.1 Physical factors

Variation of topographic conditions (mounds, depressions, waterholes), water retention, were intensively observed in 10cmX10cm segments. And all the physical characters were mapped in each quadrate sampling.

3.5.1.1 Root density/various root forms

Root density was calculated using number of roots within the plot and calculated various root forms within the plot.

3.5.1.2 Seedling density

Seedling density was counted within the plot.

3.5.1.3 Surface litter accumulation

The surface accumulation such as leaves, twigs, roots, flowers, seeds and other debris were collected in the 100 cm^2 plots.

3.5.1.4 Detritus accumulation

Accumulated detritus in 5cm deep soil layer was obtained by washing 125 cm^3 soil samples and weighing after oven drying.

3.5.1.5 Soil organic carbon

The crucibles were selected and weight them to the nearest 0.0001-g to determine tare weight. Soil samples which were dried in a 100^0C oven for 24 hrs. 2.5 g of these oven dry soils were added to each crucible and the weight it. These crucibles were placed in muffle furnace and those were heated at 360^0C for 2 hours and crucibles were cooled completely before removing from furnace. Percentage of organic matters as follows,

$$\% \text{ Organic matters} = \frac{\text{Weight of oven dry soil} - \text{Weight of soil after ignition}}{\text{Weight of oven dry soil}} * 100$$

3.5.2 Tidal inundation

In order to make easy for calculations rank was given for tidal inundation as follows;

Table 3.1: Ranks for tidal inundation

Rank	Retention time (hr /day)
1	0 - 1
2	1- 2
3	2 - 4
4	4 - 6

3.5.3 Faunal density

3.5.3.1 Epifauna

Epifaunal and epifloral species were identified as far as possible in small segments of quadrates. At each sampling station macro benthos was using a 125cm3 quadrate. Sediments were scooped to a depth of 5 cm. It was then sieved using 0.5 mm sieve before fixing in 70% alcohol in labeled specimen bottles. After sorting, the samples were than counted and identified under a stereomicroscope (Higgin and Thiel, 1988).

3.5.3.2 Infauna

Macro benthos was isolated as infauna.

Identified the Taxonomic groups.

3.5.4 Chemical factors

3.5.4.1 Soil pH

Soil pH at each segment of quadrate was measured by means of a pH meter and recorded for each zones.

3.6 Diversity index (DI)

Diversity index for microhabitats were calculated as a collective factor, assuming the variations would be caused by the combined effect of parameters stated below;

Surface litter accumulation (lac)
Inverse value of pH (1/pH)
Soil Organic carbon (Soc)
Detritus accumulation (Dac)
Root density (Rd)
Topography (mounds and depressions)(Tg)
Crab burrowing holes (Ch)
Water holes (Wh)
Seedling density (Sd)
Stem density (Std)
Level of inundation (Li)

DI=(lac) x (1/pH) x (Soc) x (Dac) x (Rd) x (Tg) x (Ch) x (Wh) x (Sd) x (Std) x (Li)

Relationship between diversity index and faunal density was determined using correlation.

CHAPTER 04

4. Results and Discussion

4. 1 Structural Parameters

4.1.1 Tree height

Tree height of the study location has been illustrated in table 4.2 and fig 4.1. Maximum tree heights were observed in the location II of the *Avicennia* zone while minimum tree heights were observed in the location I of the *Lumnitzera* zone. Tree height was ranged from 1m – 8 m.

Table 4.1: Results of ANALYSIS OF Variance (ANOVA) conducted for tree height.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	4.57	0.03	3.87	Significant
Between two locations of *Avicennia* zone	21.37	0.0000427	4.09	Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	96.70	3.785E-19	3.88	Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	965.11	6.77E-65	3.88	Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	70.64	3.158E-14	3.90	Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	782.32	7.1526E-63	3.90	Significant
Between *Lumnitzera* (I) and *Rhizophora*	241.64	2.22E-28	3.87	Significant
Between *Lumnitzera* (II) and *Rhizophora*	162.62	1.0069E-26	3.87	Significant
Between *Avicennia* (II) and *Rhizophora*	18.05	7.2263E-05	3.99	Significant
Between *Avicennia* (I) and *Rhizophora*	1.09	0.30	3.99	Not Significant

Table 4.2 Tree height of the mangrove plots in the study site.

Location	Average Tree height (m)	Range (m)	Number of trees
Lumnitzera racemosa (I)	2.32	1 – 3	206
Lumnitzera racemosa (II)	2.42	1 – 3	135
Avicennia marina (I)	4.09	1 – 7	16
Avicennia marina (II)	6.66	2.5 – 8	24
Rhizophora spp	4.72	1 – 9	42

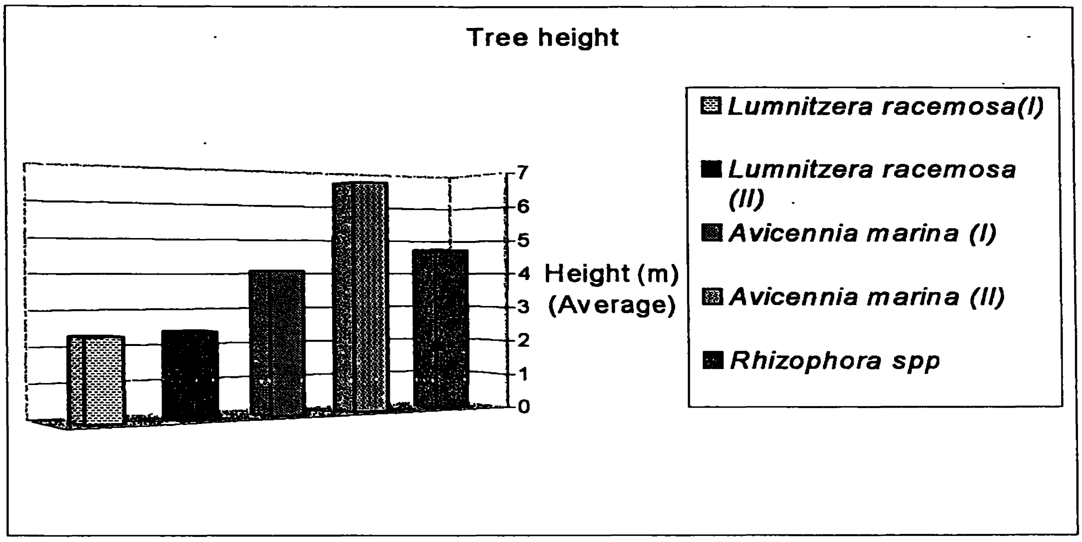


Fig 4.1 Tree height of the mangrove plots in the study site.

4.1.2 Tree density

Tree density of the each plot has been illustrated in table 4.2 and fig 4.2.Maximum tree density was counted in the location II of the *Lumnitzera* zone while minimum tree density was observed in the location I of the *Avicennia* zone.

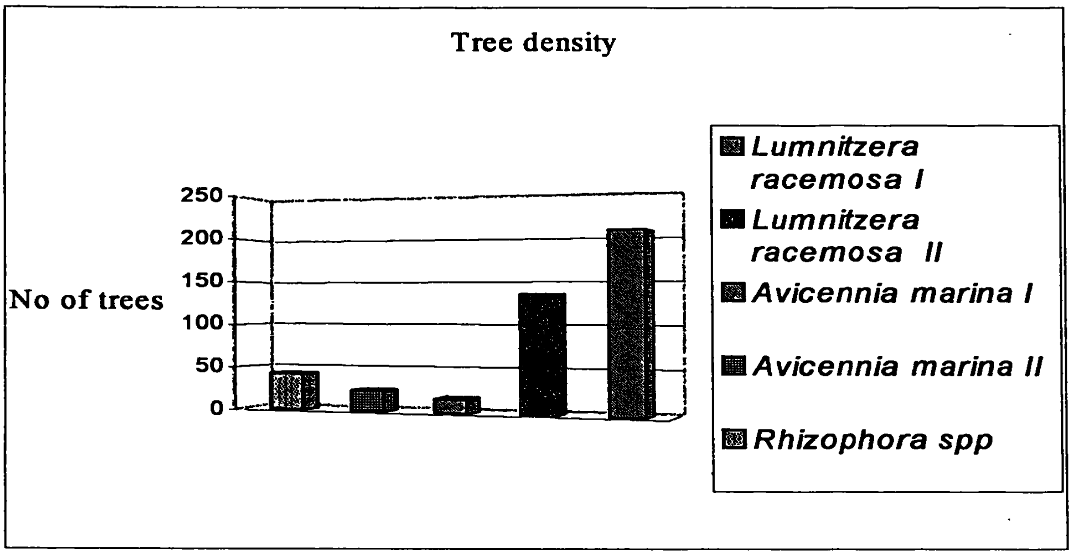


Fig 4.2 Tree density of the mangrove plots in the study site.

4.1.3 Canopy width.

Canopy width of the each study location has been illustrated in table 4.4 and fig 4.3. Maximum average canopy width was observed in the location II of the *Avicennia* zone while minimum average canopy width was recorded location II of the *Lumnitzera* zone. Canopy width was distributed range of 0.5 – 6.5 m.

Table 4.3: Results of ANALYSIS OF Variance (ANOVA) conducted for canopy width.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	0.91	0.33	3.87	Not Significant
Between two locations of *Avicennia* zone	1.83	0.18	4.09	Not Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	101.01	8.42E-20	3.88	Significant
Between *Lumnitzera* (I) and *Avicenna* (II)	965.11	6.77	3.88	Significant

Between *Lumnitzera* (II) and *Avicennia* (I)	71.63	2.25E-14	3.90	Significant
Between *Lumnitzera* (II) and *Avicennia*(II)	197.57	1.29	3.90	Significant
Between *Lumnitzera* (I) and *Rhizophora*	107.89	3.41E-21	3.87	Significant
Between *Lumnitzera* (II) and *Rhizophora*	77.51	1.25E-15	3.87	Significant
Between *Avicennia* (II) and *Rhizophora*	14.50	0.0003	3.99	Significant
Between *Avicennia* (I) and *Rhizophora*	1.96	0.16	4.01	Not Significant

Table 4.4 Canopy width of the mangrove plots in the study site.

Location	Canopy width (m) (AVG)	Range (m)
Lumnitzera racemosa (I)	1.30	0.5 – 2.5
Lumnitzera racemosa (II)	1.28	0.5 – 2.5
Avicennia marina (I)	2.87	0.5 – 6
Avicennia marina (II)	3.62	1 – 6.5
Rhizophora spp	2.32	0.5 – 4.5

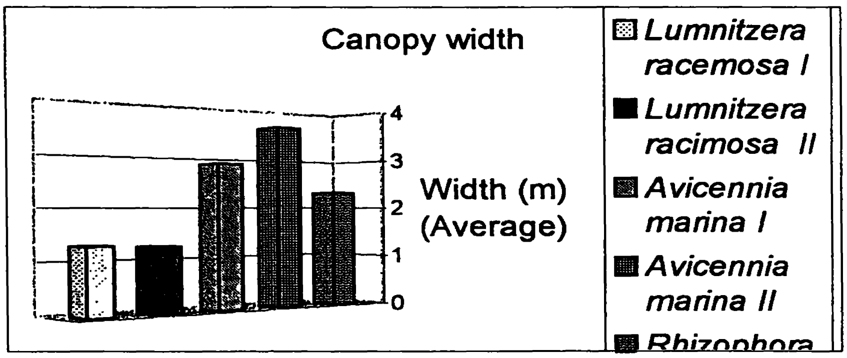


Fig 4.3 Canopy width of the mangrove plots in the study site.

4.1.4 Distribution of Seedlings

Distributions of seedlings in the study locations have been illustrated in table 4.6 and fig 4.4. Minimum seedlings were observed in the location I of the *Lumnitzera racemosa* zone and maximum seedlings were observed in the location II of the *Avicennia marina* zone. But seedling density is higher in the water front zone of *Avicennia* than the inland Avicennia zone. There is a significant difference of seedling density among five locations of study plots. (F=5.97,P=0.01, F critical =3.47).

Table 4.5: Results of ANALYSIS OF Variance (ANOVA) conducted for distribution of seedlings.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	6.33	0.06	7.70	Not Significant
Between two locations of *Avicennia* zone	2.75	0.17	7.70	Not Significant
Between *Lumnitzera* (II) and *Avicennia*(II)	10.16	0.03	7.70	Significant
Between *Lumnitzera* (I) and *Rhizophora*	7.98	0.04	7.70	Significant
Between *Avicennia* (II) and *Rhizophora*	213.98	0,00012	7.70	Significant

Table 4.6 Seedlings distribution of the study site.

Location	Number of seedlings / 100 m^2
Lumnitzera racemosa (I)	4
Lumnitzera racemosa (II)	1
Avicennia marina(I)	105
Avicennia marina (II)	285
Rhizophora spp	107

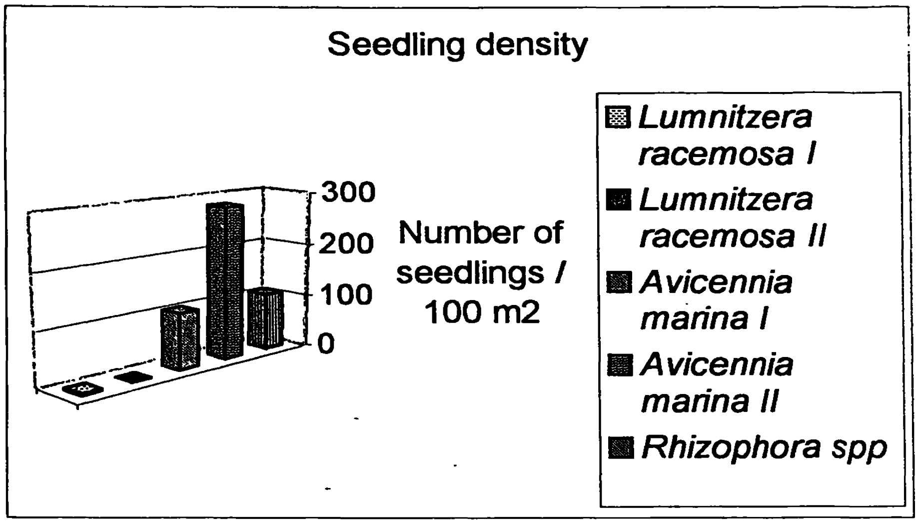


Fig 4.4 Seedlings distribution of the mangrove plots in the study site.

4.1.5 Root density

Root density in the study zones have been illustrated in table 4.7 and fig 4.5.In the *Lumnitzera* zone, prominent root systems observed were knee roots and small respiratory roots. Maximum number of such aerial roots were observed in then quadrate number 2 of the location I of the *Lumnitzera* zone (water logged zone) while minimum number of roots were observed quadrate number 3 which is not water logged and more elevated than the plot 1. In the location II of the *Lumnitzera*, maximum numbers of roots were observed in quadrate number 1 and minimum numbers of roots were quadrate number 2.

In *Avicennia* zone, higher numbers of pneumatophorus were observed in the water logged front location than in the inland location.

In *Rhizophora* zone, could be seen stilt root and prop roots. Maximum numbers of roots were observed near water front location while root density was gradually decreased with the increasing distance from the shore.

Table 4.7 Variation of various aerial root density of the study site

Location	Root density			
	Q 01	Q 02	Q 03	AVG
Lumnitzera racemosa (I)	85	13	71	56.33
Lumnitzera racemosa (II)	395	661	179	411.66
Avicennia marina (I)	135	29	62	75.33
Avicennia marina (II)	120	131	132	127.66
Rhizophora spp	27	20	5	17.33

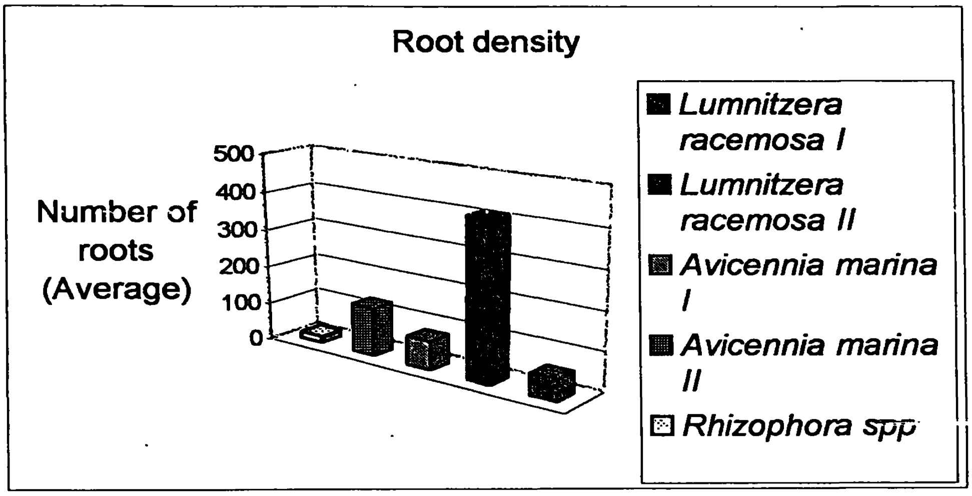


Fig 4.5 Root density of the mangrove plots in the study site.

4.2 Factors affecting Zonation

Vegetative profile of the study site is illustrated in Fig 4.6 it shows a clear zonation with three distinguished zones of *Rhizophora, Avicennia* and *Lumnitzera.*

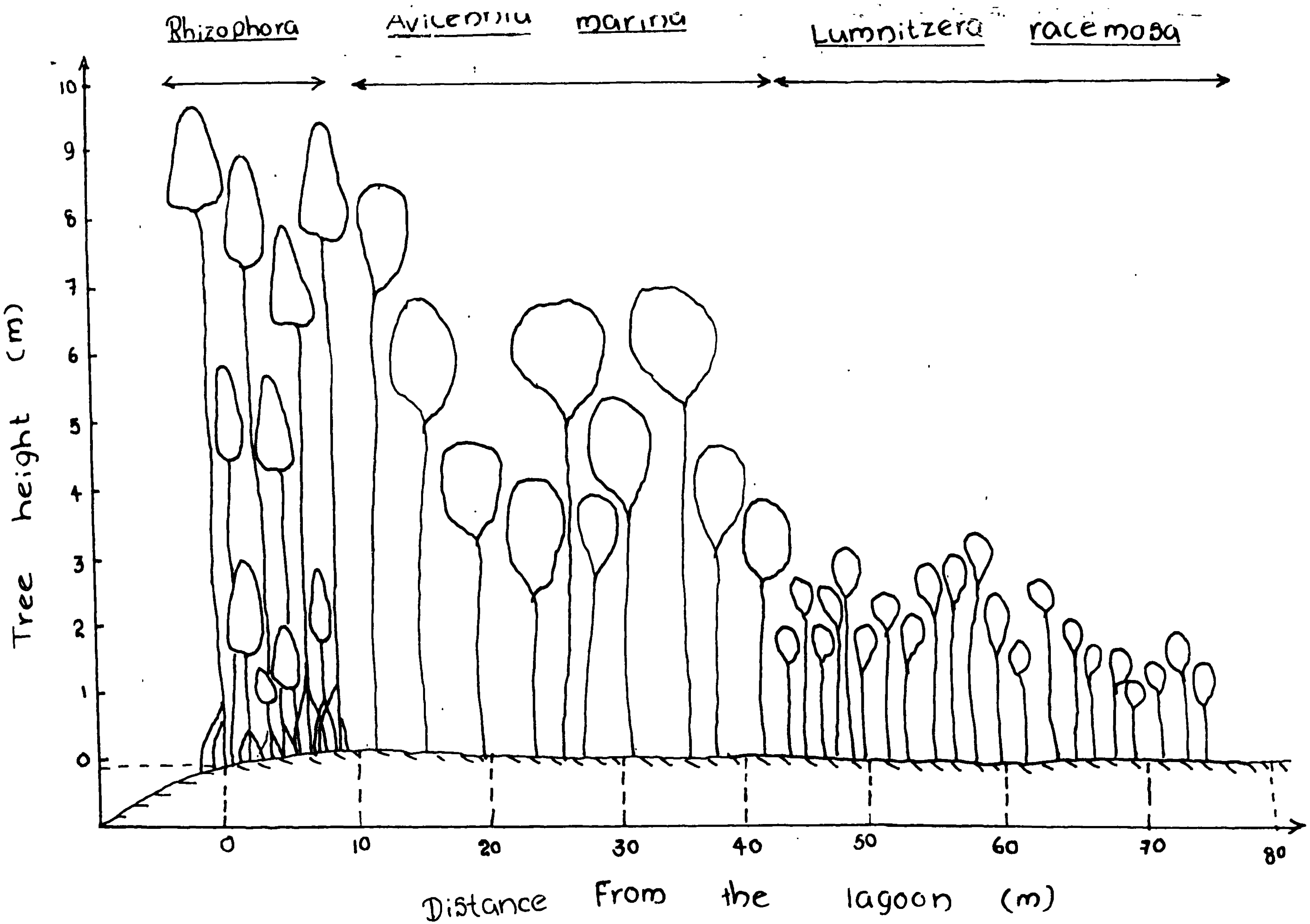


Fig. 4.6- Vegetation profile of study area representing the major zones and study locations.

4.2.1 Soil parameters

4.2.1.1 Soil pH

Soil pH of the each location has been illustrated in table 4.9 and fig 4.7.Minimum pH was 4.54 – 4.77 which was observed in the location II of the *Avicennia* zone. Maximum pH was observed in the location I of the *Lumnitzera* zone (6.56 – 7.00). There is a significant difference of pH among five locations of study site (F=5.99,P=009, F critical =3.47).

Table 4.8: Results of ANALYSIS OF Variance (ANOVA) conducted for soil pH variation.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	0.0094	0.92	7.70	Not Significant
Between two locations of *Avicennia* zone	20.49	0.01	7.70	Not Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	0.87	0.40	7.70	Not Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	0.55	0.49	7.70	Not Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	12.97	0.02	7.70	Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	16.81	0.014	7.70	Significant
Between *Lumnitzera* (I) and *Rhizophora*	5.35	0.08	7.70	Not Significant
Between *Lumnitzera* (II) and *Rhizophora*	3.78	0.12	7.70	Not Significant
Between *Avicennia* (II) and *Rhizophora*	22.69	0.008	7.70	Significant
Between *Avicennia* (I) and *Rhizophora*	3.88	0.12	7.70	Not Significant

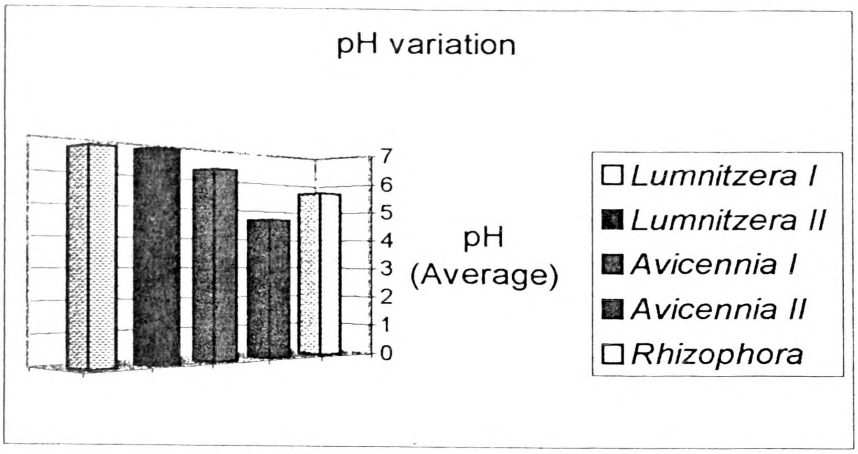


Fig 4.7 pH variation on the study site.

Table 4.9 Soil parameters.

Location	Soil pH		Salinity	Soil texture			OM %
	KCl	Water		Clay %	Silt %	Sand %	
Lumnitzera racemosa (I)	6.92	7.68	24	2.04	1.08	92.16	4.61
	6.78	7.61	30	7.20	1.70	77.55	2.67
	5.38	5.87	34	6.00	1.08	82.27	6.20
Lumnitzera racemosa (II)	7.34	7.57	41	6.00	1.61	80.94	7.20
	6.79	7.30	40	0.56	0.83	96.51	8.00
	5.56	6.14	20	3.31	0.40	90.70	2.85
Avicennia marina (I)	6.49	6.72	43	6.00	16.42	83.55	2.86
	6.41	6.58	49	2.24	0.12	89.09	5.08
	5.53	5.82	42	8.4	1.48	75.29	5.81
Avicennia marina(II)	4.78	4.88	47	11.60	2.63	64.41	10.61
	4.70	5.05	40	9.92	5.31	61.89	15.61
	4.15	4.38	40	11.99	3.67	60.82	20.97
Rhizophora spp	5.51	5.73	40	10.00	2.19	69.49	8.46
	5.40	5.60	40	8.00	6.56	63.59	5.28
	5.71	5.90	43	11.26	0.77	69.89	6.53

4.2.1.2 Soil salinity

Soil salinity of the each location has been illustrated in table 4.9 and fig 4.8.Minimum salinity was observed *Lumnitzera* zone while maximum salinity was observed in *Avicennia* zone.

There is no significant difference salinity among five locations of study site (F=3.12,P=006, F critical =3.47).

Table 4.10: Results of ANALYSIS OF Variance (ANOVA) conducted for soil salinity levels.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	0.34	0.50	7.70	Not Significant
Between two locations of *Avicennia* zone	0.53	0.50	7.70	Not Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	17.78	0.013	7.70	Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	12.16	0.025	7.70	Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	0.34	0.59	7.70	Not Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	1.43	0.29	7.70	Not Significant
Between *Lumnitzera* (I) and *Rhizophora*	14.41	0.01	7.70	Significant
Between *Lumnitzera* (II) and *Rhizophora*	1.12	0.34	7.70	Not Significant
Between A*vicennia*(II) and *Rhizophora*	0.27	0.62	7.70	Not Significant
Between *Avicennia* (I) and *Rhizophora*	2.32	0.20	7.70	Not Significant

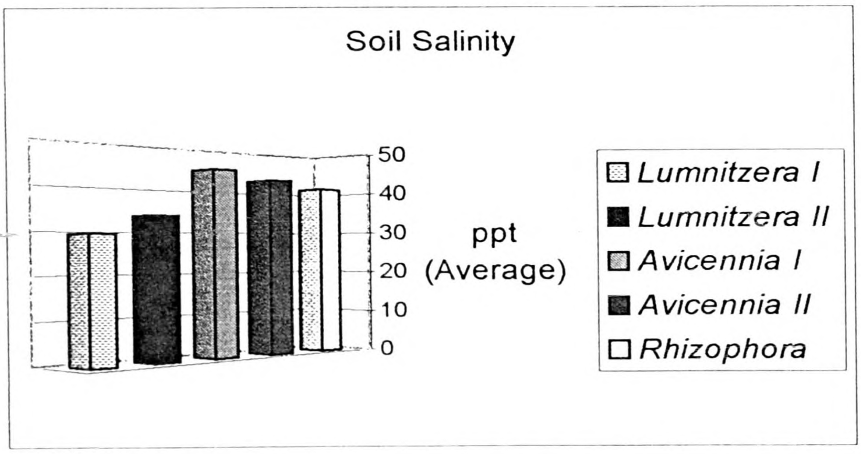


Fig 4.8 Salinity variation of study site

4.2.1.3 Soil texture

Soil texture of the each location has been illustrated in table 4.9.Maximum sand content was observed location I of the *Lumnitzera* zone and minimum sand content was observed in the location II of the *Avicennia* zone. Maximum clay and silt content was observed location II of the *Avicennia* and minimum clay and silt content was observed location I of the *Lumnitzera* zone. There is a significant difference among five location of the study site (F=5.91, P=0.01, F critical=3.47).

4.2.1.4 Soil Organic carbon

Soil organic carbon of the each location has been illustrated in table 4.9 and fig 4.9.Maximum carbon content was observed in the location II of the Avicennia zone and minimum carbon content was observed in the location I of the *Lumnitzera* zone. There is a significant difference carbon among five locations of study site (F=7.71,P=0004, F critical =3.47).

Table 4.11: Results of ANALYSIS OF Variance (ANOVA) conducted for soil organic carbon Content.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	0.62	0.4	7.70	Not Significant
Between two locations of *Avicennia* zone	12.76	0.02	7.70	Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	0.004	0.95	7.70	Not Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	12.63	0.02	7.70	Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	0.59	0.48	7.70	Not Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	1.18	0.04	7.70	Significant
Between *Lumnitzera* (I) and *Rhizophora*	2.55	0.18	7.70	Significant
Between *Lumnitzera* (II) and *Rhizophora*	0.14	0.72	7.70	Not Significant
Between *Avicennia* II and *Rhizophora*	8.24	0.04	7.70	Significant
Between *Avicennia* (I) and *Rhizophora*	2.71	0.17	7.70	Not Significant

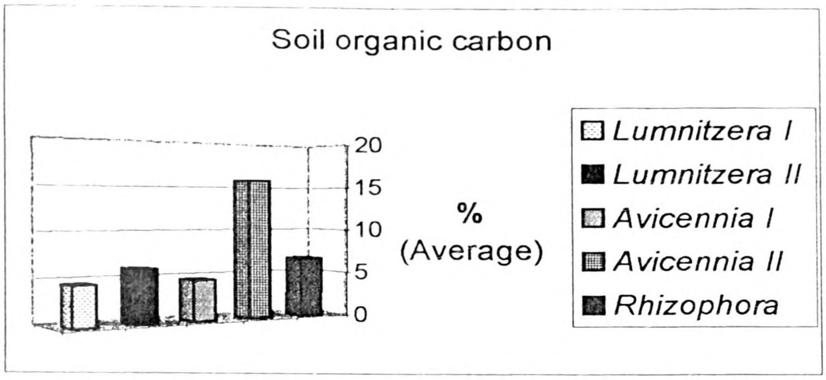


Fig: 4.9 Soil organic carbons content of the study site

4.2.2 Tidal inundation

Minimum tidal inundation was observed in *Lumnitzera* zone and maximum tidal inundation was observed in the location II of the *Avicennia* zone.

4.3 Microhabitats

Detailed maps of the microhabitats studied in the study locations are given in Plate 4.1 to Plate 4.13.

4.3.1 Physical factors

Variation of topographic conditions are given in the Appendix 1 2 and 3; Maximum number of mounds were observed in the *Rhizophora* zone and minimum number of mounds were observed in location II of the *Avicennia* zone. Maximum numbers of depression were observed in the *Rhizophora* zone and minimum numbers of depression were observed in the location II of the *Avicennia* zone. Maximum numbers of waterholes were observed in location II of the *Lumnitzera* zone and minimum numbers of water holes were observed in the *Rhizophora* plot.

4.3.1.1 Root density

Root densities of the each zone are given in the Appendix 1 2 and 3. Maximum root density observed in location II of the Avicennia zone and location II of the *Lumnitzera* zone.

4.3.1.2. Seedling density

Seedling densities of the each plot are given in the Appendix 1 2 and 3. Maximum numbers of seedling were observed in location II of the *Avicennia* zone and minimum seedling density were observed in the location I of the *Lumnitzera* zone.

4.3.1.3 Surface litter accumulation

Surface accumulations of the each zone are given in the Appendix 1 2 and 3. Maximum numbers of accumulation were observed in *Rhizophora* and minimum numbers of accumulation were observed in the location II of *Lumnitzera* zone. There is a significant difference surface litter accumulation among five locations of study site (F=3.40,P=001, F critical =2.24).

Table 4.12: Results of ANALYSIS OF Variance (ANOVA) conducted for surface litter Accumulations

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	6.24	0.01	4.00	Significant
Between two locations of *Avicennia* zone	8.64	0.05	4.00	Not Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	8.06	0.006	4.00	Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	8.64	0.005	4.00	Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	0.21	0.64	4.00	Not Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	4.18	0.04	4.00	Significant
Between *Lumnitzera* (I) and *Rhizophora*	0.34	0.56	4.00	Not Significant
Between *Lumnitzera* (II) and *Rhizophora*	3.62	0.06	4.09	Not Significant
Between *Avicennia* (II) and *Rhizophora*	1.66	0.20	4.00	Not Significant
Between *Avicennia* (I) and *Rhizophora*	4.09	0.005	4.00	Significant

4.3.1.4 Detritus accumulation

Detritus accumulations of the each zone are given in the Appendix 1 ,2 and 3 .Highest detritus accumulation was recorded in *Rhizophora* zone and the lowest was in Location II of *Lumnitzera* zone. There is a highly significant difference of detritus accumulation among five locations of study site (F=6.51, P=8.55E-05, F critical =2.44).

Table 4.13: Results of ANALYSIS OF Variance (ANOVA) conducted for detritus Accumulations.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	13.16	0.0006	4.00	Significant
Between two locations of *Avicennia* zone	4.13	0.04	4.00	Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	2.31	0.13	4.00	Not Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	0.009	0.92	4.00	Not Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	17.03	0.0001	4.00	Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	30.28	8.84E-7	4.00	Significant
Between *Lumnitzera* (I) and *Rhizophora*	0.36	0.54	4.09	Not Significant
Between *Lumnitzera* (II) and *Rhizophora*	0.10	0.74	4.09	Not Significant
Between *Avicennia* (II) and *Rhizophora*	0.36	0.54	4.09	Not Significant

4.3.1.5 Soil organic carbon.

Soil organic carbon of the each zone is given in the Appendix 1 ,2 and 3.Location II of *Avicennia* zone showed highest soil organic carbon while location I of *Lumnitzera* I zone showed the lowest soil organic carbon content. There is a highly significant difference soil organic carbon among five locations of study site (F=48.40,P=56E-24, F critical =2.44).

Table 4.14: Results of ANALYSIS OF Variance (ANOVA) conducted for soil organic carbon Content.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	28.58	1.58E-6	4.40	Significant
Between two locations of *Avicennia* zone	47.65	26E-9	4.00	Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	56.91	3.57E-10	4.00	Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	84.05	7.01E-13	4.00	Significant
Between *Lumnitzera* (I) and *Rhizophora*	0.46	0.49	4.09	Not Significant
Between *Lumnitzera* (II) and *Rhizophora*	13.41	0.0007	4.09	Significant
Between *Avicennia* (II) and *Rhizophora*	21.01	4.82E-5	4.09	Significant
Between *Avicennia* (I) and *Rhizophora*	0.46	0.049	4.09	Not Significant

4.3.2Tidal inundation

Details about tidal inundation of study locations are given in Table 4.15:

Table 4.15 Tidal inundation

Time	Location I of *Avicennia*	Location II of *Avicennia*	*Rhizophora*
7.00 am	7.5	15	8.6
8.00 am	4.3	8.5	4.3
9.00 am	2.8	5.62	2.1
10.00 am	1.9	3.22	0.8
11.00 am	1	1.25	0.1
12.00 pm	Only some plot	Only some plot	Only some plot
1.00 pm	-	Only some plot	-
2.00 pm	-	Only some plot	-

Minimum tidal inundation is observed in *Lumnitzera* zone. Maximum tidal inundation is observed in location II of *Avicennia* zone within a day.

4.3.3 Faunal density

4.3.3.1 Epifauna density

Epifauna density and crabs holes are given in the table 4.16. Maximum numbers of crabs were observed in location I of *Lumnitzera* zone and maximum numbers of crab holes were observed in location I of the *Lumnitzera* zone. Minimum numbers of crabs were observed location I of the *Lumnitzera* zone and minimum numbers of crabs' holes were observed location II of *Avicennia* zone. As well as *Cassidula musterina* were observed in the pneumatophorus of the location II of *Avicennia* zone and Mudskipper (*Periophthalmus*) was identified in location I of the *Avicennia* zone.

Table 4.16 Distribution of crabs and crab holes.

Location	Crabs			Crab holes		
	Q 01	Q 02	Q 03	Q 01	Q 02	Q 03
Lumnitzera racemosa I	8	4	4	32	25	0
Lumnitzera racemosa II	0	1	1	6	5	11
Avicennia marina I	2	1	2	11	22	1
Avicennia marina II	15	10	7	3	5	4
Rhizophora spp	4			0		

4.3.3.2 Infauna density

Infauna densities of study location are given in the Appendix 1,2 and 3. Macro benthic animals such as Isopods and polycheates taxonomic groups were identified. Maximum diversity of infauna was observed in location II of *Avicennia* zone. And minimum diversity of infauna was observed in location I of the *Lumnitzera* zone. Maximum numbers of isopods were identified in the location II of the *Lumnitzera* zone and minimum numbers of isopods were identified in the *Rhizophora* plot.

4.3.4 Chemical factors

4.3.4.1 Soil pH

1/pH are given in the Appendix 1, 2 and 3.These maximum values are observed *Avicennia* II and minimum values are observed in location I of *Lumnitzera* zone. There is a highly significant difference pH among five locations of study site (F=6.67, P=6.68E-05, F critical =2.44).

Table 4.17: Results of ANALYSIS OF Variance (ANOVA) conducted for pH variations in infauna density.

Locations	F value	P value	F critical	Level of significance
Between two locations of *Lumnitzera* zone	0.12	0.72	4.00	Not Significant
Between two locations of *Avicennia* zone	6.28	0.01	4.00	Significant
Between *Lumnitzera* (I) and *Avicennia* (I)	6.49	0.01	4.00	Significant
Between *Lumnitzera* (I) and *Avicennia* (II)	9.28	0.003	4.00	Significant
Between *Lumnitzera* (II) and *Avicennia* (I)	6.47	0.01	4.00	Significant
Between *Lumnitzera* (II) and *Avicennia* (II)	8.95	0.04	4.00	Significant
Between *Lumnitzera* (I) and *Rhizophora*	139.56	2.73E-14	4.09	Significant
Between *Lumnitzera* (II) and *Rhizophora*	63.63	1.29E-09	4.09	Significant
Between *Avicennia* (I) and *Rhizophora*	0.077	0.38	4.09	Significant
Between *Avicennia* (II) and *Rhizophora*	13.56	0.0007	4.09	Significant

4.4 Diversity index

Diversity index is high in the location II of the *Avicennia* zone. Calculated diversity index are given in the Appendix 4.

4.5 Relationship between diversity index and faunal density

Calculated diversity indices for each microhabitat of each study location that were plotted against the faunal density are illustrated in Fig 4.10 To Fig 4.14 There was no significant relationship between diversity index and benthic fauna observed in any study location.

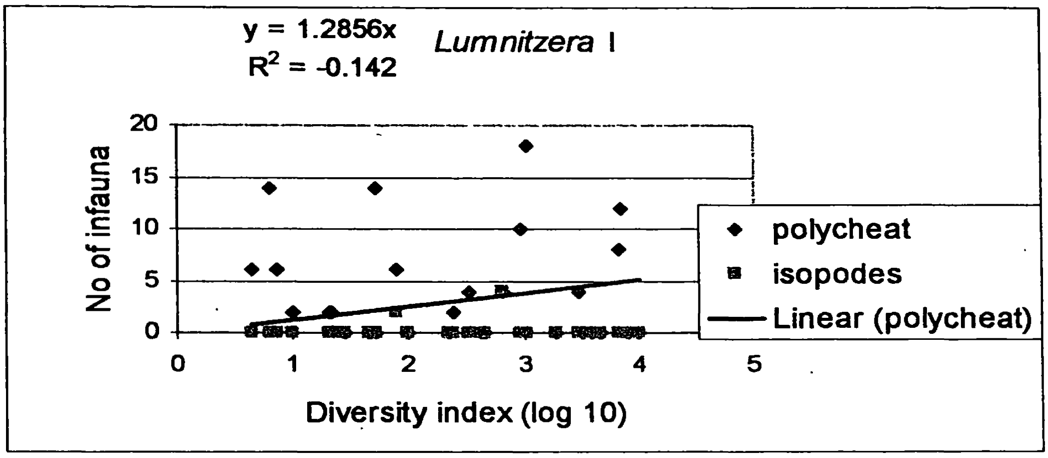


Fig.4.10 Relationship between infauna density and Diversity index in the inland location of *Lumnitzera* zone.

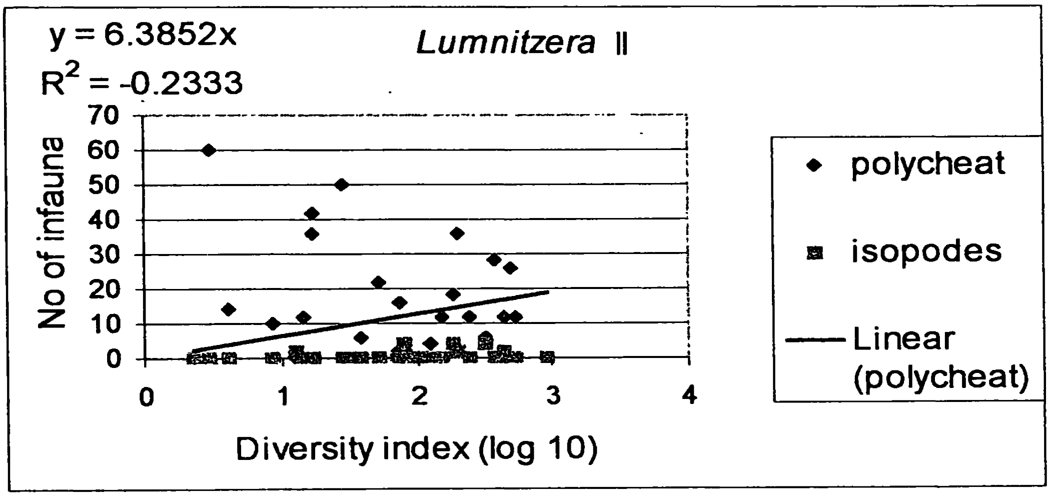


Fig.4.11 Relationship between infauna density and Diversity index in the water front location of *Lumnitzera* zone.

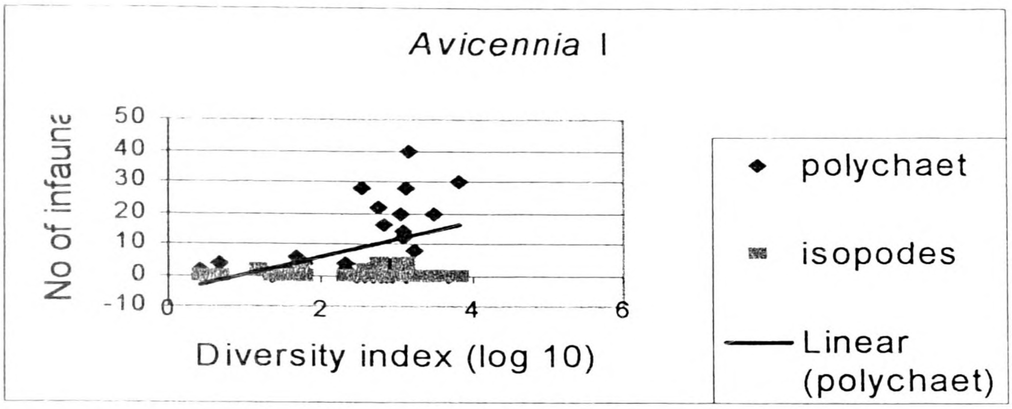


Fig.4.12 Relationship between infauna density and Diversity index in the inland location of *Avicennia* zone.

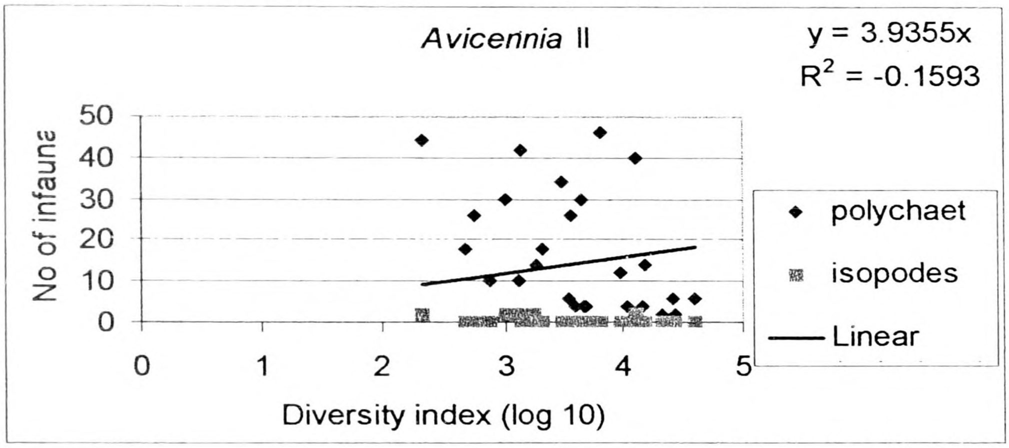


Fig.4.13 Relationship between infauna density and Diversity index in the water front location of *Avicennia* zone.

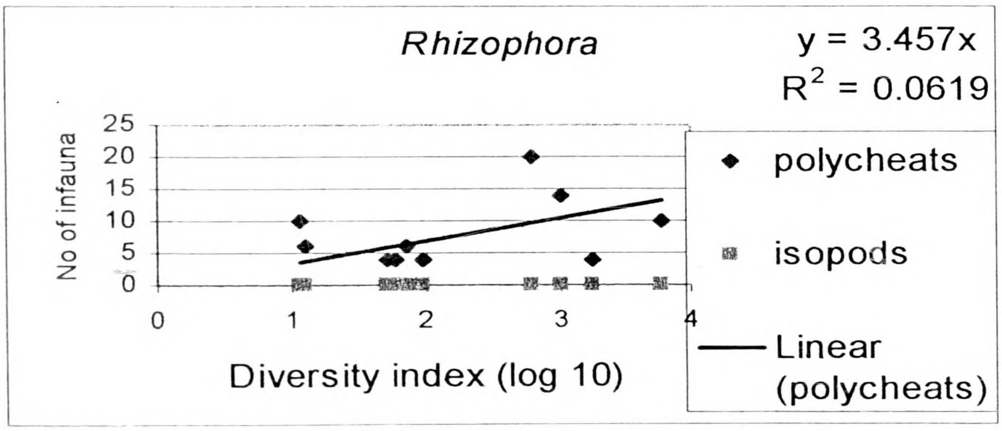
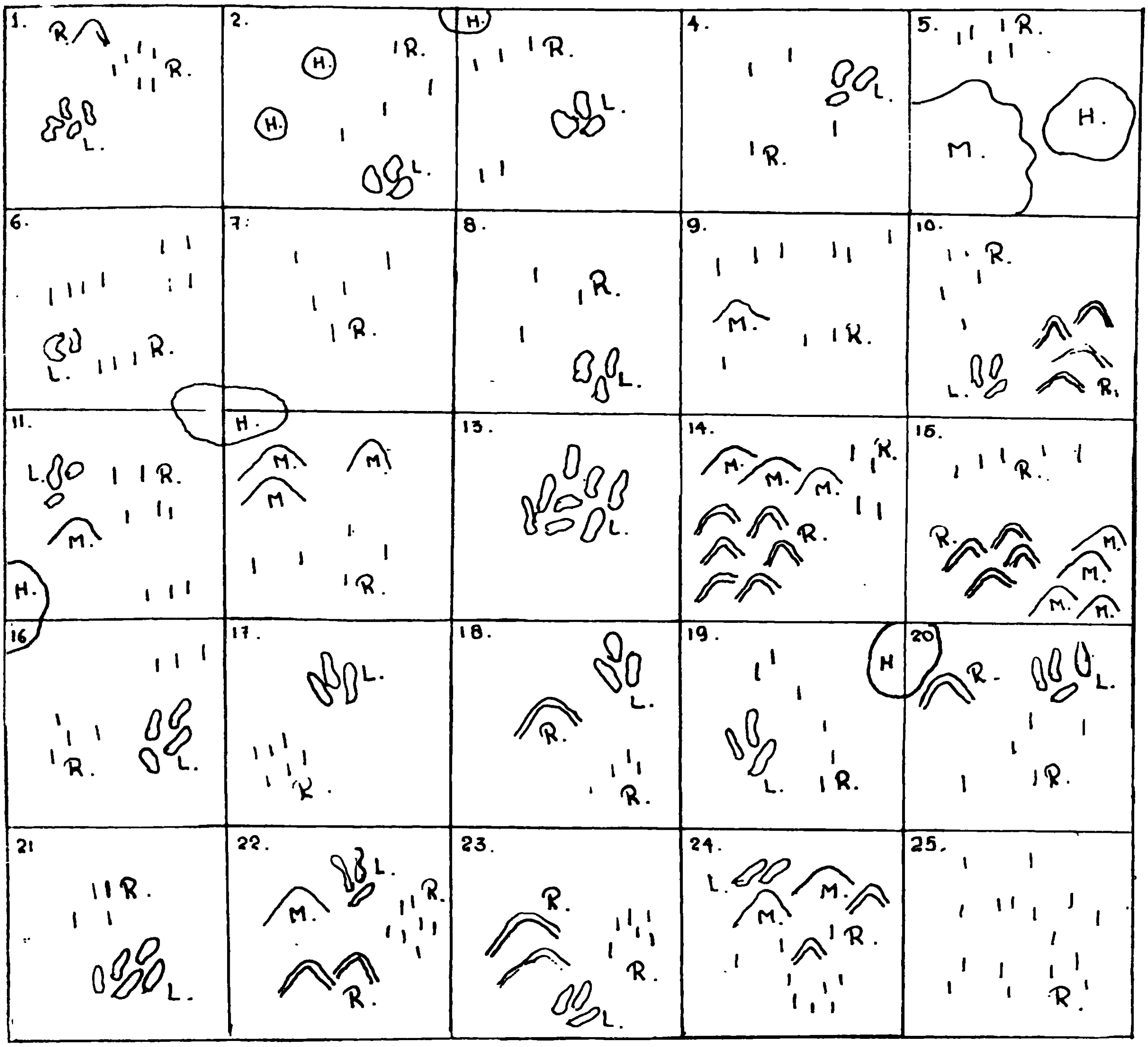


Fig.4.14 Relationship between infauna density and Diversity index in the water front location of *Rhizophora* zone.

Lumnitzera racemosa I Q - 01



01. Root (R)

02. Crab Holes (H)

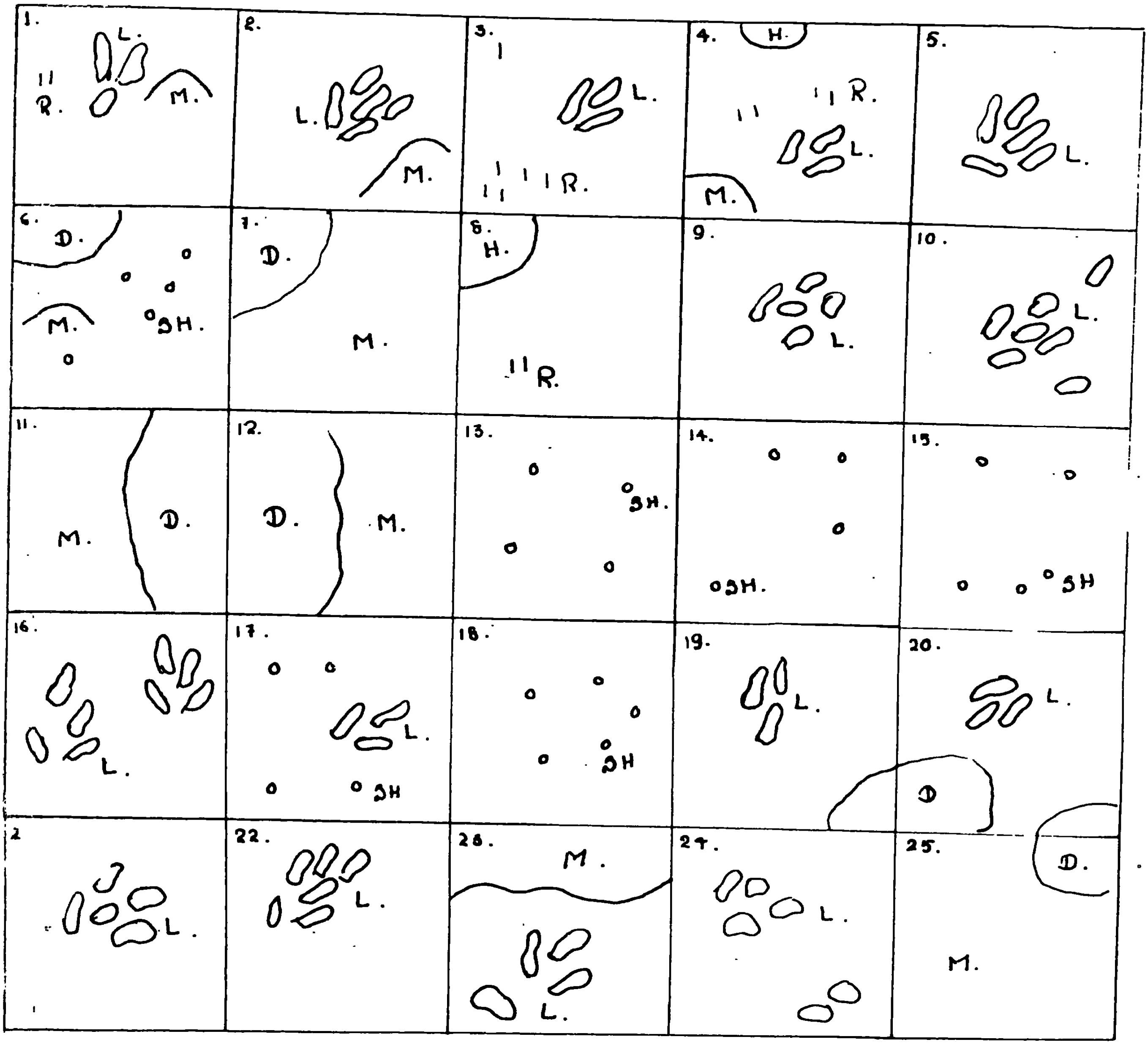
03. Mounds (M)

04. Depression (D)

05. Litter (L)

Plate:4.1 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in inland location of *Lumnitzera* zone (sample 1)

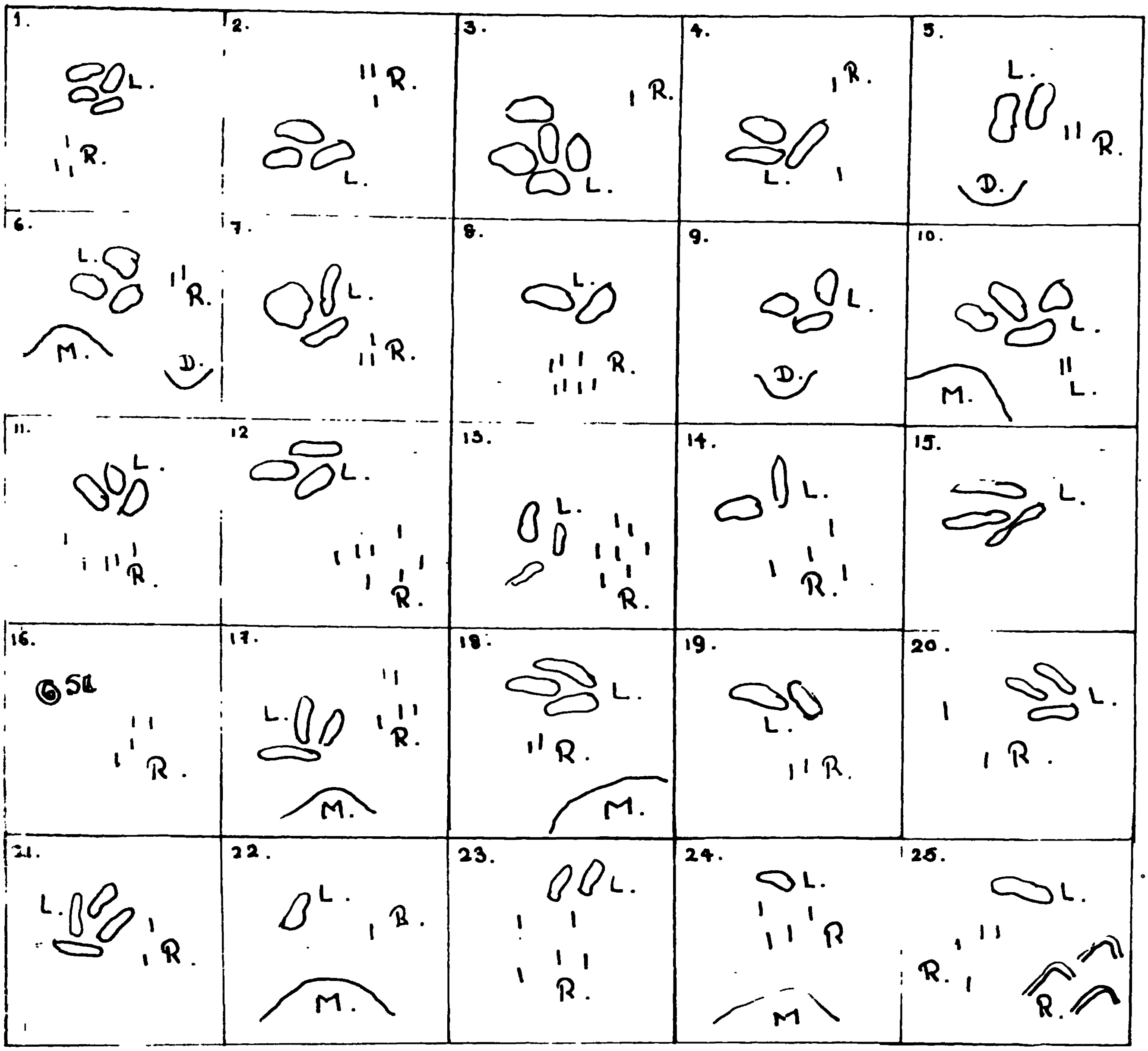
Lumnitzera racemosa I Q - 02



01. Root (R)
02. Crab Holes (H)
03. Mounds (M)
04. Depression (D)
05. Litter (L)
06. Small Hole (SH)

late:4.2 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in land location of *Lumnitzera* zone (sample 2)

Lumnitzera racemosa I Q - 03.



01. Root (R)

02. Mounds (M)

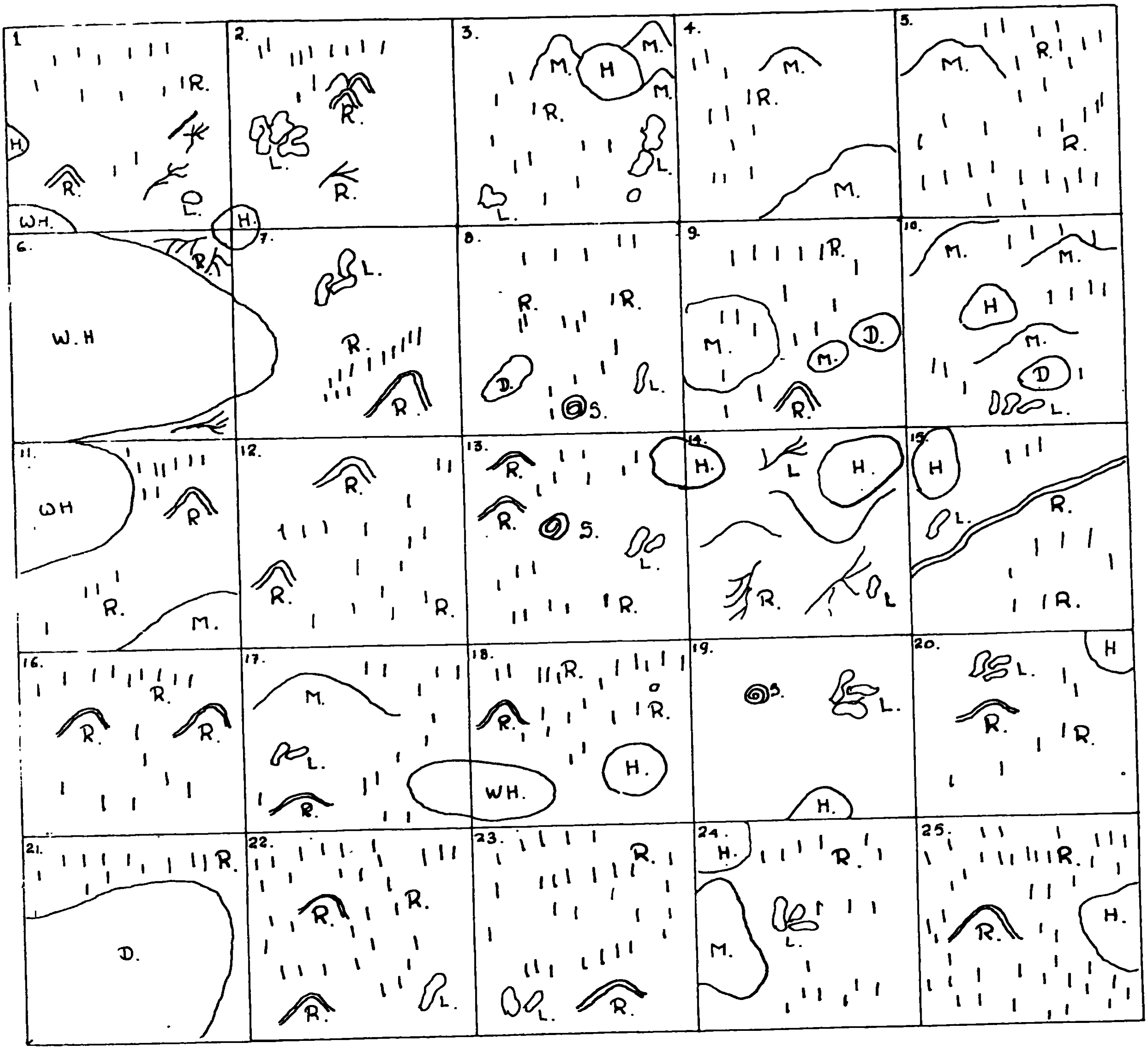
03. Depression (D)

04. Litter (L)

05. Shell (S)

Plate:4.3 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in inland location of *Lumnitzera* zone (sample 3)

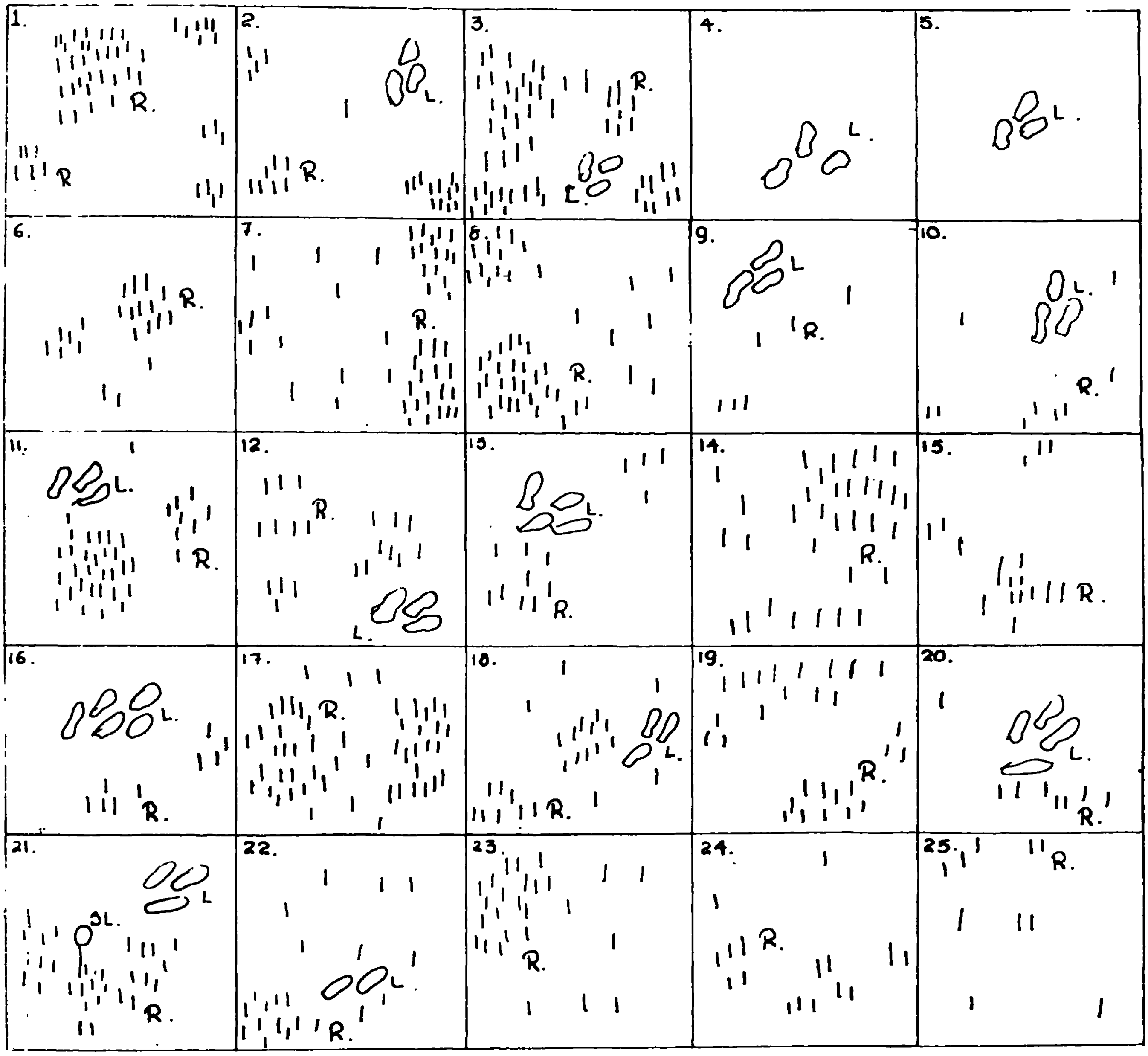
Lumnitzera racemosa II Q-01



01. Root	(R)	05. Water Holes	(WH)
02. Crabs Holes	(H)	06. Litters	(L)
03. Mounds	(M)	07. Shell	(S)
04. Depression	(D)		

Plate:4.4 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in water front location of *Lumnitzera* zone (sample 1)

Lumnitzera racemosa II Q - 02



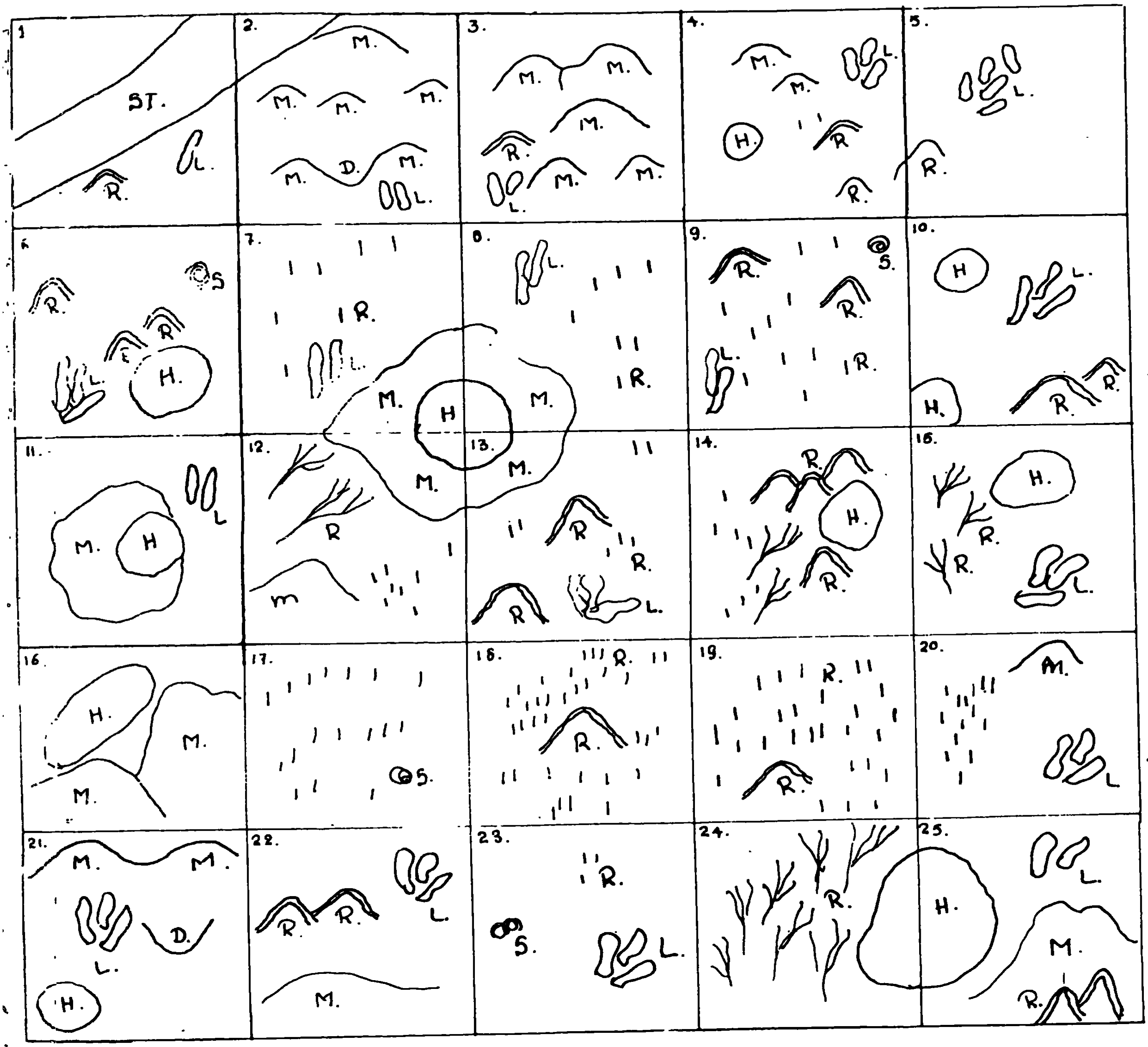
01. Root (R)

02. Litter (L)

03. Seedling (SL)

Plate:4.5 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in water front location of *Lumnitzera* zone (sample 2)

Lumnitzera racemosa II Q-03



01. Root (R)

02. Crab Holes (H)

03. Mounds (M)

04. Depression (D)

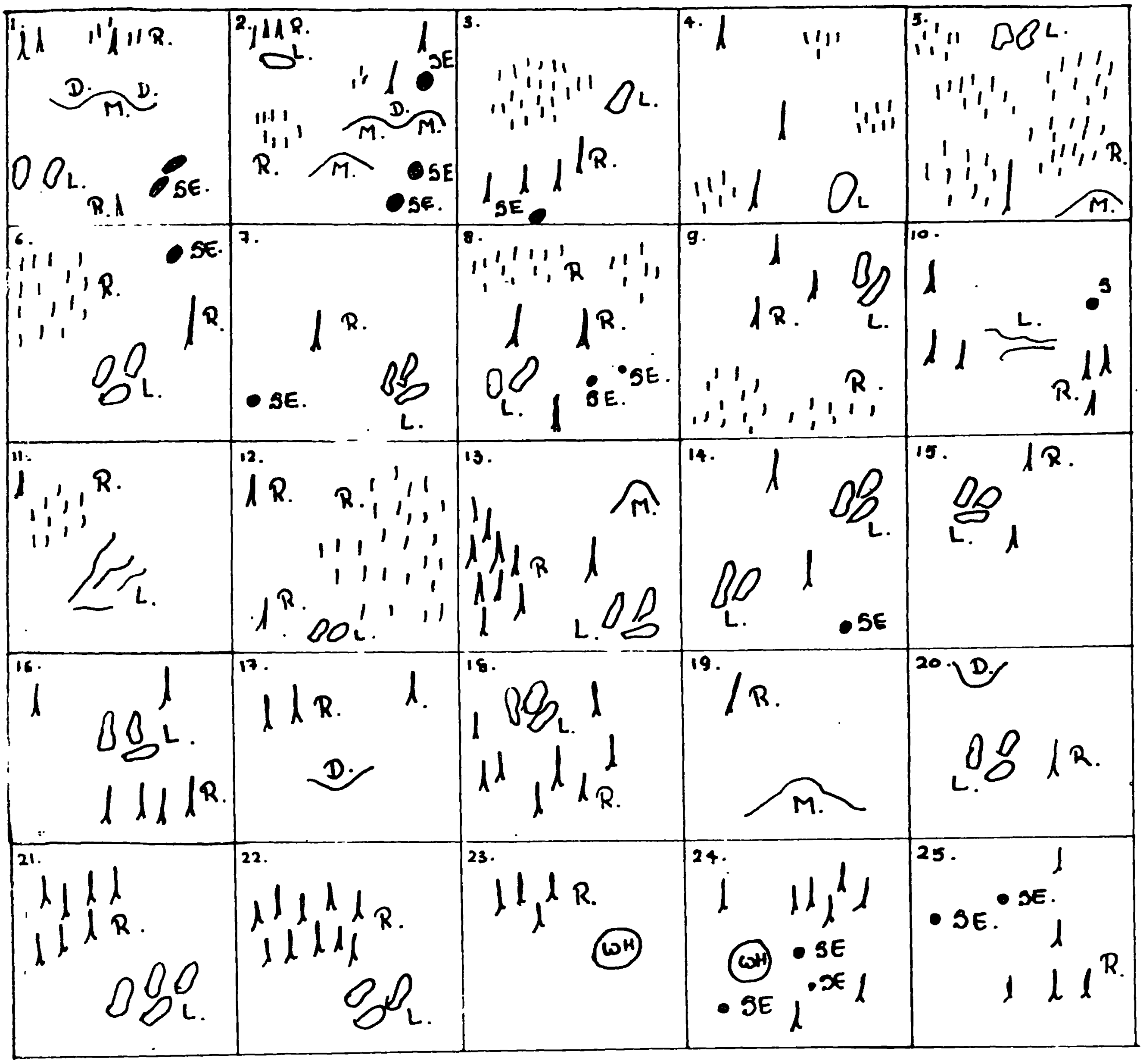
05. Litter (L)

06. Stemp (ST)

07. Shell (S)

Plate:4.6 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in water front location of *Lumnitzera* zone (sample 3)

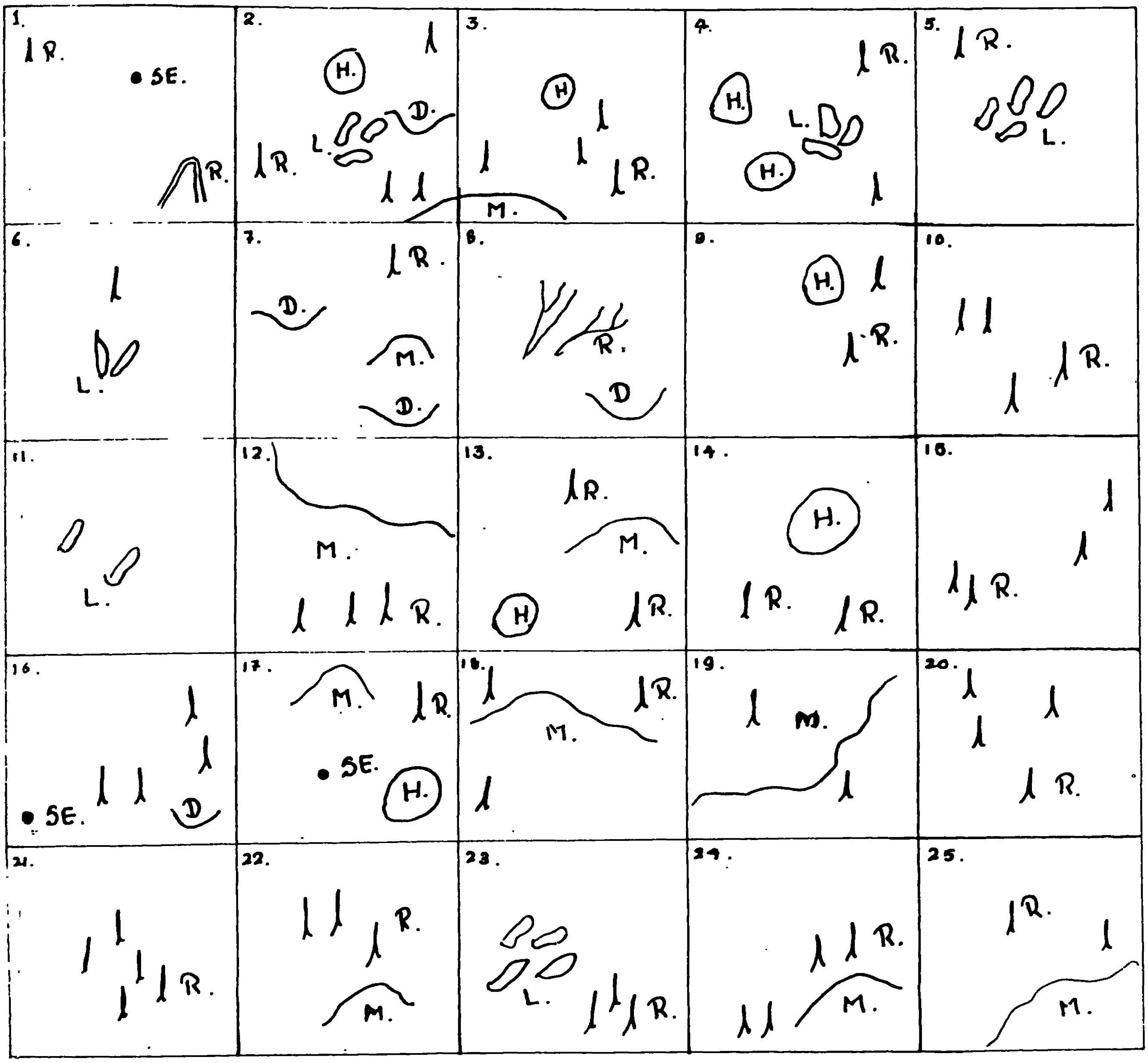
Avicennia marina I Q-01



01. Root (R)
02. Water Holes (WH)
03. Mounds (M)
04. Depression (D)
05. Litter (L)
06. Seed (SE)

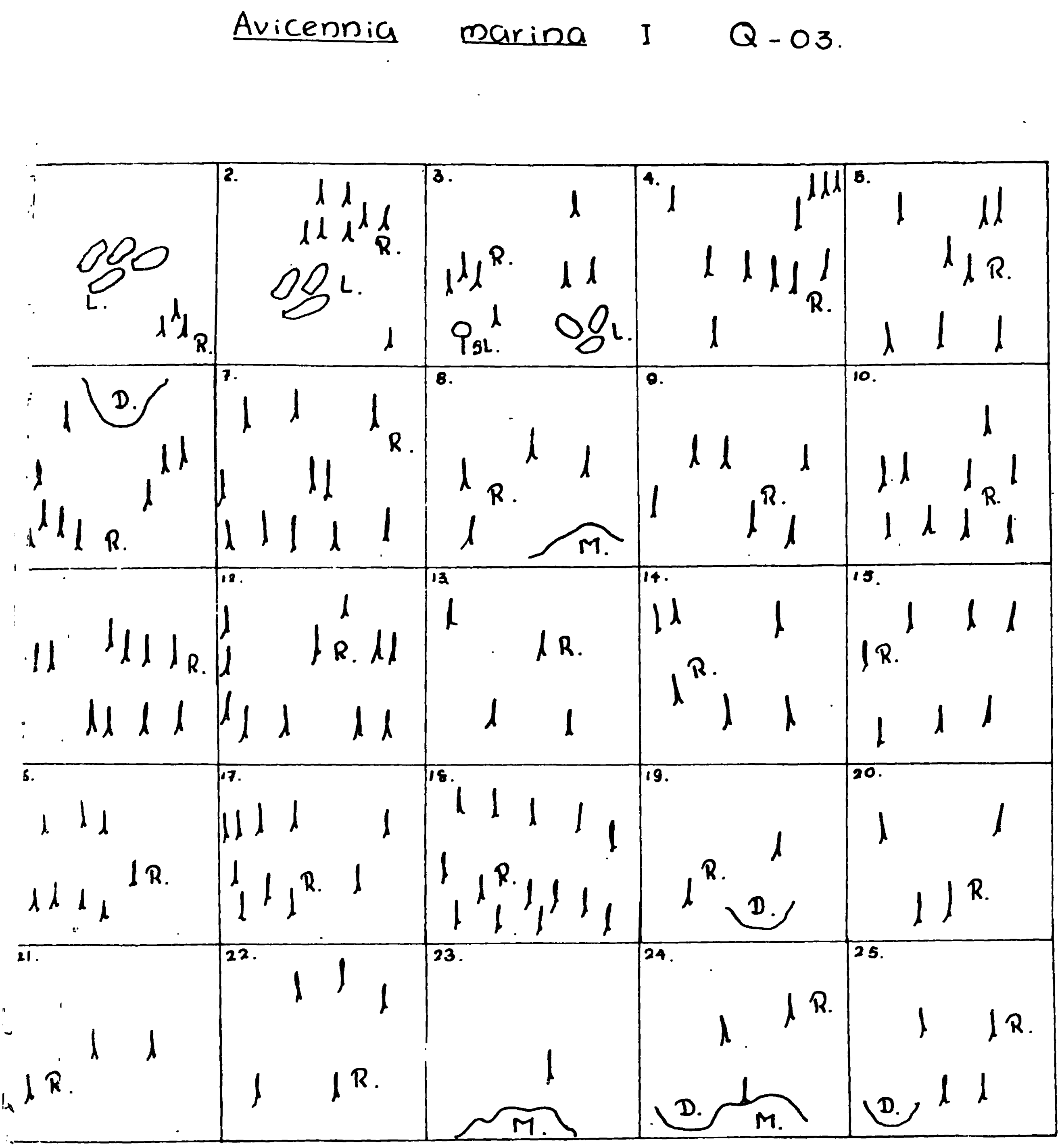
Plate:4.7 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in inland location of *Avicennia* zone (sample 1)

Avicennia marina I Q-02



01. Root (R)
02. Crab Holes (H)
03. Depression (D)
04. Mounds (M)
05. Litter (L)
06. Seed (SE)

Plate:4.8 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in inland location of *Avicennia* zone (sample 2)



01. Root (R)

02. Mounds (M)

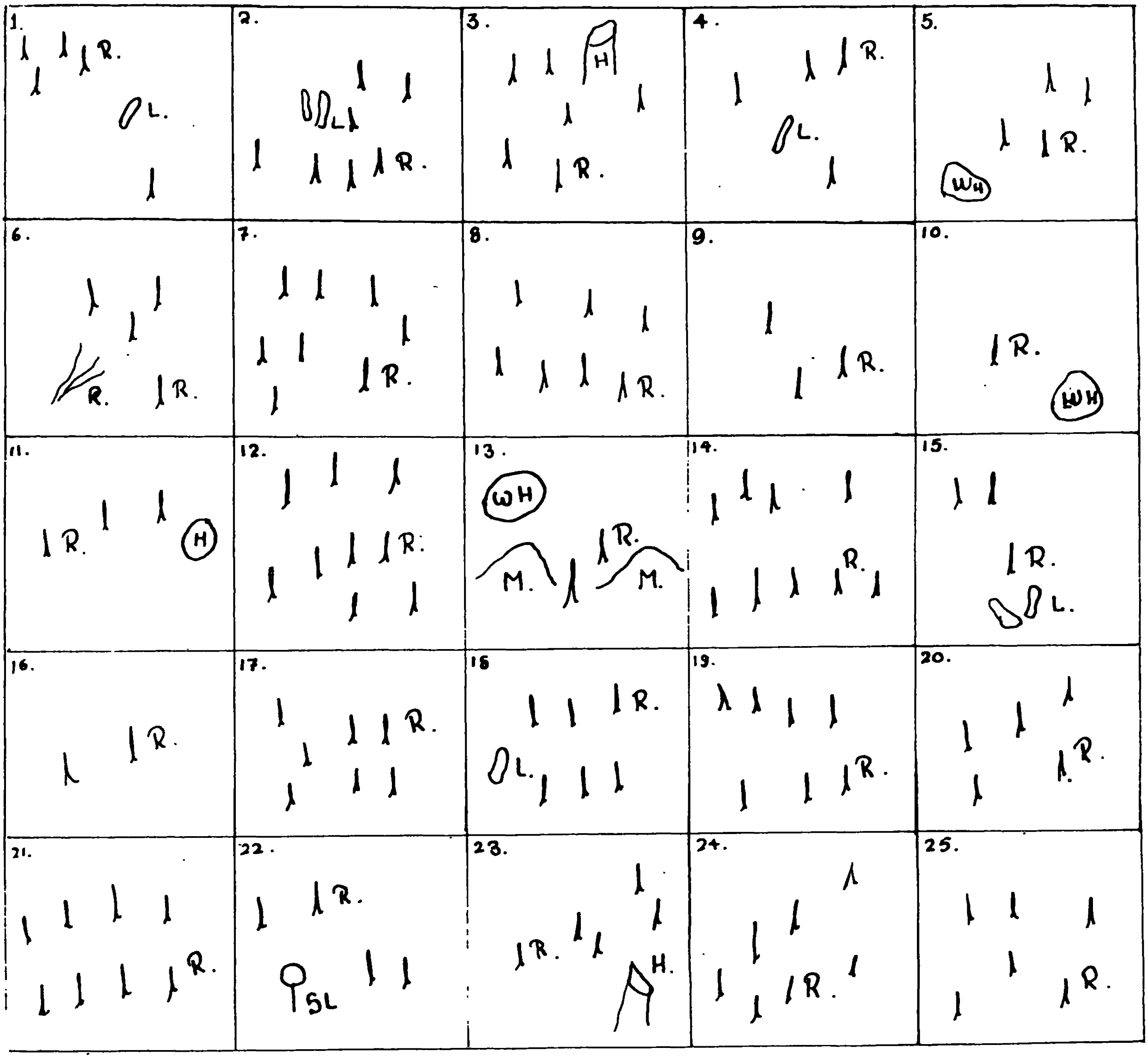
03. Depression (D)

04. Litter (L)

05. Seedling (SL)

Plate:4.9 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in inland location of *Avicennia* zone (sample 3)

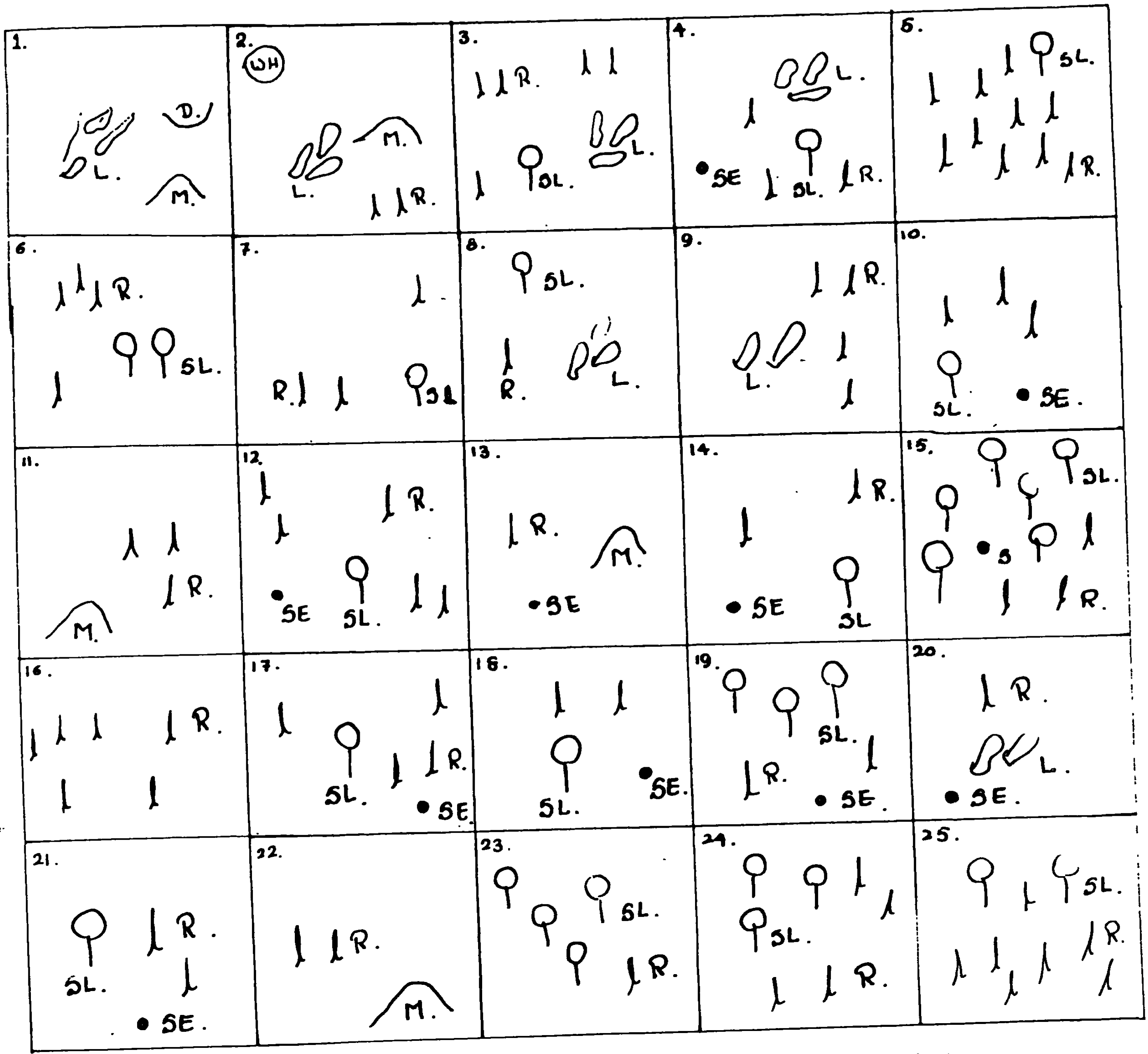
Avicennia marina II Q-01



01. Root (R)
02. water Holes (WH)
03. Crab Holes (H)
04. Mounds (M)
05. Litter (L)
06. Seedling (SL)

Plate:4.10 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in inland location of *Avicennia* zone (sample 1)

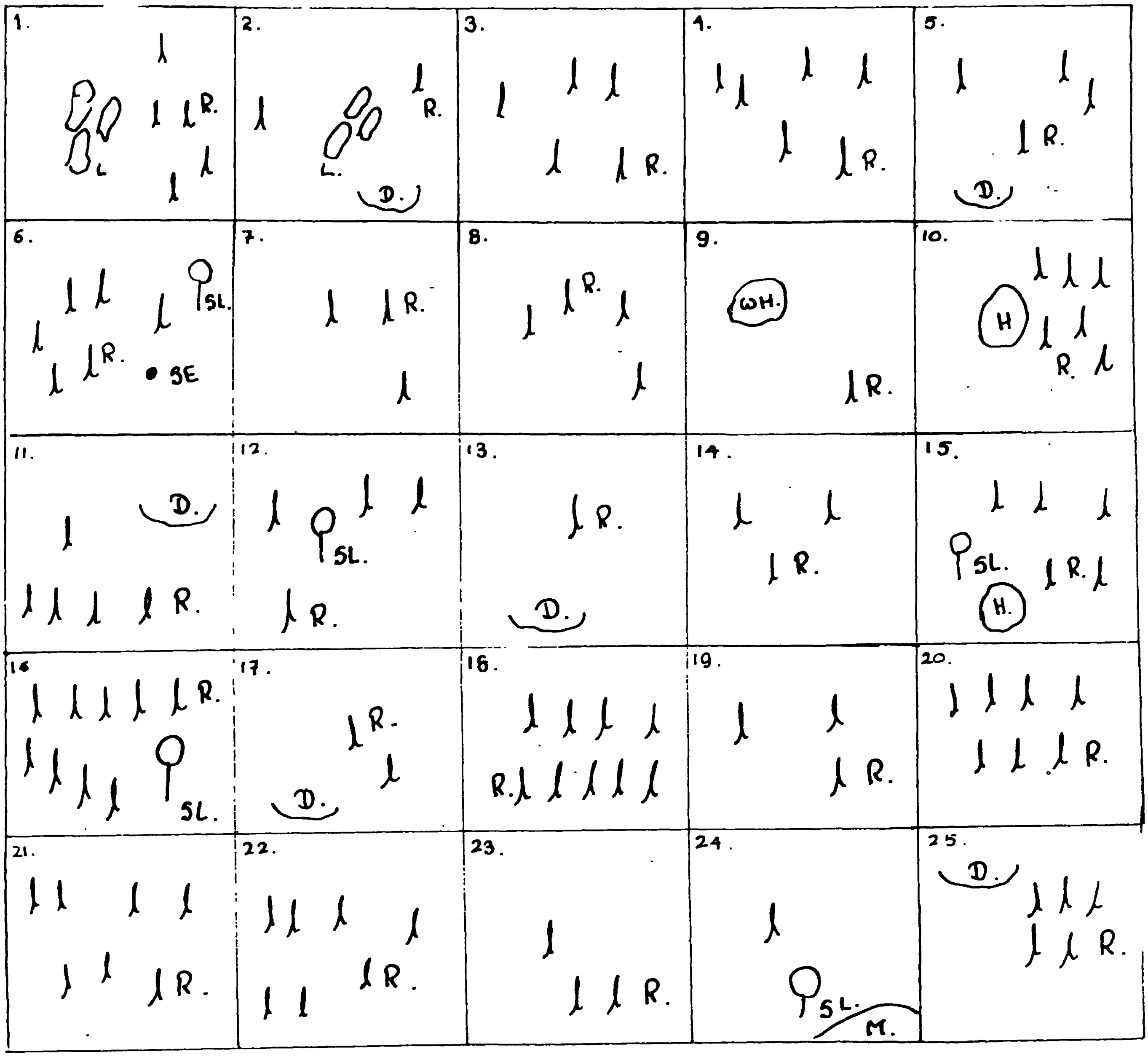
Avicennia marina II Q - 02



01. Root (R)
02. Water Holes (WH)
03. Mounds (M)
04. Depression (D)
05. Litter (L)
06. Seedling (SE)
07. Seed (SE)

Plate:4.11 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in water front location of *Avicennia* zone (sample 2)

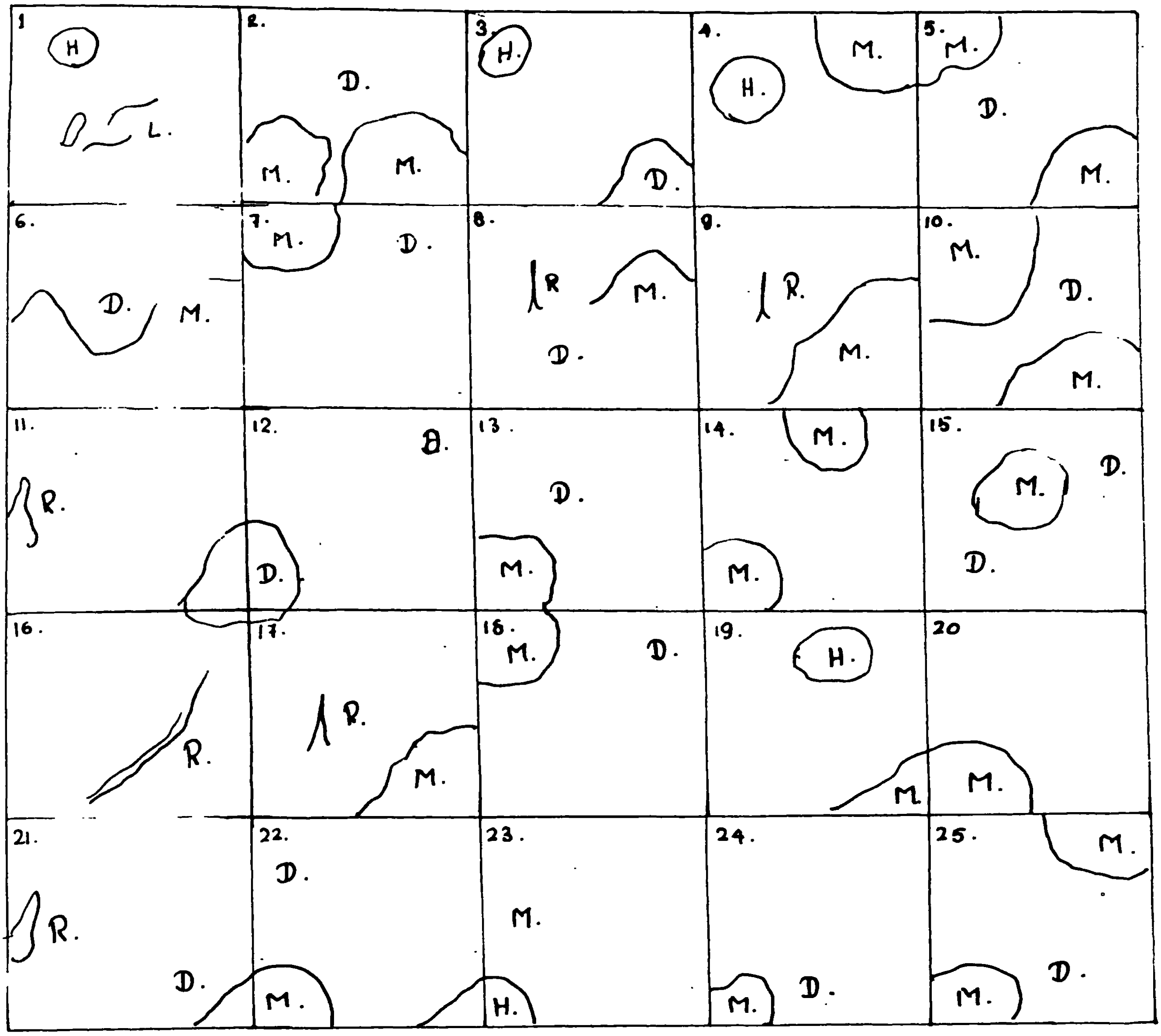
Avicennia marina II Q-03



01. Root (R)
02. Crab Holes (H)
03. Mounds (M)
04. Depression (D)
05. Litter (L)
06. Seedling. (SL)
07. Seed (SE)

Plate:4.12 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in water front location of *Avicennia* zone (sample 3)

Rhizophora



01. Root (R)

02. Crab Holes (H)

03. Mounds (M)

04. Depression (D)

Plate:4.13 Sketch of the microhabitats in 10cm x 10cm segments within 50cm x 50cm quadrate in *Rhizophora* zone

4.6 Discussion

Mangrove forests constitute a characteristic coastal ecosystem of evergreen woody plants in the tropical and sub tropical world (De silva and De silva, 1998).

In most of natural mangrove areas like large and undisturbed areas it is observed that there is a species distribution pattern. It's common in parallel to the coastline and riverbanks. The causes of mangrove zonation is still subject to debate but it is probably determined by the topography, tidal inundation level, climate, run-off, sediment deposition, inclusion of see water, and stability, soil redox state, sulphide concentration (Liyanage, 2000), soil and water salinity (Macnae, 1968b), drainage and soil moisture (Macnae, 1968a), site of propagules (Kenneally, 1982), plant and animal interactions (Kenneally, 1982) or combination of these factors.

Clear zonation of mangrove species could be seen from the lagoon to inland areas in the mangals of Kadolkele (Phalawattaarachchi, 1996). Consideration of three mangrove zones have been identifying in the study site. They were, *Rhizophora* zone, *Avicennia* zone and *Lumnitzera* zone. Tree density contributes to number of individuals in each species. *Avicennia marina* possesses the highest tree density in water front areas. But from waterfront to inland it was gradually changed and *Lumnitzera* species possesses the highest tree density up to inland. Such a fluctuation was shown by relative density due to *Avicennia marina* was prominent species in water front areas. Up to about 30 m from the lagoon front and after that *Lumnitzera* has become the prominent species in 1995(Pahalawattaarachchi, 1996). Nevertheless this study revealed that the *Avicennia* zone spread far more to the inland than 30m. This has being happened after sound management of the area by National Aquatic Resources Research And Development Agency.

There is a clear difference among tree heights of each mangal plot. The three heights are decrease from lagoon front to the inland. The results can be explained according to the the statement that low stand heights of inland areas may attribute to low inputs of tidal waters which can be caused high salinity levels in soil (Cintron *et al.*, 1978) and / or the accumulation of toxic substances (Carlson *et al.*, 1983).

Higher tree density and seedling density was observed in the inland location of *Lumnitzera* zone. This could be attributed to the lighter seeds of the species; there is a probability of wash down such of seeds by tide in the location near the lagoon. Therefore seed germination may be low and tree density and seedling density was low. In contrast to that tree density and seedling density of the water front location of *Avicennia* zone is higher than the tree density and seedling density of the inland location of *Avicennia* zone. This may be due to the fact that *Avicennia* seeds are well germinated in water logged condition and high carbon contents. (Macnae, 1968a) and also seeds are heavier than the seeds of *Lumnitzera* and it is easy to settle in the areas closer to lagoon. (Liyanage, 2000).

When consider of aerial root density of the each zone generally water logged areas possessed higher density of aerial roots. This also was confirmed by the present study. *Lumnitzera* II plot was situated in comparatively elevated area but the land is influenced by high tide water flow and has some water logged areas with very high number of aerial roots. In the other hand *Lumnitzera* II plot (nearest to the lagoon), has higher clay content than that of *Lumnitzera* I plot which is in inland. Because of these reason soils water content is high and soil oxygen content is low (Pinto, 1986). Therefore small roots grove above the soil. In contrast to that *Lumnitzera* I plot have uniform water inundation and therefore root density are uniform. Aerial roots (pneumatophores) of the water front zone are higher than that of the inland location of *Avicennia* zone. Same explanation can be applied in this case such as more tidal inundation and more soil clay content cause high soil water content. Hence it is obvious that soil oxygen is low causing high anaerobic condition and low pH. Therefore pneumatophores grow above the soil in *Avicennia* species (Pinto, 1986).

The mangrove soils are generally acidic, due to the activity of sulphar bacteria (Pinto, 1986). In this study *Avicennia* II location showed low pH values resulting high acidic soil. Further more it is observed that higher tidal retention, higher soil clay content and higher water logging than the inland location of *Avicennia*. Those observations may be the reason for anaerobic condition in the *Avicennia* II location, which is the closest location to the lagoon. Contrary to that lower clay content, lower tidal inundation in inland location of *Avicennia* zone showed higher pH values.

The salinity in mangrove soils could vary from almost nil to more than that of sea water (De silva and De silva, 1998). Higher soil salinity in waterlogged location was observed in this study. Salt accumulation may high in the water front areas due to the longer water retention time (tidal inundation). In addition high soil clay content may cause infiltration to be low resulting more salt accumulations in the upper layers of soil. Lowest soil salinity values were observed in *Lumnitzera* I location, which is the most, elevated out of the study locations. It can be suggested that this location gets no water loggings (Except isolated water logged areas) and therefore get low salt accumulation. In addition to that soil of the above location has a sandy texture, which can be caused high infiltration of salt water through soil resulting lower salinity values for surface soil. Macnae (1968) suggests that *Avicennia marina* shows a tolerance to wide range of salinity; it is able to grow in soils with ground water salinity of around 90% and also on the banks of rivers tidal limit where the salinity is low. Hence findings of the present study confirmed the above suggestion. *Rhizophora apiculata* is normally found in areas of reduced salinity (Ding Hou, 1958). As such soil salinity is relatively high in the *Rhizophora* zone at the Kadolkele mangrove reserve.

Mangrove soils have relatively small particles. Particle size less than that of fine sand (less than 0.25 mm) is common (Pinto, 1986). It has being shown that sand content is highest in *Lumnitzera* zone. The practical size increases from the shore inwards to the land (Pinto, 1986). And also it has being revealed that *Lumnitzera acemosa* occurs on well-drained sandy soils always on the landward fringe (Macnae, 1968a). Clay, silt deposition is reduced in the inland areas as tidal influence low in the landward zone. Therefore clay and silt content is high. This phenomenon is proved by the results of water front location of *Avicennia* zone and in *Rhizophora* zone where tidal inundation is high and water retention time is high. Then clay, silt deposition is increased. Confirming that it has being recorded that the soil of the *Rhizophora* is always waterlogged and soft (Macnae, 1968a). In addition tidal inundation is high causing high deposition of small partials.

High level of the soil organic carbon contain in the mangrove environment. (Viles and Spender, 1995) In the water logged location litter decomposition is high (Pahalawaattaarachchi & Amarasinghe 1997). By confirming above statements closet location to the lagoon (*Avicennia* II) showed a high organic carbon content while location I of the *Lumnitzera* zone, which is in the innermost location showed a lowest organic carbon, content. This could be attributed to low water logged condition in the innermost areas and low litter decomposition.

Surface litter accumulation is essential for forming microhabitats within mangrove areas. Litter contains mainly leaves, twigs, seeds, flowers, and other debries. Leaves of *Avicennia marina* (42% of the total leaves) and *Rhizophora apiculata* (54% of the total fall) were found to be produced throughout the year at Kadolkele (Pahalawattaarachchi, 1996). Because of litter fall is high in the *Rhizorhora* zone surface litter accumulation is high.

Number of crab halls recorded was higher in the *Lunmitzera* II location and Avicennia I location where relatively elevated from the other locations. These findings concluded that crabs like to build their halls in the elevated lands. Contrary to that as number of crabs recorded was higher in the water logged areas. It has being observed that waterlogged areas make feeding locations for crabs as more detritus and benthic fauns is accumulating in those locations. Out of all the locations studied number of crabs recorded in *Avicennia* II location is highest. This location is situated in the waterfront and accumulates more detritus. Also it has being observed that the seeds of of *Avicennia* have high sugar content. (Macnae, 1968a) and preferred by the crabs.

Sediment properties (silt %, grain size water content) vary with tidal elevation and forest type and thus affect the distribution of marofauna in the mangroves (Aongi, 1989.Organic carbon and nitrogen response the distribution of the oligocheates and capitelides (Nandi and Choudhury, 1983). Oligocheates and polycheates were most abundant at the mangrove site and their occurrence is muddy sediment rich in organic matter (Pearson and Rosenberg, 1978).

There was no significant relationship between diversity index and benthic fauna observed in any study location. This may be due to obtain of relationship between diversity indices and total taxonomic groups. Hence it is suggested to identify to species level to get a relationship in future studies. Apart from that some more factors such as canopy cover, light penetration, structural parameters, soil moisture etc. Which were not considered in the present study may effect for diversity indices. Hence further studies are suggested for the studies in microhabitats.

CHAPTER 05

05 Conclusions and Recommendation

5.1 Conclusions

Major factors affecting the zonation of mangroves of Kadolkele mangrove reservoir of Negombo lagoon are soil salinity, soil pH, soil texture and tidal influence.

Water front location of Avicennia zone provides more microhabitats for macro benthos while epifauna such as crabs were much prominent in both *Avicennia* and *Lumnitzera* zones. Microhabitats for such epifuanal species have being created according to the behavioral patterns of the same animals.

5.2 Recommendation

Further studies can be recommended to obtain sound knowledge on microhabitats in order to maintain rich biodiversity within the mangroves of Negombo lagoon

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Appendix I –

Physical Chemical and Biological Factors of the study site.

Lumnitzera I

No	Surface	pH	OM %	Detritus	Root	Mounds	Depression	Crabs hall	Water hall	Seedlings	Stems	Inundation	Polycheat	Isopods
1	3.04	0.14	4.00	30.64	4	0	0	0	0	0	0	2	0	0
2	2.61	0.15	4.76	69.68	11	0	0	1	0	0	0	2	4	0
3	3.74	0.15	5.20	36.12	9	0	0	0	0	0	0	2	0	0
4	3.25	0.14	4.61	65.28	8	1	0	2	0	0	0	2	0	0
5	2.88	0.14	6.29	91	8	0	0	1	0	0	0	2	0	0
6	3.01	0.14	8.39	45.38	20	0	0	0	0	0	0	2	8	0
7	4.53	0.16	6.56	105.28	8	0	0	1	0	0	0	2	0	0
8	2.21	0.14	5.28	24.46	5	0	0	0	0	0	0	2	0	0
9	4.29	0.15	9.75	63.16	12	0	0	0	0	0	0	2	0	0
10	3.04	0.15	6.33	37.82	15	0	0	0	0	0	0	2	0	0
11	4.41	0.14	2.85	3.06	2	1	0	0	0	0	0	2	2	0
12	7.96	0.14	2.75	4.18	2	2	0	1	0	0	0	2	0	0
13	4.16	0.14	2.67	6.62	0	0	0	0	0	0	0	2	2	0
14	6.28	0.14	1.66	2.16	0	1	1	0	0	0	0	2	0	0
15	4.35	0.14	3.51	3.06	0	0	0	0	0	0	0	2	0	0
16	2.75	0.14	3.59	2.62	0	1	1	0	0	0	0	2	14	0
17	10.22	0.15	2.18	1.04	0	0	0	0	0	0	0	2	6	0
18	6.68	0.16	4.76	3.78	0	0	0	0	0	0	0	2	14	0
19	2.39	0.16	5.05	2.44	0	0	0	0	0	0	0	2	2	0
20	1.96	0.15	5.88	1.28	0	1	0	0	0	0	0	2	6	0
20	23.66	0.15	7.10	29.58	3	0	0	0	0	0	0	2	12	0
22	5.12	0.15	7.12	27.18	3	0	0	0	0	0	0	2	10	0
23	6.75	0.17	8.34	21.42	7	0	0	0	0	0	0	2	4	0

24	4.73	0.16	11.01	12.76	5	0	0	0	0	0	0	2	18	0
25	3.33	0.16	8.81	13.78	5	0	0	0	0	0	0	2	4	4
26	1.31	0.16	7.14	15.48	2	1	0	0	0	0	0	2	0	0
27	4.56	0.16	8.91	24.24	1	0	0	0	0	0	0	2	4	0
28	1.44	0.14	7.14	26.28	1	0	1	0	0	0	0	2	6	2
29	1.59	0.14	5.99	17.32	5	0	0	0	0	0	0	2	2	0
30	1.35	0.14	6.43	21.7	4	0	1	0	0	0	0	2	0	0

Lumnitzera II

No	Surface	pH	OM %	Detritus	Root	Mounds	Depression	Crabs hall	Water hall	Seedlings	Stems	Inundation	Polycheat	Isopods
1	1.09	0.15	5.20	3.08	14	0	0	2	1	0	0	2	2	4
2	0.86	0.16	8.80	2.28	11	2	0	0	0	0	0	2	4	0
3	0.52	0.16	7.20	5.36	29	1	1	0	0	0	0	2	36	2
4	0.94	0.17	6.00	9.6	13	0	0	1	0	0	0	2	12	0
5	0.80	0.17	7.20	6.56	20	2	0	0	0	0	1	2	12	0
6	0.40	0.16	0.87	2.64	14	1	1	0	0	0	0	2	14	0
7	0.61	0.17	1.57	29.86	18	0	0	0	0	0	0	2	18	4
8	1.16	0.17	1.28	10.28	15	1	0	0	1	0	0	2	12	0
9	2.09	0.17	1.73	12.44	20	0	0	1	1	0	0	2	6	4
10	23.08	0.17	2.21	6.92	27	0	0	0	0	0	0	2	12	2
11	1.55	0.15	2.20	2.84	0	0	0	1	0	0	0	2	60	0
12	2.99	0.16	3.27	3.06	50	0	0	1	0	0	0	2	26	0
13	1.42	0.14	1.65	2.32	47	0	0	0	0	0	0	2	16	0
14	1.06	0.14	2.49	2.44	9	0	0	0	0	0	0	2	36	0
15	0.73	0.14	1.81	10.88	9	0	0	0	0	0	0	2	6	0
16	0.55	0.14	2.34	2.08	21	0	0	0	0	0	0	2	42	0
17	1.36	0.14	1.99	2.94	18	0	0	0	0	0	0	2	50	0

18	0.06	0.14	2.28	6.72	19	0	0	0	0	0	0	2	22	0
19	0.66	0.14	2.31	16.58	51	0	0	0	0	0	0	2	28	0
20	0.00	0.147	2.20	10.44	21	0	0	0	0	0	0	2	12	0
21	2.00	0.147	3.44	10.9	11	0	0	0	0	0	0	2	0	0
22	1.50	0.147	3.45	8.54	29	1	1	0	0	0	0	2	0	2
23	0.74	0.147	2.63	2.96	3	0	0	1	1	0	0	2	10	0
24	0.85	0.1428	2.05	11.08	20	2	0	0	0	0	1	2	2	0
25	3.54	0.147	3.89	8.02	14	1	1	0	0	0	0	2	0	0
26	1.43	0.1449	3.93	8.32	17	0	0	1	0	0	0	2	0	0
27	0.82	0.147	1.19	14.04	20	0	0	1	1	0	0	2	0	0
28	3.47	0.147	2.86	10.94	0	0	0	1	0	0	0	2	0	0
29	1.36	0.147	2.91	10	10	0	1	0	0	0	0	2	0	0
30	0.27	0.147	1.67	16.76	27	0	0	0	0	0	0	2	0	0

Appendix II

Physical Chemical and Biological Factors of Study site

Avicennia I

No	Surface	pH	OM %	Detritus	Roots	Mounds	Depression	Crab halls	Water hall	Seedlings	Stems	Inundation	Polychaet	Isopods
1	2.1	0.14	5.30	26.68	5	1	2	0	0	0	0	4	8	0
2	1.37	0.14	7.51	30.8	4	0	0	0	0	0	0	4	4	0
3	0.13	0.14	3.65	21.96	8	1	0	0	0	0	0	4	6	0
4	3.8	0.14	2.86	19.62	3	0	0	0	0	0	0	4	0	2
5	3.7	0.15	7.92	12.12	6	0	0	0	0	0	0	4	0	0
6	2.9	0.14	8.04	11.332	4	0	0	0	0	0	0	4	0	0
7	2.33	0.15	7.24	13.4	6	0	0	0	0	0	0	4	0	0
8	0.84	0.14	11.85	16.54	8	0	0	0	0	0	0	4	0	0
9	0.41	0.15	11.27	17.44	10	0	0	0	0	0	0	4	0	0
10	4.49	0.14	14.48	17.92	7	0	0	0	1	0	0	4	0	0
11	0.39	0.18	6.28	0.06	4	1	0	1	0	0	0	3	2	2
12	0.54	0.20	7.00	6.48	1	0	0	1	0	0	0	3	2	2
13	5.98	0.19	5.56	5.86	2	0	1	0	0	0	0	3	2	0
14	0.04	0.19	9.70	11.58	1	0	0	1	0	0	0	3	2	0
15	1.82	0.19	13.94	4.3	0	0	0	0	0	0	0	3	4	0
16	4.57	0.17	7.54	12.1	1	1	0	1	0	0	0	3	4	0
17	0.82	0.18	6.75	3.18	4	0	0	0	0	0	0	3	2	0
18	0.37	0.17	5.93	4.4	1	1	1	0	0	0	0	3	4	0
19	1.73	0.17	12.40	13.06	2	0	0	0	0	0	0	3	0	0
20	1.42	0.18	8.13	3.76	1	1	0	0	0	0	0	3	0	0
21	2.29	0.14	5.89	18.96	8	0	0	0	0	1	0	4	14	2
22	2.4	0.14	5.81	22.1	7	0	0	0	0	0	0	4	12	0

23	1.93	0.15	6.63	44.5	9	0	1	0	0	0	0	4	20	0
24	2.94	0.17	4.29	25.98	6	0	0	0	0	0	0	4	40	0
25	3.8	0.17	5.97	42.35	10	0	0	0	0	0	0	4	30	0
26	4.07	0.17	4.89	16.6	6	0	0	0	0	0	0	4	28	4
27	2.14	0.15	5.99	34.42	2	0	1	0	0	0	0	4	22	4
28	2.35	0.16	6.31	40.96	3	0	0	0	0	0	0	4	20	4
29	4.06	0.15	4.11	33.92	1	1	0	0	0	0	0	4	28	0
30	3.16	0.15	4.20	26.26	3	1	1	0	0	0	0	4	16	0

Avicennia II

No	Surface	pH	OM %	Detritus	Roots	Mounds	Depression	Crab halls	Water hall	Seedlings	Stems	Inundation	Polychaet	Isopods
1	0.87	0.19	13.65	12.54	4	0	0	0	0	0	0	4	18	0
2	5.69	0.18	12.72	14.84	8	0	0	0	0	0	0	4	46	0
3	4	0.17	10.67	20.32	7	0	0	0	0	0	0	4	30	0
4	5.16	0.21	25.56	12.54	9	0	0	0	0	0	0	4	40	2
5	1.87	0.18	10.84	14.9	9	0	0	0	0	0	0	4	18	0
6	3.16	0.17	12.94	6.24	3	0	0	0	0	0	0	4	26	0
7	1.49	0.18	15.61	9.84	6	0	0	0	0	0	0	4	30	2
8	1.21	0.18	24.19	8.78	7	0	0	0	0	0	0	4	42	0
9	3.21	0.18	19.33	13.38	5	0	0	0	0	0	0	4	34	0
10	0.88	0.18	4.842	8.66	8	0	0	0	0	0	0	4	44	2
11	2.73	0.20	19.94	40.34	2	1	0	0	1	0	0	4	26	0
12	1.69	0.19	10.61	41.44	3	0	0	0	0	1	0	4	0	2
13	0.76	0.19	9.43	45	3	0	0	0	0	1	0	4	10	0
14	3.49	0.21	22.75	55.7	4	0	0	0	0	0	0	4	14	0
15	4.4	0.20	4.84	34.22	3	0	0	0	0	1	0	4	14	0
16	5.17	0.22	9.26	44.08	2	0	0	0	0	1	0	4	0	0
17	2.84	0.21	15.61	41.14	6	0	0	0	0	0	0	4	12	0
18	3.61	0.20	21.55	18.1	4	0	0	0	0	1	0	4	4	0

19	3.65	0.21	17.60	24.12	1	0	0	0	0	0	0	4	10	2
20	3.94	0.20	25.97	30.08	8	0	0	0	0	2	0	4	6	0
21	4.6	0.18	32.64	7.88	4	0	0	0	0	0	0	4	6	0
22	3.44	0.18	17.80	28	3	0	0	0	0	0	0	4	4	0
23	2.91	0.27	36.76	25	4	0	0	0	0	0	0	4	4	0
24	3.29	0.20	47.89	84.74	1	0	0	0	1	0	0	4	4	0
25	4.38	0.19	31.64	22.76	6	0	0	1	0	0	0	4	4	0
26	7.31	0.85	34.67	24.36	1	0	1	0	0	0	0	4	2	0
27	2.58	0.19	29.27	27.28	3	0	0	0	0	0	0	4	4	0
28	6.29	0.20	31.33	23.72	7	0	0	0	0	0	0	4	2	0
29	4.52	0.20	32.89	30.18	7	0	0	0	0	0	0	4	6	0
30	9.71	0.20	29.97	20.98	1	1	0	0	0	0	0	4	4	0

Appendix III

Physical Chemical and Biological factors of the study site.

Rhizophora Plot

No	Surface	pH	OM %	Detritus	Roots	Mounds	Depression	Crab hall	Water hall	Seedlings	Stems	Inundation	Polycheats	Isopods
1	27.68	0.18	8.46	45.06	0	0	0	1	0	0	0	3	10	0
2	0.47	0.18	4.59	43.82	0	1	0	1	0	0	0	3	4	0
3	11.34	0.18	5.36	26.58	0	2	1	0	0	0	0	3	4	0
4	8.80	0.18	5.00	42.00	0	1	1	0	0	0	0	3	14	0
5	1.15	0.18	7.4	20.86	1	1	0	0	0	0	0	3	4	0
6	5.77	0.19	5.28	16.94	1	2	1	0	0	0	0	3	20	0
7	0.09	0.18	5.73	41.58	1	0	0	0	0	0	0	3	10	0
8	1.01	0.18	3.67	28.76	1	1	0	0	0	0	0	3	4	0
9	0.90	0.19	6.53	21.28	0	1	1	0	0	0	0	3	6	0
10	0.53	0.18	3.6	12.08	0	1	1	0	0	0	0	3	6	0

Appendix: IV

Diversity index

Number	*Lumnitzera* (I)	*Lumnitzera* (II)	*Avicennia* (I)	*Avicennia* (II)	*Rhizophora*
1	445.24	79.344	1748.5933	463.6015	5951.5096
2	2940.36	126.4863	735.504	6401.4595	52.2184
3	1949.40	197.1705	47.6388	4368.986	1815.8902
4	4681.54	242.695	377.1506	12641.8273	1042.3634
5	3942.78	530.2075	1353.3653	2035.5112	97.4501
6	6863.54	4.1467	631.077	547.7759	599.6049
7	8092.24	184.454	848.5647	996.5766	11.9974
8	426.09	152.2005	763.7531	1347.3825	59.6778
9	9916.95	322.99	488.6398	3035.597	71.486
10	3313.35	439.7011	4795.4379	215.413	13.1392
11	20.69	2.9395	55.7983	3521.4146	
12	52.29	483.1127	15.3133	1715.372	
13	21.35	73.204	225.1275	761.8966	
14	45.20	17.0809	2.6429	14898.054	
15	27.48	38.1622	62.9496	1812.8308	
16	6.42	16.5508	219.5622	3777.2767	
17	7.25	28.4083	38.428	9394.8764	
18	53.45	51.4284	4.9939	4588.4053	
19	9.85	368.4742	294.9506	1301.5833	
20	4.47	14.201	24.1102	40119.2272	
21	7098.86	88.288	1203.8118	3485.4687	
22	943.94	13.0282	1270.2084	3852.3958	
23	2961.62	8.4995	3152.7986	14261.9895	
24	1085.46	71.7281	1403.9902	10917.6462	
25	651.96	32.5153	6626.2343	14641.0598	
26	98.18	135.5448	1369.3768	21119.2597	

27	333.97	133.1095	561.0378	4707.2217	
28	79.48	926.6775	1175.5958	26978.3762	
29	242.56	93.1243	354.1589	26169.4896	
30	218.55	2.2349	664.2165	4885.5938	

Appendix V

Diversity index ($\log_{10}$)

Number	*Lumnitzera* (I)	*Lumnitzera* (II)	*Avicennia* (I)	*Avicennia* (II)	*Rhizophora*
1	2.64	1.89	3.24	2.66	3.77
2	3.46	2.1	2.86	3.8	1.71
3	3.28	2.29	1.67	3.64	3.25
4	3.67	2.38	2.57	4.1	3.01
5	3.59	2.72	3.13	3.3	1.98
6	3.83	0.61	2.8	2.73	2.77
7	3.9	2.26	2.92	2.99	1.07
8	2.62	2.18	2.88	3.12	1.77
9	3.99	2.5	2.68	3.48	1.85
10	3.52	2.64	3.68	2.33	1.11
11	1.31	0.46	1.74	3.54	
12	1.71	2.68	1.18	3.23	
13	1.32	1.86	2.35	2.88	
14	1.65	1.23	0.42	4.17	
15	1.43	1.58	1.79	3.25	
16	0.8	1.21	2.34	3.57	
17	0.86	1.45	1.58	3.97	
18	1.72	1.71	0.69	3.66	
19	0.99	2.56	2.46	3.11	
20	0.65	1.15	1.38	4.6	
21	3.85	1.94	3.08	3.54	
22	2.97	1.11	3.1	3.58	
23	3.47	0.92	3.49	4.15	
24	3.03	1.85	3.14	4.03	
25	2.81	1.51	3.82	4.16	

26	1.99	2.13	3.13	4.32
27	2.52	2.12	2.74	3.67
28	1.9	2.96	3.07	4.43
29	2.38	1.96	2.54	4.41
30	2.33	0.34	2.82	3.68

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