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DOWN-CORE VARIATIONS OF FORAMINIFERAL DISTRIBUTION IN THE MANGROVE SEDIMENTS OF KAPAR AND MATANG, WEST COAST OF PENINSULAR MALAYSIA

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Abstract : The foraminiferal distribution in two mangrove core sediment samples collected from contrasting environments i.e., one from coastal plain (Kapar) and other from estuarine plain (Matang), was investigated. Altogether, 29 species represented by 12 families and 21 genera were encountered. At Kapar where salinity and pH are presumably high (sandy loam soil), the marine/calcareous forams (655 ± 826 ind cm^{-3}, mean ± 1SD) dominated the population, while Matang sediment was represented by agglutinated forams (94 ± 115 ind cm^{-3}) characteristic of brackish-water, and distributed under low salinity and pH regimes (silty loam with peat). The foraminiferal diversity indices are low for both Kapar (mean *d'* 0.7, *H'* 0.8 and *J'* 0.5) and Matang (mean *d'* 0.6, *H'* 0.9 and *J'* 0.8), albeit the population was rich in Kapar (404 ± 654 ind cm^{-3}). On the basis of routines (e.g. BVSTEP, SIMPER) implemented in PRIMER (Plymouth Routines in Multivariate Ecological Research, UK), it was possible to demonstrate that species such as *Ammonia beccarii, Arenoparrella mexicana, Elphidium discoidale* and *Haplophragmoides wilberti* played a key role in discriminating the foraminiferal species associations (groupings) at Kapar and Matang. The faunal abundance (root-transformed data) indicated 7 groupings (Bray-Curtis similarity: 44%) in the down-core samples. While Groups 1-5 represented the combination of species found exclusively in Kapar, Groups 6-7 were characteristic of Matang environment. In summary, the fauna at Kapar implies brackish intertidal environment with hyperhaline condition (salinity: 25-30 psu and pH: 7-8), where *Ammonia beccarii* (375 ± 620 ind cm^{-3}) and *Elphidium discoidale* (68 ± 118 ind cm^{-3}) outnumbered all others; Matang species indicated an estuarine upper to uppermost intertidal environment (salinity: 18-26 psu and pH: 6-7) dominated by *Haplophragmoides wilberti* (44 ± 63 ind cm^{-3}) and *Arenoparrella mexicana* (25 ± 30 ind cm^{-3}). Species distribution throughout the core sample (surface to bottom) collected from Kapar also signifies an active rate of sedimentation process close to river (Kapar Besar) mouth than the estuarine plain.

KEYWORDS: benthic foraminifera, core sediment, Kapar and Matang mangroves, Malaysia, species association/groupings, univariate and multivariate analysis

Introduction

Mangroves are salt tolerant plants that live in tropical intertidal regions where the coastal water is mixed to a greater or lesser extent with water discharged from land (Tomlinson, 1986; Duke, 1992). Being specific in their requirements, mangroves develop best under quiescent physical milieu, where low wave energy and shelter facilitate accretion of soft sediments that enable them to establish roots and grow (Spalding et al., 1997). They could well be a hope against disasters, a regulator of coastal ecosystem processes and an alcove of a variety of productive forest resources (Lakshmanan, 1985).

In Malaysia, the mangroves occupied 564,606 ha and nearly 16.2% (91,779 ha) were distributed along the west coast of peninsular Malaysia, while the east coast consisted of a mere

1% (5,738 ha) (Shamsudin and Nasir, 2005). Mangroves are more prevalent here on the west coast due to its sheltered environment, whereas the east coast is entirely exposed to the South China Sea (Lokman and Sulong, 2001). Another 83% of the population is present in the states of Sarawak (126,400 ha) and Sabah (340,689 ha) in East Malaysia (Shamsudin and Nasir, 2005).

Scientists from all over the world have realized the need to protect mangrove forests because of their vulnerability; high degree of denudation through several threats imposed by man (Macintosh, 1984; Gallin et al., 1989; Robertson and Alongi, 1992; Dahdouh-Guebas, 2001; Satyanarayana et al., 2002). Furthermore, mangrove areas provide invaluable information on paleoenvironmental reconstructions (e.g. climate, oceanic/sea-level condition and environmental changes) due to sediment accumulation and preservation of pollen, spores, microfauna etc (Boersma, 1978; Wang and Chappell, 2001; Barbosa et al., 2005). Within the wider context of mangrove research, study of unicellular marine organisms such as foraminifers also extremely important in recognizing geological strata and for dating deposits (Jennings and Nelson, 1992). In recent years, several noteworthy observations have been carried out on foraminiferal species' significance and distribution within the mangrove areas (e.g. Bronnimann et al., 1979; Hiltermann et al., 1981; Murray, 1991; Sasekumar, 1994; De Rijk, 1995; Debenay et al., 2002, 2004; Horton et al., 2003). However, most of the studies are largely restricted to certain areas of interest, and still to arise from several locations in tropical and sub-tropical mangrove habitats (Scott and Medioli, 1980; Alongi and Sasekumar, 1992).

This study was aimed at addressing the diversity and distribution of foraminiferal species in down-core mangrove sediments collected from Kapar and Matang on the west coast of peninsular Malaysia. The variation and assemblages (groupings) of forams inside these two swamps were portrayed and discussed in response to sediment nature/zonal distributions. Findings made during the study are worth mentioning, given that methods used for comparing populations are based on statistical procedures, known for their extreme usefulness (regardless of sample size), simple explanation and transparent interpretation (Clarke and Warwick, 1994).

Materials and methods

Kapar mangroves (4,555 ha) are located in the state of Selangor (Latitude, 3° 00' - 3° 09' N and Longitude, 101° 18' – 101° 24' E) with a network of creeks and canals emanating from Kapar Besar and Kecil Rivers (Fig. 1A). These intermittent channels are subjected to daily inundation by raising tides and constituted a dynamic environment for the growth of several true mangrove species (*Avicennia alba, Bruguiera cylindrica, B. gymnorrhiza, Rhizophora apiculata, R. mucronata and Sonneratia alba) and mangrove associates (Acanthus ilicifolius, Ipomoea pes-caprae, Hibiscus tiliaceus, Acrostichum aureum and Nypa fruticans*).

Larut Matang mangroves (40,466 ha) (Fig. 1B) comes under the administrative district of Matang in the state of Perak (4° 15' - 5° 00' N and 100° 25' - 45° 00' E), and extended over 51 km along the coastline between Kuala Gula and Panchor. There are seven forest reserves (Larut Matang, Pulau Sangga Kecil, P. Selinsing, P. Sangga Besar, P. Kecil, P. Kelumpang and P. Terong) within the sanctuary separated by local rivers and creeks. The present study was conducted near Larut Matang (about 10 km away from Sangga Besar River mouth), where the mangroves are dominated by *Rhizophora, Avicennia, Sonneratia, Bruguiera* and *Xylocarpus spp.*, in the order of their prevalence. Both Kapar and Matang areas are strongly influenced by their location in the tropics with a mean annual temperature of 23.7 - 33.4°C and high humidity (76.5 - 83.5%). The (mean) annual precipitation was 2380.1 mm (unpublished data).

Two sediment core samples, each from Kapar and Matang stations, were collected at the waterfront areas using a D-section corer (1 m length x 2 cm diameter). The samples are wrapped in plastic bags, labeled and brought to the laboratory for foraminiferal species identification and sediment textural (sand, silt and clay) analysis. At first, the shells of foraminifera (living + empty tests) are stained with 10-20 ml of buffered formaldehyde (10% solution) and 2-3 drops of Rose Bengal. They were afterwards separated by means of floatation technique on carbon tetrachloride solution (1.594 g cm^{-3} density) (Feyling-Hansen, 1983), and identified and counted under a binocular microscope (LICA, Japan). Finally, all taxa were arranged according to standard nomenclature (e.g. Loeblich and Tappan, 1988), and a checklist of foraminifera in the mangrove core sediments of Kapar and Matang prepared. The sediment grain size was estimated through initial (wet) sieving method (mesh No. 240, British Standard) followed by pipette analysis (Krumbein and Pettijohn, 1938).

Multivariate methods (PRIMER, Plymouth Routines in Multivariate Ecological Research, UK) used in this study are based on similarity coefficients calculated between every pair of sample. The present data was analyzed on the basis of hierarchal clustering (Bray-Curtis similarity) and multidimensional scaling (MDS) implemented in PRIMER. Species diversity indices such as species richness (*d*') (Margalef, 1958), species diversity (*H'*) (Shannon and Weaver, 1949), and evenness (*J'*) (Pielou, 1977) were calculated following appropriate protocols in PRIMER. Simple *t*-test was used to determine the significance of foraminiferal abundance at both sites. Combinations of species responsible for biotic assemblages were investigated through the BVSTEP routine in PRIMER. Similarity percentage (SIMPER) was calculated to evaluate the percentile contribution of individual species contributing for those biotic assemblages/groups. All procedures were followed according to PRIMER *v*.5 (Clarke and Warwick, 1994; Clarke and Gorley, 2001).

Results and discussion

A total number of 29 foraminiferal species (12 families and 21 genera) were identified from the core sediment samples taken at the intertidal mudflat (waterfront area) of the mangrove fringe on the coastal (Kapar) and estuarine (Matang) plains (Appendix-1). The Kapar sediment was represented by 23 species (*Ammonia beccarii, Ammotium fragile, Amphistegina lessonii, Asterorotalia* sp., *Bucella frigida, Cibicides refulgens, Discorbis* sp., *Elphidium reticulosum, E. craticulatum, E. discoidale, E. incertum, E. poeyanum, Elphidium* sp., *Hanzawaia* sp., *Haynesina depressula, Lagena sulcata, Nonion depressulus, Nonionella aurius* and *Quinqueloculina* sp.), while Matang consisted of 10 species (*Ammoastuta salsa, Jadammina macrescens, Quinqueloculina seminula, Textularia earlandi, Trochammina comprimata* and *T. inflata*), among which 4 species (*Ammotium salsum, Arenoparrella mexicana, Haplophragmoides wilberti* and *Miliammina fusca*) were common at the both sites.

Figure 2 shows group-wise dominance (% composition) of species in relation to their affinity towards marine or brackish-water as well as sediment characteristics. In Kapar, calcareous forams dominated the population (655 ± 826 ind cm^{-3}, mean ± 1SD) followed by agglutinated (469 ± 381 ind cm^{-3}) and porcellaneous tests (13 ± 9 ind cm^{-3}) (Fig. 2A). All the agglutinated forms encountered were euryhaline or brackish-water (e.g. *Ammotium fragile, A. salsum, Arenoparrella mexicana, Haplophragmoides wilberti* and *Miliammina fusca*) (Fig. 2B), and most abundant in the mangrove areas (Gregory, 1973; Boltovskoy, 1976; Boltovskoy and Wright, 1976; Reiss and Hottinger, 1984; Wang and Chappell, 2001). However, their prevalence only at the topmost layer of the sediment (0-4 cm) is indicating those species' affinity towards silty-clay substrates (Fig. 2C). The remaining calcareous/porcellaneous forams (*Ammonia beccarii, Amphistegina lessonii, Asterorotalia* sp., *Bucella frigida, Cibicides refulgens, Discorbis* sp., *Elphidium reticulosum, Elphidium craticulatum, Elphidium discoidale, Elphidium incertum, Elphidium poeyanum, Elphidium* sp., *Hanzawaia* sp., *Haynesina depressula, Lagena sulcata, Nonion depressulus, Nonionella aurius and Quinqueloculina* sp.) are mostly marine and brackish-water representatives (Fig. 2B) preferred sandy bottom (Fig. 2C). Percentile contribution of these both forams reached peak with the increase of sand down the core.

Matang sediment was represented by agglutinated (94 ± 115 ind cm^{-3}) (*Ammoastuta salsa, Ammotium salsum, Arenoparrella mexicana, Haplophragmoides wilberti, Jadammina macrescens, Miliammina fusca, Textularia earlandi, Trochammina comprimata and T. inflata*) and porcellaneous (20 ± 13 ind cm^{-3}) (*Quinqueloculina seminula*) forams characteristic of brackish-water (Fig. 2 D-E). In contrast with the Kapar sediment, they are widely distributed where silt and clay composition was high and decreased with the increase of sand content (Fig. 2F). No forams were observed below 42 cm of the core sediment here.

Majority of the foraminiferans were marine or marginal marine from intertidal to the deepest ocean trenches with greater diversity, whereas low-diversity assemblages are noticed in brackish water lagoon/salt marshes (Boersma, 1978). The foraminiferal diversity (Margalef, *d'*; Shannon-Wiener, *H'* and evenness, *J'*) was rather low for both Kapar (mean *d'* 0.7, *H'* 0.8 and *J'* 0.5) and Matang (mean *d'* 0.6, *H'* 0.9 and *J'* 0.8) (Table 1), albeit the population was rich in Kapar (404 ± 654 ind cm^{-3}), where *Ammonia beccarii* (375 ± 620 ind cm^{-3}) and *Elphidium discoidale* (68 ± 118 ind cm^{-3}) outnumbered all others. Simple *t*-test also indicated that the abundance of foraminifera within the Kapar core sediment was significant (*t*-value: 4.06, $P < 0.05$).

Figure 3 shows down-core variations of foraminiferal (23 species) distribution and grain size (silt + clay and sand ratio) at 2 cm intervals in Kapar. As the sampling site was located nearby coast (Fig. 1A), seawater inundates the area semi-diurnally (salinity: 25-30 PSU and pH: 7-8). There are four zones with different species assemblages which were recognized. Zone-1 (0-4 cm) having silty loam with plant debris supported the distribution of (agglutinated/brackish-water) *Ammotium fragile* (128 ± 90 ind cm^{-3}), *A. salsum* (116 ± 153 ind cm^{-3}), *Miliammina fusca* (105 ± 104 ind cm^{-3}), *Arenoparrella mexicana* (72 ± 79 ind cm^{-3}) and *Haplophragmoides wilberti* (12 ± 6 ind cm^{-3}) in the order. Zone-2 (5-12 cm) characterized by silty loam was totally devoid of species where it could be considered as the transitional zone (De Rijk, 1995). Zone-3 (13-46 cm) composed of silty loam to sandy loam substrate was dominated by calcareous forams notably, *Ammonia beccarii* (51 ± 45 ind cm^{-3}), *Bucella frigida* (8 ± 3 ind cm^{-3}) and *Elphidium discoidale* (4 ± 2 ind cm^{-3}). Sandy loam soil with rich and well-preserved forams was observed in Zone-4 (47-93 cm). *Ammonia beccarii* (615 ± 734 ind cm^{-3}) remains widespread comprising over 79% of the population followed by *Elphidium discoidale* (86 ± 128 ind cm^{-3}), *Nonionella aurius* (26 ± 26 ind cm^{-3}), *Nonion depressulus* (24 ± 32 ind cm^{-3}) and *Bucella frigida* (22 ± 21 ind cm^{-3}) in the order of their rankings. The rest of (13) species have less than 1% contribution. The fauna here indicates brackish intertidal environment with hyperhaline condition at the core-top sample dominated by *Ammotium fragile,* while exclusive calcareous tests below 13 cm imply a rather high pH (>8) in the sediment (Wang and Chappell, 2001).

The variations of foraminiferal distribution and sediment nature in the core sample collected from Matang estuary (about 10 km upstream) were shown in Figure 4. Both salinity (18-26 PSU) and pH (6-7) are relatively low owing to its proximity towards the land with a considerable influence of freshwater (unpublished data). The fauna is poorer (10 species) than Kapar and completely absent at some zones in the sample. There were only two zones recognized based on the pattern of faunal distribution. Zone-1 (0-40 cm) with silty loam and peat supported greater wealth of taxa dominated by brackish-water forams (agglutinated and porcellaneous), while no species were encountered in Zone-2 (41-93 cm) composed of silty loam soil. *Haplophragmoides wilberti* (44 ± 63 ind cm^{-3}) constituted 49% of the population followed by *Arenoparrella mexicana* (25 ± 30 ind cm^{-3}), *Quinqueloculina seminula* (20 ± 12 ind cm^{-3}), *Jadammina macrescens* (14 ± 10 ind cm^{-3}) and *Trochammina inflata* (11 ± 7 ind cm^{-3}) in the order of their prevalence. The remaining species i.e., *Miliammina fusca* (mean, 5 ind cm^{-3}), *Textularia earlandi* (2 ind cm^{-3}), *Trochammina comprimata* (2 ind cm^{-3}), *Ammoastuta salsa* (1 ind cm^{-3}) and *Ammotium salsum* (1 ind cm^{-3}) have contributed less than 1%. In general, the fauna indicated an estuarine upper to uppermost intertidal environment with low salinity and pH, where *Haplophragmoides wilberti* and *Arenoparrella mexicana* outnumbered others.

On the basis of Bray-Curtis similarity using faunal abundance (root-transformed) data, it was possible to identify 7 species associations (groupings) in the down-core samples (similarity 44%, Fig. 5). While Groups 1-5 represented the combination of species noticed exclusively in Kapar, Groups 6-7 were characteristic of Matang environment. The percentile contribution (SIMPER) of different species in the above mentioned groups was shown in Table 2. A stepwise search of combinations of species ultimately responsible for these groupings was carried out by BVSTEP routine in PRIMER.

Group 1 consisted of *Elphidium incertum* and *Elphidium* sp. was distributed between 50 and 80 cm (18 ± 14 ind cm^{-3}), whereas Group 2 species (*Ammonia beccarii, Bucella frigida, Elphidium discoidale, Nonion depressulus, Nonionella aurius* and *Quinqueloculina* sp.) were predominant in the inner core sediment with a gradual increase from subsurface (13-14 cm) (201 ind cm^{-3}) to bottom (up to 93 cm) (2149 ind cm^{-3}) (Fig. 3). Groups 3-5 (*Amphistegina lessonii, Asterorotalia* sp., *Cibicides refulgens, Discorbis* sp., *Elphidium craticulatum, E. poeyanum, E. reticulosum, Hanzawaia* sp., *Haynesina depressula* and *Lagena sulcata*) are also distributed beyond 80 cm (77 ± 72 ind cm^{-3}), however, their abundance decreased with the increase of depth. Factors controlling distribution of foraminifers in the sediment include grain size, depth of oxic surface layer and availability of food (Murry, 1991). Overall, Groups 1-5 represented their characteristic nature of inhibiting sandy loam soil, where salinity and pH are presumably high (Hiltermann et al., 1981; De Rijk, 1995; Wang and Chappell, 2001).

Group 6 species (*Trochammina inflata, Jadammina macrescens, Quinqueloculina seminula, Haplophragmoides wilberti* and *Arenoparrella mexicana*) (114 ± 141 ind cm^{-3}) were distributed in upper portion of the sample (0-40 cm) collected from Matang. Earlier, the combination of these species in mangrove areas was reported by Bronnimann et al. (1981) and Sasekumar (1981). Williams (1994) explained that *A. mexicana* and *T. inflata* were present in higher densities even up to one meter below the surface sediment, while *Q. seminula* was at 1.5-2.5 m in the core samples collected from the Texas Gulf Coast. Group 7 (*Ammoastuta salsa, Ammotium fragile, A. salsum, Miliammina fusca, Textularia earlandi* and *Trochammina comprimata*) was confined to the core-top sediment (0-4 cm) (356 ± 354 ind cm^{-3}), and both these groups seemed to have preferred only silty loam soil with plant debris. As mentioned elsewhere, *Ammotium salsum, Arenoparrella mexicana, Haplophragmoides wilberti* and *Miliammina fusca* were common at the both sites (Kapar and Matang), and grouped together due to their similar habitat preferences. Furthermore, Groups 1-5 are mostly composed of marine/calcareous forams, while agglutinated/brackish-water forms represented Groups 6-7. Absence or decrease in calcareous forams towards low saline areas in the marginal marine environments was reported by Debenay et al. (2004).

Conclusion

Although constrained by poor foraminiferal preservation in some zones in the core samples, our results indicate significant variations in their distribution in response to contrasting environments i.e., coastal plain (Kapar) and estuarine plain (Matang). While fauna at the coastal plain denotes brackish intertidal environment with hyperhaline conditions (high salinity and pH), the estuarine plain taxa indicated upper to uppermost intertidal estuarine environment (low salinity and pH). Nevertheless, the present analysis also benefits future paleoenvironmental investigations from this area. Distribution of foraminiferal species throughout the core sample (surface to bottom) collected from Kapar signifies an active rate of sedimentation close to river (Kapar Besar) mouth than the estuarine plain.

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Table 1. Foraminiferal species abundance and diversity in the core samples

Diversity index	Kapar Range (mean ± 1 SD)	Matang Range (mean ± 1 SD)
No. of species	1 – 8 (3 ± 2)	2 – 10 (3.5 ± 2)
Numerical abundance (ind cm^{-3})	8 – 2364 (404 ± 654)	3 – 390 (106 ± 128)
Margalef (*d'*)	0.1 – 1.5 (0.7 ± 0.3)	0.4 – 1.6 (0.6 ± 0.3)
Shannon-Weaver (*H'*)	0.2 – 2 (0.8 ± 0. 5)	0.5 – 1.4 (0.9 ± 0. 3)
Evenness (*J'*)	0.2 – 1 (0.5 ± 0.2)	0.6 – 1 (0.8 ± 0.1)

Table 2. SIMPER showing percentile contribution of individual foraminiferal species to the average similarity within each group/assemblage

Species	Kapar core Average abundance	Matang core Average abundance	Average dissimilarity	Dissimilarity /SD	Contribution (%)	Cumulative (%)
Average dissimilarly: 98.5						
Ammonia beccarii	357.52	0.00	27.32	2.60	27.74	27.74
Haplophragmoides wilberti	0.57	55.45	21.47	4.26	21.79	49.53
Arenoparrella mexicana	3.43	29.45	19.50	2.59	19.79	69.32
Elphidium discoidale	45.48	0.00	6.53	1.05	6.63	75.95
Quinqueloculina seminula	0.00	11.95	6.51	1.14	6.61	82.56
Bucella frigida	8.79	0.00	2.75	0.68	2.80	85.36
Nonion depressulus	10.07	0.00	2.35	0.72	2.38	87.74
Nonionella aurius	10.10	0.00	2.31	0.72	2.35	90.09

FIGURE LEGENDS

Figure 1. Study area: (A) Kapar and, (B) Matang mangrove environments (dark shade) on the western peninsular Malaysia. Stars in both panels indicates the location of study

Figure 2. Group-wise dominance (% composition) of species in relation to their affinity towards marine or brackish-water as well as sediment characteristics: Kapar mangrove core sediment (A-C) and Matang mangrove core sediment (D-F)

Figure 3. Down-core variations of foraminiferal (%) concentrations at Kapar. Order of taxa chosen to show down-core progression of faunal associations. Number of zones marked according to species distribution and the nature of sediment

Figure 4. Down-core variations of foraminiferal (%) concentrations at Matang. Order of taxa chosen to show down-core progression of faunal associations. Number of zones marked according to species distribution and the nature of sediment

Figure 5. Bray-Curtis similarity and Multi-Dimensional Scaling (MDS) plots showing species association/groupings in the core sediment samples of Kapar and Matang. The location of individual species encountered was represented by (K): Kapar, (M): Matang and, (K/M): Kapar and Matang (Genus names: A: *Ammotium;* Am: *Ammonia;* Amm: *Ammoastuta;* Amp: *Amphistegina;* Ar: *Arenoparrella;* B: *Bucella;* C: *Cibicides;* E: *Elphidium;* Hap: *Haplophragmoides;* Hay: *Haynesina;* J: *Jadammina;* L: *Lagena;* M: *Miliammina;* N: *Nonion;* Non: *Nonionella;* Q: *Quinqueloculina;* T: *Textularia;* Tro: *Trochammina*)

APPENDIX -1

Taxonomic list of foraminifera in the core sediment samples of Kapar and Matang mangroves (classified according to Loeblich and Tappan, 1988)

Phylum	: Protozoa
Class	: Rhizopodea
Order	: Foraminiferida
Family	: Rzehakinidae
Genus	: *Miliammina* Heron-Allen and Earland, 1930
Species	: *Miliammina fusca* (Brandy)
Family	: Lituolidae
Genus	: *Haplophragmoides* Cushman, 1910
	Ammotium Loeblich and Tappan, 1953
	Ammoastuta Cushman and *Bronnimann,* 1948
Species	: *Haplophragmoides wilberti* Andersen, 1953
	Ammotium fragile Warren, 1957
	Ammotium salsum (Cushman and Bronnimann, 1948)
	Ammoastuta salsa Cushman and Bronnimann, 1948
Family	: Textulariidae
Genus	: *Textularia* Defrance in de Blainville, 1824
Species	: *Textularia earlandi* Parker, 1952
Family	: Trochamminidae
Genus	: *Trochammina* Parker and Jones, 1859
	Arenoparrella Andersen, 1951
	Jadammina Bartenstein and Brand, 1938
Species	: *Trochammina inflate* (Montagu)
	Trochammina comprimata Cushman and Bronnimann, 1948
	Arenoparrella mexicana (Kornfeld, 1931)
	Jadammina macrescens (Brandy)
Family	: Miliolidae
Genus	: *Quinqueloculina* d'Orbigny, 1839
Species	: *Quinqueloculina seminula* (Linne)
	Quinqueloculina sp.
Family	: Nodosariidae
Genus	: *Lagena* Walker and Jacob, 1798
Species	: *Lagena sulcata* (Walker and Jacob, 1798)
Family	: Discorbidae
Genus	: *Bucella* Anderson, 1952
	Discorbis Lamarck, 1804
Species	: *Bucella frigida* (Cushman)
	Discorbis sp.
Family	: Rotaliidae
Genus	: *Ammonia* Brunnich, 1772
	Asterorotalia Brandy, 1884
Species	: *Ammonia beccarii* (Linne)
	Asterorotalia sp.

Family	:	Asterigerinidae
Genus	:	*Amphistegina* d'Orbigny, 1826
Species	:	*Amphistegina* lessonii d'Orbigny, 1826
Family	:	Cibicididae
Genus	:	*Cibicides* Montfort, 1808 *Hanzawaia A*sano, 1944
Species	:	*Cibicides refulgens* (Montfort, 1808) *Hanzawaia* sp.
Family	:	Nonionidae
Genus	:	*Nonionella* Cushman, 1926 *Nonion* Montfort, 1808
Species	:	*Nonionella aurius* (d'Orbigny) *Nonion depressulus* (Walker and Jacob)
Family	:	Elphidiidae
Genus	:	*Elphidium* Montfort, 1808 *Haynesina* Banner and Culver, 1978
Species	:	*Elphidium cf. reticulosum* Cushman, 1933 *Elphidium craticulatum* (Fichtel and Moll, 1798) *Elphidium discoidale* (d'Orbigny) *Elphidium incertum* (Williamson) *Elphidium poeyanum* (d'Orbigny, 1826) *Elphidium* sp. *Haynesina depressula* (Walker and Jacob, 1798)

FIGURES

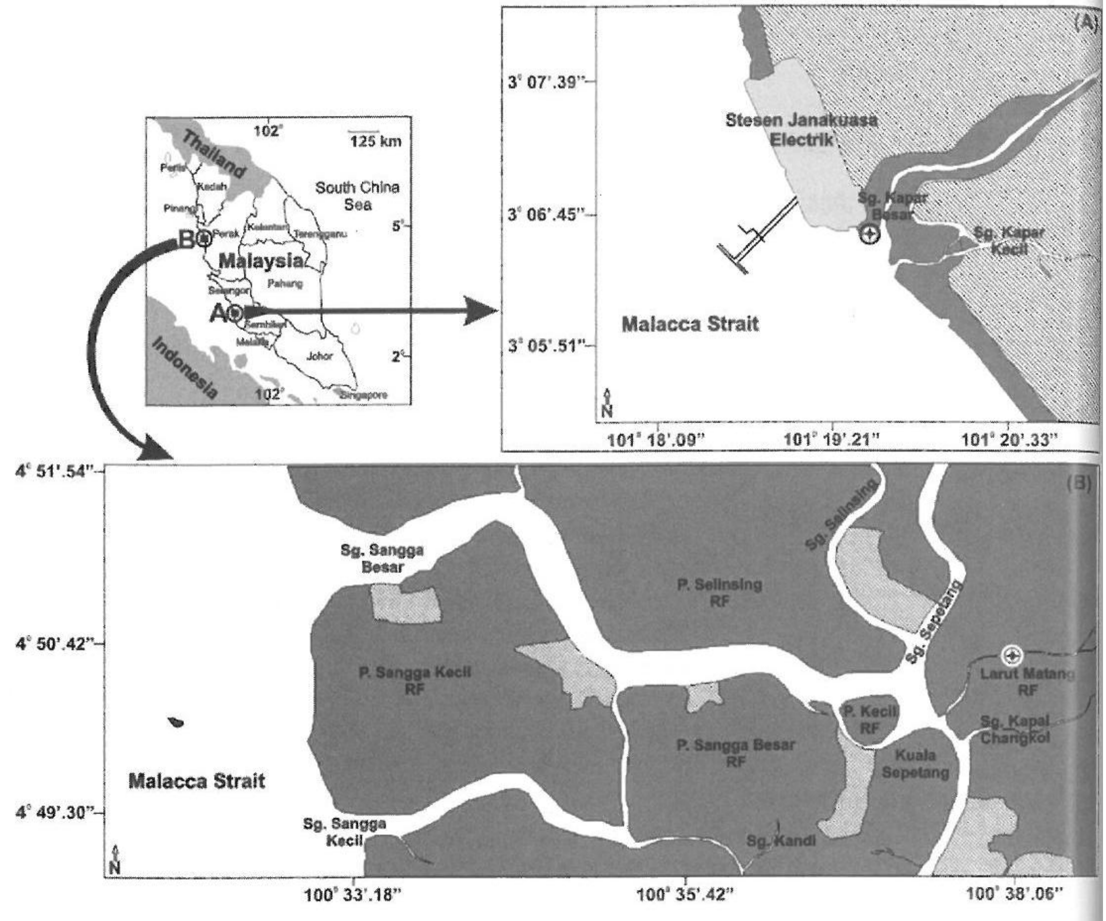


Figure 1

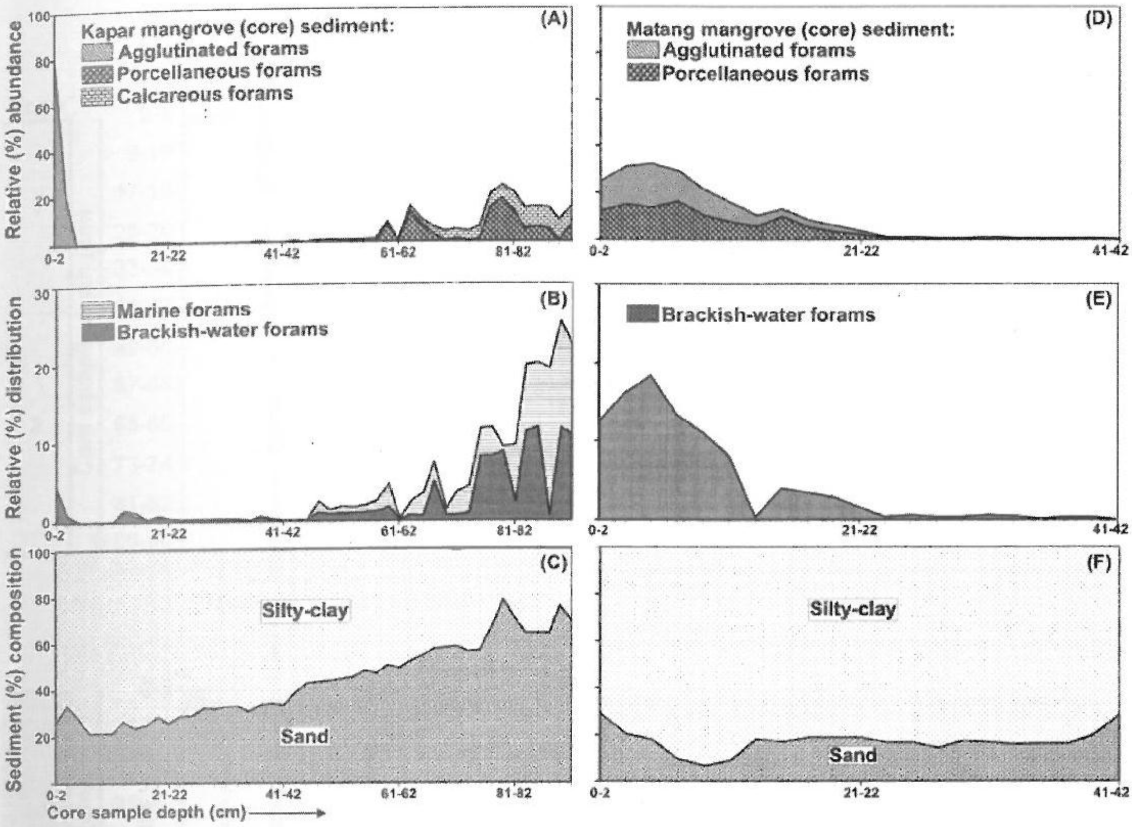

Kapar mangrove (core) sediment:
Agglutinated forams
Porcellaneous forams
Calcareous forams
(A)
Relative (%) abundance
Matang mangrove (core) sediment:
Agglutinated forams
Porcellaneous forams
(D)
Marine forams
Brackish-water forams
(B)
Relative (%) distribution
Brackish-water forams
(E)
Silty-clay
Sand
(C)
Sediment (%) composition
Silty-clay
Sand
(F)
0-2
21-22
41-42
61-62
81-82
Core sample depth (cm)

Figure 2

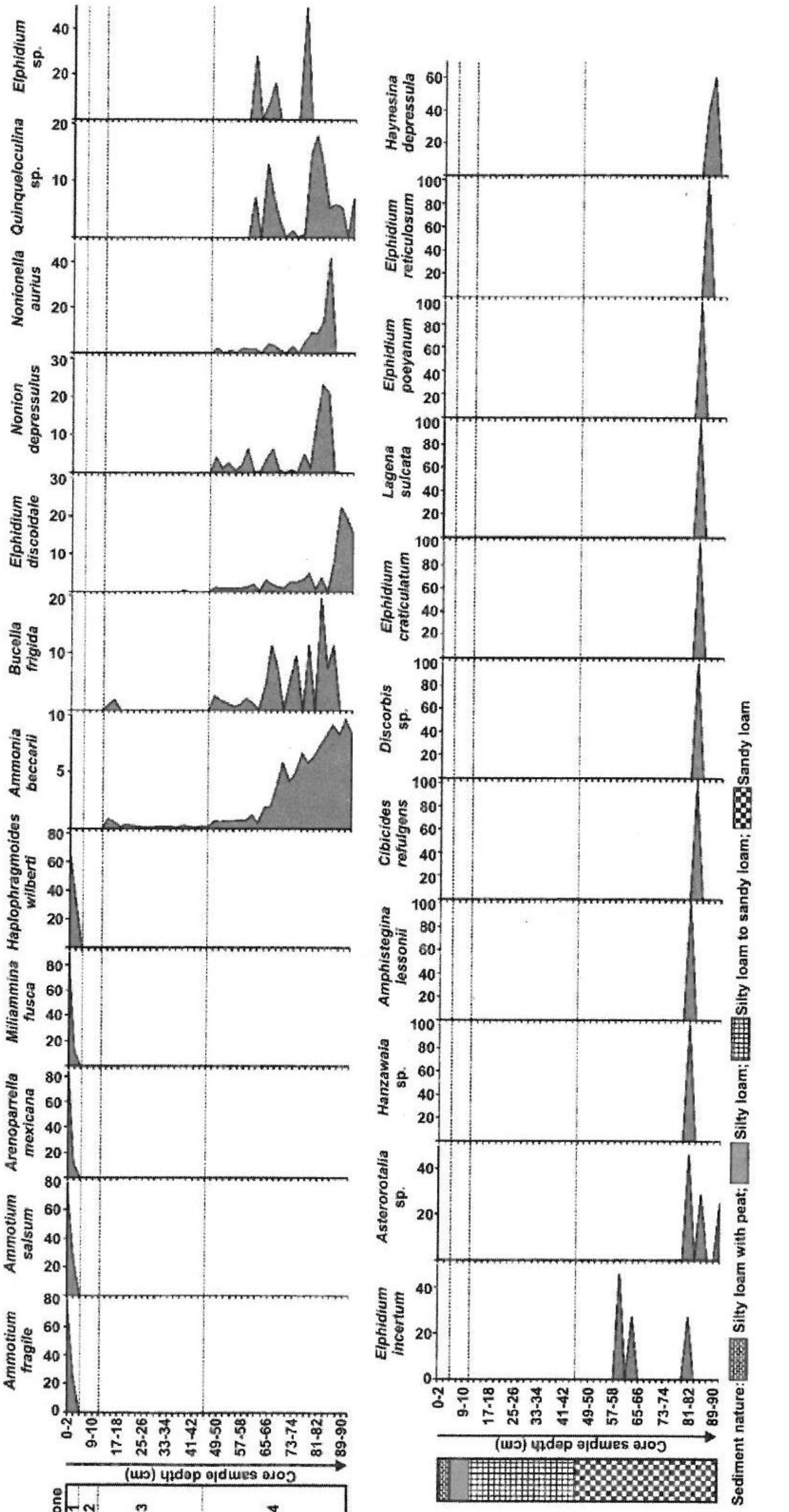
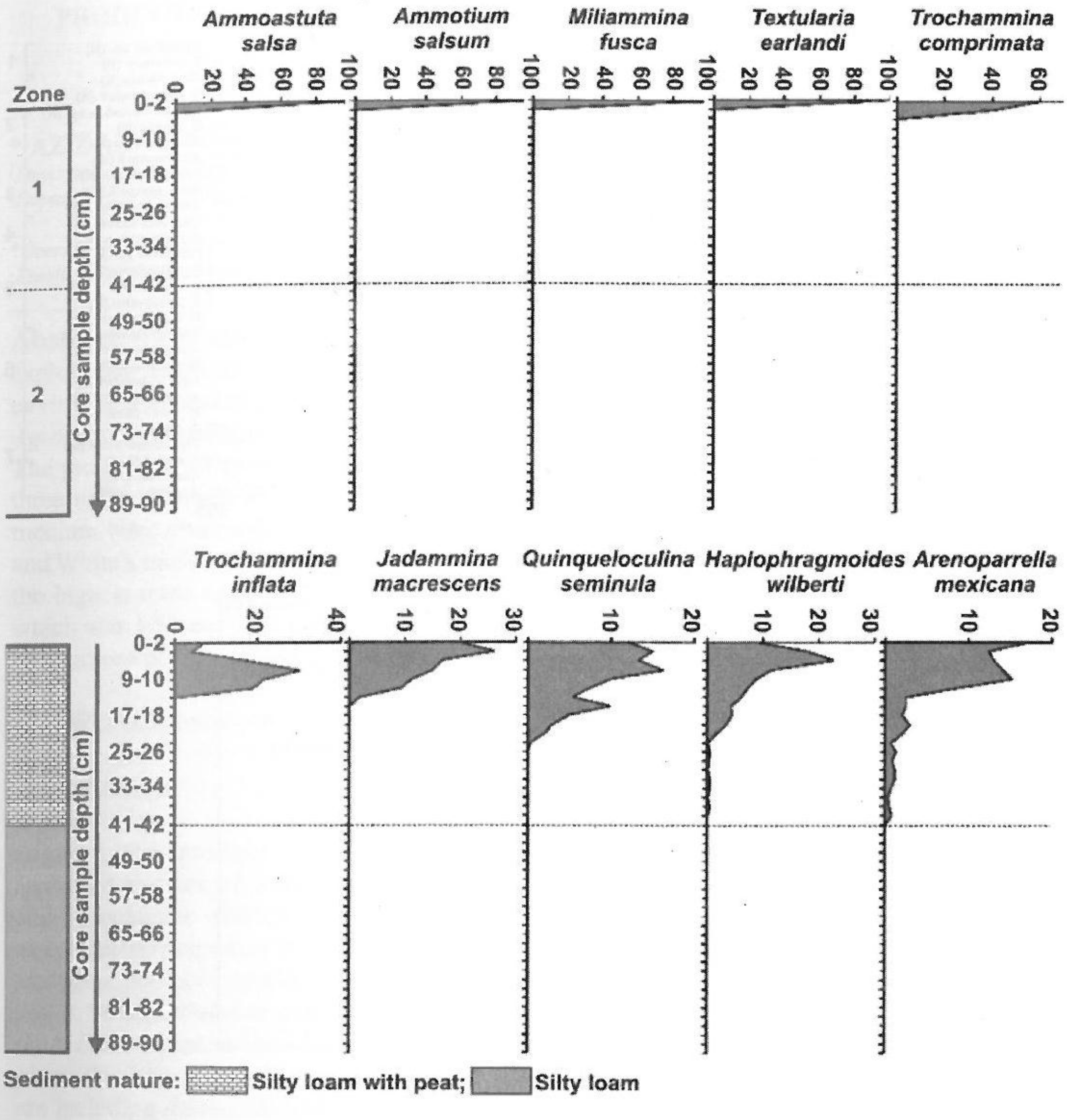
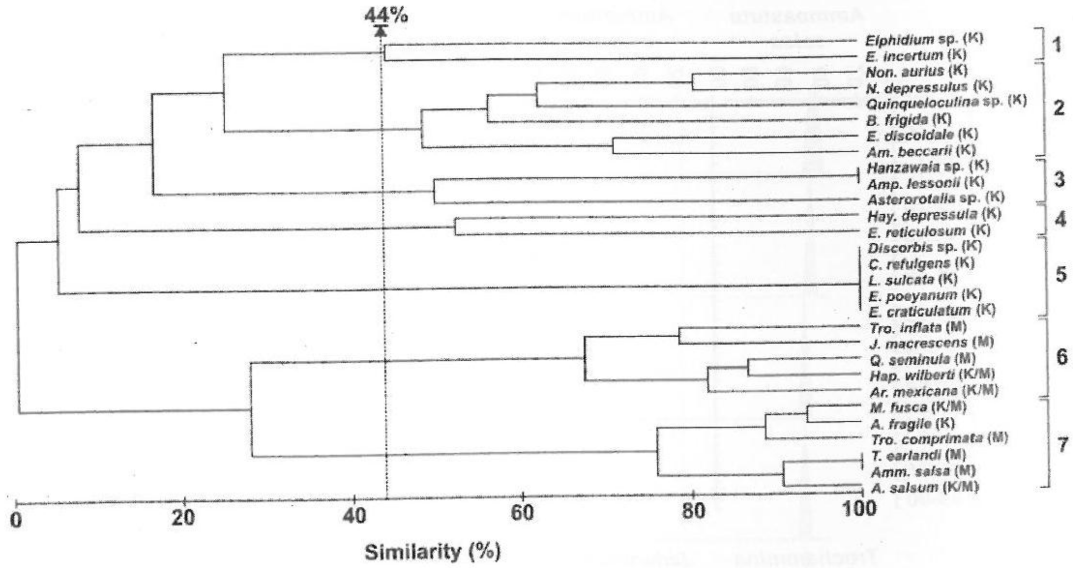

Elphidium sp.
Quinqueloculina sp.
Nonionella aurius
Nonion depressulus
Elphidium discoidale
Bucella frigida
Ammonia beccarii
Haplophragmoides wilberti
Miliammina fusca
Arenoparrella mexicana
Ammotium salsum
Ammotium fragile
Zone
1
2
3
4
Core sample depth (cm)
0-2
9-10
17-18
25-26
33-34
41-42
49-50
57-58
65-66
73-74
81-82
89-90
Haynesina depressula
Elphidium reticulosum
Elphidium poeyanum
Lagena sulcata
Elphidium craticulatum
Discorbis sp.
Cibicides refulgens
Amphistegina lessonii
Hanzawaia sp.
Asterorotalia sp.
Elphidium incertum
Sediment nature:
Silty loam with peat;
Silty loam;
Silty loam to sandy loam;
Sandy loam

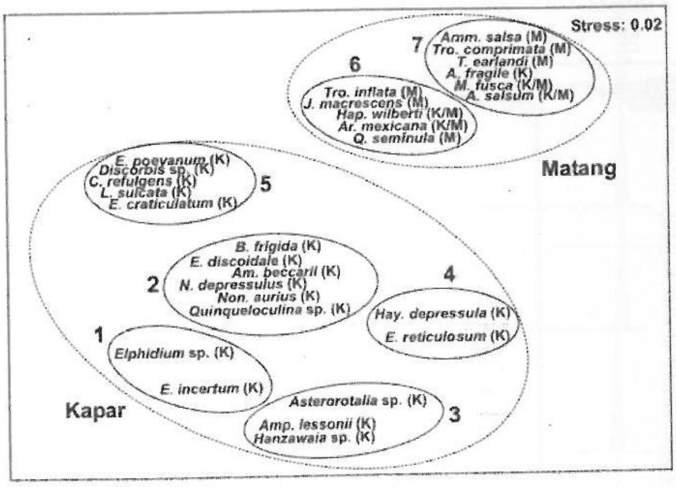
Figure 3



Ammoastuta salsa
Ammotium salsum
Miliammina fusca
Textularia earlandi
Trochammina comprimata
Zone
1
2
Core sample depth (cm)
0-2
9-10
17-18
25-26
33-34
41-42
49-50
57-58
65-66
73-74
81-82
89-90
Trochammina inflata
Jadammina macrescens
Quinqueloculina seminula
Haplophragmoides wilberti
Arenoparrella mexicana
Sediment nature:
Silty loam with peat;
Silty loam

Figure 4





Multi-dimentional scaling (MDS)

Figure 5