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Benthic Foraminiferal Assemblages as Potential Ecological Proxies for Environmental Monitoring in Coastal Water

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Abstract. This study assess the benthic foraminiferal assemblage, distribution and composition along the coastal water of Penang National Park, Malaysia. A total of 192 samples were collected bimonthly between October 2010 and April 2011 at four sites (i.e. Teluk Bahang, Teluk Aling, Teluk Ketapang and Pantai Acheh). From this study 14 gene were identified namely*; Ammonia, Elphidium, Ammobaculites, Nonion, Bolivina, Asterorotalia, Reophax, Eggerella, Textularia, Quinqueloculina, Astacolus, Lagena, Fissurina* and *Hopkinsina.*The foraminiferal assemblage at Teluk Bahang was low in diversity (H'= 0.22) but high in abundance (4351 ind/8cm^3). Stress tolerant taxa, *Ammonia* (756.48 ind/8cm^3) dominated the distribution in Teluk Bahang. Meanwhile in Teluk Ketapang, high foraminiferal diversity (H'=0.76) was noted but low in abundance (201 ind/8cm^3). One way ANOVA test showed that *Ammonia – Elphidium* Index (AEI) was significantly different between sampling sites (P<0.05, df=3, n=192). High AEI value (97) and low FORAM Index (FI=1.05) recorded in Teluk Aling indicating more indicating more hypoxic sediments condition and the impact of anthropogenic stressor. Higher FORAM Index (FI=1.18) at Teluk Ketapang indicated less human induced activities. *Ammonia* spp. and *Elphidium* spp., showed a distinct decrease in density with increasing distances from the shore. From this study, the foraminiferal assemblages would make an excellent indicator of environmental condition in shallow tropical coastal water.

Keywords: Benthic foraminifera, Coastal water, *Ammonia*, Water quality

1. Introduction

Penang is a rapidly developing island with major population concentrated at its coastal area. Induced human activities such as land reclamation, domestic and agricultural waste and industrial effluent have degraded most of Penang coastal areas [1]. To evaluate the impact of human activities, effective and low cost bio-indicators are sought to monitor the condition of the coastal environment. Foraminifera turn out to be a good candidate due to their high preservation potential [2], high in abundance [3][4] and sensitivity towards any slight changes in the environmental conditions [3][4][5].

Furthermore, foraminiferal sampling itself has negligible impacts towards marine environment [3]. The potential use of foraminifera as proxies in monitoring coastal waters was recognised in Florida, Caribbean, Australia and many other subtropical regions [6][7][8]. FORAM (Foraminifera in Reef Assessment and Monitoring) index (FI) and *Ammonia*-*Elphidium* index (AEI) provide a good tool in coastal monitoring [6]. The application of these indices in Penang coastal waters might help to determine its health condition and hence, help to create better sustainable coastal management. This study aimed 1) to assess the water quality of Penang National Park coastal waters; 2) to describe the distribution of benthic foraminiferal assemblages and 3) to investigate the potential use of benthic foraminifera as an ecological proxy for coastal water monitoring.

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2. Material and Methods

2.1. Study Area

Samples collections were carried out in the vicinity along Penang National Park coastal water of Penang Island (Figure 1). Four sites were chosen based on the degree of human activities. Teluk Bahang a fishing village. Teluk Aling, is where the Centre for Marine and Coastal Studies (CEMACS) is located. Teluk Ketapang acts as a reference site due to less human activities. Pantai Acheh is situated closer to mangrove ecosystem where intrusion of freshwater occurs at the mouth of Pinang River.

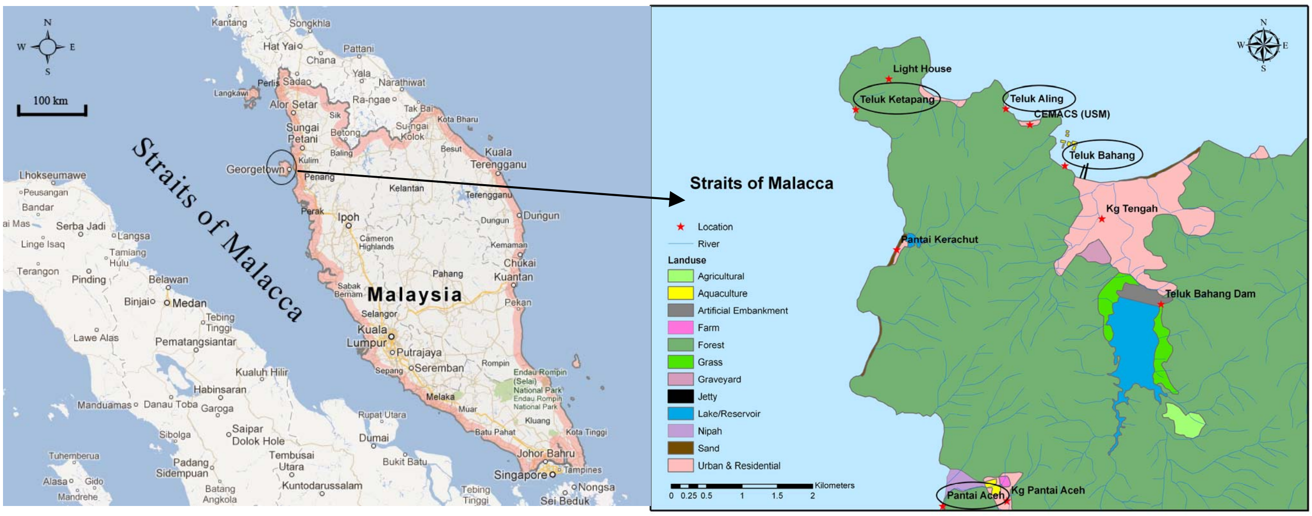

Fig. 1: Map of Malaysia and sampling sites in Penang Island

2.2. Samples Collection

Samples were collected (bimonthly) in October 2010, December 2010, February 2011 and April 2011. Sediment samples were obtained from six stations which were distributed along a transect in the subtidal zone at every 200 m intervals, extending up to 1200 m offshore. Bulk sediments were obtained using a Ponar grab from a small vessel, and these were then sub-sampled immediately on board using a hand corer with 5cm inner diameter to give a sample of 200 ml volume. The sub-samples collected were transferred into 250 ml pre-labelled containers and immediately fixed with 4% formalin to minimise Foraminifera test degradation [9]. *In-situ* bottom environmental parameters measured at every station were salinity (ppt), temperature (^{0}C), dissolved oxygen (mg/L) and pH. Water samples for nutrient determination were collected at the bottom layer using a water sampler and immediately stored in an ice chest to minimize microbial activities.

2.3. Samples Analysis

In the laboratory, two sub-samples of 8 cm^3 from the sediment containing Foraminifera were taken randomly from each 200 ml preserved sample. The subsamples were wet-sieved using 1000 µm and 63 µm sieves. The residue on 63 µm sieve was then carefully transferred into a 10 ml counting chamber using distilled water [10]. Counting and sorting were completed with the aid of dissecting microscope. A micro-pipette was used to pick up wet specimens and place them in 10 ml pre-labelled vials containing 70% ethanol solution for preservation purposes. Sample identification was based on references by Sen Gupta (2003), Loeblich &Tappan (1998) and Cushman [5][11][12]. Selected samples were dried and sent for Scanning Electron Microscopy. For micronutrients (nitrite, nitrate, ammonium and orthophosphate) and total suspended solids determination, the water samples collected were analysed based on Strickland and Parsons, 1972 [17]. Foraminiferal assemblages, diversity indices, FORAM Index (FI) [8] and the *Ammonia – Elphidium* Index (AEI) [5] were determined for each sediment sample collected.

3. Results

3.1. Physical and Chemical Parameters

Results indicated that the environmental data and micronutrient concentration varied temporally but not spatially. There were no significant differences between distances and sites except for salinity ($p<0.05$, ANOVA). However, there were significant different ($p<0.05$, df =3, n = 192) between months for measurement on temperature, salinity, dissolved oxygen, pH, nitrite, nitrate, ammonia, orthophosphate and total suspended solid.

3.2. Foraminiferal Distribution and Species Composition

A total of 14 benthic Foraminifera genera were identified in this study. The benthic foraminiferal assemblage was found to be dominated mostly by *Ammonia*(91%), followed by *Elphidium*(3%) and *Ammobaculites*(1%). Teluk Bahang showed high in mean abundance of Foraminifera (4453 indv/8cm^3) followed by Teluk Aling (3537 indv/8cm^3) and Pantai Acheh (996 indv/8cm^3). Low mean abundance of Foraminifera was recorded at Teluk Ketapang (191 indv/8cm^3) (Figure 2). Low Foraminifera diversity (H=0.27) was recorded at Teluk Bahang with existence of high dominance in stress-tolerant taxa i.e. *Ammonia*(94.56%), *Elphidium*(1.99%), *Ammobaculites*(1.76%) and *Bolivina*(0.03%) (Table 1). Foraminifera seems to be more diverse (H=0.33) in Teluk Aling whereby 97% comprises of stress-tolerant taxa. Teluk Ketapang was characterized with highest diversity (H=0.81) and less composition of stress-tolerant taxa (75%). Samples from Pantai Acheh showed high diversity index (H=0.73) with 91% dominated by stress-tolerant taxa (Table 1). At 200 m distance from the edge of the lowest mean tide, density *Ammonia* and *Elphidium* were 1064 indv/8cm^3 and 30 indv/8cm^3 respectively. However, as the distance approached 1200 m away from the shore, the density of *Ammonia* (49.5 indv/8cm^3) and *Elphidium* (7 indv/8cm^3) decrease drastically.

Table 1: Average relative abundance, functional groups, diversity index (H), evenness index (J), dominance index (D), FORAM index (FI) and *Ammonia-Elphidium* index (AEI). ST- stress-tolerant; AG- agglutinated; OSM- other smaller miliolids

Genus	Functional Groups	Relative abundance (%)			
		Teluk Bahang	Teluk Aling	Teluk Ketapang	Pantai Acheh
Ammonia	ST	94.56	92.94	69.77	79.89
Elphidium	ST	1.99	2.91	1.75	8.56
Ammobaculites	ST	1.76	1.61	1.83	1.07
Nonion	ST	0	0.01	0.51	1.30
Bolivina	ST	0.03	0.01	0.74	0.74
Asterorotalia	ST	0	0	0.37	0.05
Reophax	AG	0.09	0.48	16.48	0.73
Eggerella	AG	0	0	0	0.40
Textularia	AG	0.14	0.22	6.76	0.73
Quinqueloculina	OSM	0	1.02	0.37	1.19
Astacolus	OSM	1.26	0.47	0.44	2.04
Lagena	OSM	0	0	0	0.56
Fissurina	OSM	0	0.07	0	0.37
Hopkinsina	OSM	0	0	0	0.12
Mean abundance (indv/8cm^3)		4453	3537	191	996
Shannon-wiener diversity index (H)		0.27	0.33	0.81	0.73
Evenness index (J)		0.17	0.15	0.39	0.32
Dominance index (D)		0.83	0.85	0.61	0.68
FORAM index (FI)		1.10	1.07	1.27	1.14
Ammonia-Elphidium index (AEI)		95	97	78	86

4. Discussion

The environmental data (temperature, salinity, pH, and dissolved oxygen) showed no significant different between sites and distance due to the shallowness of the coastal water (i.e. <10 m), which results in better nutrient mixing throughout the sampling stations. Slight variations in temperature, salinity, dissolved oxygen, pH, nitrite, nitrate, ammonia, orthophosphate and total suspended solid readings at different months can be due to the occurrence of two tropical monsoons which affect West Peninsular Malaysia [13]. Foraminifera species composition showed variations between sampling sites. From all the analysed samples, Teluk Bahang was least diverse (H=0.27) but high in mean abundance (4453 indv/8cm^3), similar to study by Narayan & Pandolfi () [15]. High dominance (98%) of stress-tolerant taxa results in low mean FORAM Index (FI =1.10) which indicates stressed and unfavourable condition. Meanwhile, high *Ammonia*-*Elphidium* Index (AEI) = 95 in Teluk Bahang reflect the hypoxia influence on bottom sediment. Teluk Aling species assemblage was characterized with dominant stress-tolerant taxa, low mean FI (1.07) and high AEI = 97 which indicates the presences of anthropogenic stressor as well as hypoxic environment. Teluk Ketapang foraminiferal assemblage was high in diversity (H=0.81) but considerably low in mean abundance (191 indv/8cm^3). Due to less dominance of stress tolerant taxa and increase relative abundance of agglutinated taxa, the FI value (FI= 1.27) in Teluk Ketapang is somewhat higher. Lower AEI value (AEI=78) was also recorded in Teluk Ketapang indicates irregular hypoxia condition [5][6]. The foraminiferal assemblages in Pantai Acheh were predominated by *Ammonia* (79.89%) and *Elphidium* (8.56%) which indicates typical adjacent estuarine settings [15]. The freshwater discharge and adjacent mangrove ecosystem might influence foraminiferal assemblages in Pantai Acheh. *Ammonia* is an established and consistent indicator of low salinity and hypoxic environment in marine pollution monitoring [2][4][6][15]. Several studies showed similar results of high *Ammonia* assemblages in coastal area under the influence of anthropogenic stressor [4][16]. Therefore, the predominance of *Ammonia* in Teluk Bahang could be associated with the presence of anthropogenic stressor especially at area closer to shore. Since physical parameters do not affect Foraminifera distribution, high in organic matter and nutrients originated from human induced activities such as nearby floating cage culture could be the possible factor that allows stress tolerant taxa (*Ammonia*, *Elphidium* and *Ammobaculite*) to thrive better in the environment.

5. Conclusion.

There were no significant different between water quality parameters (nitrite, nitrate, ammonia & orthophosphate) between sampling site. Foraminiferal assemblages differed between sites. Stress-tolerant taxa seem to dominate the foraminiferal assemblages especially in Teluk Bahang and Teluk Aling. Based on foraminiferal assemblage, Teluk Bahang and Teluk Aling are subject to high anthropogenic stressor and exposure to hypoxic condition. Foraminiferal assemblage together with other environmental parameters would make an excellent tool in monitoring the tropical coastal water of North West Penang Island.

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