Sediment Profiling of the Nesting Grounds of Horseshoe Crabs at East Peninsular Malaysia

B. Akbar John, S. Sihin, B. Y. Kamaruzzaman (Corresponding author) & K. C. A. Jalal
Institute of Oceanography and Maritime studies (INOCEM), Kulliyyah of Science
International Islamic University Malaysia, Jalan Sultan Ahmad Shah
Bandar Indera Mahkota, Kuantan Pahang 25200, Malaysia
E-mail: kama@iium.edu.my

K. Zaleha
Institute of Tropical Aquaculture, University Malaysia Terengganu
Kuala Terengganu 21030, Terengganu, Malaysia

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Abstract

Horseshoe crabs prefer beaches with loosely packed sediment for the nesting of their eggs. In present study, Sediment profile at the observed the nesting grounds of horseshoe crabs along the east peninsular Malaysian coast were investigated. Two sampling sites (Balok and Pekan) were observed to be the nesting grounds of horseshoe crabs along the Pahang coast, east coast Malaysia. Mean sediment size analysis (ø phi) showed that during the non-monsoon and monsoon seasons, the distribution of sediment at the nesting grounds was mostly were of median sediment (1.88±0.378ø) and finer sediment (2.249±0.114ø) at Balok station respectively. Whereas, the distribution of sediment at the Pekan nesting ground was median sediment (1.073±0.388ø) at non monsoon and coarse sediment (0.641±0.075ø) at monsoon season. The nature of sediments were of moderately well sorted in both the sampling stations. There was no significant difference in sediment size or sorting value during monsoonal cycle. The results clearly showed that the sediment nature at the Balok and Pekan are still conducive for the better nesting of horseshoe crabs.

Keywords: Horseshoe crabs, *Tachypleus gigas*, *Carcinoscorpius rotundicauda*, Nesting ground, Sediment profiling

1. Introduction

Like number of species, horseshoe crabs lay their eggs on beaches in the intertidal zones. They migrate from continental shelf to the shallow coastal area during full and new moon days and their spawning is well synchronized with spring tides (Penn and Brockmann, 1994). It is interesting to note that out of four extant species of horseshoe crabs *Limulus polyphemus*, *Tachypleus gigas*, *T. tridentatus* and *Carcinoscorpius rotundicauda*, later three are inhabiting Malaysian coastal waters while the distribution of *T.tridentatus* is restricted to East Malaysian coast (Borneo) (John et al., 2010; Kamaruzzaman et al., 2011). Considerable amount of studies has been carried out on the nesting behaviour of American horseshoe crab *L.polyphemus* (Jackson et al., 2005; Tanacredi et al., 2009; Sekiguchi et al., 2009), Japanese tri spine horseshoe crab *T.tridentatus* (Yang et al., 2009; Hsieh and Chen, 2009; Hong et al., 2009). However, studies on other two conspecifics are still scanty (Zaleha et al., 2010).

Balok and Pekan were observed to be the nesting grounds of horseshoe crabs along the Pahang coast in the East coast of Peninsular Malaysia (Zaleha et al., 2010) where *T.gigas* and *C.rotundicauda* being frequently encountered throughout the year with peak spawning period between May-August (Kamaruzzaman et al., 2011a). The adaptive significance of nest preferences of horseshoe crabs are still unclear, but it has been suggested that they nest at elevated portion of the beaches where environmental conditions such as sediment nature, physicochemical parameters and macrobenthic diversity are more suitable to egg development besides minimizing the loss of eggs due to beach erosion (Botton et al., 1992). It is evident from previous studies that

horseshoe crabs prefers nesting beaches with loosely packed sediments for easy digging and deposition of their eggs. Thus, we have studied the sediment nature of horseshoe crab nesting grounds along the Pahang coast.

2. Materials and Methods

2.1 Study area description

Balok (Lat3°56.194' N, Long103°22.608' E) and Tanjung Gosong (Pekan: Lat3°36.181' N, Long103°23.946' E) in the Pahang state of East coast of Malaysia were observed to be the nesting grounds of horseshoe crabs (Zaleha et al., 2010) (Figure 1). The sediments of the sampling location were observed to be soft and loosely packed which may contribute to the ease of laying eggs and egg burial by the female horseshoe crab. Adult horseshoe crabs migrate from the off shore continental shelf to spawn on intertidal sandy (*T.gigas*) and mud sandy beaches and mangrove area (*C. rotundicauda*) at every full and new moon at these sampling locations. Meteorological data have shown high rainfall during monsoon season (November to January) along the east peninsular Malaysia. Twenty years (1968 to 1987) of accumulated data obtained from the Malaysian Meteorological Department (MMD) showed that the monsoon seasons with strong winds and long frequency periods with mean annual rainfall of 3064mm occurred from November to January. Meanwhile the non-monsoon seasons with low rainfall occurred during April, May and June. Field observation unveiled the intensive fishery activities along the sampling locations besides industrial activities and human inhabitation processes which could possibly introduce considerable level of contaminants into the water body.

2.2 Sample collection

Line transect method was adopted to collect the sediment samples from sampling sites. Sampling areas were divided into multiple transect depending on the total length of the horseshoe crab nesting grounds. A total of 10 and 6 sampling transects were measured at 25meter distance each from Balok and Pekan respectively and sediment samples were collected in replicates using hand scoop device. Samples were kept in labeled plastic bags and transported to the INOCEM marine laboratory for further analysis.

2.3 Wet lab analysis

Dry sieving method was adopted to analyze the particle size of sediments. The sediments were left air-dried for a week and 100g of samples were weighed for the coarse size analysis. The samples were transferred on a mechanical shaker using a several series of mesh opening for grade classification of particle size. The samples were allowed to stand for 15 minutes in mechanical shaker and the samples of each individual sieve were weighed (McLachlan and Brown, 2006). Sediment samples were graded and type of sediments was classified and sorted using standard method Robertson and Alongi (1992) and Crozier (1979). The formula used to calculate mean sediment size and sediment sorting values are

2.4 Mean sediment size

$$X\,ø = \sum fm/n$$

Where,

f = percentage weight of each grade of particle size

m = median of each particle size in ø

n = total number of samples in 100 where f is in percentage form

Sediment sorting

$$\mathbf{Sd}\ ø = \sqrt{\sum \boldsymbol{f}\frac{(\boldsymbol{m} - \boldsymbol{x}ø)^2}{\mathbf{100}}}$$

2.5 Data analysis

Analysis of Variance (ANOVA) test was performed to check the variation in the sediment size and sorting value between the sampling stations. The influence of monsoonal cycle on the significant variation in the sediment size and sorting value were also calculated. The conventional significance level of 0.05 and below was used to identify the statistical significance. Statistical analyses were carried out using SPSS software package version 17.

3. Results

3.1 Sediment characteristics

3.1.1 Mean sediment size (ø phi)

Mean sediment size varied between two sampling sites ($p < 0.001$ with $t = 9.962$) while there was no significant difference noted in mean sediment size within the sampling station during full and new moon days. During the non-monsoon and monsoon seasons, the distribution of sediment at the nesting grounds was mostly were of median sediment (1.88±0.378ø) and finer sediment (2.249±0.114ø) at Balok station respectively with the highest value recorded during full moon days of July-2010 (2.446ø) and the lowest value obtained during full moon days of September-2010 (1.245ø). The distribution of sediment at the Pekan nesting ground was median sediment (1.073±0.388ø) at non monsoon and coarse sediment (0.641±0.075ø) at monsoon season with the highest value recorded during full moon days of July-2010 (1.968ø) and the lowest value obtained during full moon days of November-2010 (0.529ø) (Figure 2). In general, comparatively higher phi (ø) value was noted during full moon days compared to new moon days in both the sampling stations but it was not statistically significant.

3.2 Sediment sorting classification

As it was observed in mean sediment size characteristics, significant difference in the mean sediment size was noted between sampling stations ($p < 0.001$) while there was no significant difference noted within the sampling station during full and new moon days. During the non-monsoon and monsoon seasons, the sorted values of sediment at the nesting grounds showed that the nature of sediments were of moderately well sorted (0.591±0.068ø) and (0.55±0.04ø) at Balok station respectively with the highest value recorded during new moon days of August-2010 (0.68ø) and the lowest value obtained during full moon days of November-2010 (0.5ø). The sediment sorting value at the Pekan nesting ground showed that the nature of sediments were of moderately well sorted during both non-monsoon and monsoon season with average phi (ø) value of 0.751±0.081ø and 0.75±0.07ø respectively. The highest value recorded during full moon days of July-2010 (0.86ø) and the lowest value obtained during new moon days of October-2010 (0.54ø) (Figure 3). Overall variations in the mean sediment size and its sorting values at the nesting grounds of horseshoe crabs are presented in Table 1.

4. Discussion

The two study beaches generally comprised sediments of smaller grain sizes, i.e., medium sand particles during non-monsoon period with the mean sediment size range of 2.446-1.245ø at Balok and 1.968-0.473ø at Pekan stations respectively. On the other hand, finer and coarse sediments were noted in the nesting ground during monsoonal period at Balok and Pekan respectively. The nature of sediments was observed to be moderately well sorted in both the stations, suggesting that the substrata are of medium porosity and permeability (Hayward, 1994). Such a sand type, with generally high oxygen levels in the incoming waters, may help create a well oxygenated micro-environment for the normal development of horseshoe crab eggs and larvae, as well as juveniles. Botton et al., (1988) reported that adult horseshoe crabs are capable of discriminating between beaches of different geochemical regimes. An ability to detect beach characteristics may enable them to spawn in areas where their eggs will be best able to survive and hatched larvae and grow. As horseshoe crab juveniles are generally observed on sheltered flats where they are protected from strong oceanic waves, this implies that adults tend to select such beaches for spawning. There are various anthropogenic activities such as jetty construction, intense fishing activities besides discharging domestic wastes are taking place in both the sampling areas. However, horseshoe crabs tend to select these beaches that ensure the laid eggs are less likely to be washed out of the sand, and hatched juveniles can occupy the sand safely. Rudloe, (1979) also suggests that sheltered beaches with weak tidal action provide protection for developing eggs and hatched larvae. In general, horseshoe crabs prefer undisturbed beaches as their preferred habitat (Botton et al., 1988). According to Berkson et al., (1999), the movements of horseshoe crabs towards beaches during the spawning season may be guided primarily by prevailing underwater currents and the shoreline. Alterations to tidal currents in the vicinity of the beach might, already, have adversely affected, or even impeded, spawning pairs from coming to Balok and Pekan nesting grounds. This might be a factor which has led to the currently low recorded numbers of juveniles on this beach. However, horseshoe crabs prefer these beaches for their nesting purposes due to low profile and moderately well sorted sediment nature of the sites. It can, thus, be stated that a preferable horseshoe crab nursery beach is of low profile and characterized by median sediment particles resulting not from wave sorting but, probably fluvial sorting, though still typified by high porosity and overlain by estuarine waters of intermediate salinity. Such beaches are typically richer in nutrients, providing habitats for a meio and macrofauna that are the diet of juvenile horseshoe crabs.

5. Conclusion

In conclusion, sediment nature of horseshoe crab nesting grounds at Pahang coast is still conducive for the better nesting of Malaysian horseshoe crabs. Sediment size and sorting value analysis showed that the distribution of median and finer sediment particles at the elevated beaches of Pahang coast helps in creating well oxygenated micro environment for developing eggs. However, data on macrobenthic community composition together with physicochemical parameters of inundating water at horseshoe crab nesting ground would give additional support for the shore reaching horseshoe crabs and developing eggs at Pahang nesting grounds.

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Table 1. Monthly and seasonal variations in the sediment characteristics recorded in Balok and Pekan

		Sediment Mean Size (ø)		Sediment Sorting value (ø)	
		Balok	Pekan	Balok	Pekan
Mar-10	NM	1.673	1.119	0.57	0.82
	FM	2.321	1.829	0.62	0.78
Apr-10	NM	1.721	1.147	0.64	0.75
	FM	1.937	1.151	0.66	0.73
May-10	NM	2.109	1.091	0.58	0.71
	FM	1.899	0.995	0.53	0.69
Jun-10	NM	1.587	0.942	0.61	0.81
	FM	1.927	1.113	0.57	0.71
Jul-10	NM	1.777	1.198	0.66	0.79
	FM	2.446	1.968	0.55	0.86
Aug-10	NM	1.605	0.857	0.68	0.84
	FM	1.744	0.785	0.62	0.74
Sep-10	NM	1.278	0.855	0.65	0.82
	FM	1.245	0.473	0.61	0.65
Oct-10	NM	2.445	1.113	0.44	0.54
	FM	2.361	0.527	0.47	0.77
Nov-10	NM	2.229	0.733	0.56	0.8
	FM	2.401	0.529	0.5	0.68
Dec-10	NM	2.189	0.653	0.52	0.73
	FM	2.367	0.621	0.61	0.79
Jan-11	NM	2.212	0.712	0.58	0.65
	FM	2.098	0.598	0.53	0.83
Non monsoon	Average	1.88	1.073	0.591	0.751
	Max	2.446	1.968	0.680	0.860
	Min	1.245	0.473	0.440	0.540
	SD	0.378	0.388	0.068	0.081
Monsoon	Average	2.249	0.641	0.55	0.75
	Max	2.401	0.733	0.61	0.83
	Min	2.098	0.529	0.50	0.65
	SD	0.114	0.075	0.04	0.07

NM - New moon days; FM – Full moon days.

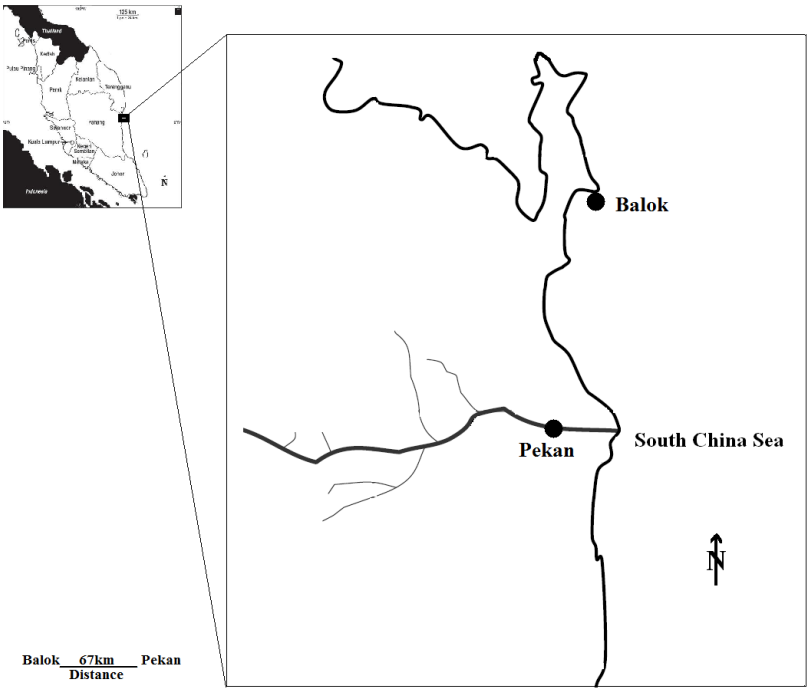

Figure 1. Location of the sampling area

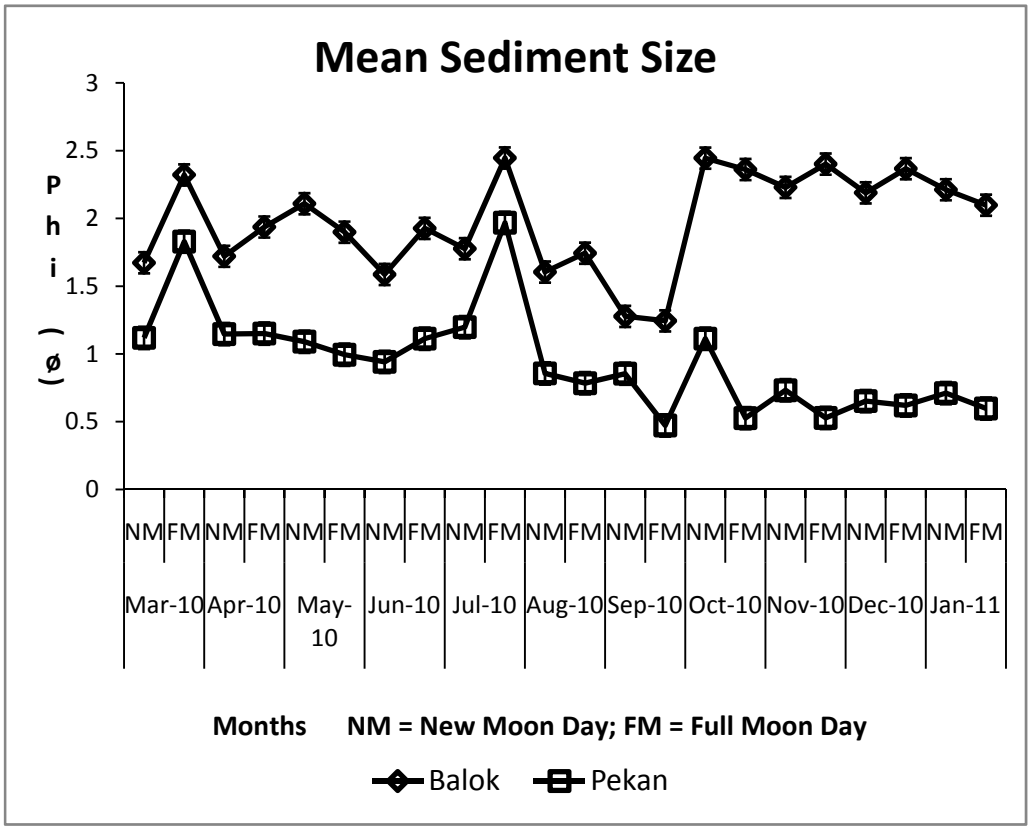

Figure 2. Monthly variations in the distribution of mean sediment size at the sampling stations during the full and new moon days

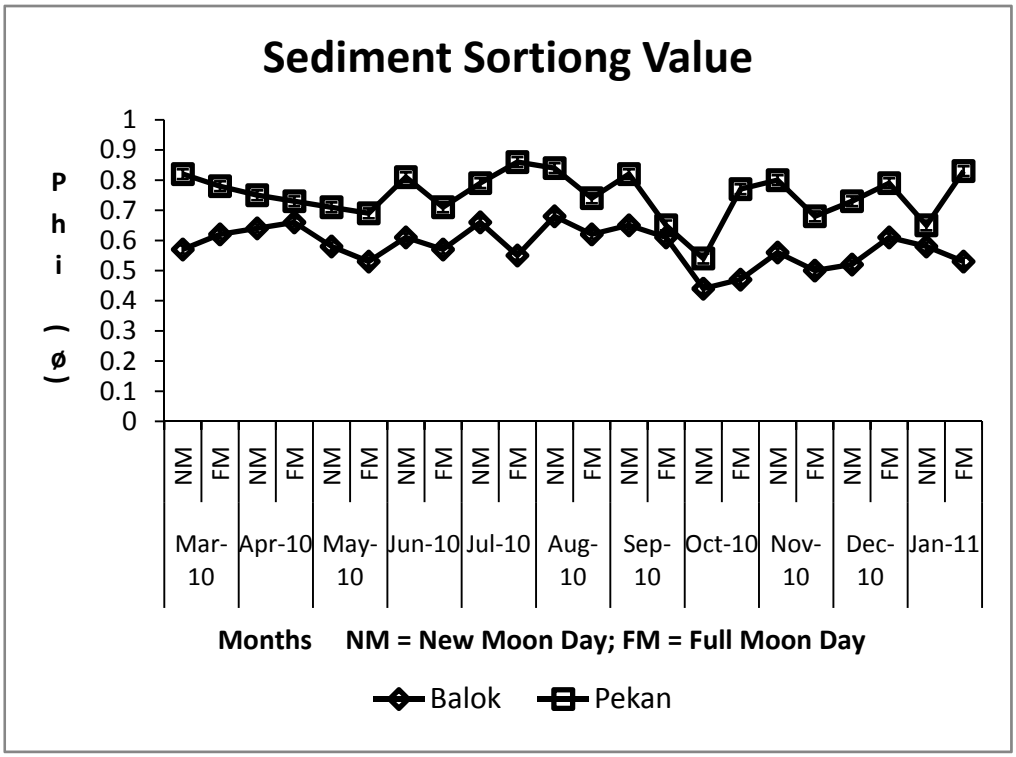

Figure 3. Monthly variation in the sorted sediment values (phi ø) of the sampling stations during the full and new moon days