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Do habitat, month and environmental parameters affect shrimp assemblage in a shallow semi-enclosed tropical bay, Thailand?

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Abstract. Assemblages of shrimp in association with habitat, season, and environmental parameters were examined. The tested hypotheses was that habitat, season, and water parameters affect species diversity, density, and community structure of shrimps in the shallow semi-enclosed tropical bay, Thailand. Samples were collected monthly at five different habitats with different bottom characteristics and vegetation between February 2011 and January 2012 by an encircling seine net. Altogether, 32,523 shrimps from 14 species were collected. *Acetes sp.*, *Metapenaeus moyebi*, and *Metapenaeus lysianassa* dominated the catch with 50.6%, 22.0%, and 17.6%%, respectively. Most of them were juveniles or adults of small sized-species. Both habitat and month had highly significant impacts on density of shrimps ($P<0.005$), but only monthly factor affected species richness ($P<0.05$). Cluster dendogram indicated further that the difference in community structure of shrimps was based mainly on seasonal impact. Canonical correspondence analysis (CCA) recorded different responses of shrimp assemblages to specific water quality parameters. Water temperature was the major factor structuring shrimp assemblage in the bay.

Key words. Gulf of Thailand, shrimp ecology, shrimp and environment, decapod crustacean

INTRODUCTION

Shallow coastal habitats are ecologically dynamic and productive areas used by larvae, juveniles, and adults of many estuarine-dependent species for reproduction, foraging, and shelter (Peterson & Whitfield, 2000; Harris et al., 2001; Schaffmeister et al., 2006; Hajisamae et al., 2013). Commercial shrimps, such as *Penaeus* and *Metapenaeus*, normally have a life cycle where they spawn offshore, and post-larvae or juveniles move to estuarine backwaters for growing out in inshore and estuarine waters (Staples & Vance, 1985; Dall et al., 1990). They remain and use these habitats as nurseries during their critical early life stages. After a few months, the sub-adult shrimps emigrate offshore. Generally, the structure of this nursery ground is characterised by the presence of vegetation including mangrove forests, seaweeds, and seagrass beds.

Mangroves have long been recognised as important habitat for shrimp (e.g., Robertson & Duke, 1987; Sasekumar et al., 1992; Vance et al., 1996; Primavera, 1998). In Indo-Pacific region, many penaeid species prefer mangrove habitat as their nursery ground such as *Penaeus indicus* (see Chong et al., 1990), *Penaeus merguiensis* (see Robertson & Duke, 1987), *Penaeus monodon*, and *Penaeus penicillatus* (see Chong et al., 1990). There are many reasons why juveniles of many shrimps utilise these habitats including food abundance, shelter from predation, and the hydrodynamic ability of mangroves to retain immigrating larvae and juveniles (Robertson & Blaber, 1992; Ronnback et al., 1999; Chong et al., 2001). However, some species prefer to distribute specifically in different habitat types including seagrass and algal beds such as *Penaeus duorarum* (see Sheridan, 1992), *Penaeus esculentus*, and *Penaeus semisulcatus* (see Robertson & Duke, 1987). Some shrimps including *Metapenaeus monoceros* (see de Freitas, 1986) and *M. ensis* (see Robertson & Duke, 1987) are widely scattered on seagrasses, mud flats, and mangrove channels. Juveniles of *Penaeus esculentus* and *Penaeus semisulcatus* are normally found in seagrass community and other littoral vegetations (Loneragan et al., 1994, Haywood et al., 1995). Physical structure of seagrass beds play the role in reducing the likelihood of being detected and eaten by predators (Bell & Pollard, 1989; Heck & Crowder, 1991). Kenyon et al. (1995) proved that small juvenile tiger prawn, *Penaeus monodon*, suffers higher rates of predation in short, thin seagrass, and unvegetated habitats, and this leads to a decrease in abundance in these habitats. Kenyon et al. (1997) also found that two species of juvenile tiger prawns particularly preferred seagrass over unvegetated areas when given the choice between seagrass and bare sediment. This indicates that the distribution of juvenile prawns is mainly based on an active choice of habitat due to the greater predation rates in open areas. However, there is a paucity of scientific information to simultaneously compare and analyse the linkages of shrimp community between seagrass, mangrove or nearby mangrove forest, muddy substratum, and seaweed beds in tropical estuarine bay. In despite of tropical coastal ecosystems, especially those in Southeast Asia, being recognised worldwide as important habitats for aquatic resources (Chou, 1996; Hajisamae et al., 1999), only few studies have investigated even a basic knowledge

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of assemblages and ecological aspects of shrimps in the region (Chong et al., 1990).

In the Gulf of Thailand, although shrimps, especially *Peneaus* and *Metapeneaus*, are the main target species of fishermen and some of them have been intensively cultured (Songsangjinda et al., 2005), knowledge on the ecology of shrimp in estuarine and coastal areas, which is crucial for management of shrimp resources, is limited. Some information can only be found in research reports and unpublished conference papers. These include studies on shrimp ecology in Songkhla Lake (Prajuab, 1965; Angsunee & Julaporn, 2001), the coast of Prajuabkhirikhan to Songkhla (Mala, 1979) and Pak Phanang Bay, Nakornsritammarat (Thanate et al., 2003). It is therefore appropriate to use Pattani Bay as a model of sampling site to simultaneously investigate the importance of different habitats and seasons on species composition and pattern of assemblages, since the bay is a small-sized semi enclosed structure, characterised by various types of bottom habitats and vegetations.

The aims of this study were to: 1) determine the impact of habitat characteristics and seasons on species composition, distribution, and density of shrimp; and 2) assess the relationship between water parameters with community structure of shrimp in Pattani Bay, Thailand. The hypothesis is that bottom habitats, seasons, and water parameters affect species diversity, density and community structure of shallow water shrimps in the semi-enclosed tropical bay, Thailand.

MATERIAL AND METHODS

Study sites. Pattani Bay is a 74 km^2 semi-enclosed estuarine bay protected on its northeastern side by a 12 km-long sand spit (Fig. 1). The bay area is characterised by tropical monsoonal climate. Two major rivers, the Pattani River and Yamu River, drain into the bay. Areas of mangrove, both natural and managed (estimated at 900 ha), are found in the eastern part. The water regime is complex, with tidal influences from the Gulf of Thailand. The average water depth is between 0.2–1.5 m with a maximum of 5 m at the bay's mouth. The tidal amplitude varies from 90 cm at spring tides to 40 cm at neap tides. Mangrove forests, mainly *Rizophora* spp., dominate the surrounding areas and seagrasses, mainly *Halophila* spp. and *Halodule uninervis*, cover large area of the bay.

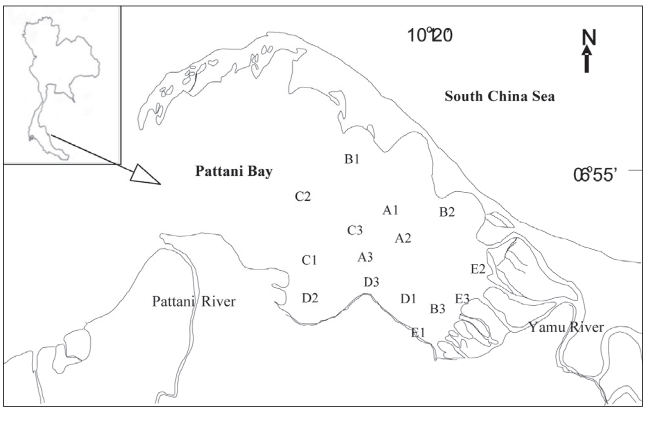

Fig. 1. Map of study area, Pattani Bay, Thailand, showing habitat characteristics (A1–3 = Sandy habitat, B1–3 = Seagrass habitat, C1–3 = Shell-doposited habitat, D1–3 = Muddy habitat, and E1-3 = Mangrove habitat).

Five different habitats based on their bottom characteristics and vegetation were selected around the bay. Sandy substrata habitat was defined as non-vegetated bottom with >40% sand composition. Muddy substrata habitat referred to non-vegetated bottom with >90% of silt and clay. The seagrass habitat had a bottom substrate with >50% seagrass coverage. The mangrove habitat was a representative area within the mangrove forest. The shell-deposited habitat had a bottom substrata covered largely with shells of bivalves deposited by fishermen or natural phenomena. Three replicates were selected for each habitat throughout the bay.

Sampling methodology. Three replicated samplings were done monthly at five different habitats from February 2011–January 2012 using a 4 m depth × 50 m long shallow water encircling knotless net, with a stretched mesh size of 0.5 cm and weighted with lead (see also Hajisamae et al., 2006). The net is commonly used by traditional fishermen in the area and is considered the most effective fishing gears suitable for catching shrimps in Pattani Bay without towing the net to the coast. Daytime collections were made to avoid tidal bias. Altogether, 36 sampling efforts were collected equally at each habitat.

The net was set by slowly releasing one end of it from the boat which moved in an encircling direction to meet the other end of the net. The net was carefully pulled to the boat by pulling both ends of the net and the catch was concentrated in the cod-end. The area covered by the net for each haul was approximately 198 m^2.

The shrimp catches were immediately iced and transported to the laboratory for sorting, identification, and measurements of carapace length. All materials were preserved with 10% formalin solution and deposited in The Fishery Technology collection, Faculty of Science and Technology, Prince of Songkla University, for future reference.

Water quality parameters analysis. Prior to shrimp sampling, dissolved oxygen, pH, salinity, and temperature were measured in situ by a YSI 556 MPS meter at a depth of 0.5 m from the water surface. Salinity was measured using the Practical Salinity Scale.

Statistical analysis. Catch data from each site collected monthly were pooled and analysed for: 1) mean species richness; and 2) relative abundance.

A two-way analysis of variance (ANOVA) was used to compare the density of shrimp and species richness among habitats and months. Prior to analysis, data on abundance and species richness were log (X+1) transformed to approximate normality and homogeneity of variance.

Table 1. Average water parameters recorded from five different habitats in different months in Pattani bay during February 2011–January 2012.

Habitat/Month	Water Parameters			
	Salinity (psu)	**Dissolved Oxygen (mg/L)**	**pH**	**Temperature (°C)**
Habitat				
Sandy-substrata habitat	19.3	6.1	8.3	28.3
Seagrass bed habitat	12.1	6.7	8.2	28.4
Shell-deposited habitat	18.9	6.3	8.2	28.5
Muddy-substrata habitat	18.2	6.4	8.1	28.3
Mangrove habitat	10.6	6.0	8.1	28.5
Month				
February 2011	27.0	5.1	8.0	27.9
March 2011	27.8	5.2	8.1	28.3
April 2011	22.2	5.6	8.1	29.0
May 2011	18.7	8.4	8.3	31.6
June 2011	6.6	6.2	7.7	27.9
July 2011	10.9	7.4	8.0	26.6
August 2011	16.1	5.9	8.3	26.8
September 2011	12.6	8.1	8.3	30.0
October 2011	14.8	6.8	8.0	29.9
November 2011	10.1	6.8	8.1	28.1
December 2011	7.3	5.9	8.1	26.6
January 2012	27.0	5.1	8.3	27.9
Average (SD)	**15.8(9.3)**	**6.3(2.1)**	**8.1(0.4)**	**28.4(1.7)**

Table 2. Results of ANOVA on water parameters at different habitats and months in Pattani Bay.

Sources	*df*	Salinity		Dissolved Oxygen		pH		Temperature	
		MS	**F ratio**	**MS**	**F ratio**	**MS**	**F ratio**	**MS**	**F ratio**
Habitat	4	567.4	7.7***	2.8	0.6^{ns}	0.5	3.7**	0.4	0.1^{ns}
Month	11	792.1	21.0***	17.8	6.9***	0.5	4.4***	34.2	77.5***

Levels of significant difference; ns, not significant; *, P<0.05; **, P<0.01; ***, P<0.005

A cluster analysis was carried out using the PRIMER statistical package version 5.0 (Clarke & Gorley, 2001), with Bray-Curtis similarity and complete linkage on fourth root transformed data, to examine the difference in shrimp community assemblages between all habitats and months. Analysis of similarity (ANOSIM) was used to determine whether the assemblage separated by cluster dendogram differed significantly. Once the significant difference was found, a similarity percentage (SIMPER) was used to examine which species contributed most to the difference.

To examine the effect of environmental variables including pH, salinity, temperature, and dissolved oxygen on 12 shrimp species, canonical correspondence analysis (CCA) was used. The option used for CCA was bi-plot scaling with focus on interspecies distance. A Monte Carlo test (199 iterations) was run to detect significant pattern.

RESULTS

Condition of water quality. Details of water quality parameters of each habitat are in Table 1. Temporally, analysis of variance indicated highly significant differences of salinity (P<0.005), dissolved oxygen (P<0.005), pH (P<0.005), and water temperature (P<0.005) in different months (Table 2). Spatially, the differences were found only for salinity (P<0.005) and pH (P<0.01). There were no differences between dissolved oxygen and water temperature between habitats (P>0.05).

General shrimp catch data. A total of 32,523 shrimps from 14 species were collected by the encircling-seine net. *Acetes* sp., *Metapenaeus moyebi*, and *Metapenaeus lysianassa* dominated the catch composition with 50.6%, 22.0%, and 17.6%, respectively. It was followed by *Macrobrachium lanchesteri* (4.1%) and *Fenneropenaeus merguiensis* (2.8%). Most of the shrimps were juvenile or adult of small sized-species. Detailed catch information including density of shrimps, average length, and relative density at each habitat are in Table 3.

Effects of habitat and month. Fig. 2 showed relative density (%) and species richness indicating distribution pattern of shrimps in different habitats with sandy substrata habitat demonstrating the minimum density. Fig. 3 shows the relative density (%) and species richness of shrimps at different months.

Table 3. Density of shrimps (no. hectare^{-1}), average carapace length and relative density at each habitats collected by encircling-seine net in Pattani Bay during February 2011 to January 2012.

Species	Density (no. hectare^{-1}) (%)	Length (cm±SD)	Relative Density at each Habitat (%)				
			Seagrass	Mangrove	Mud	sand	Shell
Metapenaeus moyebi	2,010 (22.0)	4.3±1.3	21.8	22.6	25.6	11.3	18.8
Metapenaeus lysianassa	1,606 (17.6)	4.7±1.0	16.4	27.3	20.6	10.9	24.7
Macrobrachium lanchesteri	375 (4.1)	3.3±1.4	21.6	32.0	18.1	11.6	16.6
Fenneropenaeus merguiensis	254 (2.8)	7.7±1.8	20.9	20.2	18.7	17.6	22.6
Metapenaeus affinis	101 (1.1)	4.9±1.5	28.0	13.9	26.9	16.6	14.7
Heterocarpus sp.	46 (0.5)	5.2±1.3	44.2	14.7	16.6	8.6	16.0
Penaeus semisulcatus	41 (0.5)	6.4±1.2	28.3	15.2	12.4	13.1	31.0
Penaeus monodon	26 (0.3)	8.3±3.1	29.8	6.4	19.1	24.5	20.2
Metapenaeus brevicornis	19 (0.2)	6.1±1.3	20.9	32.8	26.9	11.9	7.5
Metapenaeus ensis	14 (0.2)	5.6±0.6	25.5	13.7	15.7	23.5	21.6
Alpheus sp.	12 (0.1)	2.3±0.5	20.9	18.6	18.6	7.0	34.9
Metapenaeus dobsoni	10 (0.1)	6.9±2.1	0.0	85.7	11.4	0.0	2.9
Macrobrachium rosenbergii	0.3 (0.0)	12.2	0.0	100.0	0.0	0.0	0.0
Acetes sp.	4,621 (50.6)	2.0±0.4	27.5	16.4	24.9	11.5	19.8
Total	**9,136 (100)**		**23.9**	**20.5**	**23.7**	**11.6**	**20.3**

Analysis of variance (ANOVA) indicated highly significant differences between shrimp densities from the five different habitats ($P<0.005$) and months ($P<0.005$). The highest density was found in seagrass bed habitat and the lowest in sandy-substrata habitat. For species richness, there was a highly significant difference between month ($P<0.05$) but no difference between habitat types ($P>0.05$).

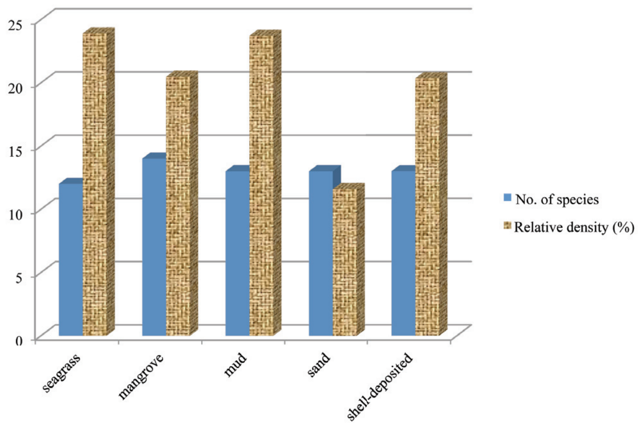

Fig. 2. Relative density (%) and species richness of shrimps collected at different habitats in Pattani Bay between February 2011–January 2012

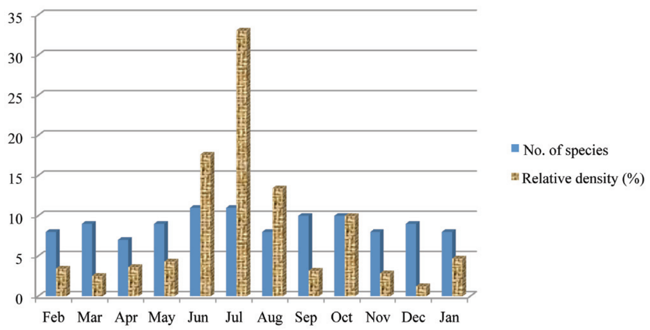

Fig. 3. Relative density (%) and species richness of shrimps collected in different months in Pattani Bay between February 2011–January 2012 at five different habitats.

Cluster dendogram clearly separated the shrimp community into three main groups based mainly on month rather than habitat (Fig. 4). The first group (G1) consisted almost entirely of the shrimp samples collected in January at four habitats including mangrove, shell, sandy and muddy habitats. The second group (G2) comprised entirely of shrimp samples from the months of February, March, April, and May. The third group (G3) consisted of those from the months of June, July, August, September, October, November and December. Non-parametric multidimensional scaling (nMDS) confirmed the stronger formation of groups based on months than that of habitats (Fig. 5).

Analysis of similarity (ANOSIM) demonstrated a significant difference between compositions of shrimp samples from these three groups based on month (Global $R = 0.451$, $P <0.005$). For habitat factors, ANOSIM indicated no difference between shrimp samples collected from different habitats (Global $R = –0.051$, $P>0.05$). Results of a pairwise test are in Table 4.

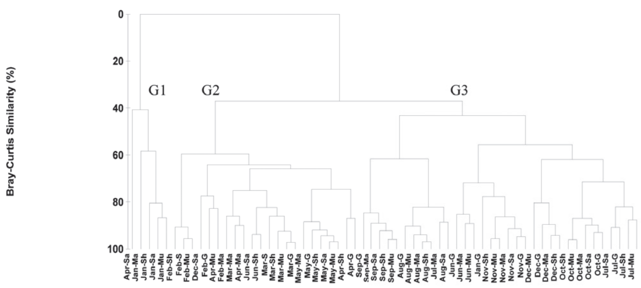

Fig. 4. Cluster dendogram demonstrating grouping of shrimps by month and habitat (Jan…Dec = January…December; Sa = sandy habitat, Ma = Mangrove habitat, S = Shell-deposited habitat, Mu = Muddy habitat and G = Seagrass habitat; G1, 2, 3 = cluster group 1, 2, and 3).

Table 4. Results of the ANOSIM pairwise test to analyse the differences of the same clusters using groups resulting from the cluster analysis.

Global Test
Global R = 0.522, Significant level = 0.1%

Pairwise Tests

Groups	R-statistics	Significance level %
b,a	0.975	0.1
b,c	0.425	0.1
a,c	0.641	0.1

A similarity percentage analysis (SIMPER) showed, in the case of G1, that the shrimp species that made up >70% of the definitive group were *Acetes* sp. and *M. lanchesteri* (Table 5). For the group G2, SIMPER indicated that *M. lysianassa, M. moyebi*, and *F. merguiensis* made up >70% of this group. *Metapenaeus moyebi, Acetes* sp., and *M. lysianassa* contributed for the formation of G3.

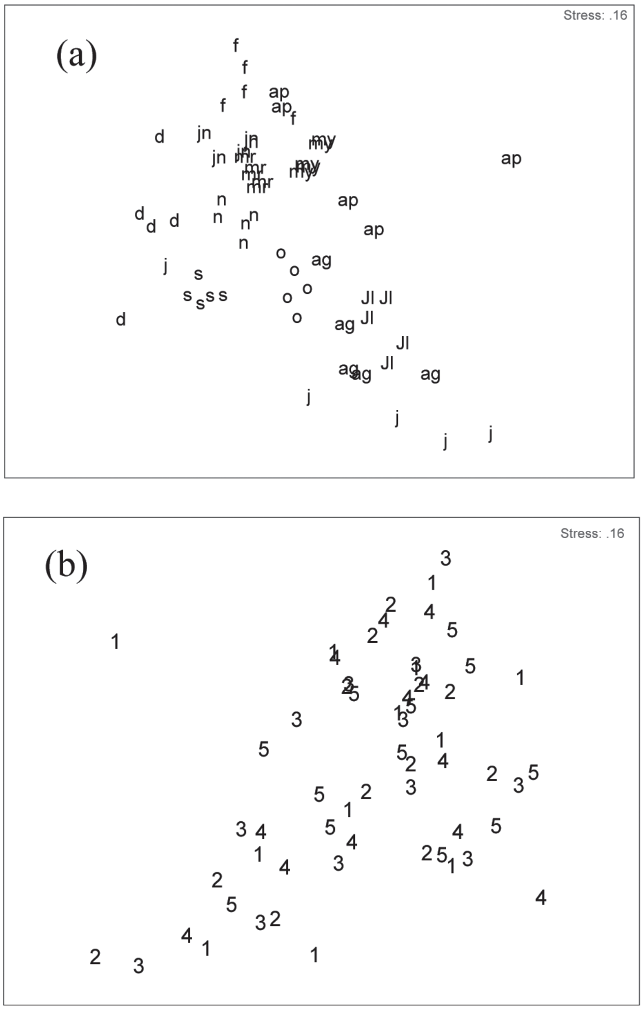

Fig. 5. A non-metric multidimensional scaling (MDS) ordination of abundance data (log N+1 transformation) for shrimps (a) collected between 12 different months (j = January, f = February, mr = March, ap = April, my = May, j = June, Jl = July, ag = August, s = September, o = October, n = November, d = December) and (b) at five different habitats in Pattani bay (1 = sandy habitat, 2 = mangrove habitat, 3 = shell-deposited habitat, 4 = muddy habitat and 5 = seagrass habitat).

Relationship between water parameters and shrimp assemblage. In the CCA of species related to environmental parameters, three axes explained 23.5% of the variance explained (Fig. 6; Table 6). The strongest axis was axis 1, explaining 19.0% of the variance (eigenvalue = 0.331, P=0.01), whereas axes 2 and 3 explained only 2.6% and 2.0%, respectively. Four environmental variables including temperature, salinity, dissolved oxygen, and pH demonstrated different contributions to the ordination. Based on axis 1, the strongest contribution of environmental factor was temperature.

A positive correlation of increasing temperature with some shrimp species such as *M. lysianassa*, *M. moyebi*, *P. semisulcatus*, *M. brevicornis*, and *F. merguiensis* indicated that these species prefer a condition with relatively higher temperature and slightly lower dissolved oxygen, pH, and salinity compared to other species. Shrimps such as *Acetes* sp. preferred a condition with lower temperature and slightly higher dissolved oxygen, pH, and salinity. However, the contribution of dissolved oxygen, pH, and salinity was smaller compared to that of temperature. Species including *M. dobsoni, M. ensis*, and *M. affinis* reflected a capability of lower influence by those four main environmental parameters.

DISCUSSION

At least 14 species of shrimps utilise a shallow semi-enclosed bay, Pattani Bay, as their habitat, either as a nursery ground, feeding ground, or living ground. The bay plays a significant role in supporting many economically important shrimp species, especially *M. moyebi*, *M. lysianassa*, and *F. merguiensis*. These shrimps are of high economic value being utilised by fishermen as their main source of income. Generally, there are two main reasons why estuaries function as nursery grounds; reduced predation levels and/or greater availability of food than alternative nursery areas (Robertson & Blaber, 1992). The refuge function may result from three factors: 1) availability of large areas of complex habitat such as mangrove forests; 2) reduction of efficiency of visual predators due to high turbidity; and 3) availability of large areas of shallow water that contains few predators (Johnston & Sheaves, 2007). In Pattani Bay, differences in density, species richness, and community structure of shrimps between months, likely reflect seasonal preference for recruitment and settlement among species. Most of the shrimps occurred throughout the year, but some were found specifically at particular months such as *Heterocarpus* sp.

Table 5. Summary results of similarity percentage analysis (SIMPER) on the contribution of shrimps found in Pattani Bay in the formation of groups resulting from the cluster analysis.

Groups	Species	% Contribution
G1	*Acetes* sp.	58.1
	Macrobrachium lanchesteri	24.7
	Metapenaeus affinis	5.0
G2	*Metapenaeus lysianassa*	26.7
	Metapenaeus moyebi	23.5
	Penaeus merquiensis	17.9
	Acetes sp.	14.2
G3	*Metapenaeus moyebi*	22.9
	Acetes sp.	22.0
	Metapenaeus lysianassa	18.1
	Macrobrachium lanchesteri	11.2

Table 6. Results of the main ordination for the canonical correspondence analysis on the relationship between shrimps and water parameters.

Axes	1	2	3
Intraset correlation of environmental variables			
Saliniy	0.060	0.488	0.500
Dissolved oxygen	0.308	0.543	0.268
pH	0.156	0.047	0.923
Temperature	–0.844	–0.495	–0.206
Eigenvalues	0.331	0.045	0.035
Variance in species data			
% of variance explained	19.0	2.6	2.0
Cumulative % explained	19.0	21.5	23.5
Pearson Correlation, species-environment	0.710	0.530	0.399
Inertia	1.749		

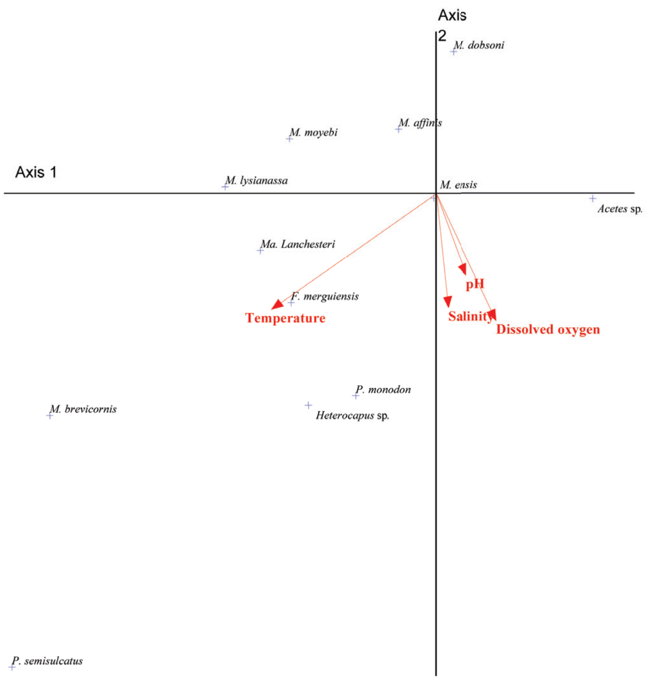

Fig. 6. Biplots of some shrimp species and environmental variables (arrows) on the first two canonical axes derived from CCA of shrimp abundance and environmental variables in Pattani bay during February 2011 and January 2012.

during July to September, *Alpheaus* sp. in December and *P. semisulcatus* during September and October.

Seasonally, the assemblage pattern of the shrimp community in Pattani Bay, based on result from cluster analysis and ANOSIM, can be divided into three different settlement periods, namely: 1) January; 2) February to May; and 3) June to December. Seasonal pattern of shrimps seems to be a typical characteristic in tropical habitat, although some particular species occur the whole year round (Chong et al., 1996). In Thailand, the present result supports the study by Pensri & Suchat (1996) who found seasonal recruitment and distribution of shrimp in Phangnga Bay. These authors reported the higher abundance of *F. merguiensis* and *Metapenaeus* spp. during the south-west monsoon season and *Parapenaeopsis* spp. and *Metapenaeopsis* spp. during the north-east monsoon season. *Acetes* sp. was found predominantly in April, which is coincident with south-west monsoon season. Furthermore, several studies also supported seasonal abundance of shrimps in many parts of the world. Arshad et al. (2011) found *Penaeus* post larvae recruiting mainly on a seasonal basis in Malaysian waters. Zafar & Mahmood (1989) reported the highly seasonal occurrence of *Lucifer* spp. in Bangladesh waters. Staples & Vance (1987) reported that season and rainfall directly affect the immigration of postlarvae and emigration of juveniles of *Penaeus merguiensis*. Different seasons of the year lead to different characteristics of water quality that may bear differently on the shrimp assemblage and distribution. Salinity is considered the major factor determining shrimp population, inducing an emigration of adult prawns, and influencing postlarval recruitment (Garcia & Le Reste, 1981). For penaeid shrimp, Pensri & Suchat (1996) found that *P. merguiensis* and *Parapenaeopsis* spp. are euryhaline species, capable of tolerating a broad salinity gradient ranging from 2.3–33.4 psu. In contrast, lesser *Metapenaeus* spp. and *Metapenaeopsis* spp. individuals were found in lower salinity area. Results from CCA demonstrated that water parameters associated with shrimp assemblages in this study. Temperature seems to be the most influential factor for the assemblages of shrimps in this study as strongly explained by axis 1. Despite the small range in temperature change with season (Table 2), the influence of temperature on the shrimp assemblage may be evident in Pattani Bay. However, a contribution of pH, dissolved oxygen, and salinity was relatively lower compared to that of temperature.

Habitat, different bottom characteristics and vegetation, is also an important factor in structuring shrimp assemblages in the bay. Result from this study confirmed that it significantly affects the density of shrimps, although not on species richness. Higher number of shrimps is found in more vegetated-habitats such as seagrass and mangroves than those in bare habitats such as sandy-substrata habitat. Moreover, it is also found that shrimps in Pattani Bay prefer muddy (with high silt content) than sandy bottom for settlement and refuge. It is also observed that some species prefer over different habitats. *Macrobrachium lanchesteri, M. brevicornis*, and *M. dobsoni* are more mangrove oriented species. *Metapenaeus affinis*, *P. semisulcatus*, *Heterocarpus* sp., and *P. monodon* prefer seagrass habitat. *Alpheaus* sp. and *P. semisulcatus* show preference over shell-deposited habitat. Several studies reported that juvenile penaeid species prefer structurally complex micro-habitats as shelter from predation (Primavera & Lebata, 1995; Primavera, 1997; Macia et al., 2003; Crona & Ronnback, 2005) and the present study further support these findings. Johnston & Sheaves (2007) reported a similar pattern of habitat preference by small fish and prawn in the tropical north-eastern coast of Australia. They reported that the composition of the small fish and prawn assemblage was clearly different between sand and mud substrata. Mud substrata consistently had many taxa present in relatively high abundance. Somers (1994) also recorded that sediment and depth were important factors influencing the spatial distribution of prawns in the Gulf of Carpentaria, Northern Australia.

In summary, the present study has clarified the impacts of habitat and season on the abundance, species richness, and community structure of shrimps in Pattani Bay and related with water quality parameters. As the bay harbors many economically important shrimp species harvested by traditional fishermen together with some threats from the development projects around the bay, this finding will help managers to draw a management practice for sustainable fisheries and imbalance utilisation of resources in this area.

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LITERATURE CITED

Angsunee C & Julaporn R (2001) Status of Fisheries in Songkla Lake. Institute of Coastal Aquaculture, Department of Fisheries, Songkhla. 17 pp.

Arshad A, Ara R, Amin SMN, Effendi N, Zaidi CC & AG Mazlan (2011) Influence of environmental parameters on shrimp post-larvae in the Sungai Pulai seagrass beds of Johor Strait, Peninsular Malaysia. Scientific Research and Essays, 6: 5501–5506.

Bell JD & Pollard DA (1989) Ecology of fish assemblages and fisheries associated with seagrass. In: Larkum AWD, McComb AJ & Shepherd SA (eds.) Biology of Seagrasses: A Treatise on the Biology of Seagrasses with Special Reference to the Australian Region. Elsevier, Amsterdam. Pp. 565–597.

Chong VC, Sasekumar A, Leh MUC & D'Cruz R (1990) The fish and prawn communities of a Malaysian coastal mangrove system, with comparisons to adjacent mud flats and inshore waters. Estuarine, Coastal and Shelf Science, 31: 703–722.

Chong VC, Low CB & Ichikawa T (2001) Contribution of mangrove detritus to juvenile prawn nutrition: a dual stable isotope study in a Malaysian mangrove forest. Marine Biology, 138: 77–86.

Chong VC, Sasekumar A & Wolanski (1996) The role of mangroves in retaining penaeid prawn larvae in Klang Strait, Malaysia. Mangrove and Salt Marsh, 1: 11–22.

Chou LM (1996) Importance of Southeast Asian marine ecosystem in biodiversity maintenance. In: Turner IM, Diong CH, Lim SSL & Ng PKL (eds.) Biodiversity and the Dynamics of Ecosystem; Diversitas in Western Pacific and Asia Series 1. Pp. 227–235.

Clarke KR & Gorley RN (2001) Primer v5: User Manual/Tutorial PRIMER-E, Plymouth.

Crona BI & Ronnback P (2005) Use of replanted mangroves as nursery grounds by shrimp communities in Gazi Bay, Kenya. Estuarine, Coastal and Shelf Science, 65: 535–544.

Dall W, Hill BJ, Rothlisberg PC & Staples DJ (1990) The Biology of the Penaeidae. Advances in Marine Biology. Academic Press, London, 489 pp.

de Freitas AJ (1986) Selection of nursery areas by six Southeast African Penaeidae. Estuarine, Coastal and Shelf Science, 23: 901–908.

Garcia S & Le Reste L (1981) Life Cycles Dynamics, Exploitation and Management of Coastal Penaeid Shrimp Stocks. Food and Agriculture Organization of the United Nations. Rome, Italy, 215 pp.

Hajisamae S, Ruangchuay R & Kwanthong N (2013) Can wave breaking walls in shallow coastal areas serve as habitat for aquatic organisms? Journal of Coastal Research, 29: 339–346.

Hajisamae S, Yeesin P, Ibrahim S & Sirimontaporn P (1999) Abundance and diversity of juvenile fishes in Saiburi estuary, Pattani. Songklanakarin Journal of Science and Technology, 21: 265–276.

Hajisamae S, Yeesin P & Chayamongkol S (2006) Habitat utilization by fishes in a shallow, semi-enclosed estuarine bay in the southern Gulf of Thailand. Estuarine, Coastal and Shelf Science, 68: 647–655.

Harris SA, Cyrus D & Beckley LE (2001) Horizontal trends in larval fish diversity and abundance along an ocean-estuarine gradient on the northern KwaZulu-Natal coast, South Africa. Estuarine, Coastal and Shelf Science, 53: 221–235.

Haywood MDE, Vance DJ & Loneragan NR (1995) Seagrass and algal beds as nursery habitat for tiger prawns (*Penaeus semisulcatus* and *P. esculentus*) in a tropical Australian estuary. Marine Biology, 122: 213–223.

Heck KL & Crowder LB (1991) Habitat structure and predator-prey interactions in vegetated aquatic systems. In: Bell SS, McCoy ED & Mushinsky HR (eds.) Habitat Structure: The Physical Arrangement of Objects in Space. Chapman and Hall, New York. Pp. 281–299.

Johnston R & Sheaves M (2007) Small fish and crustaceans demonstrate a preference for particular small-scale habitats when mangrove forests are not accessible. Journal of Experimental Marine Biology and Ecology, 353: 164–179

Kenyon RA, Loneragan NR & Hughes JM (1995) Habitat type and light affect sheltering behaviour of juvenile tiger prawns (*Penaeus esculentus* Haswell) and success rates of their fish predators. Journal of Experimental Marine Biology and Ecology, 192: 87–105.

Kenyon RA, Loneragan NR, Hughes JM & Staples DJ (1997). Habitat type influences the microhabitat preference of juvenile tiger prawns (*Penaeus esculentus* Hasswell and *Penaeus semisulcatus* De Haan). Estuarine, Coastal and Shelf Science, 45: 393–403.

Loneragan NR, Kenyon RA, Haywood MDE & Staples DJ (1994) Population dynamics of juvenile tiger prawns (*Penaeus esculentus* and *P. semisulcatus*) in seagrass habitats of the western Gulf of Carpentaria, Australia. Marine Biology, 119: 133–143.

Macia A, Abrantes KGS & Paula J (2003) Thorn fish *Terapon jarbua* (Forskal) predation on juvenile white shrimp *Penaeus indicus* (H. Milne Edwards) and brown shrimp *Metapenaeus monoceros* (Fabricius): the effect of turbidity, prey density, substrate type and pneumatophore density. Journal of Experimental Marine Biology and Ecology, 291: 29–56.

Mala S (1979). Shrimp fisheries in Gulf of Thailand. Thai Fisheries Gazzette, 32: 137–143.

Pensri B & Suchat S (1996) Ecology of Penaeid Shrimps in Mangrove Forest and the Vicinity of Phangnga Bay. Department of Fisheries, Bangkok. Pp. 320–332.

Peterson AW & Whitfield AK (2000) Do shallow water habitats function as refugia for juvenile fishes? Estuarine, Coastal and Shelf Science, 51: 359–364.

Prajuab S (1965) Juvenile Shrimps in Songkla Lake and the Vicinity. Annual Report. Department of Fisheries, Thailand, 60 pp.

Primavera JH (1997) Fish predation on mangrove-associated penaeids: the role of structures and substrate. Journal of Experimental Marine Biology and Ecology, 215: 205–216.

Primavera JH (1998) Mangroves as nurseries: shrimp populations in mangrove and non-mangrove habitats. Estuarine, Coastal and Shelf Science, 46: 457–464.

Primavera JH & Lebata J (1995) Diel activity patterns in *Metapenaeus* and *Penaeus* juveniles. Hydrobiologia, 295: 295–302.

Robertson AI & Blaber SJM (1992) Plankton, epibenthos and fish communities. In: Robertson AI & Alongi DM (eds.) Tropical Mangrove Ecosystems. American Geophysical Union, Washington, USA. Pp. 173–224.

Robertson AI & Duke NC (1987) Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. Marine Biology, 96: 193–205.

Ronnback P, Troell M, Kautsky N & Primavera JH (1999) Distribution pattern of shrimps and fish among *Avicennia* and *Rhizophora* microhabitats in the Pagbilao mangroves, Philippines. Estuarine, Coastal and Shelf Science, 48: 223–234.

Sasekumar A, Chong VC, Leh MU & D'Cruz RD (1992) Mangroves as a habitat for fish and prawns. Hydrobiologia, 247: 195–207.

Schaffmeister BE, Hiddink JG & Wolff WJ (2006) Habitat use of shrimps in the intertidal and shallow subtidal seagrass beds of the tropical Banc d'Arguin, Mauritania. Journal of Sea Research, 55: 230–243

Sheridan PF (1992) Comparative habitat utilization by estuarine macrofauna within the mangrove ecosystem of Rookery Bay, Florida. Bulletin of Marine Science, 50: 21–39.

Somers IF (1994) Species composition and distribution of commercial penaeid prawn catches in the Gulf of Carpentaria, Australia, in relation to depth and sediment type. Australian Journal of Marine and Fresh Water Research, 45: 317–335.

Songsangjinda P, Limsuwan C, Pornpinidvorakul P, Keawtawee T, Muangyao P & Klaysri S (2005) Sediment quality and production data of black tiger shrimp (*Penaeus monodon*) culture under Code of Conduct for Responsible Shrimp Aquaculture (CoC) system and ordinary system of intensive shrimp farms. Songklanakarin Journal of Science and Technology, 27 (Supplement 1): 17–24.

Staples DJ & Vance DJ (1985). Short-term and long-term influences on the immigration of postlarval banana prawns *Penaeus merguiensis*, into a mangrove estuary of the Gulf of Carpentaria, Australia. Marine Ecology Progress Series, 23: 15–29.

Staples DJ & DJ Vance (1987) Comparative recruitment of the banana prawn, *Penaeus merguiensis*, in five estuaries of the south-eastern Gulf of Carpentaria, Australia. Australian Journal of Marine and Fresh Water Research, 38: 29–45.

Thanate S, Julapron R & Aranya A (2003) Species, Diversity and Production of Aquatic Animals in Pak Phanang Bay. Institute of Coastal Aquaculture, Department of Fisheries, Songkhla, 22 pp.

Vance DJ, Haywood MDE, Heales DS, Kenyon RA, Loneragan NR & Pendrey RC (1996) How far do prawns and fish move into mangroves? Distribution of juvenile banana prawns *Penaeus merguiensis* and fish in a tropical mangrove forest in northern Australia. Marine Ecology Progress Series, 131: 115–124.

Zafar M & Mahmood N (1989) Studies on the distribution of zooplankton communities in the Satkhira Estuarine System. Chittagong University Study. Part II: Science, 13: 115–122.