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Spatial and Temporal Variability of Intertidal Rocky Shore Bivalves and Gastropods in Sichang Island, East Coast of Thailand

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Abstract Spatial and temporal variability of intertidal rocky shore bivalves and gastropods in Sichang Island, east coast of Thailand were studied over 12 months (March 2008 to February 2009). The study area experiences mixed tides with the largest tidal range of 3.6 m above MTL during spring tides. Shores are exposed to the prevailing northeast monsoon in the winter (November to February), resulting in stronger wave action during this season than in summer (March to May) and rainy season (June to October). Transects were positioned at five different heights from mid shore to high shore (2.5 to 3.5m above MTL) dominated by rock oysters in the mid shore. At each height, abundance of bivalves and gastropods were recorded within fifteen replicate quadrats (25 x 25 cm) on a monthly basis. A total of 2 bivalves and 10 species of gastropods were identified. In the high shore, the littorinid *Echinolittorina malaccana* dominated. Dense beds of the bivalve *Isognomon nucleus* were abundant in crevices at 2.5 and 2.75 m above MTL, whilst a large number of snails (*Planaxis sulcatus*) were found near the midshore. Below this, the rock oyster *Saccostrea cucculata* was dominant, with a variety of mobile gastropods (*Cellana grata, C. toreuma, Patelloidea saccharina* and *Siphonaria japonica*). The general sequence of zonation patterns were clear over time, but the vertical extent of some mobile species varied in accordance with the monsoon effect and increasing tidal range in winter, especially on the more exposed of the two sites. The high shore littorinids, *E. malaccana* moved up shore and were more abundant near the supralittoral line in winter suggesting that the seasonal monsoon effect and tidal range were important factors determining the distribution of some species of mobile gastropods, allowing them to exploit higher tidal levels.

Key words: Spatial and temporal variability, bivalves, gastropods, intertidal rocky shore, Sichang Island

INTRODUCTION

Intertidal rocky shores are heterogeneous environment supporting variable assemblage of sessile and mobile organisms which can be found in shoreline throughout the world. In the environment these organisms are distributed in a particular way, occurring with the strong vertical pattern- zonation- which is strongly influences by the vertical gradient caused by tide and also the horizonal gradient cause by wave action (Little et al, 2009). The pattern, however, are known to vary in some part of the world but have been suggested to be very stable in tropics (Menge and Lubchenco, 1981; Lubchenco et al. 1984; Menge et al. 1985, 1986; Williams, 1994).

Although the spatial and temporal distributions of intertidal organisms have been well documents in many parts of the world (i.e. Chelazzi and Vannini, 1980; Underwood, 1981; Williams et al., 2000; Kelaher et al., 2001; Benenetti-Cecchi et al., 2003; Schiel, 2004; Araujo et al., 2005; Underwood et al., 2008), there are very few studies on such work in Southeast Asia where the changes in the monsoon are strong. Thailand has experienced 2 monsoon, southwest monsoon in rainy season (June to

October) and norteast monsoon in winter season (November to February). During northeast monsoon strong wind generated from high pressure air mass blows down from mainland China to Indo-China Penninsular resulting strong wave action along the east coast of Thailand. This is a descriptive paper of spatial and temporal pattern of bivalve and gastropods, the dominant organisms from an understudied intertidal rocky shore, Sichang Island, east coast of Thailand. The aim of the present study was to determine whether seasonal variation in distribution of these oragnisms as has been shown in other tropical area where changes of wave action in the monsoons are strong.

MATERIALS AND METHODS

Study area

The study was carried out between March 2008 to February 2009 on two sites of different degree of exposed rocky shore (more sheltered: A and and shelter :B) in Sichang Island (13º08'.52''N; 100º48'.11''E) which is located in the inner Gulf of Thailand, 12 km offshore Chonburi province (Fig. 1). The rocky shore is typically karst. The coast experiences mixed tides with the largest tidal range of 3.6 m above mean tidal level (MTL) during spring tides (in daytime with the exception from September to February when spring tide start in night time). Shores are exposed to the prevailing northeast monsoon in the winter (November to February), resulting in stronger wave action during this season than in summer (March to May). June to October is the rainy season with a mean annual rainfall of 1,448.8 mm. Average temperature varied between season with the average temperature of 30.9℃, 28.5℃ and 23.0℃ in summer, rainy and winter, respectively.

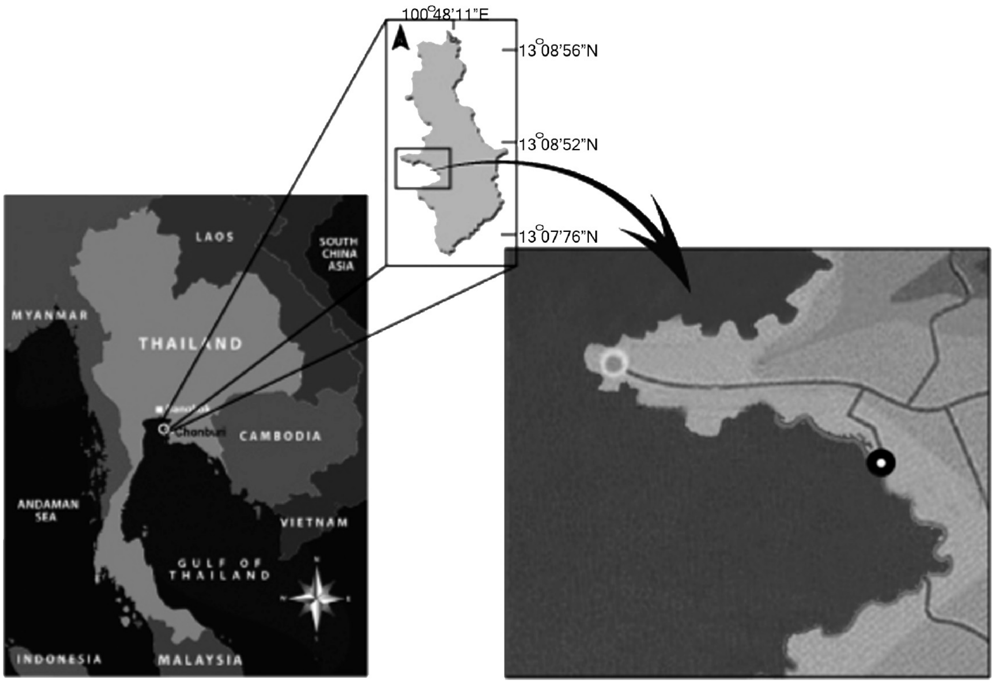

Fig. 1. Srichang Island and sampling site. Solid circle: sampling site

Sampling

At each site 15m transects were positioned at five different heights from mid shore to high shore (2.5 to 3.5m above MTL). In each month, 15 replicate quadrats (25 x 25 cm) were placed randomly at each height. All gastropods were counted whilst photographs of each quadrat were taken with a digital camera (Canon G9-3.0 mega pixels with autofocus). In the laboratory, the abundance of bivalves was assessed using Image J®. Specimens which could not be identified in the field were collected and identified in the Invertebrate laboratory, Division of Animal Production Technology and Fisheries, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang.

Data analysis

Sample similarity was calculated with the Bray-Curtis coefficient, after log (x+1) data transformation. Non-metric multidimentional scaling (nMDS) was used to produce two-dimensional ordination plots using PRIMER v5 software (Clarke and Gorley, 2001). Spatial and temporal distribution of specific taxa of bivalves and gastropods were analysed using 3-factors ANOVA (tidal level: L; sampling site: S and season:Se) Homogeneity of variance was assessed using Cochran's test. LSD test were used for multiple comparisons of the mean (at $\alpha = 0.05$).

RESULTS

A total of 2 species of bivalves and 10 species of gastropods were recorded from Sichang Island (Table 1). The small bivalve, Isognomon nucleus, accounted for more than 80% of all bivalves sampled. Among the gastropods the most abundant species were grazers i.e. the high shore littorinids (*Echinolittorina malaccana* and *E. radiata*), coiled gastropods (*Planaxis sulcatus*) and the small tiny periwinkle (*Peasiella roepstorffiana*). Limpets (*Cellana grata, C. toreuma, Patelloidea saccharina*) and false limpets (*Siphonaria japonica* and *S. lacineosa*) were also found, but in lower numbers (Fig. 2a and 2b).

Clear vertical differences in species distributions could be distinguished between tidal levels for both two sites (Fig. 3a and 3b) which could be categorized into 3 vertical groups: (1) 2.5 m to 2.75 m above MTL (2) 3.0 m to 3.25 m above MTL and (3) 3.5m above MTL. The first group (mid shore,

Table 1. Species list of Sichang Island intertidal rocky shore bivalves and gastropod

Phylum	Class	Family	Species
Mollusca	Bivalvia	Isognomonidae	*Isognomon nucleus*
		Ostreidae	*Saccostrea cucullata*
	Gastropoda	Lottiidae	*Patelloida saccharina*
		Siphonariidae	*Siphonaria japonica*
			S. lacineosa
		Patellidae	*Cellana grata*
			C. toreuma
		Planaxidae	*Planaxis sulcatus*
		Littorinidae	*Echinolittorina malaccana*
			E. radiata
			Peasiella roepstorffiana
		Muricidae	*Thais clavigera*

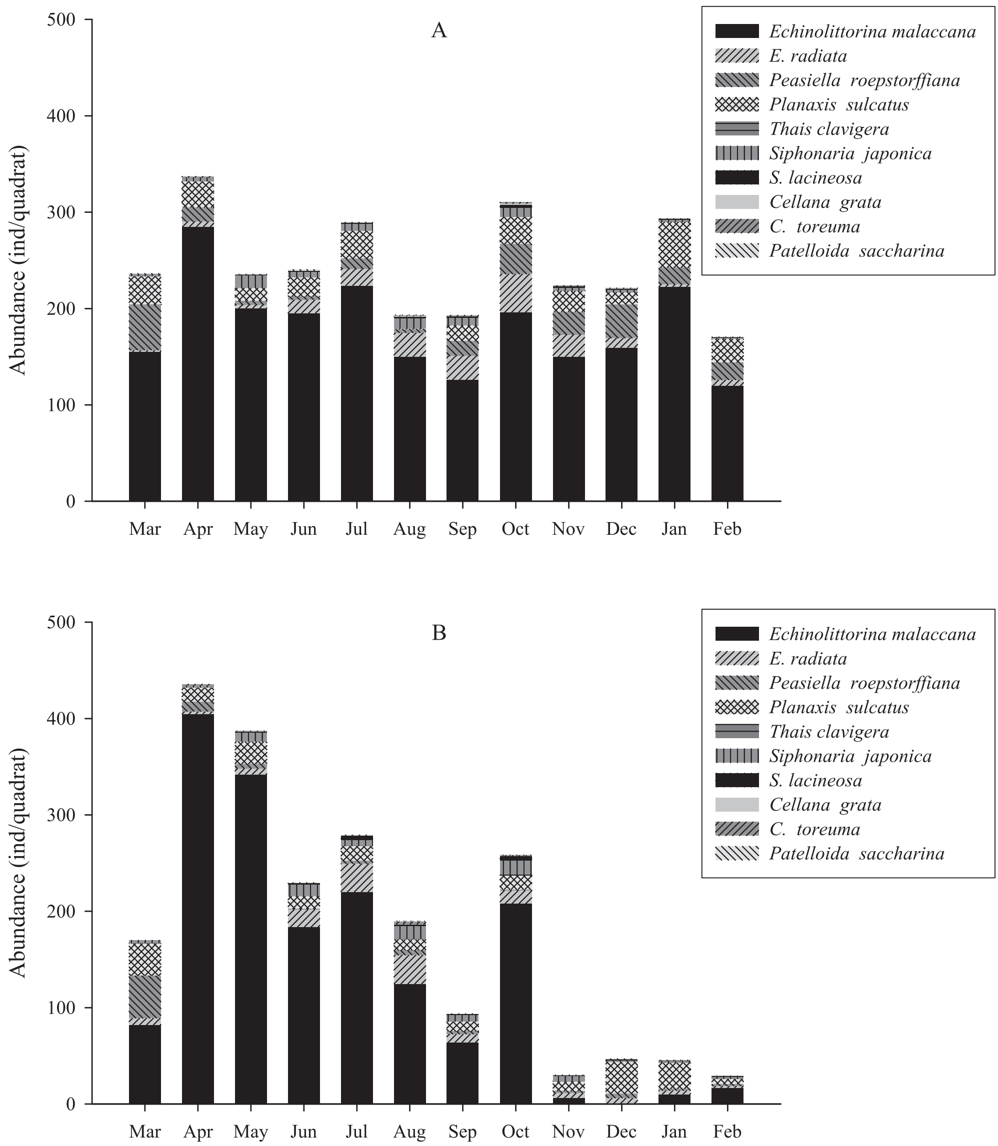

Fig 2A. Abundance (ind/quadrat) of gastropod at site A and B.

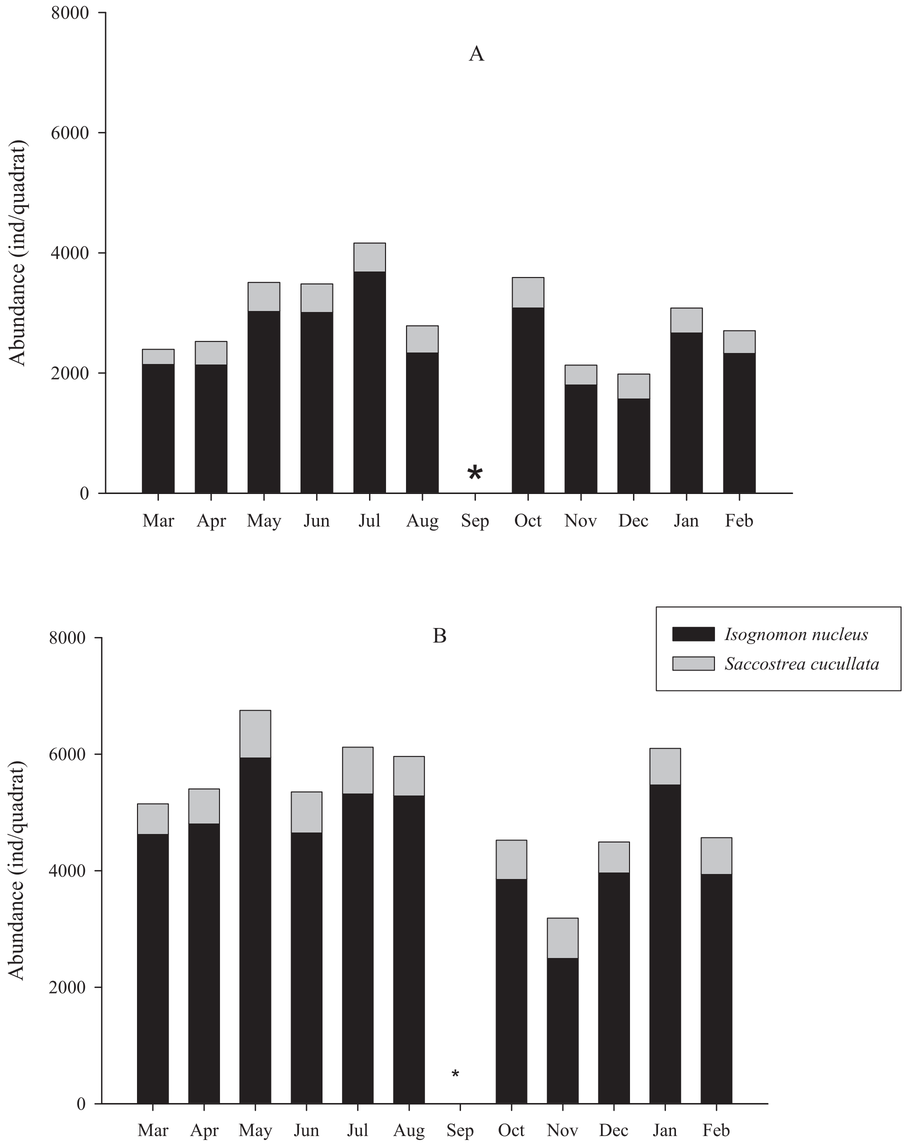

Fig 2B. Abundance (ind/quadrat) of bivalve at site A and B. Asterisks indicate no data

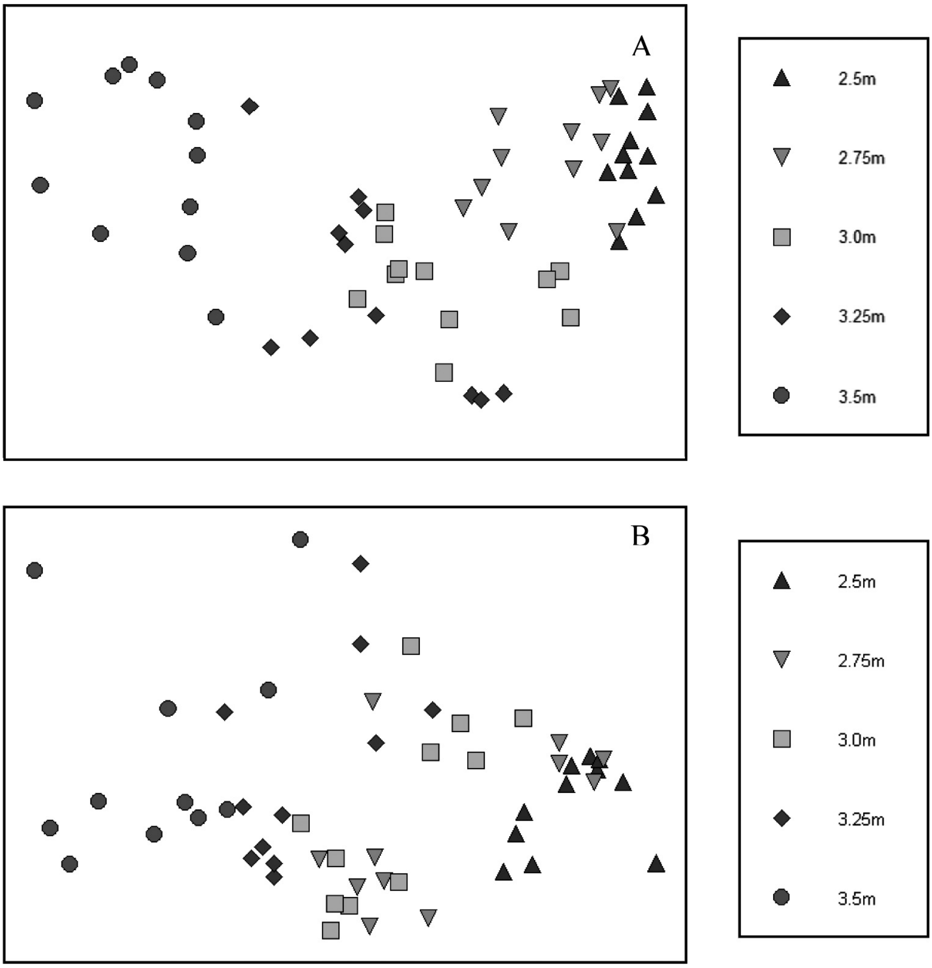

Fig. 3. Two-dimentional nMDS camparing zonation among tidal level for site A and B. Each point refer to all replicates and each symbol to a different tidal level.

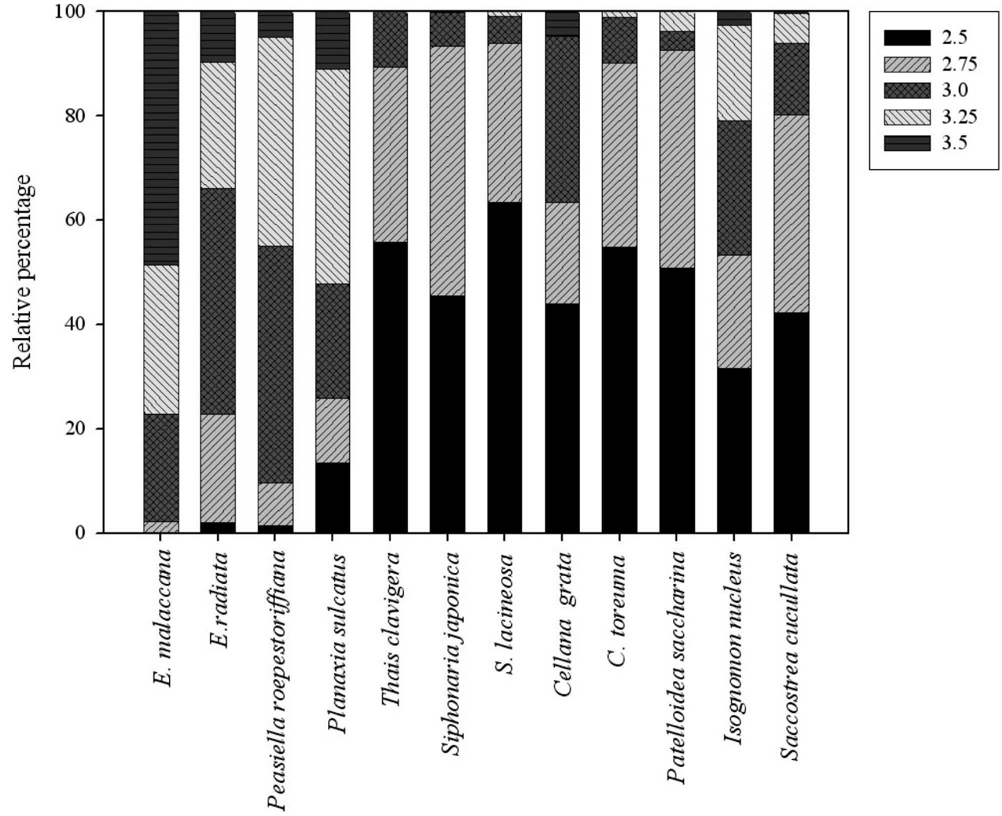

Fig. 4. Relative precentage of gastropod and bivalve categorized by each tidal level

2.5-2.75 above MTL) was characterized by limpets and false limpets (*Cellana grata, C. toreuma, P. saccharina, S. japonica* and *S. lacineosa*). More than 60% of the littorinids (*E. radiata*) coiled gastropods (*P. sulcatus*) and tiny periwinkle (*P. roepstorffiana*) were distributed between 3.0 to 3.25 m above MTL. The most abundant bivalve in this study, *I. nucleus* and the rock oyster (*S. cucullata*) were widely distributed form mid to high shore but dense populations could be found between 2.5 m to 3.25 m above MTL. In the highest shore group 3, the littorinid *E. malaccana* dominated with ~ 45% of their total abundance being found at 3.5 m above MTL (Fig. 4).

To determine effect of season to spatial and temporal variability, data of high abundance bivalves and gastropod (*S. cucullata, I. nucleus, P. sulcatus, E.mallacana*) were analyzed whereas data of all limpest were pooled together. Rock oyster, *S. cucullata* and *I. nucleus* were more abundant at sheltered shore (site B) than more sheltered shore (site A). For both 2 sites, high abundance of the rock oyster was found at lower mid shore (2.5 m to 2.75 m) but this decreased moving upshore (Table 2; Fig. 5). Variability in spatial distribution in *I. nucleus* for both sites was also observed (Table 2). Dense beds of the bivalves were abundant in rock crevices from 2.5m to 3.25 m above MTL reaching densities of ~. 200-400 ind./25 x 25 cm (Table 2; Fig. 5). Statistically difference in abundance between seasons was observed only for *I. nucleus* with grater abundant in rainy season. The significant Level x Site interaction indicated that spatial changes in the abundance of these bivalves differed from site A to site B (Table 2). The coiled gastropod (*P. sulcatus*) showed significantly

Table 2. ANOVA on mean abundance of gastropod90

Source of variation	*df*	All limpets			*Planaxis sulcatus*			*Echinolittorina malaccana*			*Isognomon nucleus*			*Saccostrea cucullata*		
		MS	F	Sig.	MS	F	Sig.	MS	F	Sig.	MS	F	Sig.	MS	F	Sig.
Site (S)	1	0.248	1.395	0.242	0.322	1.196	0.27	0.715	1.000	0.321	16.842	123.596	0.000	13.018	44.021	0.000
Level (L)	4	12.914	72.773	0.000	3.951	14.645	0.000	36.391	50.898	0.000	8.228	60.383	0.000	35.525	120.128	0.000
Season (Se)	2	3.307	18.634	0.000	0.346	1.282	0.285	39.446	55.170	0.000	0.612	4.494	0.015	0.529	1.788	0.176
S × L	4	0.491	2.765	0.035	0.521	1.931	0.117	2.792	3.905	0.007	2.948	21.634	0.000	1.231	4.163	0.005
S × Se	2	0.200	1.126	0.331	0.134	0.498	0.610	4.409	6.166	0.004	0.041	0.297	0.744	0.131	0.443	0.644
L × Se	8	0.720	4.060	0.001	2.652	9.831	0.000	3.714	5.195	0.000	0.032	0.235	0.983	0.069	0.233	0.996

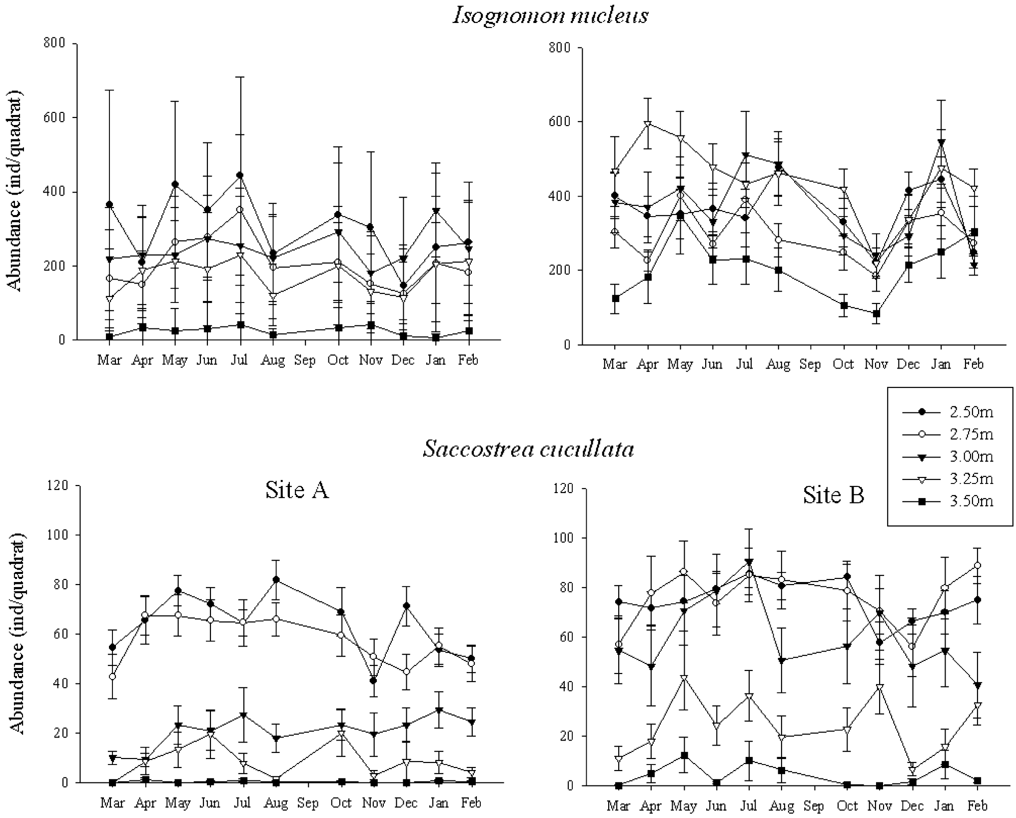

Fig 5. Mean abundance (± S.E.) of bivalves at different tidal levels.

different only between tidal levels, with their distribution confined between 3.0 to 3.25 m above MTL (Table 2; Fig. 6). No seasonal variation and any interaction within factors were observed. For group 3 (3.5 m above MTL), abundance of the littorinid, *E. malaccana* varied between tidal level, being most abundant at high shore (Table 2) and their distribution between sites varied in relation to tidal level (SxL interaction). There was, however, a strong temporal change in abundance of the littorinid, being ~ 2 times more abundant in winter (December to February) than in the rainy season (Table 2; Fig. 6). From December to February, the littorinid was distributed only at 3.5 m above MTL. Abundance of limpets showed significant differences with tidal level and season (Table 2; Fig. 6), mainly distributed between 2.5 m to 2.75 m above MTL. Abundances of limpets progressively decreasing in winter (November to February). Subsequently, the abundance of limpets increased again until September to October.

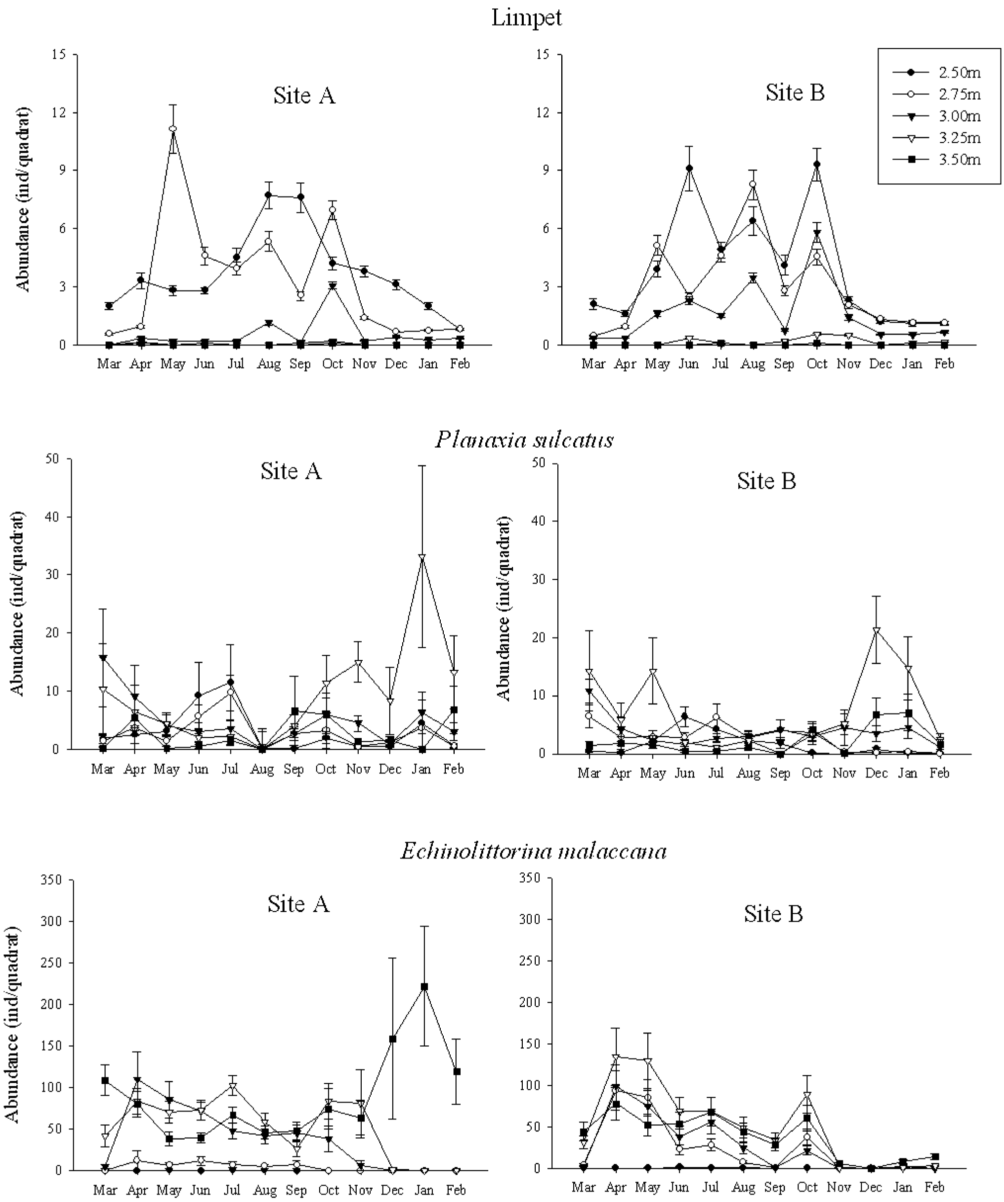

Fig 6. Mean abundance (± S.E.) of dominant gastropods at different tidal levels.

DISCUSSION

No previous study has provided detailed description of spatial and temporal patterns of sessile and mobile organisms on rocky shore in the east coast of Thailand. Few studies have been done on intertidal rocky shore macrobenthos survey. Ganmanee et al. (in press) reported 50 species of macrobenthos (15 of these were molluscs) on intertidal rocky shore at Chumporn province, southern of Thailand and also found that the vertical zonation of rocky shore macrobenthos was considerable to tidal level. The 12 species of bivalves and gastropod obtained in the present study were lower that those reported in other tropical rocky shore in Asia i.e. 29 species in Hong Kong (Williams, 2003). It is noted that all taxa of bivalve and gastropod in Sichang rocky shore are common, with the same as Hong Kong rocky shore. However, number of speices of bivalve and gastropod in Thailand rocky shore were greater compared with intertidal rocky shore in temperate zone in Asia i.e 9 species in Hokkaido, Japan (Fuji and Nomura, 1990).

Results in the present study clearly showed vertical pattern -zonation- of bivalve and gastropod of Thailand intertidal rocky shore. The bivalves, *Sacosstrea cucullata* and *Isognomon nucleus* could distribute from lower mid shore to high shore but for *S. cucullata* the major inhibited at lower mid shore (2.5-3.0 m above MTL). It was differed compared with *I. nucleus* which their dense bed could be found wider from lower mid shore (2.5 m above MTL) to mid shore (3.25 m above MTL), with extremely abundance in the rock crevice. At the lower mid shore (2.5 to 2.75 m above MTL), limpets are common and dominant gastropod in this zone. The important role of limpets as grazer and generate structuring force in intertidal algal communities (Underwood, 1980; review in Branch, 1981; Jernakoff, 1983; Della Santina et al., 1993; Williams, 1993). Moreover, limpets were found to be responsible for setting some algae species' upper limits of distribution (Underwood and Jernakoff, 1981, 1984; Boaventura et al., 2002). The reasons for the abrupt decline of the limpet at the high shore are not obvious. However, the zonation of foliose algae which is the food sources may be reponsible for distribution of limpets, apart form any physical factors (i.e. thermal stress during daytime tide, wave action). Further study on spatial and temporal distribution on the algal community at Sichang intertidal rocky shore should be carried out in order to clarify the assumption. At the mid shore (3.0 to 3.25 m above MTL) is the important habitat for many gastropods i.e. coiled gastropods (*Planaxis sulcatus*), small tiny periwinkle (*Peasiella roepstorffiana*) and littorinid (*Echinolittorina radiata*). As suggested by Underwood (1981), the presence of predatory whelk (*Thais clavigera*) in low abundance level at mid shore in the study area may involve abundance of these gastropods in this zone. At the high shore (3.5 m above MTL), as is commonly found on intertidal rocky shore in other part of the world, the numericaly dominant gastropod were high shore littorinid (McQuaid, 1996). Very few gastropods could inhabit in such extremely stressful high shore. This indicated that a littorinid, *E. mallacana* has a higher level of tolerance than other oraganism in intertidal rocky shore habitat.

Differences in abundances of bivalves (*S. cucullata* and *I. nucleus*) between site (more sheltered; A and sheltered; B) may reflect the effect of either exposed and submerge time or habitat selection. The bivalves had greater abundances in the sheltered shore (B) than more sheltered shore (A). The more sheltered had the long exposure time whilst bivalve need the long submerge time for their feeding. As a result, survival of the bivalves should be higher in site B. Another explanation is site B would experience higher degree of wave exposure. Subsequently, the high degree of wave exposure may generate rock crevice which is suitable for the habitat of the bivalves.

In the present study, some speices dominant bivalve (*I. nucleus*) and gastropod (*E. mallaccana*) showed statistically difference between seasons. The reason for the seasonal variability for sessile species (*I. nucleus*) is unclear. More study in several aspects on population dynamic of the bivalve (i.e. gemetogenic cycle, recruitment pattern) in relation to physical factors is needed. As for mobile gastropod, *E. malaccana*, the seasonal variability in abundance may correlate with some physical factors. Strong wave action in winter as well as extremely high water sping tide (EHWS) in the east coast of Thailand may generate wider area of splash zone which could support space and food for the littorinid to move up near the supralittoral line.

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