Species Diversity and Ecological Characteristics of Benthic Macroinvertebrates in the Intertidal Zone of Satun Province, Thailand and the First Record of *Petersenaspis* sp.

Khwanta Tantikamton, Nathawut Thanee, Suwit Jitpukdee, and Murray Potter

***Abstract*—**The aims of this research were to investigate diversity of benthic macroinvertebrates and their ecological characteristics in intertidal zone of Pak Bara and Pak Bang beaches,Thailand during 2012-2013. Sediment and water samples were collected and measured seasonally from nine stations. In comparison, both beaches were mostly similar in water and sediment qualities excepting organic matter content and sediment particle sizes. All beaches had moderate species diversity. The major components of benthic macroinvertebrates were polychaetes, molluscs and crustaceans. Principal component analysis showed that water temperature, sediment particle sizes, and nitrate in sediment were important factors to biodiversity index, whereas water temperature, dissolved oxygen, salinity and nitrate in sediment were related to biodiversity of polychaete. The results of benthic macroinvertebrate composition showed that *Dendronereis arborifera* and *Dotilla intermedia* distinguished the two beaches. *Sternaspis andamanensis* had wider habitats, while *Petersenaspis* sp. was found only in Pak Bara beach and it was the first record in Thailand.

***Keywords*—**Diversity, benthic macroinvertebrate, intertidal zone, *Sternaspis andamanensis*, *Petersenaspis* sp.

I. Introduction

SATUN province is located at the Andaman Sea Coast of Thailand. Most of the area is mountainous with plain lands in the centre near the coast. Brooks lie in the east of Satun and mangroves can be found along the coast. Pak Bara and Pak Bang beaches are quite shallow and are located near the mouth region of the estuary, which brings organic materials from the upper reaches and then deposits in the estuary. Moreover, the intertidal zone of these beaches is affected by many anthropogenic activities such as shrimp farms, tourism and transportation from a pier nearby the beach.

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Benthic macroinvertebrate plays a key role in the cycling of organic materials in the aquatic ecosystems and used as potential bioindicators. The study on the ecological characteristics of benthic macroinvertebrates concerns their certain habitat types and the environmental variables which are used to determine the basis for patterns of them and to evaluate the beach environments by the presence or absence of these invertebrates to a greater extent [1]. The polychaete family (Sternaspidae), typically found in mud or sandy mud, are thought to be subsurface deposit feeders [2, 3]. In Thailand, only the genus *Sternaspis* (*S. scutata* and *Sternaspis* sp.) belonging to this family was recorded [4-6]. Therefore, the objectives of this study were to determine species diversity and some ecological characteristics of benthic macroinvertebrates in beach intertidal zone of Satun province, Thailand.

II. Materials and Methods

A. Sampling Areas

The study was conducted on 2 beaches along the sea coast of Satun province including Pak Bara and Pak Bang beaches.

Pak Bara beach is about 3 km long where the Pak Bara pier is located on the northern side of the beach. It has a long sandy/muddy intertidal flat but the landward side is sandy. Pak Bang beach is about 6 km long. It has long, moderate and sandy slope below, which is a long muddy flat and is never drained completely even during lowest tides. On the southern side, the beach is scattered with rocky patches. Sediment, water and the benthic macroinvertebrate samples were collected from 3 stations at Pak Bara beach and from 6 stations at Pak Bang beach. The sampling areas are shown in Fig. 1.

B. Sampling Methods

The sediment was sampled during Northeast monsoon (December 2012), in the dry season (April 2013) and during Southwest monsoon (August 2013). Quadrate sampling was done at intertidal zone during low tide. The sampling areas in each quadrate transect were 2.25 m^2. Samples were collected along the beach every 500 m long with three transects in each station. Sampling positions were estimated by global positioning system (GPS). Each sample was sieved in the field using a 1000 μm mesh. The materials retained on the sieve were fixed in 4% buffer formalin and then preserved in 70%

ethanol. The samples were brought back to a laboratory for sorting and taxonomic identification.

The benthic macroinvertebrates were sampled and identified under an Olympus SZX7 microscope with DP camera and the Cellsens Dimension program to magnify the detail of the specimens based on the keys to marine invertebrates and previous identification reports [7-12].

C. Sediment Analysis

Surface sediment was collected for sediment grain size and organic content analysis. Sediment grain size structure was determined by dry sieving, using vibrating-sieving machine and a sieve series of 0.5 phi resolution. Before sieving, each sample was washed with deionized water over a filter paper (20 µm mesh size) to remove salt and then oven-dried at 80^{o}C for 24 h. The percentage weight of gravel, sand and mud were calculated for each sediment sample. The statistical parameters of the grain size distribution were calculated in each size and the sediment particles size fractions were determined following a standard mechanic sieving procedure and classified according to Wentworth scale. The classified particle sizes were: gravel ($\varnothing$ > 2 mm), very coarse sand (2 mm > $\varnothing$ > 1 mm), coarse sand (1 mm > $\varnothing$ > 0.5 mm), medium sand (0.5 mm > $\varnothing$ > 0.25 mm), fine sand (0.25 mm > $\varnothing$ > 0.125 mm), very fine sand (0.125 mm > $\varnothing$ > 0.062 mm) and silt ($\varnothing$ < 0.062 mm) [13, 14].

Sediment for the analysis of organic content was collected at a depth of 15 cm and stocked with ice during fieldwork, and then frozen at -20^{o}C in the laboratory. The percentage of organic content in sediment was estimated by loss on ignition (500^{o}C for 24 h) [15].

D. Water Analysis

Water quality parameters including dissolved oxygen, salinity, temperature and pH were recorded *in situ* by using multi-probe instrument. Turbidity, biochemical oxygen demand (BOD) and nutrients (phosphate and nitrate) in water were analyzed in a laboratory [16].

E. Data Analysis

Benthic macroinvertebrate structures were analyzed using the calculation diversity indices including Shannon-Wiener index, evenness index, Margalef richness index, and dominance species index. Principal Component Analysis (PCA) was performed by PASW statistics 18.

III. Results and Discussion

A. Benthic Macroinvertebrates

The benthic macroinvertebrate species diversity was determined by biodiversity indices from 9 selected stations. The result showed that station 1 at Pak Bara beach (ST-PR st1) had the highest species diversity and richness, whereas station 9 of Pak Bang beach (ST-BB st9) showed the lowest species diversity and richness (Table I). It could be due to the fact that Pak Bara beach station 1 is near the mouth region of the estuary, which is more exposed to the terrestrial anthropogenic activities than other stations. In case of station 9, it is situated close to open coastline site and therefore, the intertidal habitat was the least affected area from the shore (Fig. 1).

Samples from the two beaches in the three seasons during 2012 to 2013 yielded a total of 4,036 individuals of 64 species benthic macroinvertebrates.

These samples contained four phyla, including Annelida, Brachiopoda, Mollusca, and Arthropoda. All annelids found were belonging to the class Polychaeta and only a single species was found in the class Lingulata under the phylum Brachiopoda. Molluscs found were classified in the classes Bivalvia and Gastropoda. Malacostraca was only a class found under the phylum Arthropoda (Table II). The density of species recorded from both beaches was likely to be conformable. The abundance of polychaetes was the highest, comprising of 20 species in Pak Bara beach and 30 species in Pak Bang beach. The molluscs represented 17 species in Pak Bara beach and 11 species in Pak Bang beach. The crustacean abundance was lower than those of polychaetes and molluscs that documented 7 species in Pak Bara beach and 8 species in Pak Bang beach. The densities of the benthic macroinvertebrates are shown in Table II.

Although the species composition between Pak Bara and Pak Bang beach were not different distinctively, some species composition in both beaches typified the ecological characteristics. The species, *D. arborifera* was the most abundance in Pak Bang beach compared to other taxa recorded in the beach, whereas *D. intermedia* occurred at the highest density in Pak Bara beach. Abundance of *D. arborifera* distinguished Pak Bang beach from Pak Bara beach markedly. However, *D. arborifera* were abundant at the sites which were characterized by muddy substrata and high organic content [17, 18], whereas *D. intermedia* were associated with sandy substrata.

TABLE I
BIODIVERSITY INDICES OF BENTHIC MACROINVERTEBRATES FOUND IN PAK BARA AND PAK BANG BEACHES, SATUN PROVINCE

Station	Number of species	Shannon-Wiener index (H)	Evenness index (J)	Magalef index (R)	Dominance species index
ST-PR st1	49	2.70	0.69	7.85	0.12
ST-PR st2	29	2.28	0.68	5.02	0.14
ST-PR st3	26	2.12	0.65	4.06	0.19
ST-BB st4	29	2.29	0.68	4.52	0.15
ST-BB st5	33	2.22	0.64	5.21	0.15
ST-BB st6	29	2.21	0.66	4.52	0.16
ST-BB st7	29	2.09	0.62	4.42	0.18
ST-BB st8	30	2.17	0.64	4.65	0.17
ST-BB st9	18	1.70	0.59	2.94	0.26

ST-PR = Pak Bara beach, ST-BB = Pak Bang beach, st 1-9 = station 1-9

TABLE II
SPECIES AND DENSITIES OF BENTHIC MACROINVERTEBRATES FOUND IN PAK BARA AND PAK BANG BEACHES, SATUN PROVINCE

Phylum/ Class	Species	Density (individuals/m^2) Pak Bara	Pak Bang
Annelida			
Polychaeta	*Scoloplos* (*Scoloplos*) *tumidus*	80	17
	Scolepis (*Scolepis*) sp.	4	5
	Paraprionospio cf. *oceanensis*	0	18
	Paraprionospio sp.	0	33
	Prionospio (*Prionospio*) *steenstrupi*	7	13
	Magelona cf. cincta	8	10
	Mediomastus sp.	48	158
	Heteromastus filiformis	5	0
	Heteromastus sp.1	0	17
	Heteromastus sp.2	0	9
	Heteromastus sp.3	0	8
	Euclymene annandalei	5	3
	Ophelina sp.1	3	3
	Ophelina sp.2	0	34
	Asclerocheilus sp.	0	3
	Anaitides sp.2	3	4
	Phyllodoce sp.	5	8
	Lepidonotus sp.	0	3
	Sigambra pettiboneae	0	52
	Neanthes caudata	24	100
	Dendronereis arborifera	0	580
	Glycera alba	78	4
	Glycera natalensis	0	6
	Glycera sp.	0	8
	Goniadopsis incerta	25	1
	Linopherus canariensis	6	4
	Diopatra amboinensis	6	41
	Diopatra semperi	0	53
	Diopatra sp.	2	0
	Scoletoma sp.1	34	14
	Scoletoma sp.2	0	60
	Sternaspis andamanensis	4	2
	Peternaspis sp.	1	0
	Lanice conchilega	3	0
Brachiopoda			
Lingulata	*Lingula* sp.	17	0
Mollusca			
Bivalvia	*Anadora granosa*	1	0
	Tellina sp.1	17	23
	Tellina sp.2	34	71
	Donax incarnatus	36	72
	Donax faba	103	293
	Gari (*Psammotaea*) *elongata*	0	3
	Meretrix meretrix	2	0
	Timoclea scabra	4	3
	Pitar sp.	12	62
Gastropoda	*Umbonium vestiarium*	3	0
	Clithon oualaniensis	5	0
	Natica tigrina	15	1
	Natica vitellus	2	4
	Nassarius pullus	4	0
	Nassarius livescens	5	0
	Nassarius jacksonianus	3	0
	Nassarius stolatus	58	20
	Nassarius globosus	0	1
	Turricula javana	3	0
Arthropoda			
Malacostraca	*Diogenes klassi*	82	95
	Philyra olivacea	2	8
	Matuta victor	15	5
	Dotilla intermedia	178	26
	Dotilla myctiroides	2	0
	Ocypode macrocera	28	34
	Ocypode ceratopthalma	0	3
	Scopimera proxima	0	35
	Macrothalmus convexus	4	0
	Camptandrium sexdantatum	0	14

Donax faba (molluscs), *Diogenes klassi* (crustaceans) and *Mediomastus* sp. (polychaetes) were also represented high density in both beaches (Table II). These occurrences may partially determine that they are poorly being considered as indicator species to define the ecological characteristics because of their wider distribution ranges but they are appropriate enough to indicate environmental changes from pollution [19-21].

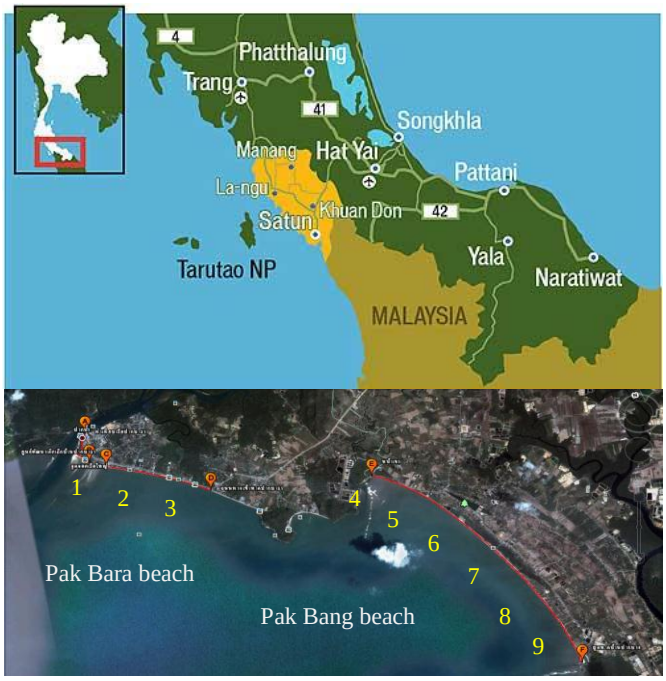

Fig. 1 Map of Satun province and sampling areas, 1-9= station1-9

B. Ecological characteristics of Pak Bara beach and Pak Bang beach, and their relations to benthic invertebrates

Pak Bara beach and Pak Bang beach most likely had acidic substrates where pH in both beaches was ranged from 5 to 6.8. In spite of the closer proximity to the adjacent estuary, nutrients of these beaches were low (Table III), and Pak Bara beach had relatively low content of organic matter. Having being an semicircle coast line and a low gradient beach slope, Pak Bang beach had higher organic matter (up to 13%), whereas Pak Bang beach had moderate slope and low organic matter content (<1%). Polychaete abundance was inversely correlated with the increase in organic enrichment (Fig. 2) [22].

The results from Principal Component Analysis showed that water temperature, and sediment particle sizes of 0.15 mm and 0.075 mm were the positive important factors to the biodiversity index, while nitrate in sediment and 0.3 mm sediment particle size were negatively related to the biodiversity index. According to this relation, the abundance of benthic macroinvertebrates decreased when the sediment became coarser. Moreover, water temperature, and dissolved oxygen in water and salinity were positively correlated to biodiversity of polychaete. Similarly to biodiversity index, nitrate in sediment was negatively related to polychaete abundance. The component analysis of water and sediment characteristics and biodiversity index is shown in Fig. 2.

Pak Bang beach was characterized by coarse sand with the highest percentage of particle sizes in the range of 0.3 to 0.71 mm. The sediment samples of this site were rather muddy and gravel, whereas Pak Bara beach had finer sand with particle size in the range of 0.15 to 0.25 mm (Table IV). However, both the Pak Bara and Pak Bang had exposed beaches where sand particle sizes can be changed by tide and wave actions [23]. Sediment texture has been acknowledged to be important in benthic macroinvetebrate. Sand particle sizes on an exposed beach will change the morphodynamic state towards the reflective condition, so this ecological character affects the abundance of the benthic fauna.

TABLE III
WATER AND SEDIMENT QUALITY IN PAK BARA AND PAK BANG BEACHES, SATUN PROVINCE

Parameters	Stations	
	Pak Bara beach	Pak Bang beach
Water		
pH	7.6±0.5	7.7±0.3
Dissolved oxygen (mg/L)	5.3±1.4	7.0±1.6
Temperature (°C)	28±1	28±1.5
Salinity (ppt)	30±2	31±2
Nitrate (mg/L)	0.03±0.01	0.03±0.01
Phosphate (mg/L)	0.02±0.01	0.05±0.01
Turbidity (NTU)	16±10	25±22
BOD (mg/L)	3±0.5	1.7±0.2
Sediment		
pH	6.2±0.6	5.3±0.3
Nitrate (mg/kg)	0.08±0.04	0.04±0.04
Phosphate (mg/kg)	0.7±0.1	0.85±0.3
Organic matter content (%)	0.6±0.1	12.8±0.3

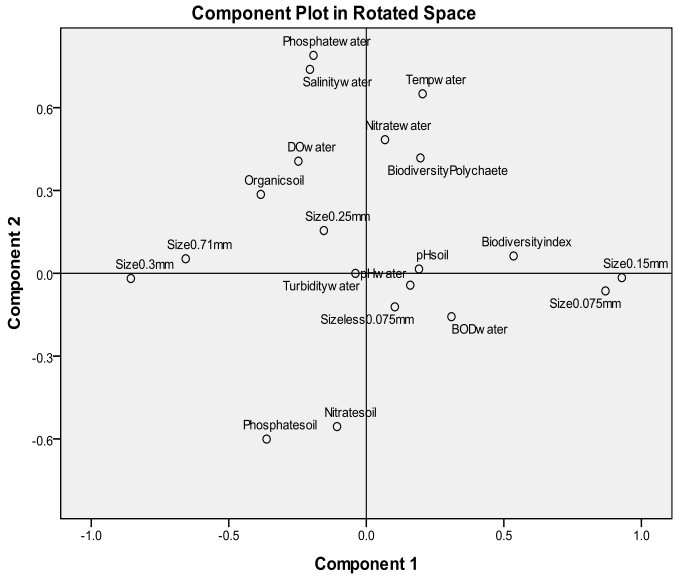

Fig. 2 Relationship between biodiversity index, biodiversity of polychaete and ecological characteristics

TABLE IV
PERCENTAGE OF SEDIMENT PARTICLE SIZES OF PAK BARA AND PAK BANG BEACHES

Particle sizes (mm)	Pak Bara beach (%)	Pak Bang beach (%)
∅ > 2 mm	13.99±1.28	33.73±9.92
0.71 > ∅ > 0.3	10.88±6.26	51.49±9.72
0.3 > ∅ > 0.25	4.21±1.54	6.23±1.90
0.25 > ∅ > 0.15	46.46±0.73	6.82±3.69
0.15 > ∅ > 0.075	24.19±10.58	1.46±2.47
<0.075	0.28±0.36	0.28±0.70

C. Sternaspis andamanensis and Petersenaspis sp.and Species Description

During the Southwest monsoon, one specimen of *S. andamanensis* was collected from Pak Bang beach station 5. During the Northeast monsoon, seven specimens of *S. andamanensis* were also found in Pak Bara beach station 1 and one specimen in Pak Bara beach station 8. The *S. andamanensis* found in this area are small with 2.5-5.0 mm in length, 1.5-2.5 mm in width and having 10-15 body segments. The first three segments have a lateral row of acicular spines. The pre-shield region is round, much wider than anterior region, which is elongate, narrow and bent inward. The shield's color is brown. Ventro-caudal shield ribs are barely noticeable but concentric lines are not visible. Body papillae are few and the color is pale yellow. Chaetae are ovally arranged on marginal of the shields. Branchiae are few and tightly coiled (Fig. 3). The specimens found in Pak Bara and Pak Bang beach were smaller than reported in Malaysia and South China Sea [24].

Two specimens of *Petersenaspis* sp. were found at Pak Bara beach, station 1 during Northeast monsoon. The first record of *Petersenaspis* sp. in this area represented a considerable expansion of the genus's distribution range. However, the species collected from this beach is small. Their bodies ranged between 3.0 and 4.0 mm in length and 1.5-2.0 mm in width. The first three chaetigers possess spatulate hooks. Genital papillae protrude ventrally from body wall. Small filamentous papillae cover most of the body. Ventro-caudal shields are dark brown, papillose with poorly defined ribs and no concentric line. Anterior margins project forward and posterior margin has a shallow median notch and two lateral notches. Chaetae ovally arranged on outer margins of the shields. Branchial filaments are few and tightly coiled (Fig. 4). The Sternaspidae family recorded in Satun province were very low in number and occurred during monsoon season but none in dry season. The highest individual number was found at Pak Bara beach where the particle size was fine sand to very fine sand. This result is similar to the previous record [24] that a Sternaspidae was found during post-monsoon in the Gulf of Thailand and the family did not appear in pre-monsoon (September to October). The influence of the monsoon has been numerously recorded in the coastal areas. Generally, the different environmental changes that are known to occur during monsoon and dry season, are rather significant and more details should be investigated. The effects of the monsoon are greatly felt in coastal areas that receive some form of sedimentation from the land [23, 25].

Fig. 3 Three specimens of *Sternaspis andamanensis* from Pak Bara and Pak Bang beaches. Prostomia are upward. Scale bar = 1 mm

Fig. 4 A specimen of *Petersenaspis* sp. from Pak Bara beach. A prostomium is upward. Scale bar = 1 mm

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