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The Ecological Characteristics of Benthic Macrofauna and the Application of Marine Biotic Index (AMBI) to Assess Tourism Beaches Health in Krabi Province, Thailand

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Abstract The objectives of this study were to examine the state of the benthic macrofauna communities, in order to determine the relations in ecological variables and to assess the beaches health by AMBI application. It was carried out in Nopparatthara, Ao-nang and Nam Mao beaches along Krabi province coast. The results showed that common benthic macrofauna species consisted of 13 species including *Glycera alba*, *Goniadopsis incerta*, *Scoloplos* (*Leodamas*) *gracilis*, *Scoloplos (Scoloplos) tumidus*, *Axiothella obockensis*, *Lumbrineris* sp., *Scoletoma* sp., *Donax cuneatus*, *Donax incarnates*, *Donax faba, Umbonium vestiarium*, *Matuta victor*, *Dotilla intermedia*. Major variables were investigated by Principal Component Analysis (PCA) and stepwise multiple linear regression was used to determine the correlation between the ecological variables and the biological indices. Dissolved oxygen, water pH, nitrate and phosphate concentration in water and organic content were the positive important factors to the biodiversity indices (species richness index, D, species diversity, H and evenness index, J), while sediment pH, phosphate and nitrate in sediment, BOD and turbidity were negatively related to the biodiversity indices. In contrast, the species dominant index (C) was conversely related. Water temperature and the sediment particle sizes showed less correlation to biological indices. The AMBI software which is applied to interpret the beach health indicated that all sampling stations were defined into undisturbed (Group I) and slightly disturbed (Group II) beach status.

Keywords: ecological characteristics; benthic macrofauna; AMBI; beaches health

Introduction

The Andaman Sea coast of Thailand presents high levels of complexity, diverse habitats and supports a high level of biodiversity such as mangrove areas, coral reefs, seagrass beds and fishery resources (Nootmorn *et al*., 2003).

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These provide goods and services that support tourism. A large proportion of human population inhabits in the coastal areas and human density is expected to increase in the coming years. Many human activities causing the coastal area to face increasing and significant impacts include physical and chemical transformation, habitat destruction and changes in biodiversity (Defeo *et al*., 2009; Ellis, 2005; Svanberg, 1996). Government and managers require tools based on sound scientific knowledge to properly monitor, manage and protect such sensitive areas (Martinez-Crego *et al*., 2010). The ecological integrity of beach environments under human pressure has been defined as the ability to support and maintain key ecological processes and communities of organisms with species compositions, diversity and functional organization similar to that of undisturbed habitats within the region. Finding the causes of reduced aquatic system integrity, and developing and implementing adequate remedial measures are now key components of environmental management (Defeo *et al*., 2009; Ellis, 2005; Svanberg, 1996; Martinez-Crego *et al*., 2010). Various studies have demonstrated that benthic macrofauna responds relatively rapidly to anthropic and natural stress (Borja *et al*., 2000; Dauvin *et al*., 2010; Gray *et al*., 1990; Teixeira *et al*., 2010). Benthic communities are used in monitoring effects of marine pollution as these organisms are mostly sessile, and they integrate effects of pollutants over time. Consequently, this research studied species, communities and distribution of benthic macrofauna in Nopparatthara, Ao-nang and Nam Mao beaches along Krabi province coast. The sampling areas were categorized into both anthropogenic and non-anthropogenic impact areas to determine the correlation between environmental factors and macrobenthic communities. Benthic macrofauna assemblages were used to characterize the present conditions of the beaches by AMBI application. These data provide important knowledge for coastal environmental management efforts that are resolving problems and preventing adverse affects in the coastal zone.

Materials and methods

Sampling areas

Krabi province is undulating with hills and mountains. The coastline of Krabi consists of alternating bays and capes. Much of the coastal area is covered by mangrove forest. The study was conducted on three beaches along the sea coast of Krabi province, including Nopparatthara, Ao-nang and Nam Mao beaches. Nopparatthara beach is located in the Nopparatthara National Park. The beach has three sections. The first section is close to Ao-nang beach.

Rocky coast and a small mountain occurred as a headland between the two beaches. Rocky barrier and road were constructed on the middle part of the beach. The end section of the beach is across a canal, adjacent to the Nopparatthara National Park office. The beach has a shallow intertidal flat.

Ao-nang beach is about 3 km southward of Nopparatthara beach. The beach is a popular tourist attraction because a pier provides access to many famous islands. Human uses in the area have been characterized by the increasing socioeconomic importance of recreational activities. Many souvenir shops, small resorts and restaurants generated a town there. A concrete wall was constructed at the beachfront to protect the land. This beach has moderate sandy slope and is located between two mountains where sediments settle near the both ends of the beach.

Nam Mao beach is separated from Ao-nang beach by a mountain which is located at the southeast of Ao-nang beach. The mainland is covered by vegetation. Rocky patches and corals are scattered around the southward end of the beach. The studied beach locations in Krabi province including Nopparatthara, Ao-nang and Nam Mao beaches are shown in Fig. 1.

Figure 1. The studied beach locations in Krabi province including Nopparatthara, Ao-nang and Nam Mao beaches (modified from Map of Thailand, 2010)

Sampling methods

The sediment was sampled during the Northeast monsoon (November-December 2012), in the dry season (March-April 2013) and during the Southwest monsoon (August-September 2013). Quadrate samplings were done at the 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 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 macrofauna samples were studied under a stereo microscope (Olympus SZX7) and a compound microscope (Olympus BX50) with the DP27 camera and the Cellsens Dimension program to magnify the details of the specimens based on the keys to marine invertebrates and previous identification reports (Environmental Monitoring and Support Laboratory Office of Research and Development, 1986; Fauchald, 1977; Poutiers, 1998; Swennen, 2001; Allen, 2010; McLaughlin, 1998).

Ecological variable analyses

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 (Marine Environmental Laboratory, 2008; De Pas *et al*., 2008).

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) (Eleftheriou and McIntyre, 2005).

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 (APHA, 2005).

Data analyses

Benthic macroinvertebrate structures were analyzed using the calculation diversity indices including Margalef richness index (D), Shannon-Wiener diversity index (H), Shannon-Wiener evenness index (J), and Simpson dominance species index (C).

Stepwise multiple regression analysis and Principal Correspondence Analysis (PCA) performed by PASW statistics 18 were used to determine the benthic macrofauna communities in relation to the environmental data.

Biological indices and ecological status of the benthic macrofauna communities were used as principal data to establish environmental status classification in each station. All detected individuals were classified into one of the five ecological groups proposed in European estuarine and coastal environment (Borja *et al*., 2000). It was mainly based on the ecological list presented in the AZTI's Marine Biotic Index (AMBI) software version 5. The newest version is downloadable from AZTI website (http://ambi.azti.es/). In order to classify the disturbance and environmental status, the software was applied to use in this study. The software provides a list of 8,000 taxa representative of soft bottom communities present at estuarine and coastal ecosystems. The instructions of indicator package (AMBI) were used for the application (Borja *et al*., 2012).

Results and discussion

Ecological data

For overall results of water variables, most variables did not exceed the Thailand Marine Water Quality Standard (Pollution Control Department, 2007). Exception were observed for pH and DO at some studied stations; these values slightly exceeded the standard but they still encouraged the benthic macrofauna growth. The sediment types of sampling stations were neutral to acidic with variation of nutrients and organic matter content. Sediment particle sizes also varied among the sampling beaches. All sampling beaches, according to Wentworth scale, had very fine sand to fine sand. All sampling stations on Nopparatthara and Ao-nang beaches had predominantly very fine sand. The highest percentage of particle size was 0.075 mm, whereas Nam Mao had fine sand with the highest percentage of particle size at 0.15 mm. The ecological variable values are shown in Table 1.

Table 1. Ecological variable values of all sampling stations in Krabi province (mean±SD)

Variables	Sampling stations								
	KB-NT st1	**KB-NT st2**	**KB-NT st3**	**KB-AN st1**	**KB-AN st2**	**KB-AN st3**	**KB-NM st1**	**KB-NM st2**	**KB-NM st3**
Sediment									
Sediment pH	6.56 ±0.29	6.61 ±0.29	6.56 ±0.38	6.56 ±0.52	6.50 ±0.48	6.50 ±0.38	6.33 ±0.38	6.61 ±0.29	6.61 ±0.29
Nitrate in sediment (mg/kg)	3.04 ±0.36	3.15 ±1.23	3.08 ±0.13	2.92 ±0.35	2.98 ±0.76	3.12 ±0.39	3.49 ±0.50	3.25 ±0.41	3.30 ±3.04
Phosphate in sediment (mg/kg)	1.80 0.38	2.30 0.08	2.15 ±0.05	1.18 ±0.16	1.49 ±0.07	1.28 ±0.84	2.03 ±0.09	2.28 ±0.29	1.38 ±1.20
Organic matter content (%)	3.37 ±0.66	3.23 ±0.76	3.23 ±0.92	3.11 ±0.62	8.40 ±9.92	3.84 ±0.60	3.48 ±0.91	3.53 ±0.97	3.50 ±0.73
Sediment particle size									
0.71mm (%)	5.26 ±0.59	1.59 ±0.21	1.05 ±0.11	13.30 ±1.17	18.06 ±3.65	7.62 ±0.72	6.95 ±0.92	14.29 ±0.70	10.08 ±0.98
0.3mm (%)	7.38 ±0.53	3.47 ±0.83	18.12 ±0.17	3.22 ±0.29	3.67 ±0.96	2.22 ±0.14	11.11 ±0.92	15.75 ±0.71	9.73 ±0.36
0.25mm (%)	0.48 ±0.05	2.46 ±0.79	10.78 ±1.79	0.74 ±0.09	0.82 ±0.25	0.37 ±0.03	7.82 ±1.03	7.18 ±0.11	2.93 ±0.25
0.15mm (%)	1.40 ±0.59	11.29 ±4.31	31.84 ±2.08	35.05 ±3.02	24.34 ±0.50	15.86 ±9.80	64.26 ±2.98	46.69 ±0.55	56.60 ±2.24
0.075mm (%)	80.93 ±1.84	78.89 ±3.26	35.15 ±0.59	46.55 ±3.78	50.73 ±4.39	68.44 ±8.64	9.07 ±2.21	15.57 ±0.58	20.10 ±1.80
<0.075 mm (%)	4.55 ±1.37	2.30 ±0.44	3.06 ±0.44	1.13 ±0.25	2.38 ±0.38	5.50 ±1.85	0.79 ±0.03	0.53 ±0.06	0.56 ±0.04
Water									
pH	7.84 ±0.02	7.89 ±0.04	7.82 ±0.03	7.83 ±0.03	7.83 ±0.06	7.87 ±0.03	7.82 ±0.05	7.75 ±0.08	7.77 ±0.04
DO (mg/L)	3.61 ±0.27	4.43 ±0.26	4.09 ±0.54	3.42 ±0.54	3.13 ±0.11	3.36 ±0.31	3.17 ±0.03	3.16 ±0.07	2.97 ±0.18
Water temperature (^{o}C)	28.20 ±0.32	27.78 ±0.40	27.71 ±0.40	28.67 ±0.40	28.64 ±0.36	28.20 ±0.15	27.99 ±0.15	27.98 ±0.04	28.23 ±0.10
Salinity (ppt)	32.22 ±0.19	31.89 ±0.19	31.78 ±0.38	32.00 ±0.38	31.22 ±0.19	31.11 ±0.38	31.67 ±0.38	31.56 ±0.19	31.89 ±0.38
Nitrate in water (μg/L)	0.04 ±0.03	0.04 ±0.04	0.08 ±0.03	1.68 ±0.03	2.10 ±0.49	2.52 ±0.08	1.19 ±0.09	1.69 ±0.09	1.31 ±0.04
Phosphate in water (μg/L)	0.02 ±0.01	0.02 ±0.02	0.03 ±0.01	0.02 ±0.01	0.12 ±0.05	0.03 ±0.01	0.02 ±0.01	0.02 ±0.01	0.04 ±0.03
Turbidity (NTU)	5.85 ±0.85	3.17 ±0.45	5.30 ±0.71	14.69 ±0.71	13.37 ±0.84	14.51 ±0.60	3.98 ±0.59	3.50 ±0.16	5.08 ±0.23
BOD (mg/L)	3.34 ±0.32	3.25 ±0.28	2.85 ±0.35	2.68 ±0.35	2.37 ±0.33	2.90 ±0.35	3.34 ±0.41	3.31 ±0.05	2.88 ±0.31

Note: KB-NT = Nopparatthara beach, KB-AN = Ao-nang beach, KB-NM = Nam Mao beach, st = station

Biological data

The mean abundance of benthic macrofauna in the sampling stations were in the range of 23-935 individuals. The highest abundance was at KB-AN st2 during the summer (935 individuals/2.25m^2). The highest abundance was at KB-NM st3 consisting of 40 species and the species richness index was at 6.15. The lowest occurrence of species richness and richness index of Krabi province was at KB-NT st2 where 14 species were found with its 2.28 species richness index. The biodata index results of 9 sampled stations in 3 seasons are shown in Table 2.

Table 2. Abundance, number of species, species richness (D), species diversity index (H), evenness index (J) and species dominance index (C) of 9 sampling stations in 3 seasons and all seasons

Stations	Seasons	Abundance (individuals/2.25m^2)	Number of species	D	H	J	C
KB-NT st1	SWM	95	7	1.32	1.53	0.79	0.27
	NEM	126	13	2.48	2.26	0.88	0.12
	SM	182	11	1.92	1.94	0.81	0.19
	Y	403	22	3.50	2.72	0.88	0.08
KB-NT st2	SWM	83	5	0.91	1.33	0.82	0.32
	NEM	108	9	1.71	1.95	0.89	0.16
	SM	106	8	1.50	1.82	0.87	0.19
	Y	297	14	2.28	2.16	0.82	0.14
KB-NT st3	SWM	70	8	1.65	1.58	0.76	0.31
	NEM	122	8	1.46	1.95	0.94	0.15
	SM	160	6	0.99	1.38	0.77	0.31
	Y	352	16	2.56	2.29	0.83	0.13
KB-AN st1	SWM	129	10	1.85	1.25	0.54	0.47
	NEM	117	6	1.05	1.51	0.85	0.26
	SM	217	11	1.86	1.81	0.76	0.20
	Y	463	20	3.10	2.32	0.78	0.12
KB-AN st2	SWM	175	10	1.74	1.23	0.53	0.45
	NEM	129	4	0.62	0.76	0.55	0.61
	SM	935	13	1.75	1.70	0.66	0.24
	Y	1239	23	3.09	2.18	0.70	0.15
KB-AN st3	SWM	484	15	2.26	1.42	0.52	0.44
	NEM	80	6	1.14	1.48	0.82	0.25
	SM	701	14	1.98	1.75	0.66	0.20
	Y	1265	24	3.22	2.08	0.65	0.19
KB-NM st1	SWM	47	10	2.34	1.74	0.76	0.26
	NEM	93	6	1.10	1.49	0.83	0.28
	SM	115	15	2.95	2.15	0.79	0.16
	Y	255	22	3.79	2.31	0.75	0.16
KB-NM st2	SWM	182	15	2.69	1.82	0.67	0.26

Stations	Seasons	Abundance (individuals/2.25m^2)	Number of species	D	H	J	C
KB-NM st3	NEM	133	14	2.66	2.19	0.83	0.15
	SM	214	12	2.05	2.03	0.82	0.17
	Y	529	26	3.99	2.52	0.77	0.12
	SWM	192	20	3.61	2.29	0.76	0.14
	NEM	94	13	2.64	2.21	0.86	0.15
	SM	281	24	4.10	2.29	0.72	0.19
	Y	567	40	6.15	2.76	0.75	0.12

Note: SWM = Southwest monsoon, NEM = Northeast monsoon, SM = summer, Y = all seasons

Common species of benthic macrofauna defined as organisms typically found in all seasons in a particular beach. The common species of this study numbered 13 species and included 7 species of polychaetes, 4 species of mollusks and 2 species of crustaceans. The dominant group accounted for 7 species including 2 polychaete species, 4 mollusk species and a crustacean species. Common species of benthic macrofauna and the dominant species found at the stations during sampling period are shown in Table 3 and figures of the species are shown in Fig. 2.

Table 3. Common specie and dominant species of benthic macrofauna found at the stations during sampling period and the percent abundance in each station of the species

Common species		
Nopparatthara beach	**Ao-nang beach**	**Nam Mao beach**
Glycera alba (Pol)	*Glycera alba* (Pol)	*Scoloplos* (*Scoloplos*) *tumidus* (Pol)
Goniadopsis incerta (Pol)	*Donax faba* (Mol)	*Axiothella obockensis* (Pol)
Scoloplos (*Leodamas*) *gracilis* (Pol)	*Donax cuneatus* (Mol)	*Glycera alba* (Pol)
Donax incarnatus (Mol)	*Umbonium vestiarium* (Mol)	*Lumbrineris* sp. (Pol)
Donax faba (Mol)	*Matuta victor* (Cru)	*Scoletoma* sp. (Pol)
		Donax faba (Mol)
		Umbonium vestiarium (Mol)
		Dotilla intermedia (Cru)

Dominant species		
Nopparatthara beach	**Ao-nang beach**	**Nam Mao beach**
Scoloplos (*Leodamas*) *gracilis* (Pol)	*Donax cuneatus* (Mol)	*Donax faba* (Mol)
Umbonium vestiarium (Mol)	*Diogenes dubius* (Cru)	*Lumbrineris* sp. (Pol)
Donax incarnatus (Mol)	*Scoloplos* (*Leodamas*) *gracilis* (Pol)	

Note : Pol = Polychaetes, Mol = Molusks, Cru = Crustaceans

Figure 2. Show common species and dominant species of benthic macrofauna found in Krabi sampling beaches.

Figure 2. (Cont.) Show common species and dominant species of benthic macrofauna found in Krabi sampling beaches.

Dotilla intermedia

Diogenes dubius

Figure 2. (Cont.) Show common species and dominant species of benthic macrofauna found in Krabi sampling beaches.

Biodata and ecological relation

The results from Principal Component Analysis (PCA) showed that dissolved oxygen, water pH, nitrate and phosphate concentrations in water and organic content were positive factors to the biodiversity indices (species richness index, D, species diversity, H and evenness index, J), while sediment pH, phosphate and nitrate in sediment, BOD and turbidity were negatively related to the biodiversity indices. In contrast, the species dominant index (C) was conversely related. Water temperature and the sediment particle sizes showed less correlation to biological indices. According to this relation, the abundance of benthic macrofauna decreased when the sediment became coarser. The component analysis of water and sediment characteristics and biodiversity indices is shown in Fig. 3.

Benthic macrofauna communities of sampling stations at Krabi province exhibited 4 models of multiple regressions. The model I was the linear regression between species richness index (D) and the environmental data. The model explained that species richness was positively related to dissolved oxygen but the correlation was relatively low (r^2 = 0.199). This model could not be exactly used to predict the data because this model could explain only 19% of all data. However, the p value was less than 0.02 which showed statistical relation between the ecological variables and the biological indices. The model II explained that species diversity (H) negatively related to phosphate and nitrate concentration in water with moderate relation. The model III had high correlation (r^2 = 0.745). It explained that the evenness index (J) had markedly negative relation with sediment particle size of 0.71 mm, nitrate concentration in sediment, phosphate concentration in water and turbidity whereas salinity was positively related to this index. The model IV showed positive relation between species dominance index (C) and nitrate concentration in sediment and phosphate concentration but the salinity result was inverse ($r^2 = 0.605$). Models of the regressions presenting the relations of biological indices and environmental variable of Krabi province are shown in Table 4. Moreover, partial regression plots provided additional insights into the patterns observed.

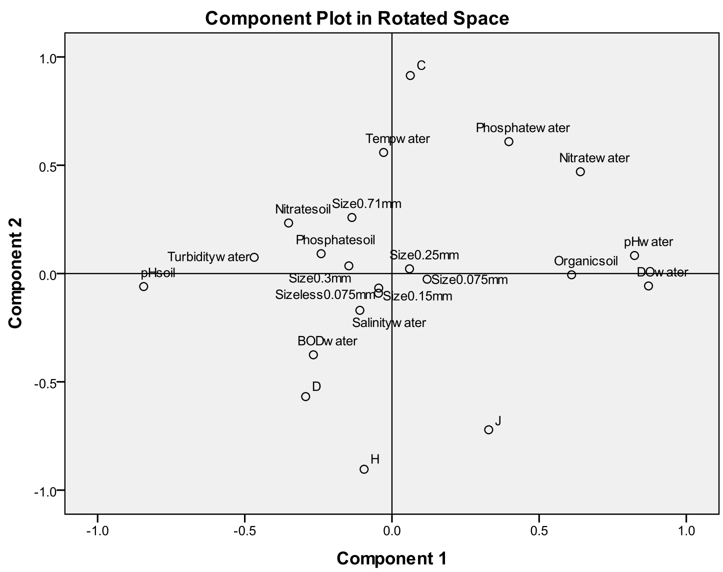

Figure 3. PCA of relationship between biodiversity indices and ecological characteristics

Table 4. Summary of predictive models for the multiple regressions between biological indices and ecological variables of sampling stations in Krabi province

Biological indices		Models
D	=	2.821 + 0.253 (DO)……………………………..…………………...….…….I $r^2 = 0.199$, $p < 0.020$*
H	=	1.908 – 2.920 (Phosphate in water) – 0.33 (Nitrate in water) ....II $r^2 = 0.345$, $p < 0.044$*
J	=	1.422 – 0.05 (Sediment particle size 0.71 mm) + 0.73 (salinity) – 0.18 (Nitrate in sediment) – 0.693 (Phosphate in water) – 0.05 (Turbidity)…........III $r^2 = 0.745$, $p < 0.028$*
C	=	1.807 + 1.094 (Phosphate in water) + 0.017 (Nitrate in sediment) – 0.051 (Salinity)…..........………………………..…………………………………IV $r^2 = 0.605$, $p < 0.037$*

Note : * Statistically significant (p<0.05)

Application of AMBI to classify the beach health

The application of benthic macrofauna community to interpret the ecological habitats base on AMBI classification program manifested that all sampling stations were defined into 2 ecological groups. Group I as undisturbed habitats included 6 sampling stations. The stations were at Nopparatthara beach station 1, all 3 stations of Ao-Nang beach, and Nam Mao beach station 1 and 2. For seasonal data, the benthic macrofauna communities varied among seasons but the ecological groups were mainly in group I or group II. In different seasons, the sampling stations KB-NT st3 had high percentage of benthic macrofauna in the ecological group IV in different seasons. Sampling station KB-NM st1 and KB-NM st3 of Nam Mao beach had benthic marofauna in ecological group V. The species is a first-order opportunistic species. Disturbed sediments are commonly invaded by opportunistic species, and this has in the past been considered a result of reduced competition (McLachlan and Brown, 2006). The species was only capable of small colonization and the sensitive fauna has been dominated. The eventual return of the normal species was then assumed to result in the sensitive and transitional species being outcompeted. Although the group IV and V were presented in the areas, the dominated communities in those 9 stations were group I or II which are classified as unpolluted or slightly impoverished benthic community. The percentage of benthic macrofauna species in ecological groups of 9 sampling stations in 3 seasons are shown in Table 5 and the summary results of AMBI value and ecological status assessed by the benthic macrofauna communities are shown in Table 6.

Table 5. Percentage of benthic macrofauna species in ecological groups of sampling stations in 3 seasons

Stations	Replicates	Ecological groups				
		I (%)	II (%)	III (%)	IV (%)	V (%)
KB-NT st1	SWM	74.1	0.0	11.1	14.8	0.0
	NEM	34.0	56.6	0.0	9.4	0.0
	SM	74.1	12.4	1.8	11.8	0.0
KB-NT st2	SWM	52.3	0.0	15.9	31.8	0.0
	NEM	50.6	35.3	0.0	14.1	0.0
	SM	34.0	41.2	0.0	24.7	0.0
KB-NT st3	SWM	43.3	0.0	26.7	30.0	0.0
	NEM	52.5	28.8	0.0	18.8	0.0
	SM	92.4	0.0	0.0	7.6	0.0
KB-AN st1	SWM	69.8	11.9	4.8	13.5	0.0
	NEM	67.0	20.0	0.0	13.0	0.0
	SM	60.7	26.7	0.0	12.6	0.0

Stations	Replicates	Ecological groups				
		I (%)	II (%)	III (%)	IV (%)	V (%)
KB-AN st2	SWM	86.0	0.0	7.0	7.0	0.0
	NEM	91.5	2.3	0.0	6.2	0.0
	SM	55.4	44.6	0.0	0.0	0.0
KB-AN st3	SWM	87.5	10.2	0.0	2.3	0.0
	NEM	62.8	21.8	0.0	15.4	0.0
	SM	80.7	18.5	0.0	0.7	0.0
KB-NM st1	SWM	73.2	17.1	2.4	7.3	0.0
	NEM	65.6	11.8	5.4	17.2	0.0
	SM	58.7	25.0	0.0	5.8	10.6
KB-NM st2	SWM	7.9	82.8	1.3	7.9	0.0
	NEM	65.6	32.0	0.0	2.5	0.0
	SM	52.7	37.9	0.0	9.3	0.0
KB-NM st3	SWM	32.4	58.4	0.0	2.2	7.0
	NEM	58.2	26.6	8.9	6.3	0.0
	SM	30.9	56.9	0.7	7.8	3.7

Table 6. Summary results of AMBI value and ecological status assessed by the benthic macrofauna communities

Stations	Number of species	AMBI	Ecological status
KB-NT st1	22	1.01	Undisturbed
KB-NT st2	14	1.60	Slightly disturbed
KB-NT st3	16	1.26	Slightly disturbed
KB-AN st1	20	0.93	Undisturbed
KB-AN st2	23	0.50	Undisturbed
KB-AN st3	24	0.53	Undisturbed
KB-NM st1	22	1.01	Undisturbed
KB-NM st2	26	1.07	Undisturbed
KB-NM st3	40	1.26	Slightly disturbed

A benthic community responds to improvements in habitat quality in three progressive steps: the abundance increases; species diversity increases; and dominant species change from pollution-tolerant to pollution-sensitive species (Weisberg, 1997). The major benthic macrofauna encountered in this study was clearly in ecological group I and group II and the results of main ecological variables were in the range of Thailand Marine Water Quality Standard. Thus, these results were consistent. Although AMBI values have been recognized as an efficient tool for detecting changes in benthic communities receiving impacts derived from human activities, the AMBI values still indicated a major presence of European species rather than Asian ones. The topology within an eco-region must have its own reference conditions. The stations from different topologies must be analysed by own benthic community datasets (Borja *et al*. 2012). Interestingly, station KB-AN st1, KB-AN st2 and KB-AN st3 had multiplicity of human activities that could have loaded pollutants to the marine environment. The benthic community inhabiting these environments is mirroring unaffected in pollutants and organic input. It is a fact that the marine environment can assimilate a certain quantity of domestic wastes without large adverse change in the sampled areas.

It is clear that nutrients in water and sediment, salinity and turbidity associated with changing of the benthic macrofauna. Hence, the relative position of the sampling stations, changed and moved away from the mouth of estuaries would involve a change in the physico-chemical conditions (Borja *et al*., 2000).

A geographical distribution for benthic macrofauna and the modelling of human pressure on coastal ecological status should be developed in order to produce maps status of marine coastal ecosystems. The basic information of benthic macrofauna and graphical data allow managers to plan in beach conservation. Moreover, it is an important decision-support implemented for tourism beach management (Parravicini, 2012).

Conclusion

Benthic macrofauna communities depend on natural factors such as temperature, salinity, nutrients and sediment particle sizes rather than organic matter content, BOD or DO depletion. Biological indices such as richness, diversity, evenness, species dominance, correlation plot by multivariate linear regression visualised the benthic communities and their ecological habitat in the sampling stations. Moreover, the AMBI software can be applied to define the sampling stations in Krabi province into undisturbed (Group I) and slightly disturbed (Group II) beach status.

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