ORIGINAL PAPER

Annual variations in diversity, distribution and abundance of the benthic macrofauna in the two most recreational sandy beaches on Sichang Island, Chonburi Province, in the Eastern Gulf of Thailand

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Abstract. Field study was conducted from January to December in 2022 to examine the diversity, distribution, and species richness of benthic macrofauna in the two famous recreation sandy beaches, Sichang Island, Chonburi Province in the Eastern Gulf of Thailand. At each location, two study stations were selected representing the areas with high tourism activities and low tourism activities. Each study station consisted of three sampling stations allocated at the upper zone, the middle zone and the lower zone. Results showed that there was a significant difference in the diversity index of benthic macrofauna between the two sandy beaches but not for the two study stations or three sampling stations. In conclusion, the results showed no decreasing benthic biodiversity, densities or a change occurring in the community in year-round at the two study stations and sampling stations at Tham Phang Bay and Tha Wang Bay, Sichang Island. As well, the authors suggest the use of *Donax* sp. as a bio-indicator for human impacts and environmental changes on the sandy beach as they could serve as potentially simple and economical tools for long-term monitoring of irreversible loss in biodiversity.

Keywords: Sandy beach, benthic macrofauna, biodiversity, distribution, abundance

1. Introduction

The coastal ecosystems across the world are being damaged due to the rapid expansion of the human population. In addition to residential uses, coastal areas – and sandy beaches in particular have long been a magnet for tourist where these areas are used for recreational activities and holiday destinations. Beaches ecosystems are therefore subjected to intense stressors as a result of increasing coastal infrastructure, the development of shoreline, beach nourishment, source exploitation, pollution, and grooming (Schlacher and Thompson 2008 Defeo et al. 2009). These activities are mainly the result of the increasing pattern of urbanization of beaches and the improvement of tourist facilities. Tourism warrants particular attention since it is the economic engine of many countries (Davenport and Davenport 2006) and involves large numbers of visitors to beaches, especially in the summer reasons. The high level of human occupation can disrupt coastal ecosystems through a wide range of activities. These actions can modify the natural physical characteristics of beaches and have a direct effect on macrofauna communities and their distribution patterns, which can in turn result in a significant loss of biodiversity (Defeo and Alava 1995). The effect of trampling on faunal communities is an important topic that has been addressed for difference ecosystems, such as rocky shores, coral reefs, and mudflats (Rodgers and Cox 2003; Ferreira and Rosso 2009) and a direct effect of the human trampling on faunal communities in sandy beaches is also investigated in various locations (McLachlan 1997; Jaramillo et al. 1996; Rossi 2007; Vieira et al. 2012; Martinez et al. 2015).

Sichang Island located in the Eastern Gulf of Thailand belonging to Chonburi Province. It is far away from mainland about 12 kilometers and it is the first island in the Eastern part of Thailand. Sichang Island and the seven adjacent islands present the rocky shore, sandy beach and coral reefs, then it is one of the famous recreational places for both domestic and international tourists as well as its popular fishing resources and their marine products. Sichang Island had only the two sandy beaches, Tham Phang Bay and Tha Wang Bay, which play the most important roles on recreational activities such as swimming, trampling, sports, sun bathing, etc. for all tourists visited this island. As we known that beach fauna plays a major role in the functioning of beach ecosystems. Benthos are involved in nutrient regeneration (Cisnoros et al. 2011), and they are trophic links between marine and terrestrial system and are stranded material decomposers (Lercari et al. 2003). The identification of factors that causes disturbance is therefore a crucial task in maintaining the continuity of sandy beaches ecosystems. If one primarily human trampling, supralittoral species have traditionally been viewed as highly vulnerable (Moffett et al. 1998) although the swash beach area, which is inhabited by the greatest diversity of macrofauna, is most commonly used by people (Alonso and Cabrera 2002; Schlacger and Thompson 2012). Despite the great social, economic, and environmental importance of sandy shores worldwide, environmental monitoring and assessment of sandy beach ecosystems is very important worldwide. A monitoring technique which uses benthic macrofauna community as biological indicators to measure the effects of human disturbance on sandy beaches has been applied on urban shores and to assess whether tramping on beaches damage the resident biota.

The objective of this study was to evaluate the eventual effect of recreational beach users on the abundance and richness of the intertidal benthic macrofauna. In addition, the most vulnerable species that can be considered as indicators of these types of impact were explored. Thus, it was hypothesized that human presence (through mechanical disturbance of substratum) might well affect the population diversity, distribution and abundances of the burrowing animals. To test this hypothesis field surveys were carried out annually on the two famous recreational sandy beaches for tourists at Tham Phang Bay and Tha Wang Bay, Sichang Island, Chonburi Province, located at the Eastern Gulf of Thailand during January to December, 2022.

2. Materials and Methods

2.1 Study area

The field studies consisted of the exclusion of beach users by dividing the beach in two areas (the center of the beach and the edge of the beach) at similar length of 100 m. The investigation was performed during January to December in 2022. The study was carried out in two sandy beaches with an anthropogenic pressure gradient consisted of two famous recreation sandy beaches at Tham Phang Bay (36^{o} 34´13´´N; 6^{o}13´29´´W) and Tha Wang Bay (36^{o} 34´13´´N; 6^{o}13´29´´W), Sichang Island, the Eastern Gulf of Thailand (Figure 1). At each location, two study stations were selected representing the following habitat types: high tourist activities (common area that high number of tourist preferred for various activities all year rounds) and low tourist activities (area that a few number of tourist preferred) and each study station was consisted of three sampling stations (Figure 2 - 5) consisted of the upper zone (the uppermost station located above the drift line), the middle zone (located on the drift line) and the lower zone (the lowest limit of the swash zone).

2.2 Sampling procedures

At each study station, six equidistant and across-shore transects were placed in a 100 m long-shore area. Each transect comprised 10 equidistant points, from the high tide water to the swash zone to cover the entire intertidal area. At each sampling level, fauna samples were collected with a 50 x 50 cm^2 quadrat and the sand was dig to a depth of 20-cm and three replicated quadrats were done. The sediment was sieved through 1.0 mm mesh size and the macrofauna were stored in 5% formalin until sorting. The macrofauna were quantified and identified in the laboratory.

2.3 Benthic macrofauna analysis

The sediment was sieved to collect all organisms greater than 1.0 mm in diameter, and these were preserved in 10% buffered formalin. In the laboratory, the benthic macrofauna were sorted,

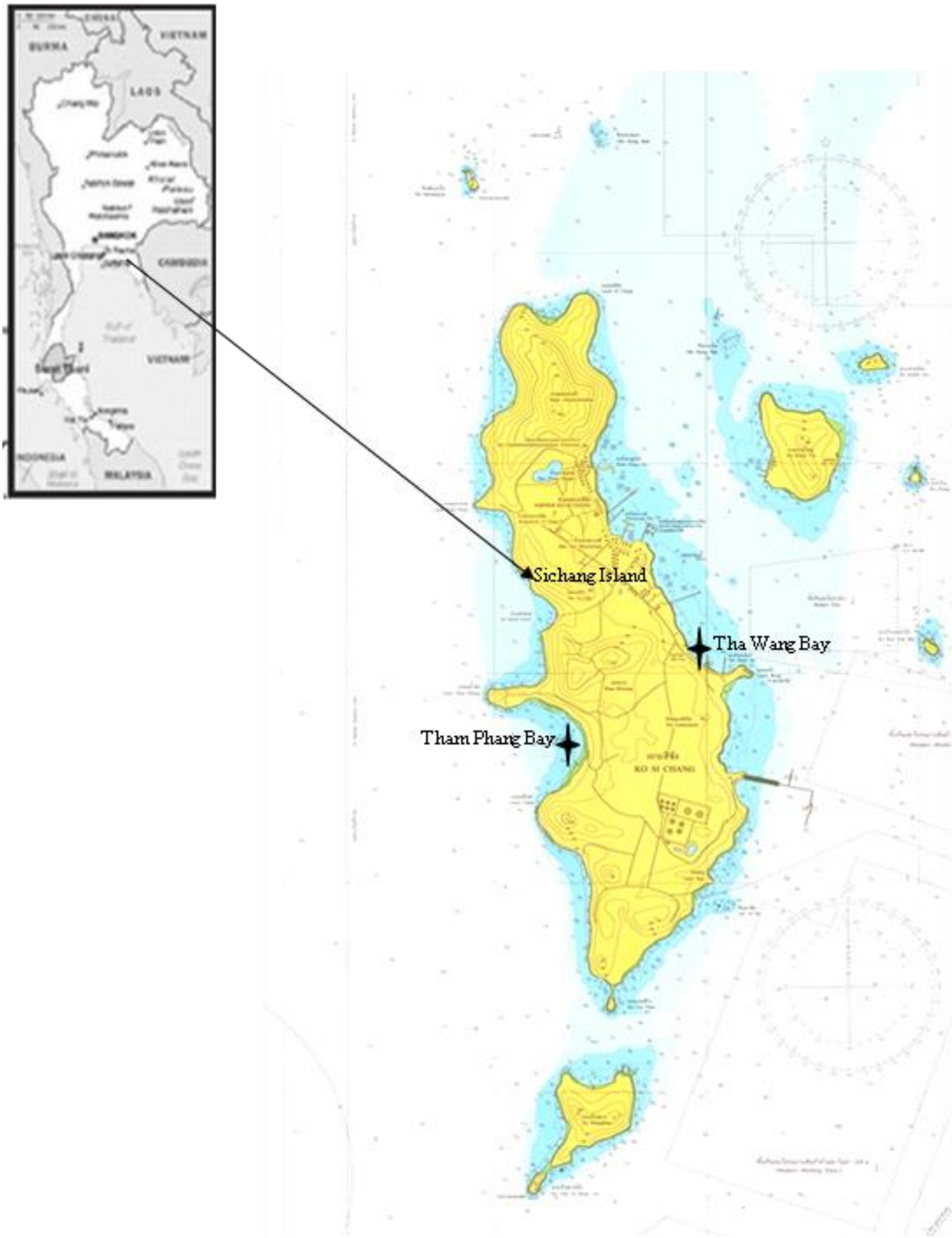

Figure 1. Two famous recreational sandy beaches at Tham Phang Bay and Tha Wang Bay, Sichang Island, Chonburi province.

counted, and identified to the family/species level. For each replicate and station, total species richness was computed as the total number of families, species, and individuals collected at each sampling station. Total densities (individuals/m^2) of benthic invertebrates were analyzed for each sampling station as follows:

Total density = (Total number of animals) / (Area of sampling unit)

A variety of diversity indices have been used in benthic ecology and the effect of disturbances on benthic macrofauna communities. In the present study, the Shannon-Wiener diversity index (H'), Pielou's evenness index (E), and Margalef's species richness index (D) were calculated for each sampling station to reflect the even occurrence of species within a community as described by Ghosh and Biswas 2015 as followings: Shannon-Wiener diversity index (H) = Sum [(p^i) *ln(p^i)], Pielou's evenness index (E) = H/H_{max}, and Margalef's species richness index (D) = (S-1)/lnN.

2.4 Statistical analysis

The data on benthic macrofauna was compared between the two sandy beaches, two study sites three sampling sites by analysis of variance (ANOVA) to test for significant differences ($P < 0.05$). If any significant differences were found, the Duncan multiple range test was used to separate the means. Statistical analysis was carried out using the SPSS statistical program version (14.0). The normality of the data and homogeneity of variances were examined from box plots, and some variables were transformed to normalize the data.

3. Results

3.1 Species Composition

The distribution and density of benthic macrofauna at three sampling stations on the low and high of tourist stations in the two famous recreation sandy beaches at Tham Phang Bay and Tha Wang Bay, located at Sichang Island, Chonburi Province, the Eastern Gulf of Thailand is presented in Table 1 - 2. At Tham Pang Bay, a total of 146.5 individuals and 14 species of benthic macrofauna was found in the high tourist stations as compared to a total of 203.6 individuals and 11 species of benthic macrofauna at the low tourist stations (Table 1). As contrast to Tha Wang Bay, a total of 192.8 individuals and 12 species of benthic macrofauna was found in the high tourist stations as compared to a total of 321.3 individuals and 17 species of benthic macroinvertebrate fauna at the low tourist stations (Table 2). The most top three dominant species of benthic macrofauna at the high and low tourist stations both in Tham Phang Bay and Tha Wang Bay were bivalves and crustaceans comprising of wedge shells (*Donax* sp.), trough shells (*Mactra* sp.) and isopod (*Lanocira* sp.). Benthic macrofauna at three sampling stations on low and high of tourist stations in the two famous recreation sandy beaches at Tham Phang Bay and Tha Wang Bay are presented in Figure 2.

3.2 Species number and individual number

Mean values for species number and individual number of benthic macrofauna at three sampling stations from low and high of tourist stations in the two recreation sandy beaches at Tham Phang Bay and Tha Wang Bay are presented in Table 4 - 5. Results showed that there was no statistically difference in species number of benthic macrofauna among the two sandy beaches ($P = 0.211$), two study stations ($P = 0.273$) and three sampling stations ($P = 0.077$), with no interaction of sandy beaches, study stations and sampling stations ($P = 0.557$) (Table 3). The average species numbers of benthic macrofauna in the high tourist station of Tham Phang Bay ranged from 4.5±2.12 to 8.0±5.66 and from 4.5±3.54 to 7.5±2.12 for those in low tourist station (Table 4), while the average species numbers of benthic macrofauna in the high tourist station of Tha Wang Bay ranged from 4.5±2.12 to 7.5±0.71 and from 6.0±1.41 to 13.0±4.24 for those in the low tourist station (Table 5).

Table 1. Density and distribution of benthic macrofauna at three sampling stations on two tourist stations during January to December in 2022 at Tham Phang Bay, Sichang Island.

Family	Species	High tourist station			Total	Low tourist station			Total
		St 1	St 2	St 3		St 1	St 2	St 3	
Molluscs									
Mactridae	*Mactra* sp.	0.4	1.5	0.4	**2.3**	0.1	4.3	8.7	**13.1**
Donacidae	*Donax* sp.	42.7	56.0	18.2	**116.9**	35.4	80.1	45.5	**160.9**
Veneridae	*Antigona* sp.	-	-	0.2	**0.2**	-	-	0.3	**0.3**
Mytilidae	*Brachiodontes* sp.	-	-	0.1	**0.1**	-	-	0.7	**0.7**
Tellinidae	*Tellina* sp.	-	-	-	**-**	0.1	0.6	-	**0.7**
Planaxidae	*Planaxi* sp.	-	-	-	**-**	0.1	-	-	**0.1**
Cerithiidae	*Cerithium* sp.	-	-	0.2	**0.2**	-	-	0.3	**0.3**
Crustaceans									
Corallanidae	*Lanocira* sp.	1.1	0.4	-	**1.5**	9.1	0.9	0.3	**10.2**
Xanthidae	Unidentified sp.	0.2	0.3	3.6	**4.0**	-	0.1	1.6	**1.7**
Matutidae	*Matuta* sp.	-	-	0.1	**0.1**	-	-	-	**-**
Diogenidae	Unidentified sp.	-	-	0.1	**0.1**	-	-	-	**-**
Polychaetes									
Orbinidae	Unidentified sp.	0.2	4.0	14.0	**18.2**	0.2	1.5	13.2	**14.9**
Nereididae	Unidentified sp.	0.7	0.2	1.0	**1.9**	0.1	-	0.8	**0.9**
Spionidae	Unidentified sp.	0.1	-	-	**0.1**	-	-	-	**-**
Cossuridae	Unidentified sp.	-	-	0.1	**0.1**	-	-	-	**-**
Nephtyidae	Unidentified sp.	-	-	0.1	**0.1**	-	-	-	**-**
Total		**45.3**	**62.3**	**38.9**	**146.5**	**45.0**	**87.4**	**71.5**	**203.6**

- = not found

St 1 = Station 1 at the upper zone, St 2 = Station 2 at the mid zone, St 3 = Station 3 at the lower zone

Table 2. Density and distribution of benthic macrofauna at the three sampling stations on two tourist stations during January to December 2022 at Tha Wang Bay, Sichang Island

Family	Species	High tourist station			Total	Low tourist station			Total
		St 1	St 2	St 3		St 1	St 2	St 3	
Mollusca									
Arcidae	*Anadara* sp.	-	-	-	**-**	-	-	0.1	**0.1**
Mactridae	*Mactra* sp.	4.5	23.8	9.4	**37.6**	3.5	34.1	23.0	**60.5**
	Eastonia rugusa	-	-	-	**-**	-	-	0.4	**0.4**
Donacidae	*Donax* sp.	23.1	53.9	58.6	**135.5**	54.8	60.0	80.5	**195.3**
Veneridae	*Antigona* sp.	-	0.1	0.1	**0.2**	-	0.2	5.4	**5.6**
	Gafrarium sp.	-	-	-	**-**	-	-	0.1	**0.1**
Tellinidae	*Tellina* sp.	-	-	-	**-**	-	-	2.4	**2.4**
Planaxidae	*Planaxi* sp.	0.6	-	-	**0.6**	0.7	0.6	0.9	**2.2**
Cerithiidae	*Cerithium* sp.	0.8	0.2	0.1	**1.1**	6.0	0.8	22.3	**29.1**
	Cerithium coralium	-	-	-	**-**	0.8	-	0.8	**1.6**
Neritidae	*Nerita* sp.	0.6	-	-	**0.6**	0.6	-	0.3	**0.9**
Thairidae	*Sermyla* sp.	0.6	-	-	**0.6**	-	-	-	**-**
Neriyidae	*Clithon* sp.	-	-	0.1	**0.1**	-	-	-	**-**
Pyramidellidae	*Pyramidela* sp.	-	-	-	**-**	-	-	0.1	**0.1**
Crustaceans									
Corallanidae	*Lanocira* sp.	12.7	0.4	0.1	**13.1**	16.8	1.6	-	**18.4**
Gammaride	Unidentified sp.	0.1	-	-	**0.1**	-	-	-	**-**
Xanthidae	Unidentified sp.	-	-	-	**-**	-	-	3.3	**3.3-**
Diogenidae	Unidentified sp.	-	-	-	**-**	-	-	0.6	**0.6**
Polychaetes									
Orbinidae	Unidentified sp.	-	1.4	1.4	**2.8**	-	-	0.7	**0.7**
Nereididae	Unidentified sp.	-		-	**-**	-	0.1	0.3	**0.4**
Nephtyidae	Unidentified sp.	-	-	0.6	**0.6**	-	-	-	**-**
Total		42.8	79.7	70.4	**192.8**	83.2	97.3	140.9	**321.4**

- = not found

St 1 = Station 1 at the upper zone, St 2 = Station 2 at the mid zone, St 3 = Station 3 at the lower zone

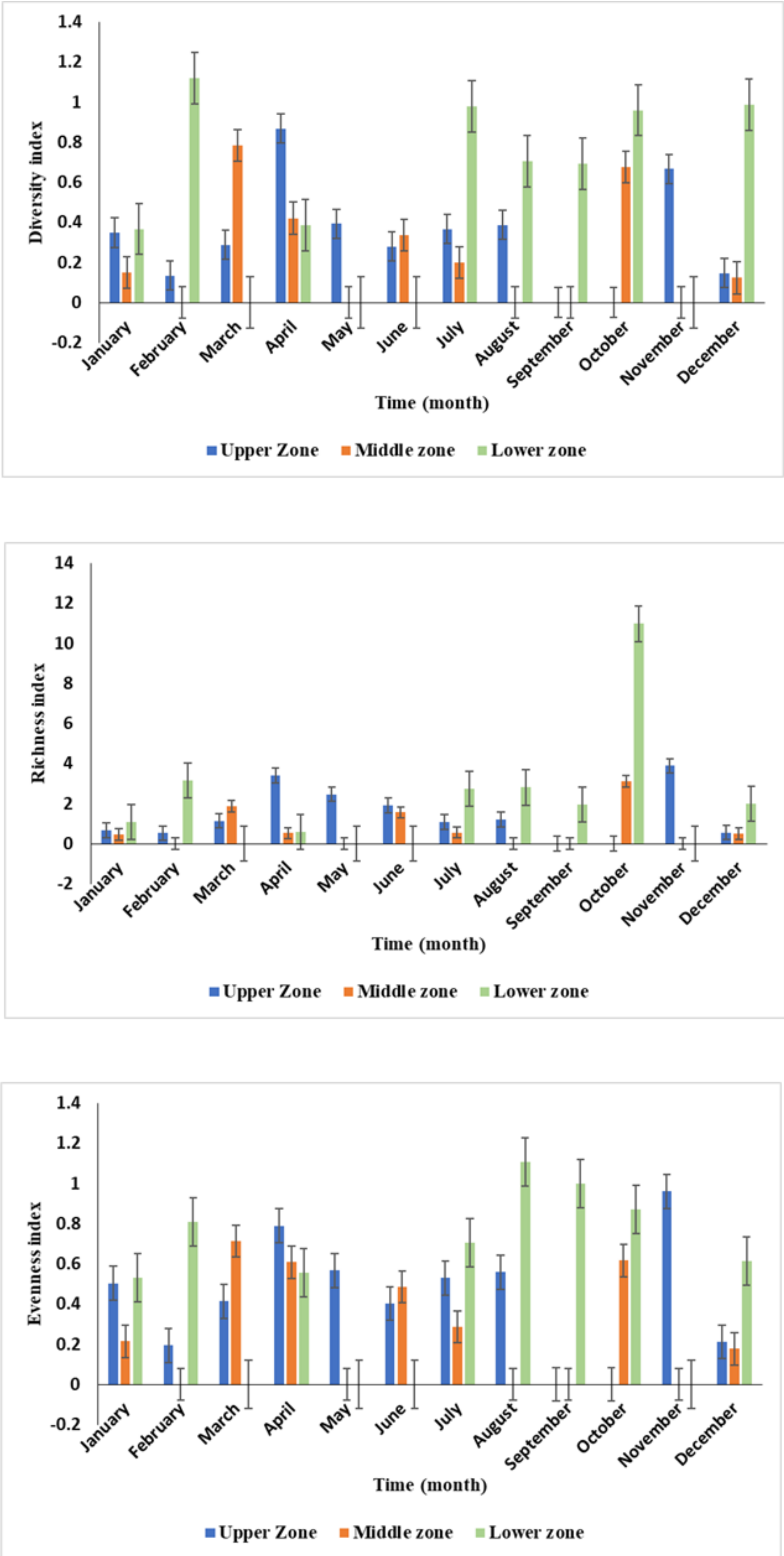

Figure 2. Diversity index, richness index and evenness index of benthic macrofauna at the three sampling stations on the high tourist station during January to December in 2022 at Tham Pang Bay, Sichang Island.

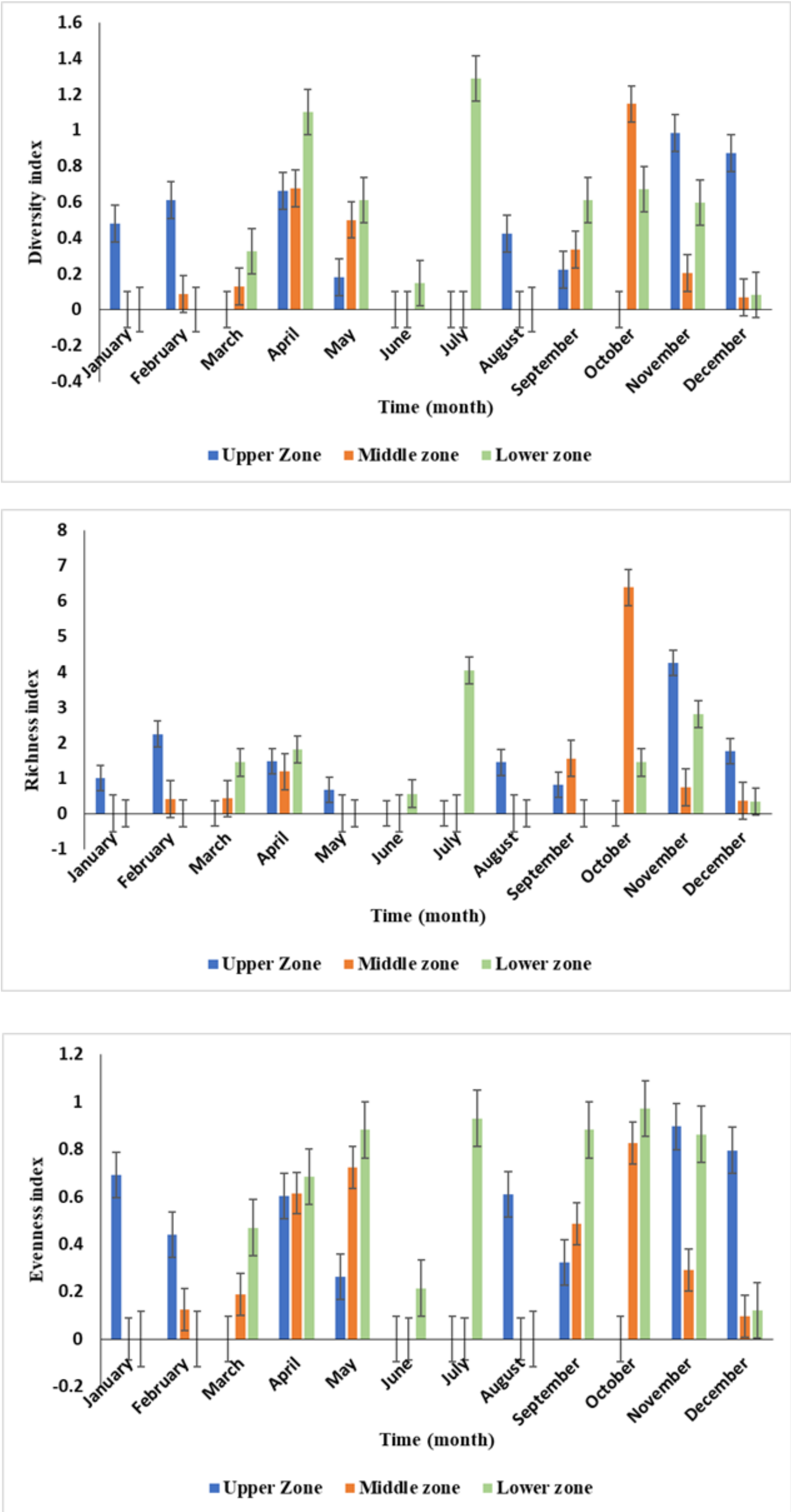

Figure 3. Diversity index, richness index and evenness index of benthic macrofauna at the three sampling stations on the low tourist station during January to December in 2022 at Tham Pang Bay, Sichang Island.

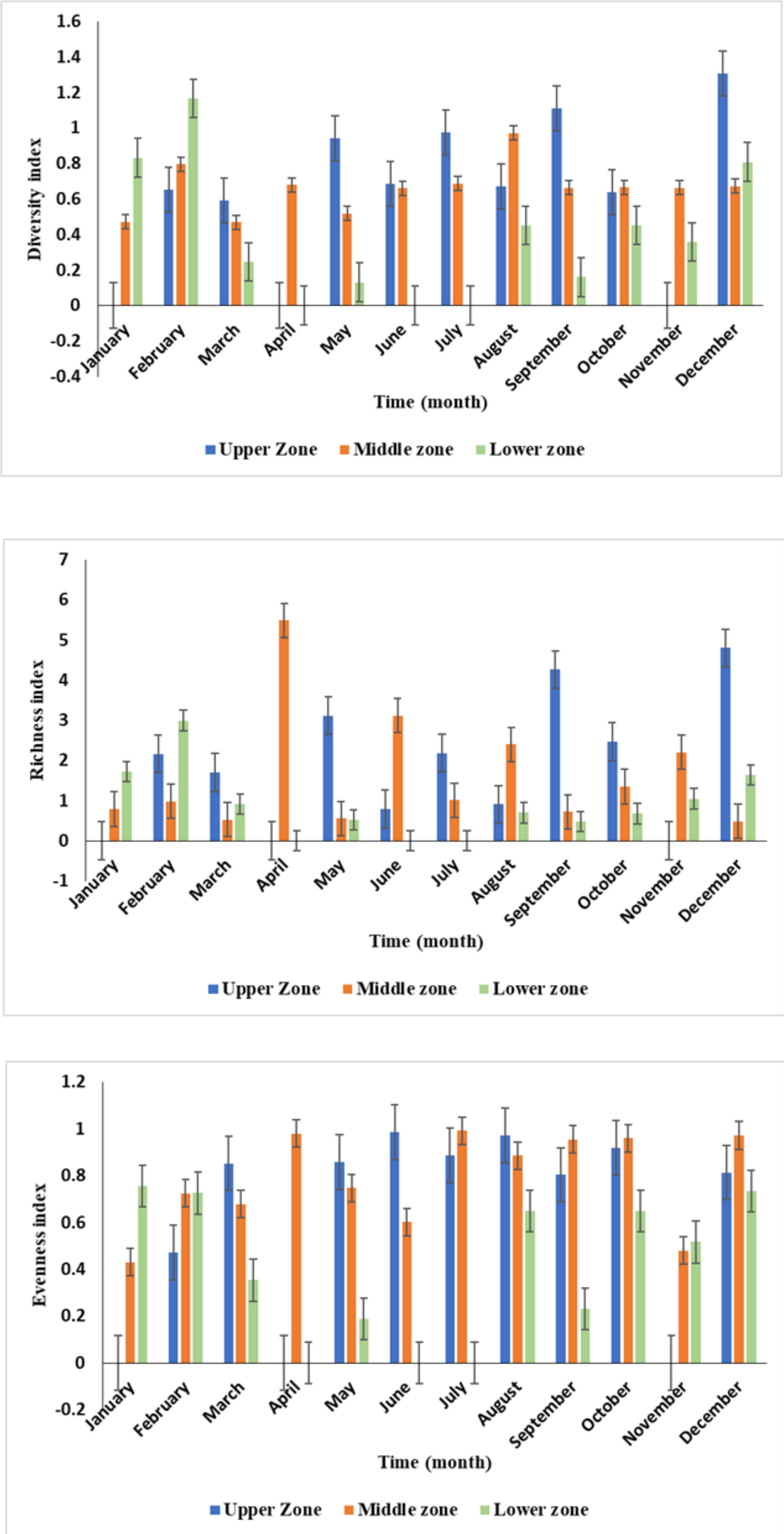

Figure 4. Diversity index, richness index and evenness index of benthic macrofauna at the three sampling stations on the high tourist station during January to December in 2022 at Tha Wang Bay, Sichang Island

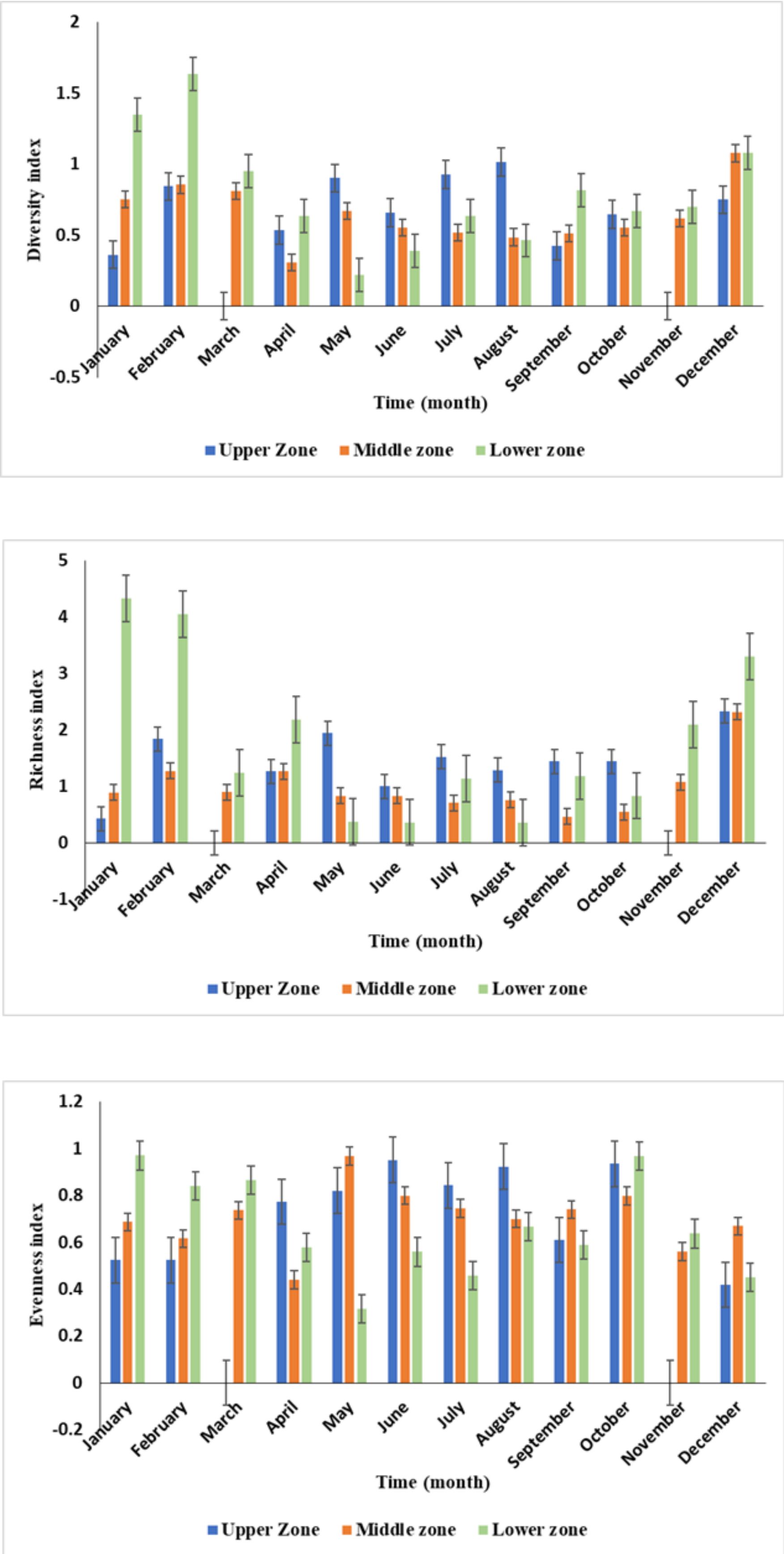

Figure 5. Diversity index, richness index and evenness index of benthic macrofauna at the three sampling stations on the low tourist station during January to December in 2022 at Tha Wang Bay, Sichang Island.

The results showed that there was statistically difference in total individual number of benthic macrofauna among the two sandy beaches (P = 0.029) and two study stations (P = 0.016) but statistically difference in the three sampling stations (P = 0.108), with no interaction of sandy beaches, study stations and sampling stations (P = 0.552) (Table 3). The average total individual numbers of benthic macrofauna in the high tourist station of Tham Phang Bay ranged from 38.95±17.04 to 62.30±22.20 and from 45.00±16.97 to 87.40±31.96 for those in low tourist station (Table 4), while the average total individual numbers of benthic macrofauna in the high tourist station of Tha Wang Bay ranged from 42.80±17.25 to 79.65±28.78 and from 83.15±33.73 to 140.95±41.08 for those in the low tourist station (Table 5).

Table 3. Summarization in analysis of variance performed on species number, total individual number, diversity index, richness index and evenness index of benthic macrofauna.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
1. Spices number					
Sandy beaches	13.500	1	13.500	1.670	0.221
Study sites	10.667	1	10.667	1.320	0.273
Sampling station	51.583	2	25.792	3.191	0.077
Sandy beaches x Study sites x sampling sites	49.083	7	7.012	0.867	0.557
2. Individual number					
Sandy beaches	4488.135	1	4488.135	6.155	0.029
Study sites	5741.227	1	5741.227	7.873	0.016
Sampling station	3935.823	2	1967.912	2.699	0.108
Sandy beaches x Study sites x sampling sites	4467.328	7	638.190	0.875	0.552
3. Diversity index					
Sandy beaches	0.493	1	0.493	16.131	0.002
Study sites	0.045	1	0.045	1.474	0.248
Sampling station	0.019	2	0.010	0.317	0.734
Sandy beaches x Study sites x sampling sites	0.117	7	0.017	0.548	0.783
4. Richness index					
Sandy beaches	0.988	1	0.988	2.236	0.161
Study sites	0.020	1	0.020	0.045	0.836
Sampling station	0.116	2	0.058	0.132	0.878
Sandy beaches x Study sites x sampling sites	0.770	7	0.110	0.249	0.963
5. Evenness index					
Sandy beaches	0.534	1	0.354	19.736	0.001
Study sites	0.035	1	0.035	1.303	0.276
Sampling sites	0.026	2	0.013	0.471	0.635
Sandy beaches x Study sites x sampling sites	0.137	7	0.020	0.725	0.655

R squared = 0.959 (Adjusted R squared = 0.924)

3.3 Diversity index, evenness index and richness index

Annual diversity, evenness index and richness index of the benthic macrofauna at three sampling stations on low and high of the two famous recreation sandy beaches at Tham Phang Bay and Tha Wang Bay, Sichang Island is presented in Figure 2 - 5. Results showed that there was statistically difference in diversity index of benthic macrofauna among the two sandy beaches (P = 0.002) but not for the two study stations (P = 0.248) and three sampling stations (P = 0.734), with no interaction of sandy beaches, study stations and sampling stations (P = 0.783) (Table 3). The average diversity index of benthic macrofauna in the high tourist station of Tham

Phang Bay ranged from 0.15±0.10 to 0.28±0.34 and from 0.21±0.07 to 0.55±0.18 for those in the low tourist station (Table 4), while the average diversity index of benthic macrofauna in the high tourist station of Tha Wang Bay ranged from 0.35±0.05 to 0.52±0.19 and from 0.44±0.21 to 0.70±0.14 for those in the low tourist station (Table 5).

Evenness index of benthic macrofauna was statistically different among the two sandy beaches (P = 0.001) but not for the two study stations (P = 0.276) and three sampling stations (P = 0.635), with no interaction of sandy beaches, study stations and sampling stations (P = 0.655) (Table 3). The average evenness index of benthic macrofauna in the high tourist station of Tham Phang Bay ranged from 0.18±0.11 to 0.28±0.32 and from 0.26±0.03 to 0.65±0.15 for those in the low tourist station (Table 4), while the average evenness index of benthic macrofauna in the high tourist station of Tha Wang Bay ranged from 0.14±0.01 to 0.67±0.16 and from 0.46±0.21 to 0.69±0.02 for those in the low tourist station (Table 5).

Richness index of benthic macrofauna was not statistically different among the two sandy beaches (P = 0.161), the two study stations (P = 0.836) and three sampling stations (P = 0.878), with no interaction of sandy beaches, study stations and sampling stations (P = 0.963) (Table 3). The average richness index of benthic macrofauna in the high tourist station of Tham Phang Bay ranged from 0.40±0.45 to 0.68±0.90 and from 0.46±0.05 to 0.65±0.70 for those in low tourist station (Table 4), while the average richness index of benthic macrofauna in the high tourist station of Tha Wang Bay ranged from 0.63±0.37 to 1.21±0.93 and from 0.75±0.34 to 1.24±0.78 for those in the low tourist station (Table 5).

Table 4 Average values of benthic macrofauna parameters at the three sampling stations on the low and high tourist stations during January to December in 2022 at Tham Phang Bay, Sichang Island

Parameters	Low tourist station			High tourist station		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**
Species number	5.0±2.83	4.5±2.12	8.0±5.66	4.5±3.54	5.5±0.71	7.5±2.12
Total individual number	45.3±13.7	62.3±22.2	38.9±17.0	45.0±16.9	87.4±31.9	71.2±28.1
Diversity index (H‘)	0.18±0.21	0.15±0.10	0.28±0.34	0.25±0.17	0.21±0.07	0.55±0.18
Evenness index (J‘)	0.23±0.27	0.18±0.11	0.28±0.32	0.28±0.15	0.26±0.03	0.65±0.15
Richness index (D‘)	0.68±0.91	0.40±0.45	0.68±0.90	0.65±0.70	0.55±0.52	0.46±0.05

Values are means± Standard error of three replicates per treatment.
P value was determined by one-way ANOVA followed by Duncan's multiple range test
* P > 0.05 = no significant difference
St 1 = Station 1 at the upper zone,
St 2 = Station 2 at the mid zone,
St 3 = Station 3 at the lower zone

Table 5 Average values of benthic macrofauna parameters at the three sampling stations on the low and high tourist stations during January to December in 2022 at Tha Wang Bay, Sichang Island

Parameters	Low tourist station			High tourist station		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**
Species number	7.5±0.71	4.5±2.12	6.0±2.83	6.0±0.01	6.0±1.41	11.0±2.83
Total individual number	42.8±17.25	79.7±28.78	70.4±22.1	83.2±33.73	97.3±35.00	140.9±41.08
Diversity index (H')	0.51±0.17	0.52±0.19	0.35±0.05	0.44±0.21	0.59±0.08	0.70±0.14
Evenness index (J')	0.52±0.15	0.67±0.16	014±0.01	0.46±0.21	0.69±0.02	0.67±0.01
Richness index (D')	1.21±0.93	1.04±0.84	0.63±0.37	0.83±0.53	0.75±0.34	1.24±0.78

Values are means± Standard error of three replicates per treatment.
P value was determined by one-way ANOVA followed by Duncan's multiple range test
* P > 0.05 = no significant difference
St 1 = Station 1 at the upper zone,
St 2 = Station 2 at the mid zone,
St 3 = Station 3 at the lower zone

4. Discussion

The present study showed that there was statistically difference in the diversity index of benthic macrofauna among the two sandy beaches but not for the two study sites and three sampling stations while the richness index was statistically different among the two sandy beaches, the two study sites and three sampling stations. The diversity index, evenness index and richness index of benthic macrofauna had no interaction among sandy beaches, study sites and sampling sites. No decreasing benthic biodiversity, densities and a change in the community occurs all year round in the two study sites and sampling sites at the two sandy beaches of Tham Phang Bay and Tha Wang Bay. Thus, the present study suggests that the distribution and diversity variations of the benthic macrofauna community are not affected by the various activities of recreations in the two sandy beaches at Tham Phang Bay and Tha Wang Bay, Sichang Island, Chonburi Province. The present results show that the high tourist sites had no significantly decreasing species diversity and richness on both Tham Pang and Tha Wang sandy beaches of Sichang Island. According to the sandy beaches with the high tourist sites reveal approximately equal of their potential species richness to those of the low tourist sites. Because most of the intertidal organisms examined in this study occur primarily in shallow sediments (no more than 10 cm below the sand surface), it was thought that human disturbance during the summer periods might well affect the abundance and distribution of this macrofauna. The results presented here do not provide any evidence of disturbance by beach users on the macrofauna during the summer studied. Similarly to our results, Wolcott & Wolcott (1984) mentioned that some of the animals studied anomuran crabs (*Emerita analoga*) are found at beach levels where the sand is relatively hard and most resistant to mechanical pressure (favourable for walking, running and gaming). However, they seem to be unaffected by this mechanical disturbance since we did not find any evidence of physical damage such as crushed carapaces. He did not find any effects of mechanical disturbance on anomuran crabs (*Emerita talpoida*) and bivalves (*Donax variabilis*) in an Atlantic beach of the USA.

In addition, Jaramillo et al. (1996) mentioned that the activity of the recreational sand beach users resulted in mound and through formation to appear, which eventually leads to sand movement (and hence erosion) towards the water line. The difference in magnitude of sand volumes removed by the effects of mechanical disturbances produced by recreational beach users versus that produced by waves or currents has not been thoroughly documented. However, it can reasonably expect that naturally occurring disturbances is a far more important disruptive event than mechanical disturbance by human activity. Even though the design of our experiment did not include the analysis of short-term effects (e.g. from tides to tides) which might show the effects of human activity, our results so far show that mechanical disturbance produced by recreational beach users is not expected to have a significant effect on the macrofauna. Most probably, in highly dynamic beaches, local effects such as those listed earlier are overrun by massive movements of sands due to the effect of a changing wave climate. However, demands for recreational facilities and property development along the Sichang Island sandy beaches have increased over the last few decades. Even when this study did not show any effect of mechanical disturbance by beach users, caution should be advised since high energy dissipative sandy beaches support quite diverse faunas. Rather than restricting use of these areas, management plans should be developed to minimise any eventual impact. In this sense, this study constitutes the first to manipulate human recreational pressures on a Sichang Island sandy beach or elsewhere; thus it provides an example of how ecological and recreational capacity of sandy beaches can be studied in order to quantify human impact on the whole sandy beach community as described by Jaramillo and McLachlan (1993); Jaramillo et al. (1993); Jaramillo et al. (1996).

On the other hand, Moffett et al. (1998) quantified the damage by tourist trampling In South Africa for intertidal macrofauna and found a loss of 5% to 70% depending on the species. The negative effect of trampling on *Talitrus saltator* (Crustacea) has been determined in different studies. According to their results, it is not possible to compensate for the losses during short periods of tourist activity during summer. In addition, the two bivalve mollusk species (*Donax* sp. and *Mactra* sp.) occurs annually as the two top dominant species in the two study stations and three sampling stations for both sandy beaches at Tham Phang and Tha Wang bays. The study sites of the high tourist activities in the sampling stations of high and middle zones did not appear to affect the abundance of these organisms. It may perhaps due to these molluscs with their capacity to burrow deep into the sands are able to withstand the mechanical disturbances from tourist activities and the presences of these molluscs may indicate that the sandy environments of both sandy beaches are still in good conditions without any signs of pollution under the sand substratum since these bivalves can moved to any place if the sandy environments are not suitable for their living. Thus, this study suggests the use of this species as a bioindicator for human impacts and environmental changes on these sandy beaches as they provide potentially simple and economic tools for long-term monitoring in irreversible loss biodiversity. However, Wilcock and Carter (1997) reported that at Van Stadens River Mouth beach, bivalves *Donax serra* were affected at the low as well as at the high intensity treatments, but in low numbers. This may be because a minimum number of *D. serra* were impacted initially, regardless of trampling intensity, and that after this initial impact, the surviving animals moved to a depth where they were not influenced by trampling. Other species, i.e. *Donax sordidus* and *Eurydice longicornis*, were impacted at the high trampling intensity only, but also in low numbers. In the volleyball courts, *D. serra* was affected to a greater extent, suggesting that such vigorous beach games may have a damaging effect on this species. Moffet et al. (1998) also investigated on the effects of varying intensities of human trampling in a holiday-activity simulation on sandy beach macrofauna at an exposed beach on the Eastern Cape coast. It was found that the clam *D. serra* was slightly impacted at all trampling intensities while *D. sordidus* and the isopod *E. longicomis* were affected only at high trampling intensities. Vigorous beach games, such as volleyball, may have a damaging effect on *D. serra* and also indicated that few members of the macrofauna were damaged at low trampling intensities but substantial damage occurred under intense trampling.

At present, no studies investigating the degree of loss under different intensities of tourist activity are available. According to tourist activity fluctuates in relation to weather, season, and week day. However, no studies are available that provide information about the level of tourist density which can be tolerated while preserving the species richness of the sandy beaches. Nevertheless, the present study mentions that sandy beach conservation is needed in order to preserve the species richness of the microbenthic fauna. A top priority is to implement long-term field experiments and monitoring programmes that quantify the dynamics of key ecological attributes on sandy beaches. As well, the immediate priority is to avoid further development of coastal areas likely to be directly impacted by retreating shorelines. In addition, zoning strategies and marine reserves, which have not been widely implemented in sandy beaches, could be a key tool for biodiversity conservation and should also facilitate negative effects into the adjacent beach habitats.

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