Diversity of zooplankton and benthic macroinvertebrates of estuarine coastal waters in Tien Giang province, southern Vietnam

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Abstract:

The Tien Giang province is located in the tropical climate zone of the Mekong delta. In this study, the diversity of zooplankton and benthic macroinvertebrates were investigated in the estuarine coastal waters of the Tien Giang province of southern Vietnam. 10 sites were observed over six time periods from 2019 (March, May, September, and November) and 2020 (March and May). The taxonomic richness, abundance, and diversity index were applied to this biodiversity assessment of the zooplankton and benthic macroinvertebrates. The results of the assessment showed that 30 species of zooplankton and 18 species of benthic macroinvertebrates were found in the study area. The density of zooplankton at each site ranged from 6 to 93 individuals/sample, while the density of benthic macroinvertebrates at each site fluctuated from 3 to 12 individuals/sample. The Shannon-Wiener diversity index of zooplankton fluctuated from 1.02 to 1.58 and that of the benthic macroinvertebrates ranged between 0.91 and 1.33. Besides, statistical analysis showed that the species richness of the zooplankton and benthic macroinvertebrates positively correlated with their density (r=0.2283-0.6423). This study contributes to the diversity information of zooplankton and benthic macroinvertebrates, which can be used to position the sustainable management of natural resources and evaluate the natural feed sources for aquaculture in this estuarine area.

Keywords: **benthic macroinvertebrates, biodiversity assessment, estuarine area, zooplankton.**

Classification number: **5.1**

Introduction

The Tien Giang province is located on the left bank of the Tien river and it borders the East Sea. The part of the Tien river that goes through the province is 103 km long [1]. It has a flat terrain with a slope below 1.0% and the altitude varies from 0 to 1.6 m from sea level. The whole province lies in the lower section of the Mekong river. This region has a tropical monsoon climate that divides the year into two seasons: the rainy season from May to November and the dry season from December to April of the following year [1]. In recent years, the Tien Giang estuarine area has received various types of wastewater from agriculture, aquaculture, industrial, and domestic activities. Specifically, environmental pollution is most evidenced in the area near the Vam Lang sea, where the seawater has turned black and has a foul odour. Besides this, waste is also scattered on the shore or floating in the water. In the areas where boats are anchored, grease and waste accumulate into floating patches on the water surface that further pollute the environment [2].

Being an integral part of river ecosystems, the zooplankton community is closely linked to other components of the aquatic ecosystem [3]. Zooplankton are the main food source for many other secondary consumers such as shrimp. Besides, they are frequently used as bioindicators for the trophic state of the water environment [4]. On the other hand, benthic macroinvertebrates such as molluscs live at the bottom of water bodies during their entire biological cycle. Among the communities that are considered as bioindicators of water quality, those most commonly used are benthic macroinvertebrates because they have several characteristics that make them easy to study. For example, benthic macroinvertebrates show clear responses to environmental conditions. The structure of the benthic communities in an aquatic ecosystem reflects ecological conditions including habitat heterogeneity [5]. In

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Europe and North America, the application of invertebrate communities to water quality assessment was developed in the first half of the twentieth century. European scientists developed an indicator species to monitor the water quality, while North American researchers applied biological indicators combined with ecological balance theory to evaluate the ecological health of water bodies [6]. In the 1970s and 1980s, Asian countries such as China, Korea, and Japan began to apply these methods to assess their water quality [7]. In 1996, Thailand was one of the first countries to build a monitoring system using macroinvertebrates in the Ping river. To match the conditions of north Thailand, Mustow (1997) modified the scoring system based on macroinvertebrates where he revised the BMWP[England] score system and called it the BMWP[Thai] [6, 8]. Only recently have aquatic biodiversity studies been conducted by scientists in Vietnam and, until now very few studies have evaluated the diversity of zooplankton and benthic invertebrates in the coastal areas of the Mekong delta.

In reports published by the MRC from 2004 to 2007, biodiversity studies of zooplankton and macroinvertebrates were only conducted in the Ba Lai estuary. The biological criteria for evaluation included taxa richness, abundance, and diversity [8]. X.Q. Ngo, et al. (2016) [9] developed a biomonitoring tool based on nematode communities in the Mekong estuaries concentrated in Ba Lai. Because studies of the effects of fishing and other aquacultural activities on the natural resources of coastal zooplankton and benthic macroinvertebrates in Tien Giang are limited, baseline data of zooplankton and benthic macroinvertebrates is crucial to the complete capture of the impacts of anthropogenic pressures.

This study evaluates the structure and composition of zooplankton and benthic macroinvertebrates in the estuarine coastal waters of the Tien Giang province, Vietnam. To the best of author's knowledge, this is the first account of the biodiversity of zooplankton and benthic macroinvertebrates in Tien Giang's estuary waters ever provided.

Materials and methods

Study area

The study area covers 100 km^2 of estuarine coastal waters along a 32-km coastline. The samples of zooplankton and benthic macroinvertebrates from 10 sampling sites were collected for 6 periods in 2019 (March, May, September, and November) and 2020 (March and May). The allocation of the sampling sites and nearby anthropogenic activities are shown in Fig. 1 and Table 1.
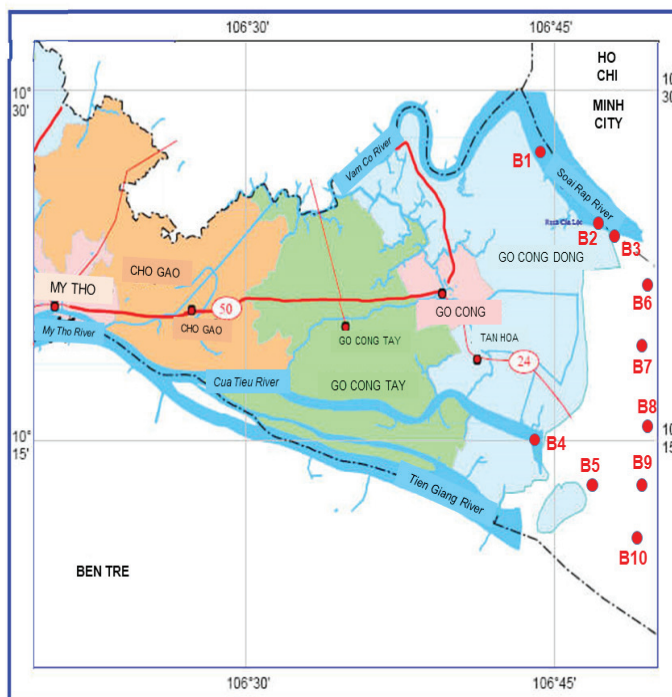
Fig. 1. The estuarine area along the Tien Giang coast with 10 sampling sites (B1-B10).

Table 1. Coordinates and locations of the sampling sites.

Sites	Local names	Describes	Longitude (N)	Latitude (S)
B1	Soai Rap river mouth	Aquaculture, fishing activities	106°46' 32.07"	10°25' 47.50"
B2	Vam Lang fishing port	Trading, fishing activities	106°47' 12.09"	10°24' 30.00"
B3	Vam Lang commune	Aquaculture, fishing activities	106°77' 92.42"	10°26' 78.83"
B4	Den Do fishing port	Aquaculture, fishing activities	106°74' 93.73"	10°26' 78.83"
B5	Phu Dong commune	Aquaculture, fishing activities	106°75' 52.95"	10°25' 11.60"
B6	Kieng Phuoc commune	Aquaculture, fishing activities	106°47' 50.08"	10°21' 43.50"
B7	Tan Dien area	Fishing activities	106°47' 29.06"	10°20' 27.90"
B8	Tan Thanh beach	Beach, aquaculture activities	106°47' 26.08"	10°17' 10.20"
B9	Tieu river mouth	Fishing activities	106°45' 31.05"	10°15' 28.10"
B10	Phu Tan area	Fishing activities	106°48' 13.06"	10°11' 10.50"

Sample collection

Zooplankton: at each site, 10 l of surface water (0-0.5 m deep) were collected in a bucket and filtered slowly through a plankton net with a mesh size of 20 μm. Water was splashed on the outside of the net to wash down any zooplankton adhering on the net [10, 11]. When there was

only about 150 ml water volume remaining in the net, the water was transferred into a 250 ml plastic jar. The sample was immediately fixed in the field with formaldehyde to a final concentration of 5% [10, 11].

Benthic macroinvertebrates: at each site, 4 sub-samples were taken with a Petersen grab sampler and pooled into a single sample, which covered a total area of 0.1 m². The contents from the grab were removed if the grab did not close properly because material such as wood, aquatic macrophytes, or stones may become trapped in the grab's jaws [10, 12]. Each sample was thoroughly washed with a sieve of mesh size 0.3 mm. The contents of the sieve were placed in jars and fixed with formaldehyde to a final concentration of 5% [10, 12]. The sample jars of zooplankton and benthic macroinvertebrates were labelled with the site name, the site's code, the date, and the sampling position [10-12].

Laboratory analysis

The identification of zooplankton and benthic macroinvertebrates were based on morphology and taxonomic books [13-21]. Zooplankton and benthic macroinvertebrates were identified to the species level. All individuals collected were identified and counted under an Olympus 41 compound microscope (with magnifications of 40-1200x) or a dissecting microscope (16-56x).

Data analysis

The qualitative and quantitative results of the zooplankton and benthic macroinvertebrates were used for the calculation of (i) taxonomic richness (number of taxa); (ii) abundance (numbers of individuals per site); and (iii) the Shannon-Wiener diversity index [22, 23]. The Shannon-Wiener diversity index is given below [24]:

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

where s is the number of species in a community and p_i is the proportion of each species in the sample.

Linear regression analysis was used to test for statistically significant relationships between the density and species richness and these were measured for all 10 sampling sites.

Results

Species richness

During the six monitoring times, there were 30 species of zooplankton and 18 species of benthic macroinvertebrates found in the study area. Among the zooplankton, hexanauplia was the dominant species composition with 19 species, which corresponds to around 63% of the total (Table 2). On the other hand, the number of polychaeta species of benthic macroinvertebrates was the highest with 9 species in total, which accounted for 50% of the total (Table 2).

Table 2. Communities of zooplankton and benthic macroinvertebrates from estuarine coastal waters in the Tien Giang province during 2019 and 2020.

Classes of zooplankton	Number of species	Proportion to total (%)	Classes of benthic macroinvertebrates	Number of species	Proportion to total (%)
Hydrozoa	1	3.3	Polychaeta	9	50.0
Eurotatoria	1	3.3	Gastropoda	2	11.1
Hexanauplia	19	63.4	Bivalvia	3	16.7
Malacostraca	3	10.0	Ophiurodea	1	5.5
Sagttodea	1	3.3	Malacostraca	3	16.7
Appendicularia	1	3.3			
Larva	4	13.4			
Total species	30	100	Total species	18	100

The zooplankton species of *Paracalanus parvus* and *Acartia clausi* (Hexanauplia) were found at all sampling sites. In addition, the species *Schamckeria speciosa*, *Oithona similis*, and nauplius copepods also occurred widely in the studied areas. Among the benthic macroinvertebrates, the polychaetes *Nereis (Ceratonereis) mirabilis* and the bivalves *Aloidis* sp. were the most species-rich groups and were found at almost all the sites.

The species richness of zooplankton at each site was highly variable and ranged from 2 to 9 species/site. The species richness of benthic macroinvertebrates at each site fluctuated from 2 to 6 species/site. The mean species richness of zooplankton and benthic macroinvertebrates are presented in Figs. 2 and 3.
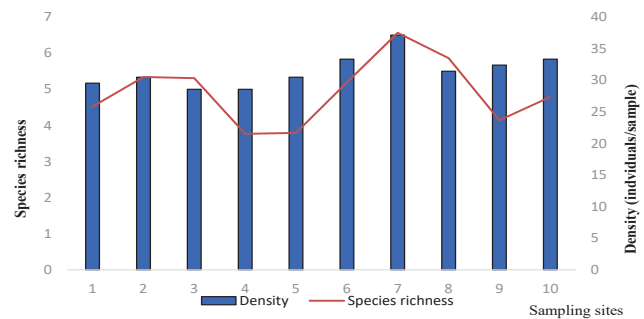
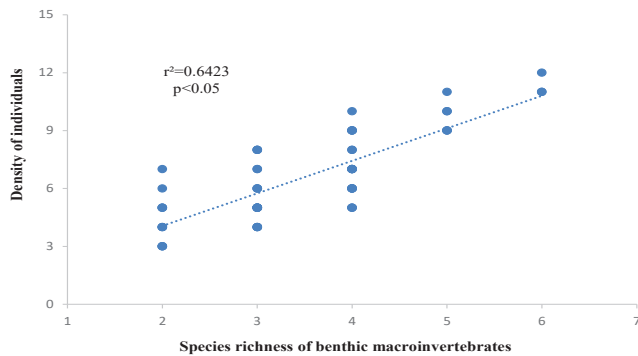**Fig. 2. Average values of density and species richness of zooplankton.**
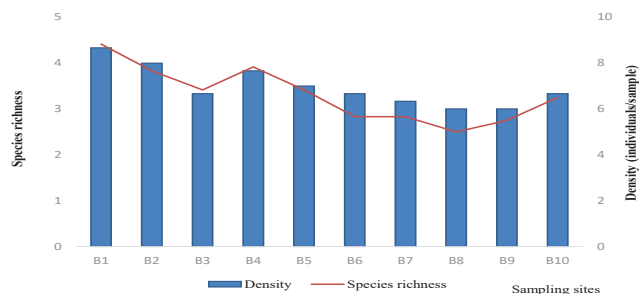
Fig. 3. Average values of density and species richness of benthic macroinvertebrates.
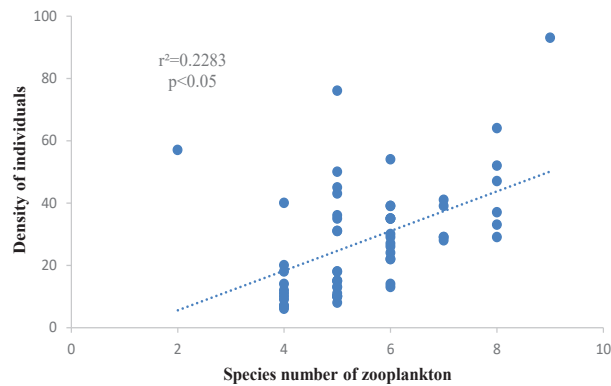
Abundance

The zooplankton abundances at each site were also highly variable and ranged from 6 to 93 individuals/site. The dominant species in the monitoring area were *Schmackeria speciosa, Oithona similis* and nauplius copepods. Among the dominant species, nauplius copepods were prevailing at most of the sampling sites. The benthic macroinvertebrates abundances at each site fluctuated from 3 to 12 individuals/site. The dominant species in the study area were *Nereis (Ceratonereis) mirabilis*, *Scoloplos (Scoloplos) marsupialis*, and *Aloidis* sp. Among the dominant species, *Aloidis* sp. prevailed at most of the sampling sites. The mean density of the zooplankton and benthic macroinvertebrates are presented in Figs. 2 and 3.

Correlation analysis

Statistical analysis showed that the species richness of the benthic macroinvertebrates had a strong positive correlation with

Fig. 4. Correlation between density and species richness of benthic macroinvertebrates.

Fig. 5. Correlation of density and species richness of zooplankton.

the abundance (r=0.6423, p<0.05) (Fig. 4), while the species richness of zooplankton also positively correlated with the abundance (r=0.2283, p<0.05) (Fig. 5).

Diversity index

The values of zooplankton biodiversity during the sampling times in 2019 and 2020 fluctuated between 1.02 and 1.58 while the values of benthic macroinvertebrates fluctuated between 0.91 and 1.33. Generally, the H' values of zooplankton and benthic macroinvertebrates do not differ significantly between sampling sites (Table 3).

Discussion

Pham, et al. (2016) [25] recorded 31 species of zooplankton in April and September 2015 from 5 sampling sites along the Can Giuoc river. The species of the copepods *Schmackeria bulbosa* and *Acartiella sinensis* were dominant in the zooplankton community. Throughout a 26-year sampling/monitoring program from 1989 to 2015 along the Thi Vai river and Cai Mep estuary, 38 benthic macroinvertebrates were reported of which polychaetes were also the dominant species composition [26]. In general, the monitoring results of zooplankton and benthic macroinvertebrates in the estuarine area are more diverse than in the coastal area.

Based on annual biological monitoring in this area, copepods and polychaetes significantly contribute to the species richness of zooplankton and benthic macroinvertebrates. This may be related to the water characteristics of the Tien Giang estuarine coastal waters, which are strongly influenced by seawater from the East Sea. Generally, the mean values of density and species richness of benthic macroinvertebrates collected from the onshore sites were higher than those in the offshore sites because of the softer bottom [27]. The mean values of density and species richness of zooplankton along the coastal bank sites were higher than those from the onshore sites because of lower turbidity [28].

The results of the correlation analysis for zooplankton and benthic macroinvertebrates showed that both organisms have a positive correlation between the species richness and number of individuals. The number of species and density of benthic macroinvertebrates in hard bottom areas may be lower than that in the soft bottom areas [27]. This may also have a similar influence on zooplankton, i.e. when strong sea waves make the bottom hard and force high turbidity, the abundance of this organism can be limited [28].

In general, the values of the biodiversity index (H') of zooplankton and benthic macroinvertebrates during the monitoring

Table 3. The biodiversity index (H') of zooplankton and benthic macroinvertebrates from the estuarine area in Tien Giang province during 2019 and 2020.

H'	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Zooplankton	1.32-1.33	1.31-1.37	1.31-1.32	1.12-1.23	1.28-1.45	1.35-1.45	1.53-1.58	1.04-1.22	1.21-1.49	1.18-1.36
Benthic macroinvertebrates	1.21-1.28	1.04-1.23	1.01-1.27	1.09-1.33	0.95-1.24	1.01-1.07	0.95-0.98	0.91-1.01	1.04-1.21	0.95-0.97

times were quite low. The H' values of zooplankton did not differ much between sampling sites, while the H' values of benthic macroinvertebrates seemed to be higher at sites near the river mouth. These results could be related to the hard bottom found in coastal areas in comparison with those near the river mouth. The recorded values of the biodiversity index for both zooplankton and benthic macroinvertebrates in this study were lower than previous research results from the Can Giuoc river, the Thi Vai river, and the Cai Mep estuary.

Conclusions

Throughout the 6 monitoring periods, the authors found 30 species of zooplankton and 18 species of benthic macroinvertebrates in the study area. Among the zooplankton, the number of species of hexanauplia dominated the species composition with 19 species in total, while the species polychaetes was the most prominent of the benthic macroinvertebrates with 9 species in total.

The density of zooplankton ranged from 6 to 93 individuals/sample. The dominant species in the monitoring area were *Schamckeria speciosa*, *Oithona similis*, and nauplius copepods. The densities of benthic macroinvertebrates fluctuated from 3 to 12 individuals/sample. The species of *Nereis (Ceratonereis) mirabilis*, *Scoloplos (Scoloplos) marsupialis*, and *Aloidis* sp. were dominant.

In general, the biodiversity of both zooplankton and benthic macroinvertebrates in the study area was low. This conclusion should be used to orient the sustainable management of natural resources and evaluate the natural feed sources of aquaculture in Tien Giang and the surrounding areas.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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