Aquatic Invertebrates and Their Correlation with Environmental Parameters in Coastal of Tien Giang Province, Mekong Delta in Vietnam

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The Tien Giang province is located in the tropical climate zone of the Mekong delta. The climate here is clearly divided into two main seasons, namely wet season and dry season and the average temperature is about 27°C. The coastline is 32 kilometers (20 mi) long with thousands of coastal warp, which is an advantage for aquatic breeding such as crab and sea-based economy development. Aquatic invertebrates are a diverse group of organisms that inhabit coastal area throughout the world, in regions spanning alpine, arid, Mediterranean, polar, temperate, and tropical climates. Estuarine coastal invertebrates include benthic, planktonic, and stygobitic taxa and range from widespread taxa to water quality assessment. Classified by size as either macroinvertebrates or smaller meiofauna, macroinvertebrates are more widely studied, although meiofauna can also be diverse and abundant in aquatic communities. The influence of environmental factors on the diversity of invertebrates was studied in the Tien Giang Coastal Area, Southern Vietnam. The study was done between March 2019 and September 2021, encompassing both dry and rainy seasons. Data from 10 sites were used as a representative example for the Tien Giang Coastal Area to conduct a qualitative study. To implement this evaluation, the analyses were based on MRC methods and classifications these improved by the scientific group. The biological and environmental variables were examined to test the analysis of variance (ANOVA) and the Pearson correlation among all the parameters using R statistical software. Significant or highly significant positive or negative correlations were assumed when the p-calculated value was < 0.05 or 0.01, respectively.

The results of the assessment showed that 32 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 85 individuals/sample, while the density of benthic macroinvertebrates at each site fluctuated from 4 to 15 individuals/sample. The calculated values for the diversity index (H') of both zooplankton and benthic macroinvertebrates fluctuated at the average level (H' ≈ 1.00 ÷ 1.72). The results also show that several environmental variables, including total suspended solid, chemical oxygen demand, and ammonium were correlated with species richness and density of aquatic invertebrates. The obtained results will be useful for the monitoring of pollution status at the study area in particular the sensitivity of aquatic invertebrates to changes of environmental characteristics.

Keywords: coastal area, aquatic invertebrates, physicochemical parameters, relationships, water quality assessment

1. Introduction

Tien Giang Province is located in the left bank of Tien River and borders the East Sea. The part of Tien River which goes through the province is 103 km long (Tien Giang Portal, 2020). It has flat terrain with a slope below 1%, and the altitude varying from 0 m to 1.6 m in comparison with the sea level. The whole province area is in the lower section of Mekong River, and borders the East Sea to the East. Tien Giang is in the climate zone of Mekong Delta – the tropical monsoon climate zone whose temperature is high and stable all year round. It is clearly divided into two seasons: the rainy season is from May to November which is at the same time with Southwestern monsoon and the dry season is from December to April of the following year which is at the same time with Northeastern monsoon (Tien Giang Portal, 2020). Currently, the Tien Giang estuarine coastal waters has been received many different effluents from agricultural, aquaculture, industrial and domestic activities by human beings.

Bioindicators are organisms or biological processes which indicate altered environmental conditions and can be used to identify and/or quantify the impact of pollutants on the environment. The aquatic organisms and their associations can monitor for changes that may indicate the problem within their ecosystem. The changes can be chemical, physiological, behavioral and ecological health. Ecological health can be viewed in terms of ecosystems, in which structural and functional characteristics are maintained. It can be expanded to include many aspects of human health and well-being. Each organism within an ecosystem has the ability to report on the health of its environment (Manickvasagam et al, 2019). In Vietnam, the zooplankton and the benthic macroinvertebrates are good indicators of river health because of particularly useful for biomonitoring (Pham, 2014). This research provided the first information on the diversity of zooplankton and benthic macroinvertebrates of estuarine coastal waters in Tien Giang in terms of species diversity, abundance, and evenness. Especially, the relationships between aquatic invertebrates and physicochemical variables for the water quality evaluation also were checked. The findings of this study could be used to predict and foresee the potential effects as well as assist decision-making in future coastal development and impact mitigation plans in the Tien Giang costal area.
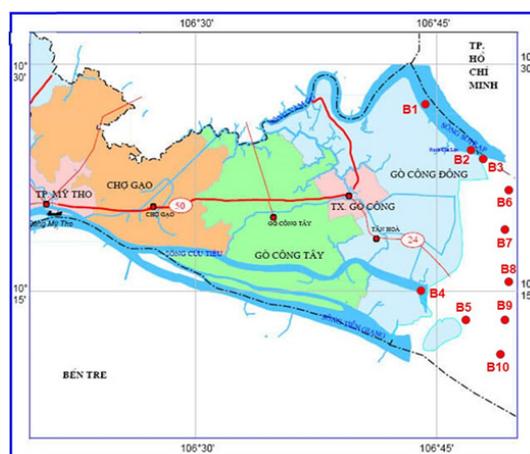
Fig. 1. Map of sample sites

Rys.1. Mapa obszaru opróbowania

Tab. 1. Coordinates and locations of the sampling sites

Tab.1. Koordynaty i lokalizacja miejsca pobierania próbek

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	106⁰ 77' 92,42"	10⁰ 26' 78,83"
B4	Den Do Fishing Port	Aquaculture, fishing activities	106⁰ 74' 93,73"	10⁰ 26' 78,83"
B5	Phu Dong Commune	Aquaculture, fishing activities	106⁰ 75' 52,95"	10⁰ 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"

Tab. 2. Communities of zooplankton and benthic macroinvertebrates in coastal of Tien Giang Province during 2019 and 2021. Numbers in the table indicated the species number of each class of zooplankton and benthic macroinvertebrates

Tab. 2. Zbiorowiska zooplanktonu i makrobezkręgowców bentosowych na wybrzeżu prowincji Tien Giang w latach 2019 i 2021. Liczby w tabeli oznaczają numer gatunku każdej klasy zooplanktonu i makrobezkręgowców bentosowych

Zooplankton	No. species	%	Benthic macroinvertebrates	No. species	%
Hydrozoa	1	3.1	Polychaeta	9	50.0
Oligogchaeta	1	3.1	Gastropoda	2	11.1
Eurotatoria	1	3.1	Bivalvia	3	16.7
Hexanauplia	19	59.5	Ophiurodea	1	5.5
Malacostraca	4	12.5	Malacostraca	3	16.7
Chaetognatha	1	3.1			
Appendicularia	1	3.1			
Larva	4	12.5			
Total species	**32**	**100**	*Total species*	**18**	**100**

The objectives of this research were to: (1) Study on the relationships between aquatic invertebrates and physicochemical variables for the water quality assessment in the Tien Giang Coastal Area, Southern Vietnam; and, (2) Provide the basic ecological health information of this area for local managers in activities water resource control.

2. Meterials and Methods
2.1. Study Sites and Sample Collection

Data from over 100 km² estuarine coastal waters of Tien Giang Province were used as a representative example for study areas. The samples of qualitative and quantitative invertebrates (both zooplankton and benthic macroinvertebrates) at 10 sites were collected in 06 times in March and September from 2019 to 2021 (Fig. 1; Tab. 1).

2.2. Sample Collection
2.2.1. Water Quality

For water quality, the samples for environmental quality analysis in the field were collected according to the guideline of water monitoring (UNWP. – GEMS/Water, 1992; ALPHA, 2012). The samples were taken in March and September of 2019, 2020, and 2021. Sample locations at each site were taken in depth layer of surface water from 30–40 cm. The water samples were collected in 2-liter plastic bottles and kept at 2°C temperature (UNWP. – GEMS/Water, 1992; ALPHA, 2012).

2.2.2. Zooplankton

Samples were taken at least 1 m from potential contaminants such as debris and aquatic plants. Before sampling at each site, the equipment is washed to remove any organisms and other matter left from the previous site. 10 L of river water at a depth of 0–0.5 m was collected in a bucket. The 10 L of river water was filtered slowly through a plankton net (with a mesh size of 20 μm) to avoid any overflow from the net. Water was splashed on the outside of the net to wash down any zooplankton adhering to the inner parts of the net (MRC, 2010; APHA, 2012)
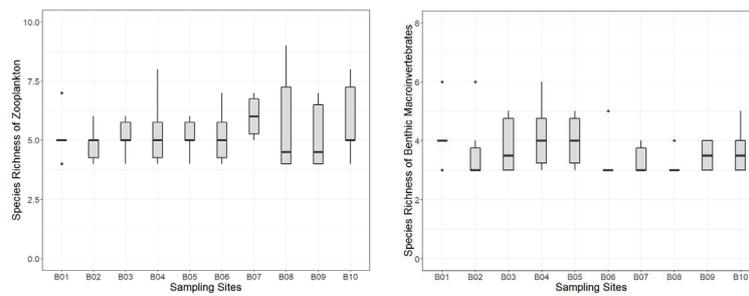
Fig. 2. Species richness of zooplankton and benthic macroinvertebrates in coastal of Tien Giang Province during 2019 and 2021
Rys. 2. Bogactwo gatunkowe zooplanktonu i makrobezkręgowców bentosowych na wybrzeżu prowincji Tien Giang w latach 2019 i 2021

Eudistylia polymorpha

Oithona similis

Fig. 3. Species indicated for rich nutrient and organic pollution in coastal of Tien Giang Province
Rys. 3. Gatunki wskazane jako bogate w składniki odżywcze i zanieczyszczenia organiczne na wybrzeżu prowincji Tien Giang

Sternaspis scutata

Paracalanus aculeatus

Fig. 4. Sensitive species with impacts of environmental pollution in coastal of Tien Giang Province
Rys. 4. Wrażliwe gatunki mające wpływ na zanieczyszczenie środowiska na wybrzeżu prowincji Tien Giang

When the water volume remaining in the net was only about 150 mL, the water (which contains the zooplankton sample) was transferred to a 250 mL plastic jar. The sample was immediately fixed in the field by adding ~75mL of 10% formaldehyde to achieve a final concentration of 4–5% formaldehyde. The sample jars were labelled with the site name, the site code, the sampling position, and the sampling date. These information were also noted in the field notebook, as was any information about the site that could be influencing the presence or abundance of different types of zooplankton (MRC, 2010; APHA, 2012).

2.2.3. Benthic Macroinvertebrates

Prior to sampling, all the equipment to be used was thoroughly cleaned to remove any material left from the previous sampling site. At each sampling location, a composite of four grabs was taken with a Petersen grab sampler, covering a total area of 0.1 m². If the sampler did not close properly because material such as wood, bamboo, large water-plants, or stones jammed its jaws, its contents were discarded and another grab was taken (MRC, 2010; Pham 2014; APHA, 2012).

The composite sample was washed through a sieve (0.3 mm) with care taken to be sure that macroinvertebrates did not escape. The contents of the sieve were then placed in jars and fixed with formaldehyde. Samples were sorted in the laboratory, because there was insufficient time at a site. The sample jar was labeled with the site location code, date, position within the river, and replicate number. The sampling location conditions, collector's name were recorded on a field sheet (MRC, 2010; Pham 2014; APHA, 2012).

2.3. Analytical Methods
2.3.1. Physical and Chemical Analysis

The aquatic environmental parameters (pH, total suspended solid – TSS, dissolve oxygen – DO, chemical oxygen demand – COD, amonium – NH_4^+, and chlorine – Cl^-) were analyzed according to standard methods (APHA, 2012).

2.3.2. Zooplankton and Benthic Macroinvertebrate Analysis

The identification of zooplankton and benthic macroinvertebrates were based on morphology based on morphology under a microscope (Olympus 41). Hydrozoa, Oligochaeta, Polychaeta, Gastropoda, Bivalvia, Ophiuroidea, and Crustacea, Chaetognatha, and Appendicularia were generally identified to species level. Insecta and Insecta larvae were classified only to genus level (MRC, 2010;
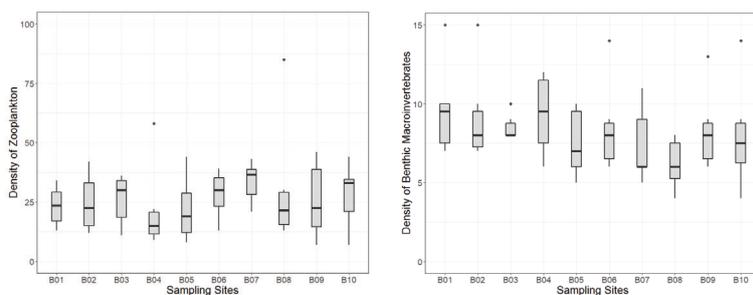
Fig. 3. Density of zooplankton and benthic macroinvertebrates in coastal of Tien Giang Province during 2019 and 2021

Rys. 3. Zagęszczenie zooplanktonu i makrobezkręgowców bentosowych na wybrzeżu prowincji Tien Giang w latach 2019 i 2021

Tab. 4. Values of biodiversity index (H') of zooplankton and benthic macroinvertebrates from Estuarine Coastal Waters in Tien Giang Province during 2019 and 2021. Notes: H' (Shannon-Wiener Diversity Index), and DS (Simpson Dominance Index)

Tab. 4. Wartości wskaźnika bioróżnorodności (H') zooplanktonu i makrobezkręgowców bentosowych z wód przybrzeżnych ujść rzek w prowincji Tien Giang w latach 2019 i 2021

Sites	Zooplankton	Benthic Macroinvertebrates	Ranking (Pham 2014)
B1	1.08 – 1.61	1.14 – 1.59	Low moderate pollution – High moderate pollution
B2	1.03 – 1.47	1.03 – 1.41	High moderate pollution
B3	1.00 – 1.52	1.04 – 1.47	Low moderate pollution – High moderate pollution
B4	1.00 – 1.52	1.03 – 1.68	Low moderate pollution – High moderate pollution
B5	1.16 – 1.52	1.01 – 1.47	Low moderate pollution – High moderate pollution
B6	1.02 – 1.54	1.01 – 1.49	Low moderate pollution – High moderate pollution
B7	1.07 – 1.61	1.01 – 1.33	High moderate pollution
B8	1.02 – 1.39	1.01 – 1.24	High moderate pollution
B9	1.03 – 1.72	1.01 – 1.32	High moderate pollution
B10	1.03 – 1.71	1.01 – 1.49	Low moderate pollution – High moderate pollution

SMEWW 10200G, 2017; SMEWW 10500, 2017; APHA, 2012). The results were recorded on data sheets and specimens are kept at the Ton Duc Thang University, Ho Chi Minh City, Vietnam.

The identification of zooplakton and benthic macroinvertebrates was based on morphology and taxonomic books such as Zooplankton (Fiji, 1993; Edmondson 1976); Microcrustacea (Edmondson, 1976; Dang et al., 1980; Dang & Ho, 2001; Karanoic, 2012); Polychaeta (Fauvel, 1953; Usakov, 1955; Day, 1967; Dejian & Raping, 1985); Oligochaeta (Dang et al., 1980; Sangpradub & Boonsoong, 2006 Thai 2007); Gastropoda (Brandt, 1974; Dillon, 2004; Sangpradub & Boonsoong, 2006; Dang & Ho, 2012); Bivalvia (Brandt, 1974; Dillon, 2004; Sangpradub & Boonsoong, 2006; Dang & Ho, 2012); Crustacea (Bouvier, 1925; Holthuis, 1950; Gurianova, 1951; Tiwari, 1963; Kensley & Schotte, 1989; Hayward & Raland, 1990; Sangpradub & Boonsoong, 2006; Dang & Ho, 2012).

2.4. Data Analysis

The following metrics of zooplakton and benthic macroinvetebrates at all sites sampled in March and September from 2019, 2020 and 2021 were calculated (i) taxonomic richness (i.e. number of taxa); (ii) abundance (i.e. numbers of individuals per site); and, (iii) the Shannon-Wiener Diversity Index (Mandaville, 2002; Stiling, 2002). The obtained data were subject to statistical analysis to test the analysis of variance (ANOVA) and the Pearson correlation among all the parameters using R statistical software. Significant or highly significant positive or negative correlations were assumed when the p-calculated value was < 0.05 or 0.01, respectively. The three metrics were tested for their potential as indicators of human impact by regressing values for two seasons of 2019, 2020 and 2021 (60 sampling events for 10 sites) against the water quality variables (pH, TSS, DO, COD, NH_4^+, and Cl^-).

3. Results and Discussions
3.1. Taxa Richness

During the six monitoring times, there were 32 species of zooplankton and 18 species of benthic macroinvertebrates in the studied area. Among the zooplankton, species number of hexanauplia was dominant in species composition with 19 species in total, gaining around 59.5% of total (Table 2). The Hexanauplia constituted comprised two groups: the Copepoda and the Tantulocarida. The Crustacea (especially Copepoda) had more abundant species than other phyla or classes (Modamed et al., 2004). While the species number of polychaeta was highest in the species composition of benthic macroinvertebrates with 9 species in total, accounting for 50.0% of the total (Tab. 2). The species richness of zooplankton and benthic macroinvertebrates recorded in Coastal of Tien Giang Province during 2019 and 2021 did not fluctuate much among the sampling sites (Fig. 2). Pham et al. (2021) also provide the information about more abundant species of Polychaeta than other classes.

The species of Paracalanus parvus and Acartia clausi (Hexanauplia) could be found in all sampling sites of zooplankton. In addition, the species of Acartia clausi, Oithona similis and nauplius copepods also occurred widely in the studied areas. For benthic macroinvertebrates, the polychaetas of Nereis (Ceratonereis) mirabilis and the bivalves of Aloidis sp. were the most species-rich groups and occurred in almost sites, while others appear in few sites.

Because of sampling in the coastal region (Pham & Le 2004; Pham et al. 2011), and these records were expressed clearly through the appearances of almost species of marine zooplankton and benthic macroinvertebrates. The species indicated for rich nutrient and organic pollution occurred in near urban and industrial areas sites, including the species of Nephthys polybranchia, Polydora sp., Eudistylia polymorpha, Scoloplos (Scoloplos) marsupialis, Goniada (Goniadopsis)
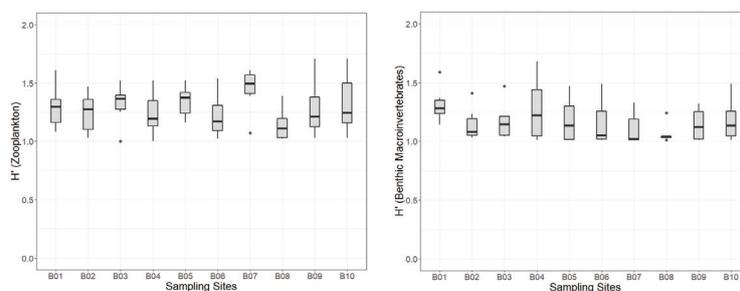
Fig. 4. Diversity index of zooplankton and benthic macroinvertebrates in coastal of Tien Giang Province during 2019 and 2021

Rys. 4. Wskaźnik różnorodności zooplanktonu i makrobezkręgowców bentosowych na wybrzeżu prowincji Tien Giang w latach 2019 i 2021

incerta, Terebellides stroemi (Polychaeta); Acartia clausi, Oithona similis (Microcrustacea) (Figure 3). While, the species of Nereis (Ceratonereis) mirabilis, Sternaspis scutata (Polychaeta); Paracalanus aculeatus, Acartia pacifica (Microcrustacea) were sensitive species with impacts of environmental pollution (Figure 4). Similar to the studies of recorded, this coastal area had a hard bottom beds, creating unfavorable conditions for the development of benthic macroinvertebrates (Pham and Le, 2004; Pham et al., 2011; Le et al., 2012; Pham et al. 2021). The studied results in the coastal of Tien Giang Province also provided information about the invertebrates richness in tropical sandy beaches along the Rio de Janeiro coast were related mainly to granulometric variables, decreasing in fine and very fine sediment (Fernanda et al. 2020).

Invertebrate assemblages responded to spatial and temporal variability with changes in their abundance and taxonomic richness. The analyses showed that local-scale factors (e.g. grain size) were the most important spatial determinants for the ordination of aquatic macroinvertebrates (Aurea et al. 2016). While Yildiz et al. (2010) determined the 4 most important environmental variables (elevation, water depth, dissolved oxygen, and temperature) affecting species distribution in general.

3.2. Density and Dominant Species

The density of zooplankton in each sites was highly variable, ranging from 9 to 85 individuals/sample. The dominant species in the monitoring area were Schmackeria speciosa, Oithona similis and nauplius copepods. Among the dominant species, nauplius copepods was dominant at most of the sampling sites. For the density of benthic macroinvertebrates in each site, it fluctuated from 4 to 15 individuals/sample. The dominant species in the study area were Nephthys polybranchia, Nereis (Ceratonereis) mirabilis, Scoloplos (Scoloplos) marsupialis, Aloidis sp. Among the dominant species, Aloidis sp. was dominant at most of the sampling sites.

The changes of density and dominant species at 07 sites expressed clearly the environmental characteristics of the study area with high suspended solid concentrations. Although the coastal in Tien Giang Province had good self-cleaning mechanisms which allow survival of these communities. However, the concentrations of TSS fluctuated from 73 (site B4) ÷ 115 mg/L (site B9) that effects on the density of both zooplankton and benthic macroinvertebrates. This findings for density and dominant species were discussed in the aquatic flora and fauna monitoring in coastal of the Tien Giang Province 2018 – 2021 (Pham et al. 2021).

3.3. Diversity Index

The values of zooplankton biodiversity index during the monitoring times in 2019 and 2021 ranged from 1.00 to 1.71; while the values of benthic macroinvertebrates fluctuated from 1.01 to 1.68 (Tab. 4). The H' values of zooplankton and benthic macroinvertebrates were not highly different between sampling sites (Tab. 4).

Generally, the bio-index values of zooplankton and benthic macroinvertebrates did not change much among the sampling sites. The bio-index analysis proved that the sustainability of aquatic flora in water column and bottom bed in the study area was not high. The water quality in coastal of Tien Giang Province fluctuated from low moderate pollution to high moderate pollution.

3.4 Relationships of Zooplankton and Benthic Macroinvertebrates with Physicochemical Variables

The results showed that the correlation between environmental and biological parameters was not high (Figure 5). While Joshi et al. (2007) concluded the level of species richness was found dependent on the abiotic factors like temperature, hardness, pH, dissolved oxygen, chloride. However, there were the significant positive correlations among the physicochemical variables, including TSS, COD, NH_4^+ (0.60 ÷ 0.79), whereas TSS exhibited a significant positive correlation with COD (0.79) and NH_4^+ (0.60). While COD showed a strong positive correlation with NH_4^+ (0.75) (Fig. 5). Additionally, there were the significant positive correlations between the species richness of zooplankton with the density and H' index (0.57 ÷ 0.59); the species richness of benthic macroinvertebrates with the density and H' index (0.62 ÷ 0.87). The monitoring results of zooplankton and benthic macroinvertebrates in coastal of the Tien Giang Province indicated that the climatic changes were the fundamental causes determining the processes leading to changes in zooplankton composition (in qualitative and quantitative terms), but anthropogenic factors may considerably influence and change the shape of these processes as Kovalev et al. (1998).

4. Conclusion

During the six monitoring times, we found 30 species of zooplankton and 18 species of benthic macroinvertebrates in the studied area. Among the zooplankton, species number of hexanauplia was dominant in species composition with 19 species in total, while the species number of polychaetas was highest in the species composition of benthic macroinvertebrates with 9 species in total.
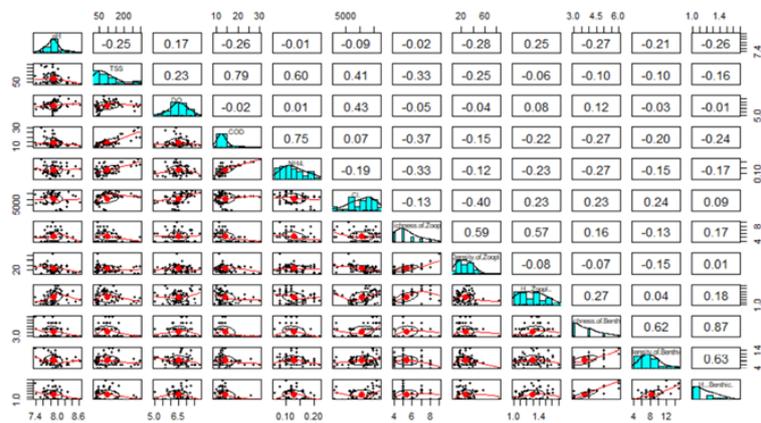

Fig. 5. Relationships between the metrics of physiochemical variables and aquatic invertebrates for sites sampled in coastal of Tien Giang Province during 2019 and 2021

Rys. 5. Zależności między metrykami zmiennych fizykochemicznych a bezkręgowcami wodnymi dla miejsc pobranych na wybrzeżu prowincji Tien Giang w latach 2019 i 2021

The density of zooplankton ranging from 6 to 85 individuals/sample. The dominant species in the monitoring area were Schamckeria speciosa, Oithona similis and nauplius copepods. The densities of benthic macroinvertebrates were fluctuated from 4 to 15 individuals/sample. The species of Nereis (Ceratonereis) mirabilis, Scoloplos (Scoloplos) marsupialis, Aloidis sp. were dominant.

Generally, the biodiversity of zooplankton and benthic macroinvertebrates was not high. The water quality in coastal of Tien Giang Province fluctuated from low moderate pollution to high moderate pollution.

The findings of this study could be used to orient the sustainable management of natural resources and evaluate the natural feed sources for aquaculture in Tien Giang and surrounding areas.

The results showed that the correlation between environmental and biological parameters was not high. However, there were the significant positive correlations among the physicochemical variables, including TSS, COD, NH_4^+ (0.60 ÷ 0.79). Additionally, there were the significant positive correlation between the species richness of zooplankton with the density and H' index (0.57 ÷ 0.59); the species richness of benthic macroinvertebrates with the density and H' index (0.62 ÷ 0.87).

The results confirmed the advantage of using benthic macroinvertebrates and their indices as useful tools for environmental monitoring and ecological health assessment. Therefore, monitoring programs should continue to control and maintain the environmental quality of the Tien Giang Coastal Area.

5. Acknowledgement

Literatura – References

1. American Public Health Asociation (APHA). (2012). Standard methods for the examination of water and waste-water, 21st Ed. American Public Health Association, American Water Works Association and Water Environment Federation, Washington.

2. Aurea, L. L. S., Jéssica R. P., Paulo R. P., and Mauricio M. P.. (2016). Distribution of aquatic macroinvertebrate assemblages in a subtropical coastal lake: Response to environmental parameters, Fundam. Appl. Limnol., 188(2), 113–127.

3. Brandt, R. A. M. (1974). The non – marine aquatic mollusca of Thailand. Frankfurt and Main.

4. Dang, N. T., Thai, T. B. & Pham, V. M. (1980). Identification of invertebrates in North Vietnam. Publisher of Science and Technology, Hanoi.

5. Dang, N.T. & Ho, T.H. (2012). Freshwater Decapoda in Vietnam: Palaemonidae, Atyidae, Parathelphusidae, Potamidae. Publisher of Science and Technology, Hanoi.

6. Day, J. H... (1967). Monograph on the Polychaeta of Southern Africa. Part 2: Sedentaria. Trustees of the British Museum (Natural History), London.

7. Dejian, Y. & Raping, S. (1985). Polychaetous Annelids commonly seen from the Chinese waters. Agriculture Publisher.

8. Dillon, Jr. R. T.. (2004). The ecology freshwater molluscs. Cambridge University Press, Cambridge.

9. Sangpradub, N. & Boonsoong, B. (2006). Identification of freshwater invertebrates of the Mekong River and its tributaries, MRC, Vientiane.

10. Edmondson, W. T.. (1976). Freshwater biology (2nd Ed.). John Wiley & Sons, New York.

11. Edokpayi, C. A., Olowoporoku, A. O. & Uwadiae, R. E.. (2010). The hydrochemistry and macrobenthic fauna characteristics of an urban draining creek. Journal of Biodiversity and Conservation, 2(8), 196-203.

12. Fauvel P.. (1953). The fauna of India including Pakistan, Ceylon, Burma and Malaya. Annelida Polychaeta. Allahabad the Indian Press, LTD.

13. Fernanda, S. A., Rafaela S. G., Francisco, G. A.. 2020. Fish and benthic invertebrate relationship and their association to environmental variables in tropical sandy beaches. Environ Biol Fish, 103, 1309–1321.

14. Gurianova, E. F.. (1951). Amphipoda of URRS sea and neighboring waters (Amphipoda – Gammaridea). URRS Academy Publisher, Moscow.

15. Hayward, P. J. & Ryland, J. S.. (1990). The marine fauna of the British Isles and North-West Europe. Volume I: Introduction and Protozoans to Arthropods. Clarendon Press, Oxford.

16. Holthuis, L. B.. (1950). Decapoda of the siboga expedition. Part X: The Palaemonidae collected by the siboga and snelluis expeditions with remarks on other species I, Subfamily Palaemininae. E. J. Brill. Leiden, Holand.

17. Joshi, P. C., Negi, R. K., Negi, T.. (2007). Seasonal variation in benthic macro-invertebrates and their correlation with the environmental variables in a freshwater stream in Garhwal region (India). Life Science Journal, 4(4), 85-89.

18. Kensley, B. & Schotte, M.. (1989). Guide to the marine Isopod Crustaceans of the Caribbean. Smithsonian Institution Press, Washington, D.C. and London.

19. Kovalev, A. V., Skryabin, V. A., Zagorodnyaya, Bingel, A., Kideys, A. E., Niermann, U., Uysal, Z.. (1999). The Black Sea Zooplankton: composition, spatial/temporal distribution and history of investigations. Tr. J. of Zoology, 23, 195-200.

20. Mandaville, S. M.. (2002). Benthic macroinvertebrates in freshwaters: taxa tolerance values, metrics, and protocols. Soil and Water Conservation Society of Metro Halifax.

21. Le, P. N., Le, P. Q. & Pham, A. D.. (2012). Study of ranking of bio-indices using benthic macroinvertebrates for Lower Dongnai River System, Vietnam. Journal Environmental Science and Engineering, 4(2), 196-205.

22. Le, T. & Le, Q. H.. (2004). The environmental characteristics of the Saigon – Dongnai River Basin. Publisher of Science and Technology, HCMC.

23. Manickavasagam, S., Sudhan, C., Bharathi, A., and Anabd, S.. (2019). Bioindicators in aquatic environment and their significance. J. Aqua Trop. 34(1), 73-79.

24. Mohamed, Z., Mahmoud, I. & Amany, M.. (2004). Impact of environmental parameters on benthic invertebrates and Zooplankton biodivrty of the Eastern Region of Delta Coast at Daietta, Egypt. Egypt J. Aquaf. BioL & Fish, 8(4), 37-52.

25. Mekong River Commission (MRC). (2010). Biomonitoring methods for the Lower Mekong Basin. MRC, Vientiane.

26. Pham, A. D.. (2014). Study on the water quality assessment using benthic macroinvertebrates for the Lower Dongnai River biomonitoring, Vietnam. PhD Dissertation, Institute for Environment and Resources, Vietnam National University, HCMC, 159 pp.

27. Pham, A. D., Nguyen. T. M. L., Pham, V. M. & Dao, T. S.. (2011). Aquatic flora and fauna monitoring in Dongnai River System 2006 – 2011. Research Project, Institute of Meteorology, Hydrology and Environment, HCMC.

28. Pham, A. D., Pham, V. M. & Dao, T. S.. (2021). Aquatic flora and fauna monitoring in coastal of the Tien Giang Province 2018 – 2021. Annual Environment Monitoring of Coastal in Tien Giang Province, Ton Duc Thang University, HCMC.

29. Pham, V. M. & Le, T.. (2004). Study on Bio-indicators for water bodies in Ho Chi Minh City. Research Project, HCMC Department of Science and Technology, HCMC.

30. Stiling, P.. (2002). Ecology: theories and applications, 4th Ed.. Prentice-Hall of India Private Ltd, New Delhi.

31. Thai, T. B.. (2007). Invertebrates. Publisher of Science and Technology, Hanoi.

32. Tien Giang Portal. (2020). People's Committee of Tien Giang Province, Tien Giang.

33. Tiwari, K. K. (1963). Alpheid Shrimps (Crustacea: Decapoda: Alpheidae) of Vietnam. Annual Faculty Science Saigon, 269-362.

34. UNWP. – GEMS/Water.. 1992. Operational Guide (3rd Ed.). UN Environment Programme, Burlington.

35. Usakov, P.. V. (1955). URRS Fauna – Polychaeta. URRS Academy Publisher, Moscow.

36. Yildiz, S., Ozbek, M., Ustaoglu, M. R., Somek, H.. (2012). Distribution of aquatic oligochaetes (Annelida, Clitellata) of high-elevation lakes in the Eastern Black Sea Range of Turkey. Turk J Zool, 36(1), 59-74.

Bezkręgowce wodne i ich korelacja z parametrami środowiska na wybrzeżu prowincji Tien Giang, delta Mekongu w Wietnamie

Prowincja Tien Giang położona jest w strefie klimatu zwrotnikowego delty Mekongu. Klimat jest tutaj wyraźnie podzielony na dwie główne pory roku, a mianowicie porę deszczową i porę suchą, a średnia temperatura wynosi około 27°C. Linia brzegowa ma 32 kilometry (20 mil) długości i bardzo urozmaiconą linię brzegową, co jest zaletą dla hodowli wodnych, takich jak kraby i rozwój gospodarki morskiej. Bezkręgowce wodne to zróżnicowana grupa organizmów zamieszkujących obszary przybrzeżne na całym świecie, w regionach obejmujących klimat alpejski, suchy, śródziemnomorski, polarny, umiarkowany i tropikalny. Bezkręgowce przybrzeżne ujść rzek obejmują taksony bentosowe, planktonowe i stygobitowe, od szeroko rozpowszechnionych taksonów do oceny jakości wody. Klasyfikowane według wielkości jako makrobezkręgowce lub mniejsza meiofauna, makrobezkręgowce są szerzej badane, chociaż meiofauna może być również różnorodna i obfita w społecznościach wodnych. Wpływ czynników środowiskowych na różnorodność bezkręgowców badano na obszarze przybrzeżnym Tien Giang w południowym Wietnamie. Badanie zostało przeprowadzone w okresie od marca 2019 do września 2021, obejmując zarówno porę suchą, jak i deszczową. Dane z 10 miejsc wykorzystano jako reprezentatywny przykład dla obszaru przybrzeżnego Tien Giang do przeprowadzenia badania jakościowego. Aby przeprowadzić tę ocenę, analizy oparto na metodach MRC i klasyfikacjach, które zostały udoskonalone przez grupę naukową realizującą badania. Badano zmienne biologiczne i środowiskowe w celu przetestowania analizy wariancji (ANOVA) i korelacji Pearsona R między wszystkimi parametrami przy użyciu oprogramowania statystycznego. Przyjęto znaczące lub bardzo istotne dodatnie lub ujemne korelacje, gdy obliczona wartość p wynosiła odpowiednio <0,05 lub 0,01. Wyniki oceny wykazały, że na badanym obszarze stwierdzono występowanie 32 gatunków zooplanktonu i 18 gatunków makrobezkręgowców bentosowych. Zagęszczenie zooplanktonu na każdym stanowisku wahało się od 6 do 85 osobników/próbę, podczas gdy zagęszczenie makrobezkręgowców bentosowych na każdym stanowisku wahało się od 4 do 15 osobników/próbę. Obliczone wartości wskaźnika różnorodności (H') zarówno zooplanktonu, jak i makrobezkręgowców bentosowych oscylowały na średnim poziomie (H' ≈ 1,00 ÷ 1,72). Wyniki pokazują również, że kilka zmiennych środowiskowych, w tym całkowita zawiesina, chemiczne zapotrzebowanie tlenu i amon, było skorelowanych z bogactwem gatunkowym i gęstością bezkręgowców wodnych. Uzyskane wyniki będą przydatne do monitorowania stanu zanieczyszczenia badanego obszaru, w szczególności wrażliwości bezkręgowców wodnych na zmiany cech środowiska.

Słowa kluczowe: *obszar przybrzeżny, bezkręgowce wodne, parametry fizykochemiczne, zależności, ocena jakości wody*