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Zooplankton assemblages in De Gi lagoon, Binh Dinh province

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Abstract
This paper presents the results of zooplankton surveys in De Gi lagoon 2009, 2010, and 2020. Change of zooplankton communities was analyzed based on species richness, diversity, abundance, and species composition over the three sampling time points. In De Gi lagoon, the copepod group (subclass Hexanauplia) dominated with 61 in 85 zooplankton identified species, followed by Hydrozoa and Malacostraca with seven and five species, respectively. The remaining groups (Polychaeta, Branchiopoda, Ostracoda, Sagittoidea, Appendicularia, Thaliacea, Tentaculata, and Gastropoda) had low species richness, varied from 1 to 2 species. The Copepod assemblages compose mainly small species and have good adaptation in high salinity variabilities, such as *Paracalanus* and *Acartia*. In the lagoon, species richness and diversity increased from the upper lagoon to the lagoon's mouth over the years, but most pronounced in 2020. The average zooplankton density this year was low, 9.136 inds.m^{-3}, much lower than in 2009 with 54.022 inds.m^{-3}. Cluster analysis demonstrated the complexity of the zooplankton structure in the lagoon when the similarity in species composition between seasons and years is ca. 27%. Seasonal changes in zooplankton assemblages presented 58-73% dissimilarity, with the dry season having higher diversity, biomass, and calanoid copepodites and larvae. After ten years, since 2010, the zooplankton assemblages differed by 60-72% with higher diversity and lower abundance but remained similar ratios between dominant Calanoida and other orders in the copepod assemblages. Invertebrate larval abundance in De Gi lagoon should be considered as an important resource for their dominance and variation between seasons and distribution. This research provides basic scientific data on the zooplankton communities of De Gi lagoon, which has not been published before, contributing the baseline to any further studies the South-Central Viet Nam.

Keywords: Zooplankton assemblages, De Gi lagoon, Binh Dinh.

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INTRODUCTION

De Gi lagoon is a relatively closed water body with 15 square kilometers, located between Phu Cat and Phu My districts, Binh Dinh province. This lagoon has freshwater input from La Tinh river, connects to the open sea through a narrow mouth, and is surrounded by aquaculture, salt field, and villages. With rich and diverse aquatic resources, the lagoon has created livelihoods for many households and provided food sources to people in neighboring communes.

There were some studies in this lagoon on fisheries and resources, such as a summary of biodiversity of the lagoon by Vu Trung Tang, 1994 [1], fish resources by Nguyen Van Luc et al. 2004 [2], mollusk in Hua Thai Tuyen, 2011 [3], and benthic animal resources by Phan Duc Ngai et al. 2015 [4]. These publications, however, focused mainly on determining the biodiversity of macrofauna. There is no publication so far about the plankton of De Gi lagoon.

Nevertheless, the lagoon is currently facing overfishing. Phan Duc Ngai et al., 2015 provided fishing effort data that indicated the exploitation pressure in this lagoon is enormous compared to neighboring lagoons [4]. In an assessment of fishing and aquaculture along the De Gi lagoon, Vo Thanh Tinh et al. 2013 [5] reported that sustainable development in this area was low-score in many criteria such as poor planning or policy to support fishermen. The environmental condition of the lagoon was not good with the number of parameters that exceeded the allowable levels, such as suspended matter, phosphate, nitrate, and coliform concentrations, especially in the rainy season 2009 [6].

Zooplankton is known as small creatures that ranging from micrometer to centimeter or even larger, typically jellyfish. They serve as the primary food source for larger groups such as fish. In addition, some are used as biological indicators for the aquatic environment. Consequently, studying the zooplankton community can partly reflect the current status and the changes in the habitat in study water. However, there have been limited studies on zooplankton in De Gi lagoon since 2000, and most of them were in grey reports of few surveys. Under these circumstances, this paper aims to assess changes in zooplankton assemblages in De Gi lagoon from data collected in 2009, 2010, and 2020.

MATERIAL AND METHOD

Study area

A total of 40 samples were collected at 23 stations in De Gi lagoon during the wet (October 2009) and dry season (April 2010 and May 2020). Sampling map is shown in figure 1.

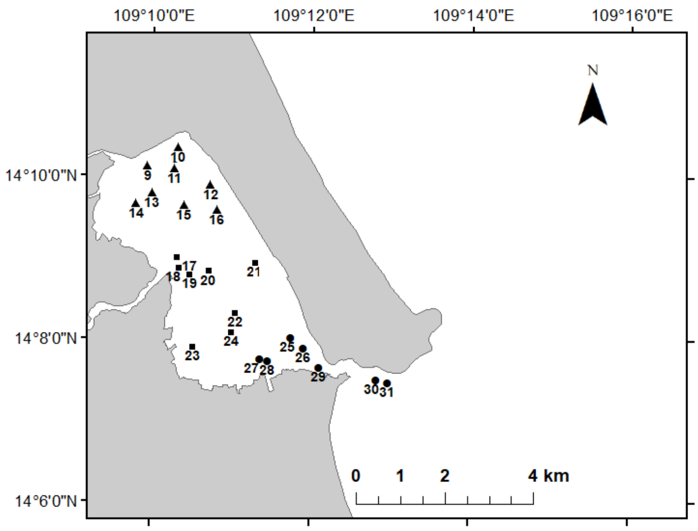

Figure 1. Sampling map in De Gi lagoon in 2009, 2010 and 2020: Upper lagoon (UP: Triangles), middle lagoon (MI: Squares) and mouth of the lagoon (MO: Solid circles)

The lagoon was divided into 3 areas including upper lagoon (UP), middle lagoon (MI) and mouth of the lagoon (MO).

Sampling and laboratory analysis

Zooplankton quantitative and qualitative samples were taken by vertical hauls using a Juday net with 37 cm of mouth diameter and 200 µm of the mesh size. Samples were collected by towing from 1 m above the bottom or surface (0.5 meter below the water surface). A net with a flowmeter (to measure the water volume filtered through the net) was horizontal towing at shallow stations. Samples were stored in 0.5L bottles and fixed with formaldehyde 5% for later analysis.

The samples were first cleaned with fresh water in the laboratory, removed trashes non-zooplankton particles, and other large organisms such as fish, squid larvae, coelenterates, which bare eyes can observe. The samples then were divided into two size classes using a 500 µm mesh size sieve: large (> 500 µm) and small zooplankton (<500 µm). Zooplankton in the large size (>500 µm) were all counted. However, this sample part may be further divided using a Folsom plankton splitter [7] if necessary. The small size class (<500 µm) was diluted with distilled water, and then 1 ml was used for counting. Zooplankton samples were identified to species level by using stereoscopic and microscope following the technique of Goswami (2004) [8]. The abundance of zooplankton in each station was standardized to the individuals per cubic meter [9] based on the depth of net tow and the net's mouth area, or the flow cytometry data, assuming a 100% filtration efficiency.

Zooplankton species were mainly identified based on the literatures of Chen (1965) [10], Chen (1974) [11], Muyaldi (2002) [12], Shirota (1966) [13], Owre and Foyo (1967) [14], Nguyen Van Khoi (1994) [15], Nishida (1985) [16] and Bradford-Grieve et al., (1999) [17]. Taxonomy information was updated based on WoRMs [18].

The abundance of zooplankton was all recorded at species level except for *Cnidaria* and *Ctenophora*, wherein only occurrence/absence was listed due to the serious damage of the specimens during sampling period, and invertebrate larvae, wherein only higher taxa were enumerated due to deficient identification at the species level.

Data analysis

Density of zooplankton was calculated by the following equation:

$$\text{Total density (inds.m}^{-3}) = [(A \times B) + (C \times D)]/V$$

Where: A: Total individuals of the large size class (> 500 µm); B: Number of the splits by using Folsom splitter (of the large size class); C: Total individuals in 1 ml of the small size class (< 500 µm); D: Volume of the small size class (< 500 µm); V: Total water volume filtering through the net.

PRIMER 6 (Primer-E Ltd.) was used for calculating some community indices such as biodiversity; cumulative dominance and illustrating temporal and spatial differences among stations and areas, and following equations were used:

Margalef index: d = (S-1)/Log(N) [19].

Pielou index: J' = H'/ln(S) [20].

Shannon index: H' = - sum(P_i*ln(P_i)) [21].

Simpson index: $(D) = \dfrac{1}{\sum_{i=1}^{s} p_i^2}$ [22].

Percentage of similarity was also calculated after [20] as an equation below:

$$BC_{ij} = 1 - \frac{2C_{ij}}{S_i + S_j}$$

Where: N_i: Individuals of species I; N: Total individuals in a sample; S: Total of number of species in a sample; P_i: Frequency of species i in a sample = present probability of species i in a sample; C_{ij}: Total of similar species between two samples i and j; S_i and S_j: Number of species in sample I and sample j.

Microsoft Excel and *Graphpad Prism* were used for calculating and drawing graphs and the basis of statistical analyses. Both cluster and SIMPER analyses were based on square-root transformed abundance data using *PRIMER 6* (Primer-E Ltd).

RESULTS & DISCUSSION

Species composition and abundance of zooplankton

Altogether, 85 species belonged to 11 classes, and seven phyla were identified in the studied area in 2009, 2010, and 2020. The Copepod (Hexanauplia) dominated with 61 species, comprised 70% of the lagoon's species composition, followed by two orders, Hydrozoa (Cnidaria) and Malacostraca (Arthropoda), with 7 and 5 species, respectively. The other groups were only 1 to 2 species. Zooplankton groups including Copepoda, Sagittoidea (Chaetognath), Tentaculata (Ctenophora), Malacostraca (Arthropoda), Appendicularia (Chordata) were the most frequently present in the lagoon in all surveys. Polychaeta (Annelida) taxa were found only at the mouth of the lagoon in 2020 (Table 1).

Table 1. Zooplankton assemblages (in species numbers) in 2009, 2010 and 2020 (UP, MI and MO: Upper, middle and mouth part of the lagoon, respectively)

PHYLUM	CLASS	2009			2010			2020			TOTAL
		UP	MI	MO	UP	MI	MO	UP	MI	MO	
Annelida	Polychaeta									1	1
Arthropoda	Branchiopoda					1	2			2	2
	Hexanauplia	11	19	22	22	20	25	14	22	40	61
	Malacostraca	1	1	1	1	1	2	1	2	2	5
	Ostracoda		2			1	1			1	2
Chaetognath	Sagittoidea	2	2	2	1	1	2		1	1	2
Chordata	Appendicularia	1		1	2	2	2	1	2	2	2
	Thaliacea						1				1
Cnidaria	Hydrozoa					1	2	1	4	6	7
Ctenophora	Tentaculata	1	1	1	1	1	1	1	1	1	1
Mollusca	Gastropoda					1	1				1
TOTAL		16	25	27	27	29	39	18	32	56	85
		35			49			65			
Average density (inds/m^3)		54,022			25,542			9,136			

In general, the species number of zooplankton in the lagoon increased over time. The species number in 2020 (65) was almost doubled in 2009 (35). Zooplankton abundance decreased sharply, with the highest mean density was in 2009 (54.022 ± 42.379 inds.m^{-3}) and the lowest in 2020 (9.136 ± 9.978 inds.m^{-3}). Comparing all areas in the lagoon over time showed that significant change in diversity and abundance was in 2020 compared to other years (Table 1). Zooplankton density at all areas of the lagoon also exhibited a temporal decreasing trend (Figure 2).

Seasonally, there is a clear difference between the rainy season (2009) and the dry season (2010) of zooplankton assemblage. Species richness in the dry season (49) was higher than in the rainy season (35). However, there was no significant difference in species number among areas in the lagoon. Abundance was also clearly variable, with average densities in the dry season (25.542 inds.m^{-3}) less than half that of the rainy season (54.022 inds.m^{-3}) for the entire lagoon and particular areas (Table 1 & Figure 2).

The dry season surveys (2010 and 2020) did not show much difference in density at the upper lagoon (UP) and the middle lagoon (MI), while at the mouth of the lagoon (MO), average densities were 11.550 ± 11.043 and 3.384 ± 1.785 inds.m^{-3}, for 2010 and 2020 respectively. These densities were much lower than the other two regions (UP & MI) in 2010 (34.283 ± 23.457 and 26.129 ± 21.383 inds.m^{-3}, respectively), and in 2020 (11.510 ± 7.045 and 13.306 ± 15.464 inds.m^{-3}, respectively) (Figure 2).

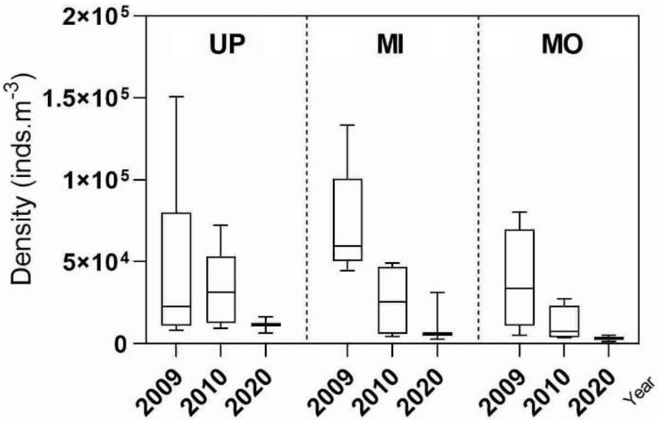

Figure 2. Zooplankton density variation in the lagoon by box plot in 2009, 2010 and 2020 (UP, MI and MO: Upper, middle and mouth part of the lagoon, respectively)

Zooplankton diversity

Four biodiversity indicators showed significant differences in zooplankton diversity and abundance in the lagoon between seasons and years. The species richness index (Margalef) and species number increased by time for all three areas (Table 1, Figure 3), higher in the dry season and the highest in 2020. The remaining diversity indices (Shannon and Simpson) showed similar trends, increasing average values over time in the middle lagoon (MI) and the mouth of the lagoon (MO). At the upper lagoon, diversity indices in 2010 were consistently higher than in the other years. However, the statistical analysis only showed the difference in species evenness between 2010 and 2020 in the upper lagoon (Kruskal Wallis test, $p < 0.05$ with post hoc, α=0.018) (Figure 3).

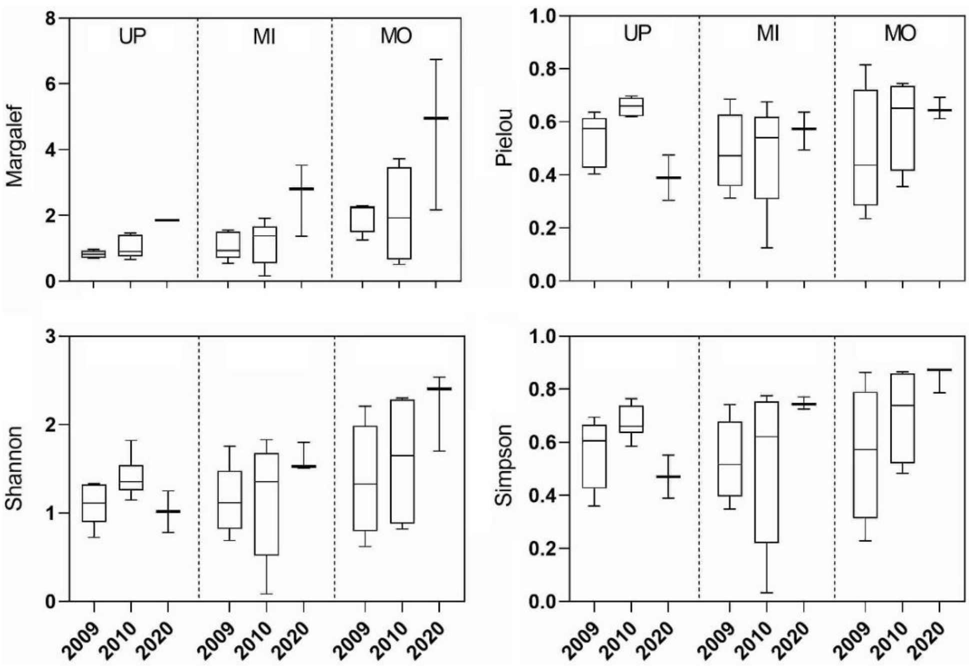

Figure 3. Temporal and spatial variability of zooplankton diversity indices in De Gi lagoon (UP, MI and MO: upper area, middle and mouth of the lagoon, respectively)

Variation of zooplankton assemblages

Zooplankton community structure in De Gi lagoon much varied with seasons and between years. The most variable and abundance groups were Copepoda and larvae. The difference of zooplankton assemblages between the rainy season (2009) and the dry season (2010) was quite clear. Calanoida was dominated over 75% abundance of zooplankton in the rainy season, while both Calanoida at their copepodite were dominant in the dry season in 2010. Between the dry season in 2010 and 2020, the composition of zooplankton assemblages had also changed. The larval group dominated some 50% of the zooplankton in 2020, while it was some lesser 25% in 2010 (Figure 4). In 2010, Harpacticoida taxa contributed ca. 25% of zooplankton abundance while almost absent in 2020.

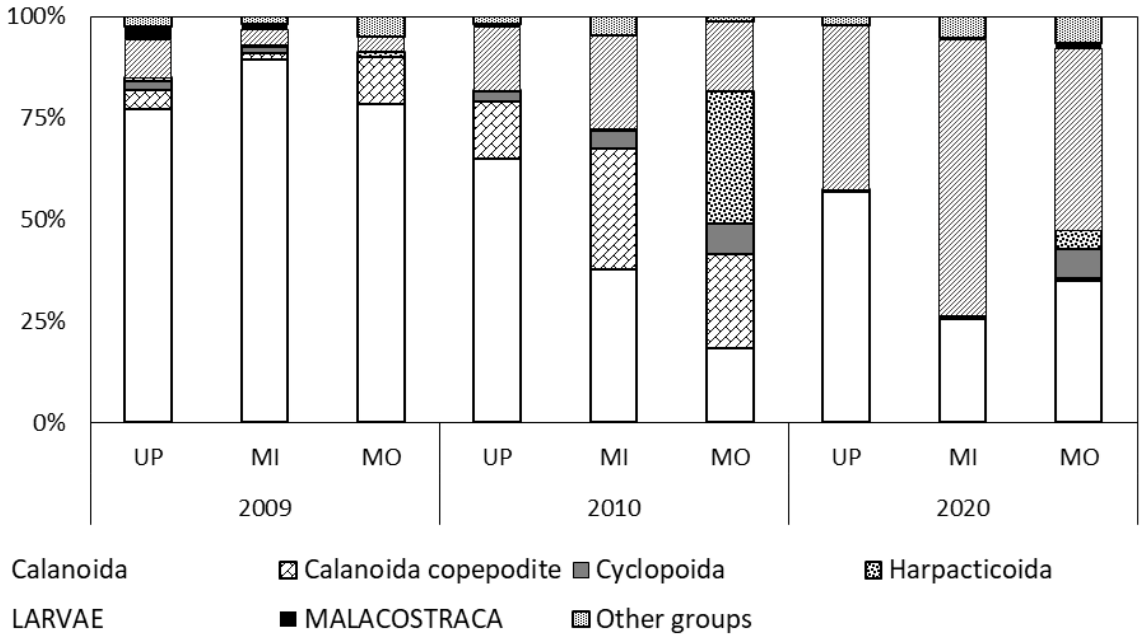

Figure 4. Zooplankton assemblage composition (by percentage abundance) of all area and surveys. (Copepoda presented by Orders Calanoida, Cyclopoida, Harpacticoida, and Calanoida copepodite; Other groups included Classes Sagittoidea, Appendicularia, Ostracoda, Branchiopoda, Gastropoda, and Polychaeta)

Dominant species in De Gi were mainly small copepods, such as *Parvocalanus crassirostris*, *Paracalanus parvus*, larvae and juveniles of genera *Acartia*, *Acrocalanus*, *Paracalanus*, and of order Calanoida. Those groups were consistently abundant each year with the mean of 50% total zooplankton density in the lagoon. Notably, in 2010 at the upper lagoon (UP) and the lagoon mouth area (MO), their density was up to more than 70%. The community structure in the lagoon changed much overtime when the dominant groups in 2009 and 2010, such as Calanoid copepodites and *Paracalanus* juvenile, did not show up in 2020 (Table 2). Changes between the rainy season (2009) and the dry season (2010) were mainly in nauplius larvae and Calanoida copepodites in the dry and *Paracalanus* juvenile in the rainy season.

CLUSTER graph indicated differences in the structure of the zooplankton assemblages of De Gi lagoon over the years is up to 80%. In 2020, all areas of the lagoon shared ca. 50-60% similarity zooplankton assemblages. The plankton communities in 2009 and 2010 showed complex spatial and seasonal variation. Zooplankton communities in 2010 were more isolated than in 2009. In 2009, zooplankton assemblages were divided into two groups with less than 20% similarity (Figure 5).

Table 2. SIMPER analysis – Contribution of dominant zooplankton taxa (% average abundance) in De Gi lagoon (UP, MI and MO: upper area, middle and mouth of the lagoon, respectively).

Dominance species	UP			MI			MO		
	2009	2010	2020	2009	2010	2020	2009	2010	2020
Acartia (Juvenile)	19.81	31.84	23.72	24.63	12.86	8.02		8.81	
Acrocalanus (Juvenile)	14.34						7.31		
Copepodite *Calanoida*	10.25	17.12			25.28		10	27.67	
Paracalanus (Juvenile)	17.92	10.19	4.19	22.01	10.73		31.56	9.63	
Paracalanus parvus							11.2		1.32
Parvocalanus crassirostris			9.37	11.72		6.48			9.36
Crustacean larvae						16.32			8.2
Polychaeta larvae			10.26					14.1	8
Nauplius larvae		16.92				15.56		12.7	17.66
Sagitta (Juvenile)					9.21				
Oikopleura (Coecaria) fusiformis						9.04			

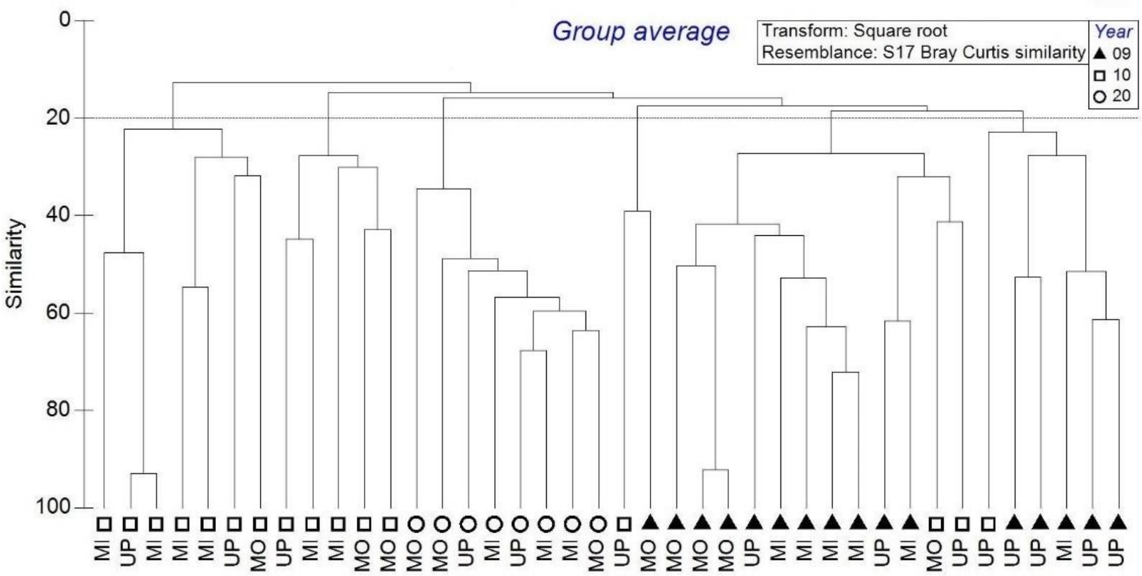

Figure 5. Temporal and spatial similarities of zooplankton assemblages in De Gi lagoon.

Invertebrate larval abundance

The abundance of the lagoon's zooplankton was mainly driven by the variation of two larval groups, Crustacean and Polychaeta. Crustacean larvae were likely to be the most dominant group, contributing at least 33% to 87% of the total mean density of larval groups in the lagoon. The Bivalvia and Gastropod were more abundant in the rainy season with higher average density than in the dry season. In the dry season 2010, Polychaeta was occupied some 30% of the total larval abundance while this group was absent in the rainy season 2009 or less dominant in the dry season in 2020. In 2020, the decline of many larval groups may be due to increased crustacean larval (Figure 6).

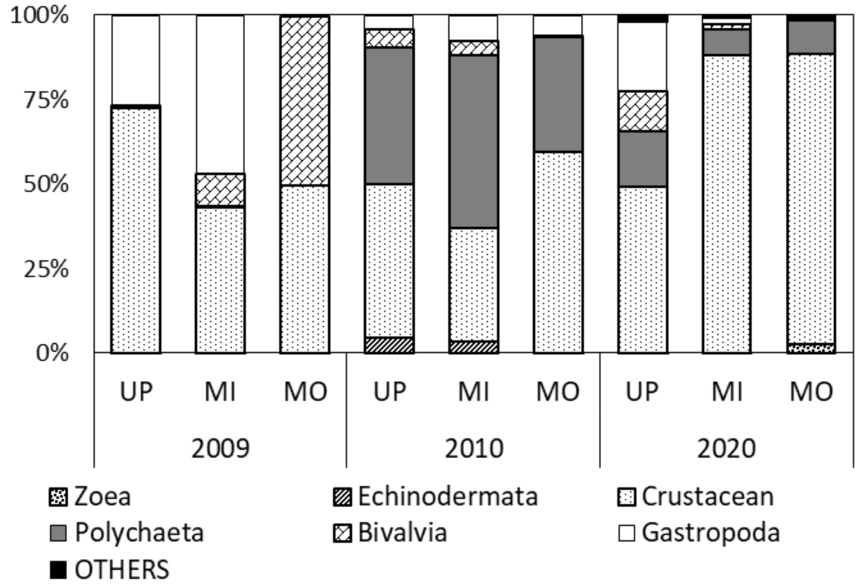

Figure 6. Invertebrate larval abundance (by percentage) variability in the lagoon with OTHERS comprises Phoronida, Pilidium, Ephyra, and Tadpole larvae.

Discussion

A total of 85 zooplankton species has found in the lagoon from 2009 to 2020, and Copepod was dominated with 60 species (70% total species). This result is similar to nearby areas such as Cu Mong lagoon, Phu Yen (70 species in 2000, unpublished data), but lower than in Xuan Dai lagoon, Phu Yen (108 species in 2000, unpublished data), Quy Nhon Bay (122 species) [23]. De Gi and Thi Nai [24] exhibit a similar zooplankton distribution trend with the increasing diversity from the top to the lagoon mouth while density is the opposite. However, the seasonal comparison shows a clear difference among the two lagoons; the number of species in the rainy season in De Gi lagoon (2009) was 35 species, two times lower than in Thi Nai lagoon (2008) 76 species. The abundance also has a considerable difference between the two lagoons; the average density in the rainy season in De Gi (October 2009) was 54.022 inds.m^{-3} and much higher than that of Thi Nai (11/2008) was only 5.836 inds.m^{-3}. The dry season 2020 also shows the same thing with the average density of De Gi lagoon (9.136 inds.m^{-3}), which is four times higher than that of Thi Nai lagoon (2.500 inds.m^{-3}); however, the species number is not different. The zooplankton assemblage structure was similar between the two lagoons (unpublished data, [25]). However, seasonal and spatial differences are observed more clearly in the De Gi lagoon. Variation of zooplankton density was high among the investigated sampling stations of the De Gi lagoon, especially in the upper lagoon. In this part of the De Gi lagoon, shrimp ponds, salt fields, and freshwater input from rivers are possibly cause its high variation environmental condition. Previous research in a coastal lagoon in Mexico indicated rapid changes in nutrients and high saline water into the upper lagoon in ten days after cultured shrimps were harvested [26]. In the De Gi lagoon, however, sampling stations in the present study were not high for all lagoon parts. Our observations would be subjects for further confirmation in future studies.

The dominant groups in De Gi lagoon are small copepods belonging to the genus *Acartia*, *Paracalanus*, and copepodite of the calanoids. These groups can adapt to high variability salinity, typical for areas subject to river and coastal impacts. These same characteristics are also presented in studies in adjacent areas such as Xuan Dai and Cu Mong lagoons in Phu Yen, Quy Nhon coastal, and Thi Nai lagoon in Binh Dinh [23, 24]. In a large tropical lagoon, e.g., Chilika lagoon (India), zooplankton small size

(< 1 mm) was also dominant, including species of genera *Acartia*, *Acrocalanus*, *Euterpina*, *Oithona*, and *Pseudodiaptomus* [27]. In such an ecosystem, environmental factors such as salinity, turbidity, and phytoplankton density were the main causes influencing the distribution of zooplankton assemblages [27, 28]. De Gi lagoon is poorly studied in such intensive investigation and our baseline data on zooplankton will be helpful for further research, especially those with the evaluation of environmental impacts.

Crustacean and Mollusc larvae groups are often the critical components in the lagoon during the surveys. This result is similar to the adjacent lagoons. The average density of larvae groups in De Gi lagoon in 2009, 2010, and 2020 was 2.748, 4.450, 5.120 inds.m^{-3}, respectively, higher than Xuan Dai Bay (2.049 inds.m^{-3}, unpublished data) and much lower than Cu Mong (21.519 inds.m^{-3}, unpublished data). Seasonal comparison with Thi Nai lagoon (adjacent lagoon in Binh Dinh province) showed a significant difference with De Gi during the rainy season 2009, Gastropoda and Bivalvia, 795 and 308 inds.m^{-3}, respectively, much higher than Thi Nai lagoon 2009 (Mollusca larvae: 17 inds.m^{-3}) [25].

CONCLUSION

We identified 85 species belonging to 7 phyla and 11 classes in the De Gi lagoon during 2009, 2010, and 2020 surveys. The number of species was relatively lower compared to other coastal waters but similar to Cu Mong lagoon (Phu Yen province). The Copepod (Hexanauplia) dominated with 61 species, comprised 70% of the lagoon’s species composition. In the De Gi lagoon, a similar trend on zooplankton diversity was reported in many other tropical coastal embayments, increasing from the upper lagoon to the lagoon’s mouth while decreasing in density.

The species number of zooplankton in the lagoon increased over time; in 2020 (65) was almost doubled in 2009 (35). Zooplankton abundance decreased sharply, with the highest mean density was in 2009 (54.022 ± 42.379 inds.m^{-3}) and the lowest in 2020 (9.136 ± 9.978 inds.m^{-3}). Seasonally, zooplankton species richness in the dry season was higher than in the rainy season. Average densities in the dry season (25.542 inds.m^{-3}) were less than half that of the rainy season (54.022 inds.m^{-3}) for the entire lagoon. Zooplankton biodiversity indices differed between seasons and years, higher in the dry season and highest in 2020.

The community structure in the lagoon changed much over time. Dominant groups in 2009 and 2010, Calanoid copepodites and *Paracalanus* juvenile, were absent in 2020. Differences in zooplankton assemblages between 2010 and 2020 were significant, with 60 to 72 % dissimilarities at all lagoon areas. Changes of the assemblages between the rainy season (2009) and the dry season (2010) were mainly in nauplius larvae and Calanoida copepodites in the dry and *Paracalanus* juvenile in the rainy season and by 58 to 73 % dissimilarity at all areas of the lagoon.

For larval resources, Crustacean and Polychaeta were the most dominant in the lagoon. The crustacean larvae contributed from 33% to 87% of the total mean density of all larval groups. In addition, Bivalvia and Gastropod larvae were more abundant in the rainy season, which may considerably connect to the lagoon's Mollusca resources.

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REFERENCES

[1] Vu Trung Tang, 1994. Estuarine ecosystems in Viet Nam. *Science and Technics Publishing House*. pp.271. Ha Noi (in Vietnamese).

[2] Nguyen Van Luc, Nguyen Tac An, Nguyen Phi Uy Vu, Le Thi Thu Thao, Tran Van Lang, Nguyen Thi Lien, 2004.

Fish resources and their utilization in De Gi - Binh Dinh province. *Collection of Marine Research Works*, XIV, 119-128 (in Vietnamese with English abstract).

[3] Hua Thai Tuyen, 2011. Molluscs in De Gi lagoon. *Proceedings of the National conference on marine sciences and technology in Viet Nam*, 4, 547-552 (in Vietnamese with English abstract).

[4] Ngai, P. D., Tuan, V. S., Van Long, N., Tuyen, H. T., & Hong, P. T. K. (2015). Characterization of benthic animal resources at the De Gi lagoon, Binh Dinh province. *Vietnam Journal of Marine Science and Technology*, 15(4), 382-391 (in Vietnamese with English abstract).

[5] Tinh, V. T., & Ly, C. D. (2013). Sustainability assessment of aquaculture in De Gi lagoon, Binh Dinh province. *Vietnam Journal of Marine Science and Technology*, 13(2), 186-193 (in Vietnamese with English abstract).

[6] Le Thi Vinh, Duong Trong Kiem, Nguyen Hong Thu, Pham Huu Tam, Pham Hong Ngoc, Le Hung Phu, Vo Tran Tuan Linh, 2012. Environmental quality of waters in De Gi lagoon, Binh Dinh province. *Collection of Marine Research Works*. Volume XVIII, 46-54 (in Vietnamese with English abstract).

[7] Longhurst, A.R. & D.L.R. Seibert. 1967. Skill in the use of Folsom's plankton sample splitter. *Limnol. Oceanogr.*, 12, 334-335.

[8] Goswami, S.C. (2004) Zooplankton Methodology, Collection and Identification, A Field Manual. Dona Paula, Goa: Natural Institute of Oceanography.

[9] Alden, R.W., III, R.C. Dahiya & R.J. Young, JR. 1982. A method for the enumeration of zooplankton samples. *J. Exp. Mar. Biol. Ecol.*, 59,185-206.

[10] Chen, Q. (1965) The planktonic copepods of the Yellow Sea and the East China Sea. I. Calanoida. *Stud. mar. sin*, 7, 20-31.

[11] Chen, Q.-C. (1974) On planktonic copepods of the yellow sea and the East China Sea, II. Cyclopoida and Harpacticoida. *Stud. mar. sin*, 9, 1-24.

[12] Mulyadi, M. (2002) New records of the Pontellid species (Copepoda: Calanoida) in Indonesian waters, with notes on its species-groups. *Treubia*, **32**(1), 1-38.

[13] Shirota, A. (1966) The plankton of South Viet-Nam: fresh water and marine plankton. Overseas Technical Cooperation Agency.

[14] Owre, H. and Foyo, M. (1967) Copepods of the Florida current. *Fauna Caribaea* No. 1. Crustacea, Part1: Copepoda. *Publications of the institute of marine science*, University of Miami, Florida.

[15] Nguyen Van Khoi, (1994) Copepoda in Tonkin Gulf. *Science and Technics Publishing House.*

[16] Nishida, S. (1985) *Bulletin of the ocean research Institute of Tokyo: Taxonomy and distribution of the family Oithonidae (Copepoda-Cyclopoida), in the Pacific and Indian oceans*. Nakano Tokyo.

[17] Bradford-Grieve, J., et al. (1999) South Atlantic Zooplankton. *Blackhuys Publishers*: Leiden, The Netherlands: p1705.

[18] WoRMS Editorial Board (2021). World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. Accessed 2021-10-20. doi:10.14284/170.

[19] Margalef, R. (1958) Information theory in biology. *General Systems Yearbook*, 3: p.36-71.

[20] Pielou, E.C. (1966) The measurement of diversity in different types of biological collections. *Journal of theoretical biology*, 13, 131-144.

[21] Shannon C.E., 1948. A mathematical theory of communication. *The Bell system technical journal*, 27, 379-423

[22] Simpson, E.H. (1949) Measurement of diversity. *Nature*, 163(4148), 688-688.

[23] Cho N. and T. S. H. Trinh, 2006. Zooplankton abundance and species diversity in Quy Nhon coastal waters, South Central of Vietnam in June 2004. *Coastal Marine Science*, 30, 328-335.

[24] Nguyen, V. T., & H, Doan-Nhu. (2020). Zooplankton community in Thi Nai lagoon in the period of 2001–2020.

Vietnam Journal of Marine Science and Technology, 20(4A), 35-44.

[25] Nguyen Cho, Truong Si Hai Trinh, Nguyen Thi Thanh Thuy, 2011. The composition, densities and distribution of zooplankton in Thi Nai lagoon, Binh Dinh province. *National conference on marine sciences and technology in Viet Nam*. Volume 4, 246-252 (in Vietnamese with English abstract).

[26] Cardoso-Mohedano, J. G., Bernardello, R., Sanchez-Cabeza, J. A., Páez-Osuna, F., Ruiz-Fernández, A. C., Molino-Minero-Re, E., & Cruzado, A. (2016). Reducing nutrient impacts from shrimp effluents in a subtropical coastal lagoon. *Science of The Total Environment*, *571*, 388-397.

[27] Srichandan, S., Tarafdar, L., Muduli, P. R., & Rastogi, G. (2021). Spatiotemporal patterns and impact of a cyclone on the zooplankton community structure in a brackish coastal lagoon. *Regional Studies in Marine Science*, *44*, 101743.

[28] Etilé, R. N. D., Kouassi, A. M., Aka, M. N. G., Pagano, M., & N'douba, V. (2009). Spatio-temporal variations of the zooplankton abundance and composition in a West African tropical coastal lagoon (Grand-Lahou, Côte d'Ivoire). *Hydrobiologia*, *624*(1), 171-189.