JJBS

Volume 17, Number 2, June 2024
ISSN 1995-6673
Pages 223 – 233
https://doi.org/10.54319/jjbs/170202

Jordan Journal of Biological Sciences

Examining the Diversity and Abundance of Zooplankton across Different Gateways in the South-western Estuary of Bangladesh

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Received: August 1, 2023; Revised: September 12, 2023; Accepted: September 17, 2023

Abstract

The Pasur-Sibsa and Baleshwari River Estuary (PSBE) is the longest estuary located in the southwest part of Bangladesh on the Ganges-Brahmaputra delta which flows into the Bay of Bengal. The study was conducted to investigate the diversity and abundance of the zooplankton from three gateways (S1 station: Pasur river gateway; S2 station: Sibsa river gateway and S3 station: Baleshwari river gateway) in the PSBE from July 2022 to December 2022. Water samples were collected from these gateways using plankton net (55 µm mesh size) and preserved for analyzing in the laboratory. A total of 34 species of zooplankton belonging to 9 orders and 17 families were documented. The dominant orders were Calanoida and Dendrobranchiata, covering 59.52% and 18.20%, respectively. *Acartia bilobata* was the dominant species, while *Sagitta* sp. was the inferior species throughout the gateways. The Pasur river estuary gateway showed the highest percentage of abundance, accounting for 36.39% of the total individuals. The study calculated the Shannon-Wiener Diversity Index, Simpson's Dominance Index, Simpson's Index of Diversity, Margalef's Richness Index, and Evenness ranged from 1.33 to 1.43, 0.24 to 0.30, 0.70-0.76, 1.11 to 1.21, and 0.74-0.80, respectively. The results showed that the zooplankton composition was rich in the S1 station, which serves as a good indicator of marine productivity like zooplankton. The density of zooplankton in a body of water is indicative of the fish stocking rate.

Keywords: Estuary, Zooplankton diversity, Diversity index, Abundance.

1. Introduction

Zooplankton is an assortment of different microscopic or non-microscopic, unseen aquatic organisms that rely on water flowing for movement (Islam, 1999). They migrate hundreds of meters regularly during the day and night despite having very weak swimming abilities. They are known as living machines because they prefer to feed at night on the water's surface, effectively grazing phytoplankton. They frequently serve as a crucial bridge connecting the microbial part and the bigger grazers (Laval-Peuto *et al*., 1986; Pierce and Turner, 1994). All aquatic ecosystems' food chains and food webs are built on zooplankton. Heinbokel (1978) and Fenchel (1987) suggest that zooplankton serve as indicators in aquatic ecosystems due to their wide distribution, small size, rapid metabolism, and diverse species range (Gajbhiye, 2002; Al-Najjar and El-Sherbiny, 2008).

Zooplankton the minute organisms that float around on the ocean's surface and feed either on one another or the microscopic plants that make up phytoplankton. Zooplankton plays crucial roles in food webs because they control phytoplankton populations by eating them (Wetzel, 2001). The presence of some planktonic groups can also be used to anticipate and determine the health of enclosed, open, and marine water bodies (Ismail and Adnan, 2016; Parmar *et al*., 2016). Therefore, variations in zooplankton density have an impact on phytoplankton dynamics (Carpenter *et al*., 1987). They also have a significant impact on the recycling of nutrients and energy in their particular ecosystems. Fish production depends on the qualitative and quantitative criteria of plankton and its relationship to environmental conditions. The species most suited for culture in different habitats depends on water quality (Dhawan, 2002). The primary factors of fish growth rates and development are the physicochemical characteristics of a water body (Jhingran, 1991). The main productivity of a water body, which serves as the foundation of the aquatic food chains, can be used to quickly determine the water body's overall productivity (Ahmed *et al*., 2004). The primary producers, which are phytoplankton and zooplankton, and the secondary producers make up the plankton community (Battish,

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1992; Ali, 2010). Zooplankton is the most preferable food for fish in the estuarine water body. According to a survey report by the UN's Food and Agriculture Organization (1985), zooplankton is relatively abundant in Bangladesh's tidal zones. Few studies have been done on the abundance of zooplankton and its ecology in the coastal and estuarine environment of Bangladesh. A study on zooplankton of the Bangladeshi coast's southeastern region, Islam and Aziz (1975) discovered a total of 18 genera and 18 species. In their observation of the macro-zooplankton in the Bay of Bengal's continental shelf, Bhuiyan *et al*. (1982) noted the presence and distribution of 18 calanoid copepods. In the coastal estuarine water in the southeast of Bangladesh, Ali *et al*. (1985) observed a periodic change in zooplankton diversity.

At the mouth of the Bay of Bengal, Bangladesh is situated. Bangladesh is a riverine country with numerous rivers, canals, floodplains, ponds, beels, haors, reservoirs, artificial lakes, and a long coastline with estuaries (Majumdar *et al*., 2020; Paul *et al*., 2021; Hemal *et al*., 2017). In Bangladeshi diets, fish alone provides over 63% of animal protein and many of the important vitamins and minerals (Majumdar *et al*., 2016; Majumdar and Rashid, 2017; Shovon *et al*., 2017). One of the top nations in the world for fish production is a country named Bangladesh (Sheikh *et al*., 2018). About 260 freshwater species and 474 marine water fish species are available in Bangladesh (Rahman, 1989; Majumdar, 2017). Both type species are highly preferred zooplankton as food in their diet. In addition to having a large nutrient yield, the near-shore upwelling zone serves as an estuary and is a significant primary producer of phytoplankton and associated zooplankton zones (Al-Nasrawi and Hughes, 2012). As a continuation of the Rupsa river, the Pasur river is significant water body in the Sundarbans region. The Bhairab or Rupsa river flows further south from Khulna, changes its name to Pasur river near Chalna, and then empties into the Bay of Bengal to the right of the islands of Trikona and Dubla. Sibsa river which is densely populated, and located in the region of Khulna in the south part of the country, with 222 inhabitants per square kilometer. The eastern and western borders of Bagerhat District and Barguna District, respectively, are shared by the Baleshwari River. The Haringhata River, which empties into the Bay of Bengal, is where the Baleshwari River empties into Pasur-Sibsa and Baleshwari river estuary (PSBE) are very important wetlands for Bangladesh. This estuary has been polluted day by day due to climate change like global warming; deforestation; industry, agriculture, and livestock farming; rubbish and faecal water dumping; maritime traffic and fuel spillages etc. For these reasons, the biodiversity of fish species is declined for inadequate zooplanktons which serve as food for the fish species. But data and research about primary and secondary production in this area are very inadequate. Therefore, this study aimed to identify the composition of zooplankton and its abundance in the Pasur-Sibsa and Baleshwari river estuary in Bangladesh.

2. Materials and Methods

2.1. Study area

The goal of the current inquiry was to learn about the zooplankton population status in Pasur-Sibsa and Baleshwari River Estuary (PSBE) of Bangladesh. The study region was separated into three sampling stations: Pasur river gateway (S1), Sibsa river gateway (S2), and Baleshwari river gateway (S3) the estuary to gather the data on species populations. Locations ranged from 21°41' to 21°48' North latitude to 89°30' to 89°41' East longitude in the Khulna district (Figure 1).

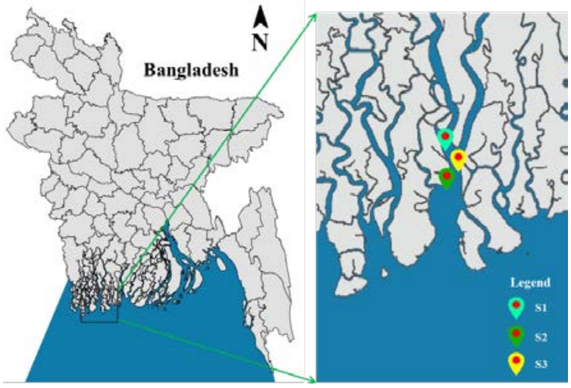

Figure 1: Map depicting the study zone of the Pasur-Sibsa and Baleshwari river estuary, indicating three sampling stations, S1 (Pasur river gateway; 21°47.209'N & 89°30.199'E), S2 (Sibsa river gateway; 21°41.316'N & 89°31.412'E) and S3 (Baleshwari river gateway; 21°48.46'N & 89°41.312'E).

Data were gathered from selected stations between the times of July 2022 to December 2022, which was the high tidal period. This area was expected highly productive because it receives a huge amount of nutrients from upstream.

2.2. Zooplankton sampling and analysis

A net with a cod end to keep the organisms and a mesh size of 55 µm was used to catch zooplankton, which was then dragged horizontally. The net was tilted at each station three times for 45 minutes each as the boat moved (around 20 km/hr) slowly. A sample was taken from the subsurface layer of the water column, specifically between 2 and 5 meters deep. The volume of flow water displaced through the plankton net was used to compute the abundance of organisms, which was then expressed as the number of individuals per cubic meter (Khan *et al*. 2015). The samples were kept in 5% formalin (45% formaldehyde) and labeled in 250 ml dark, sterile plastic bottles as soon as they were collected. Then the samples were taken to the laboratory of the Department of Oceanography under the Faculty of Fisheries and Ocean Sciences, Khulna Agricultural University (KAU) for quantitative and qualitative analysis. A phase contrast light microscope (Model No. XSZ21-05DN) with bright field and phase contrast illumination at magnifications of 16×40 and 16×10 was used to identify the zooplankton species according to the taxonomic references (Idris, 1983; Pennak, 1978; Shiel, 1995) in the laboratory of the Department of Oceanography. Zooplankton quantitative analysis was carried out in a Sedgewick-Rafter counting chamber (S-R cell). Each sample's 1 mL sub-sample was transferred to a Sedgewick-Rafter counter for analysis, and cells within 10 randomly selected squares of the cells were counted. Using Stirling's (1985) predicted zooplankton density, the cell counts were utilized to calculate the cell density using the formula. The following formula was used to determine the zooplankton abundance; the total number of zooplankton specimens equals the sum of the specimen counts divided by the volume of filtered water and total counts divided by the volume of filtered water equals the total number of specimens of a specific zooplankton taxon.

The Shannon-Wiener Diversity Index (H) of diversity, which was determined by the significant species, was an insensitive indicator of the direction of the S:N (Proportion of entire pattern represented by means of species and complete amount of all individuals of species) connection. Indicator of Shannon-Wiener Diversity Index, $H = -\Sigma [(Pi) \ln (Pi)]$; in which $Pi = (S)/N$, S stands for the entire pattern as represented by species and N is the total number of individuals in the species (Shannon and Wiener, 1963).

For Evenness (E), the following equation was used to estimate, which was a percentage of the total abundance of the many species that make up a region's richness (Pielou, 1966): $E = e^{H}/S$.

The Simpson's Dominance Index (D) was frequently used to assess the biodiversity of living spaces, which takes into account the quantity of species, just as the plenitude of every species and Simpson's Index of Diversity (1-D) was a proportion of diversity, taking into account the quantity of species present, and the overall abundance of every species, and was calculated using the following equation:

$D = \sum ni(ni-1)/N(N-1)$ and $[1-D] = [1-\sum ni(ni-1)/N(N-1)]$

Where, ni was the total number of members of a certain species and N was the total number of individuals across all species.

By using the following formula, Margalef's Richness Index (d) was used to calculate the species richness (Margalef, 1968): $d = (S-1)/\ln(N)$, where S was the number of species and N was the sample size.

2.3. Statistical Analysis

One-way ANOVA was used to statistically analyze the zooplankton parameter data using Statgraphics Version 7's statistical package, while Microsoft Excel 2010 was used to plot graphs for results dissemination. The population data was then presented in text, tabular, and Shannon-Wiener Diversity Index (H), Evenness (E), Simpson's Dominance Index (D), Simpson's Index of Diversity (1-D), and Margalef's Richness Index (d) were presented in graphical format for easier comprehension.

3. Results

The order, families and scientific name of zooplankton that are regularly found in the Pasur-Sibsa and Baleshwari river estuary of Bangladesh were presented in Table 1. The current investigation on zooplankton composition in the Pasur-Sibsa and Baleshwari river estuary estimated about 34 species belonging to 09 orders and 17 families. In Table 1, among the identified families, only 01 family belongs to Aphragmophora, 05 to Calanoida, 01 to Cyclopoida, 01 to Cydippida, 03 to Dendrobranchiata, 02 to Harpacticoida, 01 to Lobata, 01 to Onychopoda and 02 to Poecilostomatoida. In our study, the highest number of species was found under the order Calanoida and the lowest under the order Aphragmophora, Cyclopoida, Cydippida, Lobata and Onychopoda. *Acartia bilobata* was the dominant species throughout the investigated area, donated 1644 individuals/m^3 covering 16.10% and *Sagitta* sp. was the inferior species, donated 35 individuals/m^3 covering 0.34% (Table 1).

About 34 species were found in the investigated area which was divided into three stations following S1, S2, and S3 station. According to their availability state, the percentage of abundance was given that 36.39% of total individuals were found in large at S1 as well as 29.11% in small quantities at S3 in the Pasur-Sibsa and Baleshwari river estuary (Figure 2).

Table 1. List of identified main species of zooplankton together with their numbers and percentage at the Pusur-Sibsa and Baleshwari river estuary.

Order	Family	Species	Total	Percent (%) within group	Overall (%)
Aphragmophora	Sagittidae	*Sagitta* sp.	35	100	0.34
Calanoida	Calanidae	*Calanus finmarchicus*	173	2.85	1.69
	Metridinidae	*Metridia lucens*	220	3.62	2.15
	Calanidae	*Calanus pacificus*	244	4.02	2.39
	Acartiidae	*Acartia bilobata*	1644	27.06	16.10
	Diaptomidae	*Leptodiaptomus minutus*	836	13.76	8.19
	Diaptomidae	*Skistodiaptomus mississippiensis*	312	5.13	3.06
	Acartiidae	*Acartia negligens*	313	5.15	3.07
	Acartiidae	*Acartia bifilosa*	384	6.32	3.76
	Acartiidae	*Acartia clause*	258	4.25	2.53
	Acartiidae	*Acartia tranteri*	328	5.40	3.21
	Acartiidae	*Acartia hudsonica*	318	5.23	3.11
	Pontellidae	*Calanopia* sp.	143	2.35	1.40
	Calanidae	*Calanus* sp.	364	5.99	3.57
	Diaptomidae	*Leptodiaptomus sicilis*	201	3.31	1.97
	Metridinidae	*Metridia pacifica*	338	5.56	3.31
Cyclopoida	Oithonidae	*Oithona* sp.	247	100	2.42
Cydippida	Pleurobrachiidae	*Pleurobrachia* sp.	150	100	1.47
Dendrobranchiata	Sergestidae	*Acetes erythraeus*	314	16.90	3.08
	Sergestidae	*Acetes indicus*	115	6.19	1.13
	Sergestidae	*Acetes japonicus*	209	11.25	2.05
	Luciferidae	*Lucifer* sp.	112	6.03	1.10
	Penaeidae	*Metapenaeus brevicornis*	202	10.87	1.98
	Penaeidae	*Metapenaeus monoceros*	209	11.25	2.05
	Penaeidae	*Penaeus indicus*	164	8.83	1.61
	Penaeidae	*Penaeus merguiensis*	199	10.71	1.95
	Penaeidae	*Penaeus monodon*	58	3.12	0.57
	Sergestidae	*Sergestes similis*	276	14.85	2.70
Harpacticoida	Euterpinidae	*Euterpina acutifrons*	399	75.28	3.91
	Ectinosomatidae	*Microsetella* sp.	131	24.72	1.28
Lobata	Bolinopsidae	*Bolinopsis vitrea*	161	100	1.58
Onychopoda	Podonidae	*Evadue* sp.	239	100	2.34
Poecilostomatoida	Ergasilidae	*Ergasilus* sp.	671	73.49	6.57
	Oncaeidae	*Oncaea* sp.	242	26.51	2.37

During the investigation period, around 15 species of the Calanoida orders were seen i.e. *Calanus finmarchicus*, *Metridia lucens*, *Calanus pacificus*, *Acartia bilobata*, *Leptodiaptomus minutu*, *Skistodiaptomus mississippiensis*, *Acartia negligens*, *Acartia bifilosa*, *Acartia clause*, *Acartia tranteri*, *Acartia hudsonica*, *Calanopia* sp., *Calanus* sp., *Leptodiaptomussicilis*, and *Metridia pacifica* etc. Out of these 15 different species, *Acartia bilobata* was more prevalent than the others. The present study found about 34 species from the three sampling stations in the study area, demonstrating the abundance of zooplankton fauna that exists in the Pasur-Sibsa Baleshwari river estuary. Table 2 showed that the dominance of identified species among the three sampling stations in accordance with species. At station S1 (Pasur river gateway) most dominant species were *Acartia bilobata*, *Leptodiaptomus minutus*, *Skistodiaptomus mississippiensis*, *Acartia bifilosa*, *Acartia clause*, *Calanus pacificus*, *Leptodiaptomus sicilis*, *Metridia pacifica*, and *Microsetella* sp. showed in Figure 3.

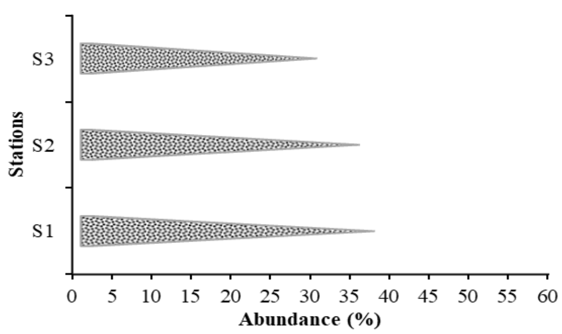

Figure 2: Abundance status of zooplankton population found in the Pusur-Sibsa and Baleshwari river estuary.

Table2: Dominance list of identified zooplankton species at Pusur-Sibsa and Baleshwari river estuary on the basis of sampling stations.

Order	Family	Species	Study area (Stations)		
			S1	S2	S3
Aphragmophora	Sagittidae	*Sagitta* sp.			✓
Calanoida	Calanidae	*Calanus finmarchicus*		✓	
	Metridinidae	*Metridia lucens*			✓
	Calanidae	*Calanus pacificus*	✓		
	Acartiidae	*Acartia bilobata*	✓		
	Diaptomidae	*Leptodiaptomus minutus*	✓		
	Diaptomidae	*Skistodiaptomus mississippiensis*	✓		
	Acartiidae	*Acartia negligens*		✓	
	Acartiidae	*Acartia bifilosa*	✓		
	Acartiidae	*Acartia clause*	✓		
	Acartiidae	*Acartia tranteri*		✓	
	Acartiidae	*Acartia hudsonica*		✓	
	Pontellidae	*Calanopia* sp.		✓	
	Calanidae	*Calanus* sp.			✓
	Diaptomidae	*Leptodiaptomus sicilis*	✓		
	Metridinidae	*Metridia pacifica*	✓		
Cyclopoida	Oithonidae	*Oithona* sp.		✓	
Cydippida	Pleurobrachiidae	*Pleurobrachia* sp.	✓		
Dendrobranchiata	Sergestidae	*Acetes erythraeus*	✓		
	Sergestidae	*Acetes indicus*		✓	
	Sergestidae	*Acetes japonicus*			✓
	Luciferidae	*Lucifer* sp.	✓		
	Penaeidae	*Metapenaeus brevicornis*		✓	
	Penaeidae	*Metapenaeus monoceros*	✓		
	Penaeidae	*Penaeus indicus*			✓
	Penaeidae	*Penaeus merguiensis*	✓		
	Penaeidae	*Penaeus monodon*		✓	
	Sergestidae	*Sergestes similis*		✓	
Harpacticoida	Euterpinidae	*Euterpina acutifrons*			✓
	Ectinosomatidae	*Microsetella* sp.			✓
Lobata	Bolinopsidae	*Bolinopsis vitrea*	✓		
Onychopoda	Podonidae	*Evadue* sp.			✓
Poecilostomatoida	Ergasilidae	*Ergasilus* sp.			✓
	Oncaeidae	*Oncaea* sp.			✓

In Figure 4, *Acartia bilobata*, *Calanus finmarchicus*, *Acartia negligens*, *Acartia tranteri*, *Euterpina acutifrons*, and *Acartia hudsonica* were the dominant species, found at Sibsa river gateway (S2). Similarly, *Acartia bilobata*, *Ergasilus* sp., *Metridia lucens*, *Acartia bifilosa*, *Euterpina acutifrons*, and *Microsetella* sp. were found at Baleshwari river gateway (S3) which was showed dominance among the others (Figure 5). Figure 6 illustrates the percentage of zooplankton in different orders. In particular, Dendrobranchiata (18.20%) showed considerable dominance among the orders, but Calanoida (59.52%) being the most dominant order.

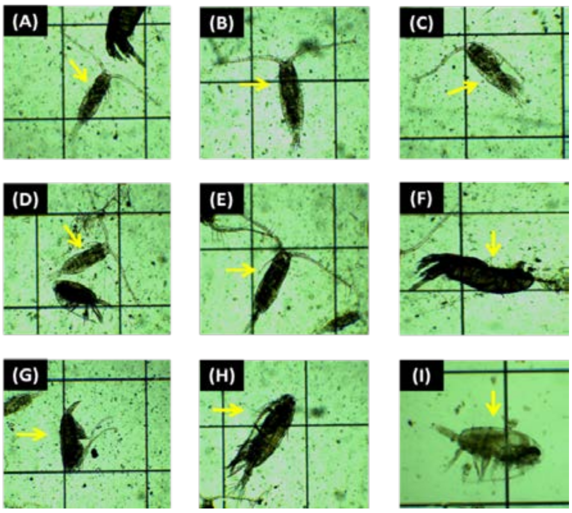

Figure 3. Photographic view of dominant major species of zooplankton (A) *Acartia bilobata*, (B) *Leptodiaptomus minutus*, (C) *Skistodiaptomus mississippiensis*, (D) *Acartia bifilosa*, (E) *Acartia clause*, (F) *Calanus pacificus*, (G) *Leptodiaptomus sicilis*, (H) *Metridia pacifica* and (I) *Microsetella* sp. found at Pasur river gateway (S1).

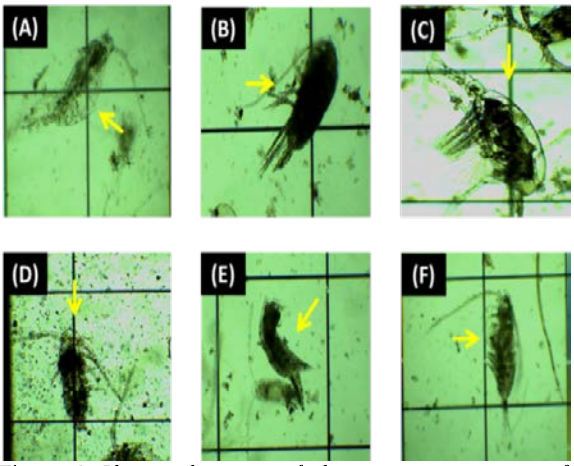

Figure 4. Photographic view of dominant major species of zooplankton (A) *Acartia bilobata*, (B) *Calanus finmarchicus*, (C) *Acartia negligens*, (D) *Acartia tranteri*, (E) *Euterpina acutifrons* and (F) *Acartia hudsonica* found at Sibsa river gateway (S2).

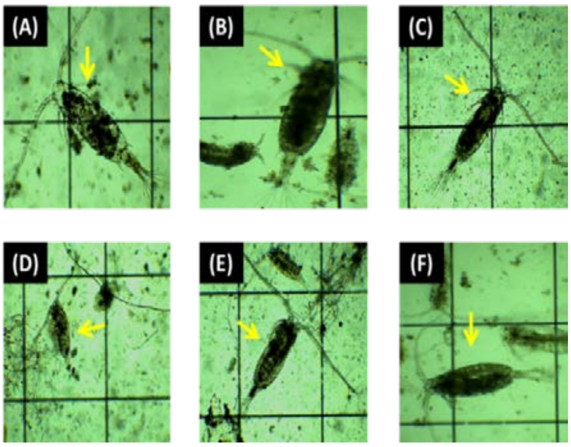

Figure 5. Photographic view of dominant major species of zooplankton (A) *Acartia bilobata*, (B) *Ergasilus* sp., (C) *Metridia lucens*, (D) *Acartia bifilosa*, (E) *Euterpina acutifrons* and (F) *Microsetella* sp. found at Baleshwari river gateway (S3).

On the contrary, Poecilostomatoida, Harpacticoida, Cyclopoida, Onychopoda, Lobata, Cydippida and Aphragmophora showed the least dominance established 8.94%, 5.19%, 2.42%, 2.34%, 1.58%, 1.47% and 0.34% contribution to the community, respectively (Figure 6). Additionally, throughout the study period, the family Acartiidae of the order Calanoida demonstrated dominance over the zooplankton fauna network of the research area (Figure 6). The families that contributed the fewest species to the network were the Sagittidae, Oithonidae, Pleurobrachiidae, Bolinopsidae, and Podonidae families throughout the study period.

Figure 7 showed the station-wise values for the Simpson's Index of Diversity (1-D), Margalef's Richness Index (d), Shannon-Wiener Diversity Index (H), Simpson's Dominance Index (D), and Evenness (E). Among these sampling stations, the S1 station had the greatest Shannon-Wiener Diversity Index value (1.43) designating the zooplankton-rich area, while the S2 station had few prosperities of zooplankton with the lowest value (1.33). Simpson's Dominance Index (D) was calculated to have the highest value in the S2 station (0.30), followed by S3 station (0.28) and S1 station (0.24), respectively. The highest Simpson's Index of Diversity value (0.76) found in S1 station, and the S2 station showed the lowest value (0.70). The greatest value for Margalef's Richness Index was 1.21 at the S1 station, while the lowest value was 1.11 at the S3 station. The S1 station recorded the maximum Evenness value was 0.80 and the minimum Evenness value was 0.74 at the S3 station (Figure 7). In contrast, the S1 station expressed a rich zooplankton profile because of its high value at Simpson's Index of Diversity, Margalef's Richness Index, and Evenness. Margalef's Richness Index ranged from 1.11 to 1.21in the current study. This value serves as a marker to distinguish between sampling stations while also indicating a species-based variance (Vyas *et al*., 2012). The highest Margalef Richness Index value, however, represents the most population in the study area. Consequently, the sampling S1 station has a Margalef's Richness Index higher than other study stations, indicating the presence of noticeably more individuals (Figure 7).

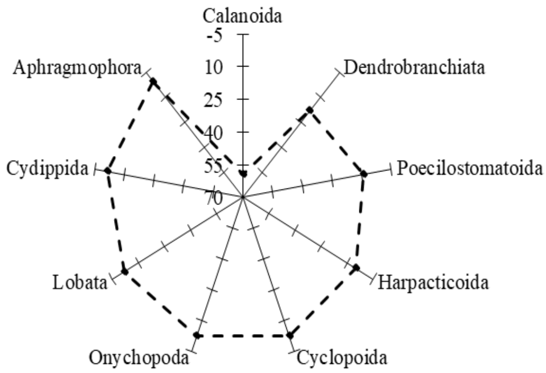

Figure 6: Zooplankton percentage based on the order in the Pusur-Sibsa and Baleshwari river estuary.

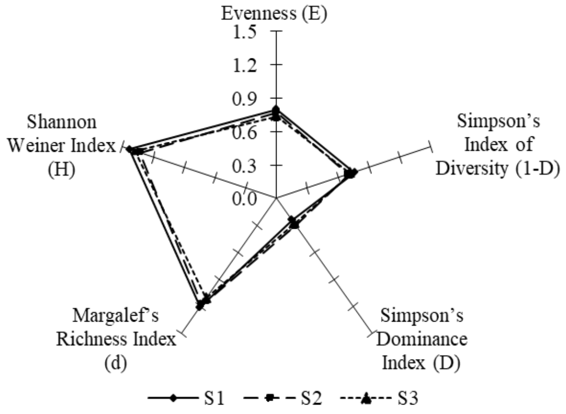

Figure 7: Distinct species diversity index of sampling stations of Pusur-Sibsa and Baleshwari river estuary.

4. Discussion

Researchers had identified 33 salt marsh estuary species (Abu-Hena *et al*., 2016) and 88 mangrove demersal zooplankton species (Melo *et al*., 2010). Around 48 species of zooplankton were discovered by Matias-Peralta and Yusoff (2015) in the Merambong Seagrass Meadow while 129 species were discovered in the Tinggi and Sibu Islands, all in Malaysia (Metillo *et al*., 2019).

According to Deepika *et al*. (2019), the density of zooplankton found in Indian seagrass meadows (89,300 to 935,300 individuals/m^3) was much higher than that found in the current study. Compared to the current study, Melo *et al*. (2010) discovered significantly lower zooplankton abundance (4,759 to 7,113 individuals/m^3) in the south-western Atlantic, and Azmi *et al*. (2016) found zooplankton abundance (3,030±855.6 individuals/m^3) at Merambong Shoal Seagrass Area, which is also lower than densities recorded in the present study. Zooplankton density measurements from certain river estuaries in the Sarawak Region of Malaysia ranged from 447 to 27,812 individuals/m^3 (Aiman *et al*., 2020). Overall, past findings supported the current results (Bhavan *et al*., 2015; Dhanasekaran *et al*., 2017; Manickam, 2015; Manickam *et al*., 2012; Manickam *et al*., 2014; Manickam *et al*., 2015). Within the orders, the highest number of species was *Acartia bilobata* (27.06%) and the lowest was *Calanopia* sp. (2.35%) in the order of Calanoida. Similarly, the highest and the lowest amount species were *Acetes erythraeus* (16.90%), *Euterpina acutifrons* (75.28%), *Ergasilus* sp. (73.49%) and *Penaeus monodon* (3.12%), *Microsetella* sp. (24.72%), *Oncaea* sp. (26.51%) in the order of Dendrobranchiata, Harpacticoida, and Poecilostomatoida, respectively. On the other hand, *Sagitta* sp., *Oithona* sp., *Pleurobrachia* sp., *Bolinopsisvitrea*, and *Evadue* sp. were the only species found under the order of Aphragmophora, Cyclopoida, Cydippida, Lobata, and Onychopoda, respectively. The richness of nutrients, accessibility of rich phytoplankton, and ocean circulation may have contributed to the diverse species and groups of zooplankton that were discovered. The results, however, are consistent with the research from Aiman *et al*. (2020), Azmi *et al*. (2016), Deepika *et al*. (2019), Melo *et al*. (2010), Matias-Peralta and Yusoff (2015).

Abdul *et al*. (2016) conducted a study in an estuary and found a relative abundance that was higher than any zooplankton species. According to Melo *et al*. (2010), copepods always had a higher relative abundance than any other zooplankton group. According to Tonapi (1980), the distribution of different species was influenced by physico-chemical factors such as water's conductivity, pH, chloride, and free CO_2 level as well as temperature.

Calanoida was found to be prominent in all groups in the current study among all orders of zooplanktons due to its distribution and similarity to results previously noted by several studies, including Abdullahi *et al*. (2007), Adeyemi *et al*. (2009), APHA (1989), Benarjee *et al*. (2008), Balamurugan *et al*. (1999). Similar findings have also been made by Boxshall and Evstigneeva (1994), Davies *et al*. (2009), Devika *et al*. (2006), Gayathri *et al*. (2014), Goswami and Mankodi (2012), Jalilzadeh *et al*. (2007), MVSSS (2000), Raghunathan and Kumar (2002).

The bulk of the copepod species from the genera *Paracalanus*, *Oithona*, and *Acartia* are found in abundance on near shore and in estuaries in Malaysian seas (Chew and Chong, 2011). The identified groups Appendicularia (2.46%), Chaetognatha (2.45%), Cladocera (2.31%), Copepoda (26.05%), Ctenophora (5.86%), Crustacean zooplankton (21.64%), Ichthyoplankton (17.77%) and Meroplankton (21.45%) were found at Sitakunda coast of Chittagong, Bangladesh (Khan *et al*. 2015). In the coastal seas of Malaysia, the copepod species *P. crassirostris*, *P. parvus* and *Bestiolina similis* were established dominating species (Johan *et al*., 2013; Matias-Peralta and Yusoff, 2015; Rezai *et al*., 2004). According to reports, *Oithona* simplex predominates in inshore and shallow seas, is suited to low salinity water, and is common in mangrove estuaries (Johan *et al*., 2013). The major dominant species were characterized by visual inspection using a light microscope according to the basis of stations (Figures 3, 4 & 5). The distribution patterns and species composition of plankton are significantly influenced by the physico-chemical characteristics and nutrient content of lake water (Horne and Goldman, 1994; Mahar *et al*., 2000; Omoregie, 2017).

Rajashekhar *et al*. (2010) further supported our findings by confirming a higher number of zooplankton genera and discovered 24 species, of which 10 species are Rotifera, 6 species are Cladocera, 5 species are Copepoda, and 3 species are Ostracoda. Their study's results on a group level are consistent with ours. However, Hossain *et al*. (2006), Rahman and Hussain (2008), Roy *et al*. (2010), Das *et al*. (2011) had all found fewer zooplankton genera than the current study. However, earlier works had also observed similar outcomes (Bhavan *et al*., 2015; Dede and Deshmukh, 2015; Dhanasekaran *et al*., 2017; Ezhili *et al*., 2013; Manickam *et al*., 2012, Manickam *et al*., 2014, Manickam *et al*., 2015; Patel *et al*., 2013; Thirupathaiah *et al*., 2011; Watkar and Barbate, 2013).

A lower Simpson's Dominance Index value indicates a higher zooplankton population (Majumdar *et al*., 2020). The plankton diversity index, according to Magurran (1988), refers to the quantification of variety in a sample or community as a single number. Due to the fact that all fish species will produce an equally plentiful population, which will consider the diversity. In order to compare the estimated values in three specifically chosen locations of the Pasur-Sibsa and Baleshwari river estuary, multiple diversity index assessments were carried out for the analysis of zooplankton diversity. But the Shannon-Wiener Diversity Index (H) varied from 1.33 to 1.43 at various sites in the area under investigation (Figure 7). The average value of species diversity in the current study served to show the health of the chosen ecosystem. Higher Shannon-Wiener Diversity Index (H) values and zooplankton populations were noted by Das (1996) and Manickam *et al*. (2012) during their research period. Lower zooplankton species diversity in the area denotes significant pollution, which is harmful to the aquatic ecology (Manickam *et al*., 2015; Ismail and ELawad, 2015). In stressed and contaminated ecosystems, there appears to be less variety of zooplankton species (Bass and Harrel, 1981). The most often used biodiversity measure for assessing species variety is Margalef's Richness Index (d).

The Evenness (E) value, which ranged from 1 to 0, counts the number of members of a species. When compared to other periods, the tidal period had very high species equitability (Evenness), which suggests that the diversity of the plankton was declining (Adesalu and Nwankwo, 2008). Studies by Abu-Hena *et al*. (2016), Aiman *et al*. (2020), Deepika *et al*. (2019), Ismail and Zaidin (2015) were found to have similar findings to the present study. Additionally, Simpson's Dominance Index (D), a measure of diversity, takes both the total number of species present and the relative abundance of each species into account. Generally, the Simpson's Dominance Index (D) value spans from 0 to 1, and the greater the range of values, the less biodiversity is often represented. As a result, while considering the Simpson's Dominance Index (D) value into account, it was discovered that the S1 location was the most enriched with species variety and the S2 site was the least enriched. The Simpson's Index of Diversity (1-D), on the other hand, is dependent upon the Simpson's Dominance Index (D), where S1 and S2 were found to have the highest and lowest Simpson's Index of Diversity (1-D), respectively. Thus, the S1 area has a wide variety of species. The temporal fluctuation in dominant status among the three sampling locations may be the cause of this slight discrepancy. Finally, this investigation demonstrated the variety and abundance of zooplankton in various regions of the Pasur-Sibsa and Baleshwari river estuaries. Based on different biodiversity index outcomes, we can declare that sampling station S1 (Pasur river gateway) is comparatively rich in zooplankton biodiversity.

5. Conclusion

Zooplankton diversity strongly impacts estuary health, serving as a key indicator of marine productivity and environmental well-being. About 34 species from the diversity of zooplankton's nine orders and seventeen families were counted in the current study. This study established that sampling station S1 (Pasur river gateway) was rich in zooplankton profile. The biodiversity is currently in threat owing to global warming; deforestation; industry, agriculture and livestock farming; rubbish and waste water dumping; maritime traffic, fuel spillages and others human activity. Maintaining updated knowledge of the aquatic species diversity like fish biodiversity is necessary for the conservation of biodiversity. Future research can be done to improve fish production and protect the diversity of zooplankton in the Pasur-Sibsa and Baleshwari river estuary in Khulna, Bangladesh. Based on the estuary's current condition, this study may be useful for the growth of fisheries production in the future.

Acknowledgments

We would like to thank Dr. Md. Asadujjaman, Assistant Professor, Department of Aquaculture, Khulna Agricultural University, Khulna- 9100, Bangladesh, for his technical assistance during the project. We also acknowledge the assistance in data collection provided by the neighborhood residents close to the study area. We sincerely thank the anonymous fishermen who contributed in a variety of ways to the implementation of this study.

Conflict of interests

The authors declare no conflicting interests.

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