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Spatial Distribution and Diversity of Marine Zooplankton Adjacent to the St. Martin's Island, Bangladesh

Md Jobaer Alam[1*], A.S.M. Maksud Kamal[2], Md. Kawser Ahmed[1], Moniruzzaman Khondker[3], Rafid Fayyaz[1]

[1] Department of Oceanography, University of Dhaka, Nilkhet Rd, Dhaka 1000, Bangladesh
[2] Department of Disaster Science and Climate Resilience, University of Dhaka, Nilkhet Rd, Dhaka 1000, Bangladesh
[3] Department of Botany, University of Dhaka, Nilkhet Rd, Dhaka 1000, Bangladesh
* Corresponding author's e-mail: jobaer_alam@du.ac.bd

ABSTRACT

Bangladesh, a country that lies on the north shores of the Bay of Bengal, has been blessed with a plethora of natural resources. St. Martin's Island, the only coral-bearing island in Bangladesh, is undoubtedly regarded as one of the most prized possessions. It is rich in biodiversity, but truly scientific information on it is lacking. In the present investigation, 14 stations adjacent to St. Martin's Island within the Bay of Bengal were sampled for determining the composition, spatial distribution, species richness, and diversity of pelagic zooplankton. Samples were collected in the pre-monsoon hot season. From the community of zooplankton, 34 species were reported. Most of the species belonged to copepods. Besides, Polychaeta and Cirripedia were also present in the community. The most significant species belonged to *Oithona, Canthocalanus, Balanus, Euterpina*, and *Microsetella.* Total zooplankton standing crop varied from 45,000–125,000 ind/m^3 and the highest number of species (8) were observed at station 7. Strong variability in the distribution of species was observed in the studied stations. The number of genera collected at each station varied from 4–8. Data on species richness (D_f) varied from 1.30–3.04 and that of the Shannon-Wiener Index (H) from 1.33–1.93. The species composition of zooplankton and the species richness and the diversity index of the population was comparable to the other studies carried out in the Central and Western Bay of Bengal.

Keywords: zooplankton, spatial distribution, abundance, richness, diversity, Bay of Bengal, St. Martin's Island, coastal water.

INTRODUCTION

In oceans, phytoplankton is efficiently grazed down by zooplankton, and the latter organism shifts energy from the primary producer level towards a series of higher organisms via the food chain. These organisms have the potential to move or are unable to move, and show vertical mobility following diurnal and seasonal cycles to determine their horizontal positions within the ocean (Thurman, 1991). Among zooplankton, in terms of biomass copepods are the main, the feeding rate of which increases with the increase in the abundance of phytoplankton until a saturation density is attained (Speight and Henderson, 2007). Besides copepods, other zooplankton, such as crustacean nauplii, euphausiids, and ciliate protozoa also graze phytoplankton. So, parallel to phytoplankton, zooplankton also plays an important role in the pelagic grazing food chain of the oceans. Zooplankton has the utmost importance in aquatic ecosystems because of its functional aspects of biotic elements. These include food chains and trophic networks, energy flow, and circulation of matters. In summary, it is at the center of pelagic food webs (Lampert, 1997). Moreover, they can be used as bioindicators as

they have a short life cycle and show swift reactions against certain environmental changes (Ferdous & Muktadir, 2009).

In order to assess the species composition and the horizontal distribution of the zooplankton community related to biophysical parameters, an in-depth investigation was conducted around St. Martin's Island, Bay of Bengal (henceforth BoB), Bangladesh. It is important to note that this investigation was the first of its kind in Bangladesh. The phytoplankton density is dramatically diminished by zooplankton grazers, for example, the population of phytoplankton is reduced by 75% at a 20% grazing rate by zooplanktons (Dawes, 1998). Zooplankton is an important component of the marine ecosystem and as they are affected by small changes in the environment, can also provide an early warning indication of an environmental hazard. They also show changes in their qualitative and quantitative aspects following the dynamics in the extent of physical parameters, acidity, as well as nutrients from farm runoff and pollution.

In Bangladesh, Islam and Aziz (1975) studied the zooplankton of north-eastern BoB where they had reported 18 species. But the species composition of zooplankton in the BoB is far higher. As it is evident from the studies carried out in different parts of the Indian BoB, a total of 163, 93, 239, and 209 species of zooplankton were reported by Fernandes and Ramaiah (2009), Sahu et al. (2010), Baliarsingh et al. (2018), and Srichandan et al. (2015), respectively. So, compared with the Indian part, the faunistic composition of zooplankton in the Bangladesh part of BoB is less investigated. In Bangladesh, in the backdrop of the concept of 'Blue Economy' based partly on the exploration of biological productivity, it is now an urgent task to carry out the floristic and faunistic composition of plankton of the BoB. Recently, Alam et al. (2021) studied the phytoplankton floristic composition of 14 stations adjacent to the St. Martin's Island of the BoB where they have reported 62 species of diatoms and 6 species of dinoflagellates. The present investigation has therefore been undertaken to study the zooplankton from the north, south, east, and western part of the coastal waters adjacent to St. Martin's Island of the BoB, Bangladesh. The data from this study can be used to manage and plan marine resources, benefit the fishery industry, and as well as preserve the ocean's biogeochemical cycles. The aims and objectives of the study were, to determine the qualitative composition, abundance, and spatial distribution of zooplankton

MATERIALS AND METHODS

Study area

The study was carried out in 14 different stations situated surrounding the St. Martin's Island and located between 20°34′ and 20°39′ N and 92°18 and 92°20′ E (Fig. 1). A detailed description of the study sites together with the GPS values of the stations have been published in Alam et al. (2021).

Collection and processing of water samples

For the collection of zooplankton samples, the study stations were visited in the pre-monsoon hot season. Each station was reached with the help of a mechanized trawler. Using a plastic bucket (10 L capacity) 100 L of seawater was passed through a plankton net having a mesh width of 60 μm and the opening mouth dia 0.57 m. The concentrate of plankton accumulated in the bucket of the plankton net was decanted in a 500 mL screw-capped polystyrene bottle. The specimen was labeled and preserved with a 5% formaldehyde solution. Finally, all the samples were transported to the Biological Oceanography Laboratory of the Department of Oceanography, University of Dhaka within the next 24 h. The field and laboratory measurements of the physicochemical parameters determined from the study stations were published in Alam et al. (2021).

During the study, the physicochemical parameters i.e., temperature, pH, dissolved oxygen (DO), and salinity of the coastal waters were recorded. Firstly, a mercury centigrade thermometer was used to determine the temperature of the coastal waters. Secondly, the pH and DO were estimated using a portable digital pH meter and DO meter (HANNA, pHep, Romania; HACH, HQ30d, USA). Finally, the salinity of the coastal water was quantified using a refractometer (Agriculture Solutions, WL0020-ATC).

Each of the concentrated zooplankton samples were collected from 14 stations was investigated firstly to identify the species. For this purpose, a compound microscope (Novel, N10E, China) with photographic attachment was used. A water mount sample, supplemented with 4%

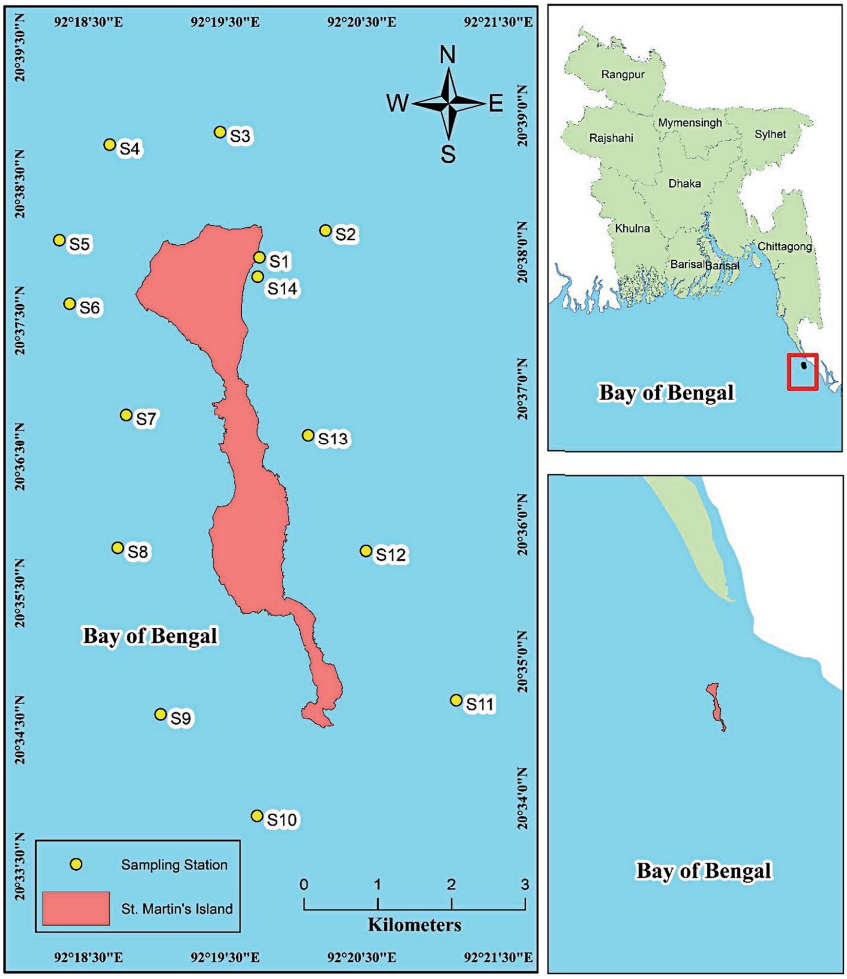

Figure 1. The study area (S1–S14) adjacent to the St Martin's Island, Bay of Bengal, Bangladesh

glycerin was prepared onto a glass slide covered with a coverslip on it and was observed through the microscope. Images of the species together with microscopic measurements of the individuals were recorded wherever possible. The species were identified with the help of Slotwinski et al. (2014), and Abou Zaid et al. (2014), Conway et al. (2003), Kasturirangan (1963), Davis (1955). The images of zooplankton have been presented in this paper (Fig. 8i–xxxiv).

The quantitative aspect of the zooplankton population from the collected samples was followed with the help of a Sedgewick Rafter Counting Cell (SRCC) and a compound microscope at a magnification of 100×. The number of zooplankton in each mount of the SRCC was measured based on the genera. The following formula was used to quantify the organisms present in each sample:

$$\text{Number of organisms } (m^{-3}) = \frac{C \times V_1}{V_2 \times V_3} \quad (1)$$

where: C = number of organisms counted;
V_1 = volume of concentrated sample (ml);
V_2 = volume of sample counted (ml);
V_3 = volume of filtered water by the plankton net (m^3).

The concept of Margalef (1958) was followed to evaluate the species richness and generic diversity in the samples, species richness (D_f) and Shannon-Wiener index were also calculated. The following methods were applied to calculate the species richness and Shannon-Wiener index:

Species richness:

$$D_f = \frac{S-1}{ln(N)} \quad (2)$$

where: S = number of genera in a sample;
N = total number of genera.

Shannon-Wiener index:

$$H = -\sum P_i \times ln\,(P_i) \quad (3)$$

$$\text{and } P_i = \frac{n}{N} \quad (4)$$

where: n = total number of individuals in a sample; N = total number of individuals.

Pielou's Evenness:

$$J = \frac{H}{ln(S)} \quad (5)$$

where: H = Shannon-wiener index; S = number of genera at a station.

All of the diversity calculations were done taking into account the population density at the genus level.

Analysis of data

Microsoft Excel database was created by digitizing the collected data on the zooplankton abundance and diversity. The data was verified carefully and then plotted and tabulated. All the maps shown in this paper were created using ArcGIS software.

RESULTS

Water quality parameters

Figure 2 shows the station-wise fluctuation of salinity, water temperature, pH, and DO for all 14 stations. Water temperature ranged from 26.6–27.2°C while the salinity ranged between 32.1 and 33.7 psu. Station 7 showed the highest water temperature and the lowest of the same was shown by station 14. Actually, the spatial distributional trend of water temperature and salinity showed an increasing order gradually from the study station 1–7 and 1–10 for temperature and salinity, respectively (Fig. 2). A similar pattern of spatial variation was also shown for DO (Fig. 2). However, the spatial distribution of pH over the sampling station was rather different. Station 1 showed lower pH which was a little elevated in station 2 but starting from stations 3–5, a drastic fall in pH was evident (Fig. 2). A gradual increase in the pH value was evident starting from stations 6–9. It fell further from station 10 to 14 (Fig. 2).

Zooplankton abundance, diversity, and distribution

In the present study, a total of 34 species of zooplankton from 14 different sampling stations were recorded (Table 1). Most of the species were copepods. Besides, Polychaeta and Cirripedia were also present in the community. Species belonging to the genera *Oithona*, *Canthocalanus*, *Balanus*, *Euterpina*, and *Microsetella* were most common in the population. The standing crop of zooplankton varied from 45,000 to 125,000 ind/m^3 and the highest population was found at station 7. The species of *Oithona* and *Microsetella* were predominant in all the stations. The highest number of species (4) was recorded from the genus *Oithona* (Fig. 8 iii, iv, v, and viii). The genera like *Oncaea*, *Clausocalanus*, *Euterpina*, *Labidocera*, and *Microsetella* all did show the records of two species in each. However, the genera *Balanus*, *Canthocalanus*, *Hyperia*, *Eutintinnus* and *Tintinnopsis* were represented by the occurrence of a single species in the community.

Figure 3 shows the spatial variation of zooplankton abundance as well as the number of

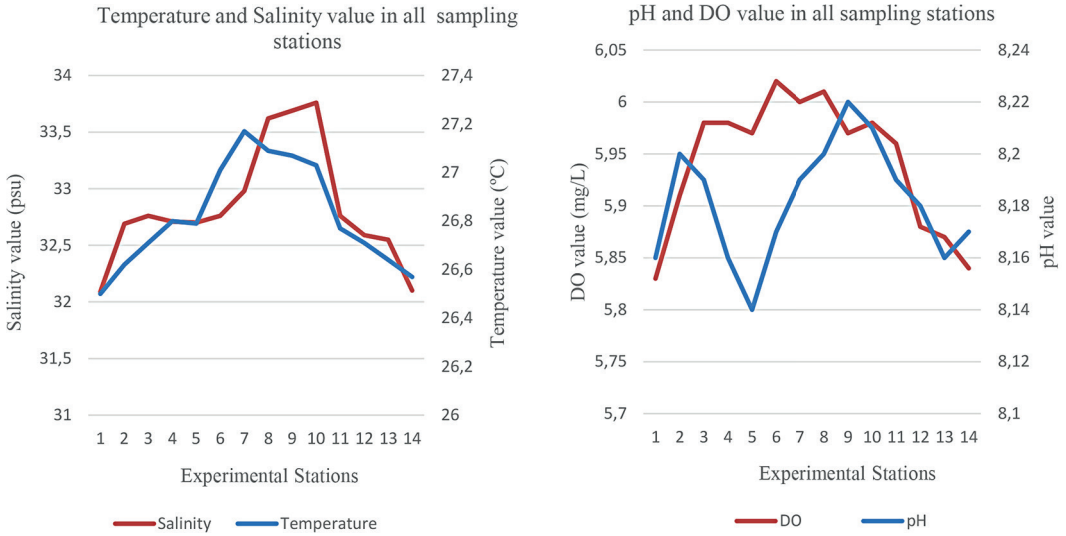

Figure 2. Water quality parameters measured at different sampling stations (Fig. 1)

Table 1. Zooplankton species recorded from sampling stations around St. Martin's Island

Serial	Genus/Species	Figures
1.	*Acartia pacifica* Steuer	8(xiii)
2.	*Balanus glandula* Darwin	8(ix)
3.	*Canthacalanus pauper* Giebrecht	8(vii)
4.	*Clausocalanus arcuicornis* Dana	8(xviii)
5.	*Clausocalanus* sp.	8(xvii)
6.	*Clytemnestra scutellata* Dana	8(xxii)
7.	*Corycaeus agilis* Dana	8(xxxi)
8.	*Ditrichocorycaeus andrewsi* Farran	8(xvi)
9.	*Euphausia* sp.	8(vi)
10.	*Euterpina acutifrons* Dana	8(xxi)
11.	*Euterpina* sp.	8(xii)
12.	*Eutintinnus* sp.	8(xxxiii)
13.	*Evadne* sp.	8(xi)
14.	*Hyperia galba* Montagu	8(xxvi)
15.	*Labidocera bengalensis* Krishnashwamy	8(xxv)
16.	*Labidocera* sp.	8(xxvii)
17.	*M. rosea* Dana	8(xx)
18.	*Metis jousseaumei* Richard	8(xix)
19.	*Metridia lucens* Boeck	8(xxiv)
20.	*Microsetella norvegica* Boeck	8(xiv)
21.	*O. brevicornis* Giesbrecht	8(v)
22.	*O. nana* Giesbrecht	8(iv)
23.	*Octolasmis* sp.	8(i)
24.	*Oithona similis* Claus	8(iii)
25.	*Oithona* sp.	8(viii)
26.	*Oncaea minuta* Olson	8(xxix)
27.	*Oncaea* sp.	8(xxiii)
28.	*Podon* sp.	8(xxxii)
29.	*Pseudonereis* sp.	8(ii)
30.	*Subeucalanus flemingeri* Prusova, Al Yamani & Al Mutairi	8(xxx)
31.	*T. longicornis* Müller O.F.	8(xv)
32.	*Temora dicaudata* Giesbrecht	8(xxviii)
33.	*Thysanoessa raschii* M. Sars	8(x)
34.	*Tintinnopsis* sp.	8(xxxiv)

genera over the 14 stations situated at different locations in the BoB adjacent to St. Martin's Island. The highest zooplankton population (125,000 ind/m^3) was found at station 7, which also had the most genera (8). While the 2nd (~95,000 ind/m^3), 3rd (~90,000 ind/m^3), and 4th (~85,000 ind/m^3) highest individuals were recorded from the stations 13, 9, and 2 respectively. Furthermore, the 2nd (7) highest number of genera was found at station 9 while the 3rd (6) highest number of genera were found at stations 2, 5, and 13 respectively (Fig. 3). An increasing trend in the population density of zooplankton was observed from stations 4–7 and 10–13. The lowest abundance was found at stations 3, 4, and 10 (Fig. 3).

Figure 4 depicts the relative abundance of zooplankton genera across 14 stations in the BoB at various locations in the BoB adjacent to St. Martin's Island. It provides an overview of the zooplankton composition at each station and the dominant genus at each site. Figure 5 shows the area plot of zooplankton abundance at a generic level attached to each station of interest, via which the highest and lowest abundance of zooplankton can easily be visualized. Most abundant populations were seen for *Microsetella* and *Oithona* at different stations.

Zooplankton richness, Shannon-Wiener Index, and Evenness

Figures 6 and 7 depict the results of species richness and the Shannon-Wiener Index together with evenness respectively. From Figure 6, it can be established that station 7 had the highest species richness (3.04). On the other hand, stations 1, 3, and, 12 showed the lowest species richness (1.30). Furthermore, from Figure 7, it is evident that the lowest diversity index (1.32) was seen at station 12 with the lowest evenness being at stations 8 and 14 (0.925789). Moreover, the highest index was seen at station 7(1.93) and evenness at station 9 (0.981546).

DISCUSSION

Zooplanktons are the key organisms to link food energy transformation between phytoplankton and the rest of the consumers of the seas (Fernandes & Ramaiah, 2009). Information on the zooplankton spatial and temporal variability in the Bangladesh part of the Bay of Bengal is scarce. In the present investigation, spatial variation of the zooplankton population among 14 different stations adjacent to St. Martin's Island was investigated during the pre-monsoon hot season. A total of 34 species of pelagic zooplankton were identified from which copepods were dominant. Zooplankton population dominated by copepods has also been observed in other parts of the Bay of Bengal, India (Fernandes & Ramaiah, 2009;

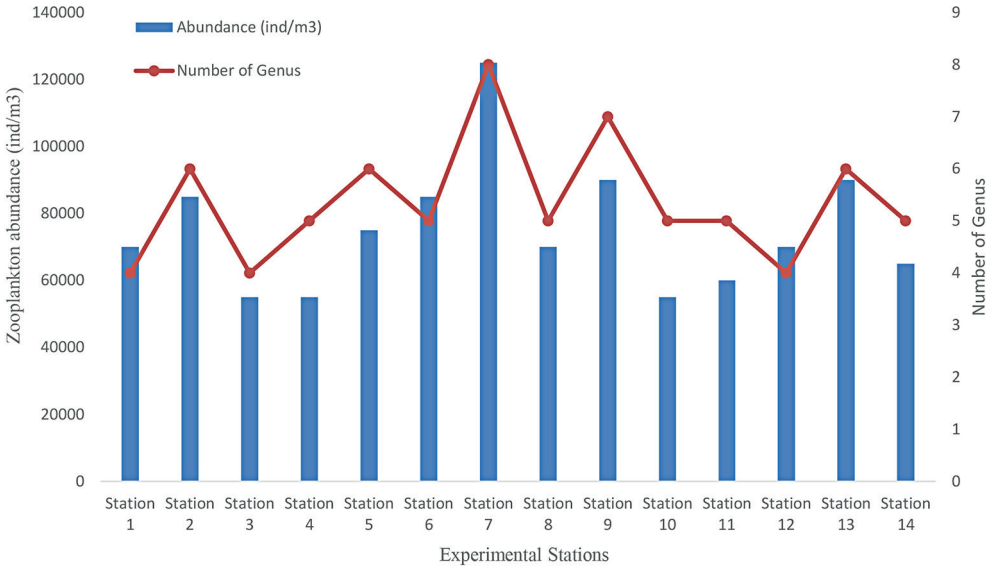

Figure 3. Comparison of Zooplankton abundance and genus composition at different sampling stations (Fig. 1)

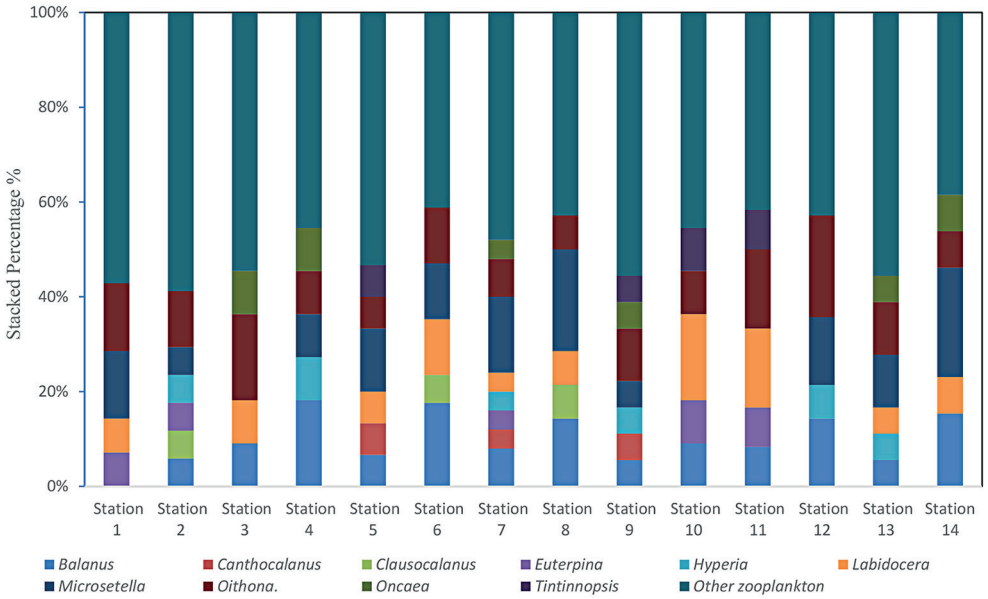

Figure 4. Relative abundance of the zooplankton genera found at different sampling stations (Fig. 1)

Srichandan et al., 2015; Baliarsingh et al., 2018). From the species composition of the present investigation *Evadne sp., Eutrepina acutifrons, Oncaea*, and *Oithona brevicornis* were also recorded in the coastal area off Gopalpur North-Western Bay of Bengal (Baliarsingh et al., 2018). All the 14 studied stations in the present investigation fell within 20° 33' 53" and 20° 38' 52" and 92° 18' 17" and 92° 21' 11" (Alam et al., 2021) and in this region of the BoB we have recorded the occurrence of zooplankton *Clausocalanus arcuicornis*, *Euterpina acutiformis*, *Oithona similis*, and *Oncaea* sp. Fernandes and Ramaiah (2009) investigated the zooplankton of Central-Western Bay of Bengal (India) (9–20° and 85–90° E) and recorded the above-mentioned species along with others. From this observation, it could be said that the region of the BoB adjacent to St. Martin's Island supports some of the typical zooplankton. In this study, along with copepods, Polychaeta and Cirripedia were also present. In the nearshore waters of the Bay of Bengal, Sahu et al. (2010) found 93 species of zooplankton belonging to 46 genera and 33 families of six phyla. Among them, copepods were represented by 49 species of 21 genera, belonging to 15 families and 3 orders. Srichandan et al. (2015) investigated zooplankton distribution in the North-Western Bay of Bengal's

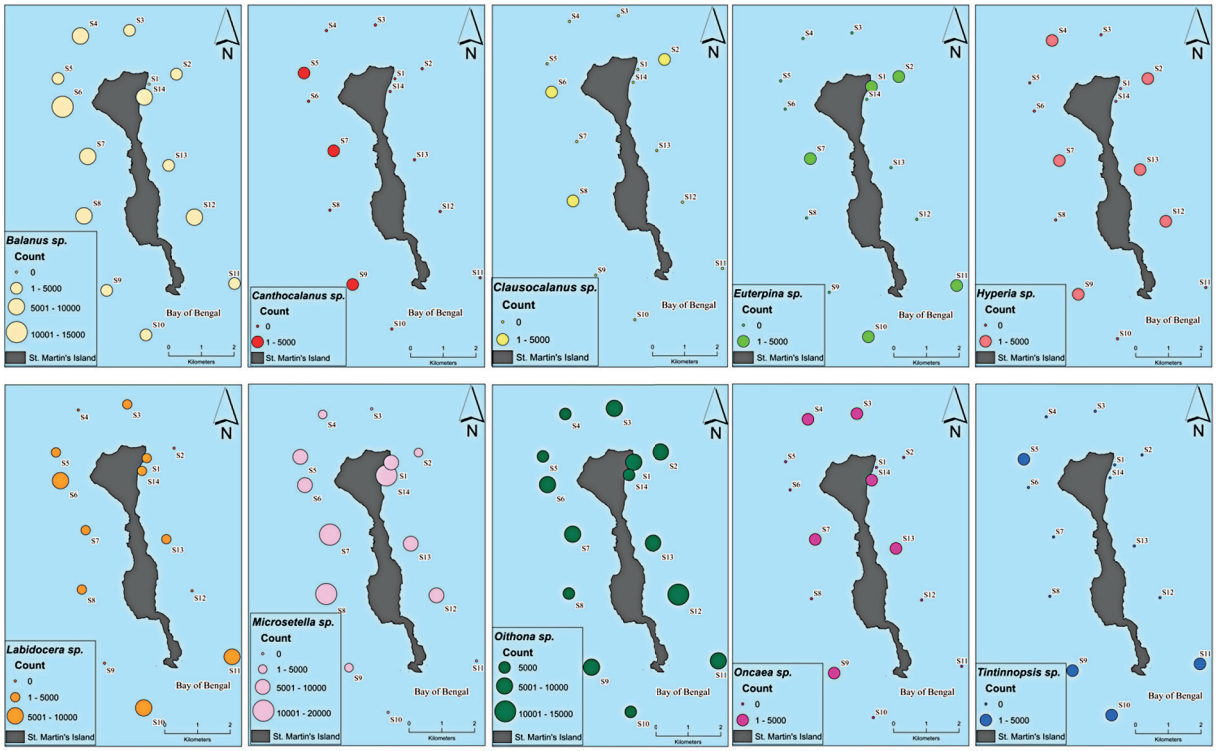

Figure 5. Zooplankton population density (ind/m^3) at a generic level at different sampling stations (Fig. 1)

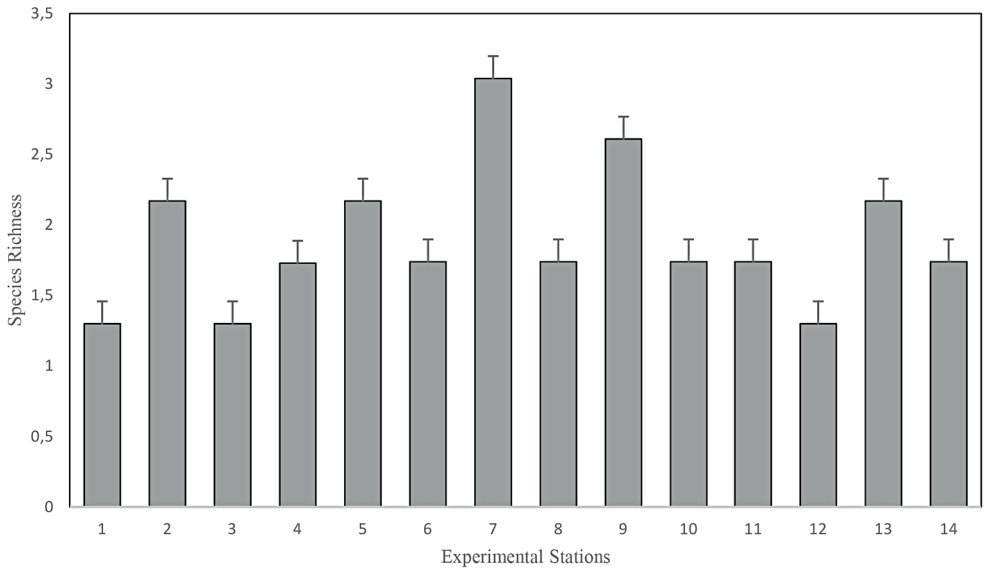

Figure 6. Mean species richness (Species richness ± SD) at different sampling stations (Fig. 1)

coastline area, finding 186 species and 23 species of holoplankton and meroplankton respectively. Copepods dominated the zooplankton group, with 112 species belonging to 4 orders and 26 families. The copepod order Calanoida developed as the most prevalent. According to Fernandes and Ramaiah, (2009), the Central and western part of the Bay of Bengal is less productive because of higher water temperature >28°C, surface salinity of 28–33 ppt, high turbidity, and low nutrient. In the present study area, the physicochemical factors ranged 26.50–27.17°C, 32.09–32.98 ppt, 8.14–8.20, and 5.83–6.02 mg/L for water temperature, salinity, pH, and dissolved oxygen (DO), respectively (Alam et al., 2021). The water temperature and salinity ranges recorded in the sea waters of the present study are closer to that of Fernandes and Ramaiah, (2009) and, Sahu et al.

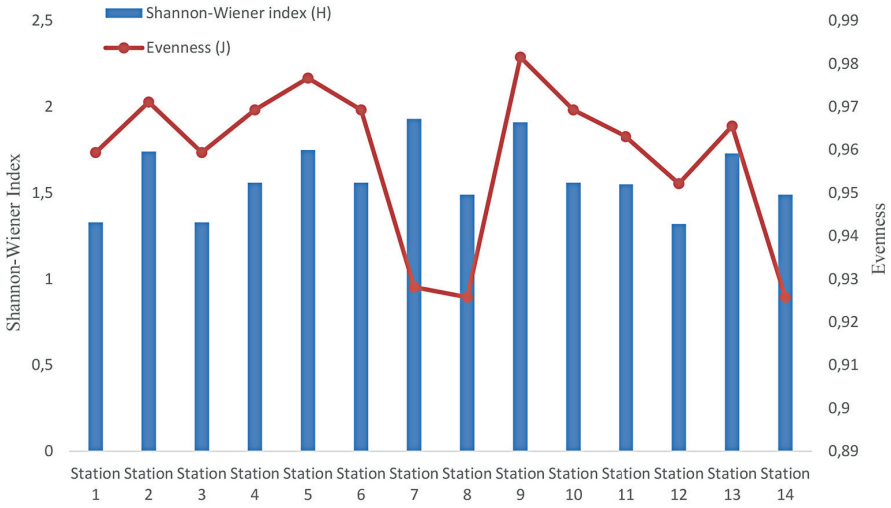

Figure 7. Variation of Shannon-wiener index and evenness index at different sampling stations (Fig. 1)

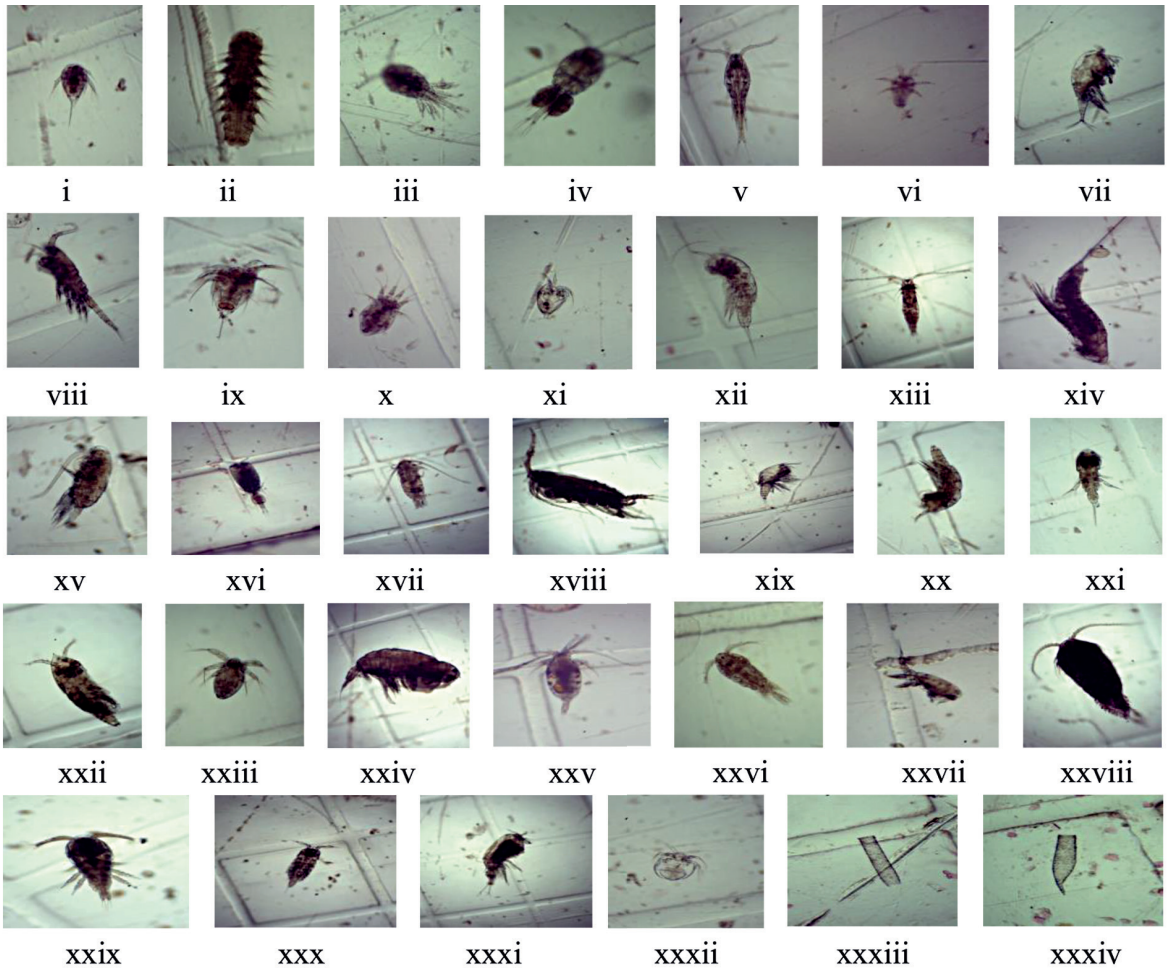

Figure 8. Zooplankton: i. *Octolasmis* sp., ii. *Pseudonereis Sp.*, iii. *Oithona similis*, iv. *O. nana*, v. *O. brevicornis*, vi. *Euphausia sp.*, vii. *Canthocalanus pauper*, viii. *Oithona sp.*, ix. *Balanus glandula*, x. *Thysanoessa raschii*, xi. *Evadne sp.*, xii. *Euterpina sp.*, xiii. *Acartia pacifica*, xiv. *Microsetella norvegica*, xv. *T. longicornis*, xvi. *Ditrichocorycaeus andrewsi*, xvii. *Clausocalanus* sp., xviii. *Clausocalanus arcuicornis*, xix. *Metis jousseaumei*, xx. *M. rosea*, xxi. *Euterpina acutifrons*, xxii. *Clytemnestra scutellata*, xxiii. *Oncaea* sp., xxiv. *Metridia lucens*, xxv. *Labidocera bengalensis*, xxvi. *Hyperia galba*, xxvii. *Labidocera* sp., xxviii. *Temora discaudata*, xxix. *Oncaea minuta*, xxx. *Subeucalanus flemingeri*, xxxi. *Corycaeus agilis*, xxxii. *Podon* sp., xxxiii. *Eutintinnus* sp., xxxiv. *Tintinnopsis* sp.

(2010) for the BoB. The maximum population density for phytoplankton was 3.75×10^5 (Alam et al., 2021) and for zooplankton: 12.5×10^4 (in the present investigation). Both the parameter varied with a magnitude of 1 order of power function, which supports the view that the area is also less productive. Srichandan et al. (2015) studied the zooplankton of Rushikulya estuary South of Odisha coast of the BoB, India, and the mean premonsoon values of the physicochemical parameters obtained were: water temperature, 28.9°C; pH, 8.04; DO, 7.79 mg/L; salinity, 31.79 PSU; PO_4, 1.41 µmol/L; and chlorophyll a (chl-a), 2.81 mg/m^3. Data also suggests an oligotrophic condition of the seawater in that region of the BoB.

Among the studied stations, a maximum number of 8 genera of zooplankton was recorded in station 7, whereas, 4 genera were recorded from each of stations 1, 3, & 12 (Fig. 3). It is to be noted here that station 7 supported a higher concentration of DO and the highest water temperature among all the studied stations (Fig. 2). The species richness (D_f) varied from 1.3–3.04, while the Shannon-Wiener Index (H) varied from 1.33–1.93 (Fig. 7). According to Fernandes and Ramaiah, (2009), in the Central and Western Bay of Bengal in the summer monsoon species diversity of zooplankton was high at 9° N i.e., 3.86 which showed decreasing trend northwards and at 20° N it was 2.72. GPS data of our study sites ranged from 20° 33' 52" and 20° 38' 53" and we recorded a range of species diversity values from 1.30–3.04. So, it could be said that the zooplankton diversity within the latitude range of the BoB as mentioned above is similar to that reported by Fernandes and Ramaiah, (2009). Zooplankton-based information from the Bangladesh part of the BoB is extremely scarce. So, under this condition, the present study could provide some guidelines for future studies on this important grazing food chain parameter of the BoB.

CONCLUSIONS

The objective of this study was to carry out a comprehensive assessment of the zooplankton of the Bay of Bengal adjacent to St. Martin's Island. The amount and nature of the zooplankton in the surface water of the study area were assessed and could be said that the attempt is the first of its kind. From 14 different sampling stations, 34 different zooplankton species were recorded. In the case of zooplankton, most of the species were copepods. Besides, Polychaeta and Cirripedia were also present in the community. The most important species belonged to *Oithona, Canthocalanus*, *Balanus*, *Euterpina*, and *Microsetella.* Total zooplankton standing crop varied from 45,000–125,000 ind/m^3 and the highest number of zooplankton in terms of genera was found at station 7. Comparing the standing crop values of phytoplankton and zooplankton from the same studied stations it was observed that the primary productivity, as well as the strength of the primary consumer, is low. The species richness and the diversity index of the zooplankton population seem to be comparable to those found in other studies of the Bay of Bengal.

Results indicated that zooplankton composition and their abundance are variable across the sampling stations. Meaning that the variability is not caused by a single factor. It is hypothesized that various water quality parameters including water circulation temperature, dissolved oxygen, pH, and salinity may be responsible for causing this variability.

Acknowledgements

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