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Plankton Biodiversity and Spatial Variation in the Moheshkhali Channel, Bay of Bengal, Bangladesh

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ABSTRACT: This study provides a comprehensive exploration of the pivotal ecological roles played by phytoplankton and zooplankton, highlighting their significance as primary producers and consumers, respectively. Delving deep into the intricate web of environmental factors influencing plankton population dynamics, a meticulous qualitative and quantitative examination was conducted at six distinct stations in the Moheshkhali channel, situated in Cox's Bazar, Bangladesh. The species composition of plankton, as well as the observed species richness and diversity index, exhibited remarkable congruence with the findings of other studies conducted within the same geographical area. In the studied stations, water temperature, salinity, pH, and dissolved oxygen (DO) ranged from 20.94 to 23.90 ºC, 10.60 to 23.98 ppt, 7.60 to 7.92, and 7.7 to 11.7 mg/L, respectively. The density of phytoplankton ranged from 5 to 90 ind × $10^3/m^3$, while the zooplankton population density ranged from 5 to 30 ind × $10^2/m^3$. Among phytoplankton, *Rhizosolenia* was found to be dominant, but the zooplankton population was dominated by the copepod nauplii stages. Variable ranges of salinity, predation, and environmental factors might be responsible for governing the biodiversity of plankton in this less saline zone of the Bay of Bengal, the Moheshkhali Channel.

Keywords: Plankton; Spatial Distribution; Diversity Index; Physicochemical Parameters; Moheshkhali Island

INTRODUCTION

The Bay of Bengal (5°N to 22°N and longitudinal constraints of 80°E to 100°E), an expansive marine ecosystem located in the northern arm of the Indian Ocean, represents a vast, semi-enclosed tropical ocean basin profoundly influenced by tropical monsoons. This region experiences a substantial influx of freshwater from both river discharge and rainfall (Vinayachandran & Mathew, 2003). The Bay of Bengal features a relatively narrow continental shelf, especially along its eastern coast, and a prominent central basin with depths ranging from 2,000 to 4,000 meters (Bastia and Radhakrishna, 2012)

In the marine ecosystem, planktonic flora and fauna play a vital role in the intricate aquatic food web which is interesting though less studied. Phytoplankton, as the primary producers of organic matter in the marine ecosystem, are instrumental in initiating the aquatic food chain and contributing to the overall production of fish, zooplankton, and other aquatic organisms (Ananthan et al., 2005; Saifullah et al., 2014; Tiwari & Chauhan, 2006). The spatial and temporal distribution of plankton communities assumes a pivotal role in modulating water quality, thereby responding to the ever-changing environmental conditions (Rahaman et al., 2013; Saifullah et al., 2014). On the other hand, zooplankton assumes a central and pivotal role within marine ecosystems, exerting substantial influence on trophic levels and the intricate dynamics of these ecosystems (Lomartire et al., 2021). Their diurnal vertical migration patterns have a profound impact on the feeding behaviors of fish, influencing food availability in the process (Perissinotto & McQuaid, 1992). These tiny organisms also serve as efficient grazers, consuming algae and bacteria, while simultaneously contributing to the essential process of nutrient recycling (Lehman & Sandgren, 1985; Sterner, 2009). Moreover, the significance of zooplankton extends to the realm of the Biological Carbon Pump, a crucial mechanism regulating atmospheric carbon dioxide levels. It accomplishes this by effectively

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governing particle export and facilitating the downward transport of Particulate Organic Carbon to deeper ocean layers (Cavan et al., 2017; Kwon et al., 2009; Parekh et al., 2006).

Phytoplankton, as primary autotroph, rely on sunlight, water, carbon dioxide, and nutrients to manufacture their own sustenance. Their distribution is intricately linked to factors such as light intensity, time of day, salinity, temperature, ocean currents, tides, nutrient availability, and seasonal patterns. In the grand scheme of ocean life, phytoplankton occupies an essential role, contributing to nearly half of the world's oxygen production (Jahan et al., 2023). Equally significant is their role in climate regulation, particularly in converting carbon dioxide into organic carbon,. At the very foundation of marine food webs, phytoplankton stands as the cornerstone. Conversely, zooplankton comprises a diverse array of aquatic animals that either drift or actively move within the oceans. They facilitate the transfer of organic energy generated by phytoplankton to higher trophic levels, playing a critical role in the intricate dance of predator-prey dynamics and in the successful recruitment of top predators, including fish and seabirds. In essence, zooplankton assume a crucial position in the pelagic food web, as they influence primary production and shape the dynamics of the entire pelagic ecosystem (Alcaraz et al., 2007).

In Bangladesh, research activities have been dedicated to cataloging plankton composition in several key regions, including the northeastern coast, Karnaphuli estuary, and the southwestern coast (Ahmed et al., 2010; Aziz et al., 2012; Islam & Aziz., 1977). More recently, comprehensive investigations have focused on the phytoplankton and zooplankton communities around St. Martin's Island (Alam et al., 2021, 2022).

It is worth noting that studies on marine plankton communities in Bangladesh remain relatively scarce when compared to the extensive research conducted in freshwater habitats (Alfasane, 2002, 2003; Islam et al., 1991; Islam & Irfanullah, 2003, 2006; Nural-Islam & Khatun, 1966), especially for marine channels, moreover the studies are conducted separately on either phytoplankton (Mehedi et al., 2017; Sarker et al., 2021) or zooplankton; (Alam et al., 2022; Ayshi et al., 2024). Given the context of the 'Blue Economy,' which emphasizes the exploration of biological productivity, there is an urgent need to conduct a comprehensive investigation into the entire plankton community including phytoplankton and zooplankton within the channels. The Maheshkhali Channel, situated at the southeastern coast of the Bay of Bengal, is important in this regard due to its fish biodiversity and coastal aquaculture (35 fin fish, 10 shrimp, and 7 species of cephalopods) and recreational purposes moreover it's vulnerable to eutrophication as well as harmful algal species (Ayshi et al., 2024).

From these perspectives, the objective of the study is to assess the physicochemical parameters, taxonomic identification of the phytoplankton and zooplankton, their diversity, and distribution of the Moheshkhali Channel. The data gathered from this study will serve as a valuable resource for the effective management of marine assets, the advancement of the fishing industry, and the preservation of intricate biogeochemical cycles.

MATERIALS AND METHODS

Study Area

The study was conducted in the Moheshkhali Channel, situated on the south-eastern coast of the Bay of Bengal. Moheshkhali stands as Bangladesh's only hilly offshore island and is separated from the mainland, Cox's Bazar, by the Moheshkhali channel. Its geographical coordinates place it between 21°30' N and 21°15' N latitude and 91°50' E to 92°5' E longitude, encompassing a total land area of 388.50 km^2 (Fig. 1). Its significance is as a large fishing ground and a center for recreation. To facilitate this study, a series of six distinct stations were selected in the eastern part of Moheshkhali Channel, and visited around the island for the purpose of collecting water samples (Fig. 1).

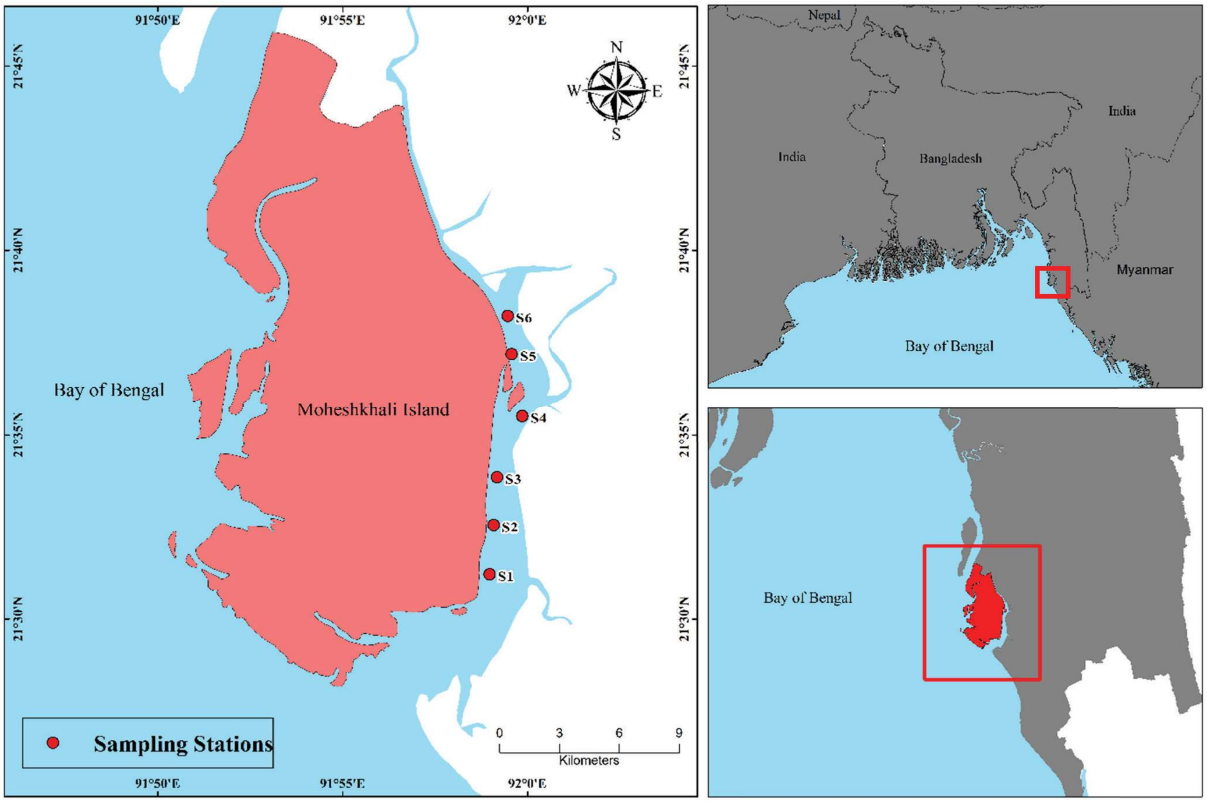

Figure 1: Map of the Study Region Showing Stations S1-S6. (Inset: Map of Bangladesh and the entire Moheshkhali Island)

Estimation of Physicochemical Parameters

Throughout the study, various physicochemical parameters of the coastal waters were measured in situ. Initially, water temperature was recorded using a traditional mercury thermometer. Subsequently, pH and dissolved oxygen (DO) levels were precisely gauged using portable digital meters, specifically the HANNA pHep from Romania and the HACH HQ30d from the USA. Lastly, a refractometer was used to quantify the salinity of the coastal water, specifically the Agriculture Solutions WL0020-ATC model.

Plankton Collection and Identification

The samples of plankton concentrates were collected by filtering 100 L of seawater through specialized plankton nets. Phytoplankton and zooplankton samples were selectively collected using nets with mesh sizes of 65 µm and 100 µm, respectively. The concentrated samples were delicately transferred into 500 mL plastic vials, with phytoplankton being preserved through a mixture of Lugol's solution and a 2% commercial formaldehyde solution, while zooplankton was adeptly preserved using 4% buffered formalin solutions. The vials were sealed and labeled with the date and time of collection and efficiently packaged for transportation.

To ensure the integrity of the samples, all collected specimens were promptly transported to the Dhaka University's Department of Oceanography laboratory, all within a stringent 24-hour timeframe. Upon arrival at the laboratory, the analysis process was promptly initiated and efficiently carried out, completing within a 72-hour timeframe.

Each of the concentrated planktons underwent a species identification process through a compound microscope (Novel, N10E, China) equipped with a photographic attachment. A water-mounted sample, with 4% glycerin, was thoughtfully prepared on a glass slide, overlaid with a coverslip, and scrutinized through the microscope. The identification of phytoplankton species was carried out using standard literatures like Ahmed et al., (2009), Davis, (1955), Hasle & Syvertsen, (1997), Tomas, (1997) In parallel, zooplankton species were identified consulting Abou Zaid et al. (2014), Conway (2003), Davis (1955), Kasturirangan (1963), and Slotwinski et al. (2014). The resulting visual documentation as photomicrographs of both phytoplankton and zooplankton species has been thoughtfully presented within this paper (Fig. 2-5).

Assessment of Plankton Abundance

The quantitative aspect of the plankton (including phytoplankton and zooplankton) populations, as derived from the acquired samples, was quantified using a Sedgewick Rafter Counting Cell and the microscope set at a 100× magnification. The abundance of plankton within each SRCC mount was gauged based on their respective genera. To quantify the organisms, present in each sample, the following formula was applied:

Number of organisms (m^{-3}) = $(C \times V1)/(V2 \times V3)$ **(1)**

Where ,

C = quantity of organisms,

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).

Biodiversity Indices Analysis

The species diversity indices are composed of species richness (D_f) and Shannon-Wiener Index (H) and Pielou's Evenness Index(J) were calculated according to Margalef(1968); Pielou (1966) and Shannon (1948). The equations used for calculating these indices are as follows:

$$\mathbf{D_f} = (S-1)/(\ln(N)) \quad \textbf{(2)}$$

Where,

S = Number of different genera in the sample,

N =Total number of individual genera in the sample.

$$\mathbf{H} = -\sum P_i \times \ln(P_i) \text{ and } P_i = n/N \quad \textbf{(3)}$$

Where,

n =Number of individuals of a genus

N = Total number of individuals

$$\mathbf{J} = H/(\ln(S)) \quad \textbf{(4)}$$

Where,

H = Shannon-wiener index

S = number of genera at a station

All diversity calculations were performed while considering the population density at the genus level.

RESULTS AND DISCUSSIONS

Water temperature ranged from 20.94 to 23.90 ºC, with the highest at stations 5 and 6 and the lowest at station 1. The salinity of water varied from 10.60 to 23.98 ppt, being the lowest at station 6 and the highest at station 1. The pH of the stations ranged from 7.60 to 7.92, while the dissolved oxygen (DO) concentration was between 7.7 and 11.7 mg/L. Station 6 had the highest oxygen concentration, and station 1 showed the lowest value for this parameter (Table 1). In some recent studies on plankton from St Martin's Island (SMI) in Bangladesh, Alam et al., (2021) obtained a range of 26.5-27.17 ºC, 32.09-33.76 ppt, 8.16-8.20, 5.86-6.12 mg/L for water temperature, salinity, pH, and DO, respectively. In the present study, both the water temperature and salinity ranges were found to be lower compared to the SMI values. The pH of the Moheshkhali channel and SMI were found to have a uniform range, but in the former habitat, the range was on the lower scale (7.6-7.92). In the present investigation, the value of DO ranged widely (7.7-11.7 mg/L), while in SMI, it was closely related (5.86-6.12 mg/L).However, temperature(18.33 to 30ºC),salinity(18.33 to 30 psu);pH(7.54 to 7.79) DO(5.68 (summer) to 6.86 mg/l(spring) in south eastern coastal waters(Kohelia channel and Kutubdia channel) in Bangladesh(Al et al., 2017).Thus the physicochemical parameters fell within the range of these study area, it suggests that environmental parametres play an important role in shaping the plankton community patterns.

Table 1: Physicochemical Features of the Studied Stations

Station No.	Temperature (ºC)	Salinity (ppt)	pH	DO (mg/L)
1	20.94	23.98	7.91	7.7
2	23	23.87	7.92	8.1
3	23.8	23.6	7.74	8.4
4	23.7	23.39	7.71	9
5	23.9	20.6	7.6	9.1
6	23.9	10.6	7.69	11.7

The phytoplankton identified in this research is composed of two major groups, Phylum Chrysophyta (diatoms) which is dominant with 20 species similar to the findings of Temkar et al, (2015),Lumeran et al, (2016), Alam et al., (2021);and the other was Phylum Dinoflagellata or dinoflagellates with 3 species. Lumeran et al, (2016) found similar but thirteen and seven species from the respective groups where *Ceratium sp* was dominant in the latter. Dinoflagellates were represented by *Ceratium sp.*; *Noctiluca sp.*; and *Gymnodinium sp.* in this study; however 62 diatoms and 6 dinoflagellates were found by Alam et al., (2021); however the unique composition for this study includes *Lithodesmium sp, Climacodium sp ,PseudoGuignardia sp, Eucampia sp., Guignardia sp* from diatom and *Noctiluca sp.*and *Gymnodinium sp* from dinoflagellate. This indicates the ecological versatility of the study areas.

Photomicrographs of the available genera and species in the collected samples from all the study stations have been presented in Figs. 2-4. Diatoms were the most dominant groups while the rest were dinoflagellates. From the diatoms, *Coscinodiscus sp.*; *Planktoniella sol*; *Thalassiosira sp.*; *Rhizosolenia sp.*; *Rhizosolenia imbricata*; *Lithodesmium undulatum*; *Chaetoceros danicus*; *Chaetoceros sp.*; *Climacodium frauenfeldianum*; *Palmeira hardmeniana*, *Pseudoguinerdia sp.*; *Eucampia sp.*; *Odontella sp.*; *Lioloma sp.*; *Thalassionema bacillare*; *Guinerdia sp.*; *Ditylum sp.*; *Lithodesmium sp.*; and *Thalasiosirea oestrupii* were recorded. However, dinoflagellates were represented by *Ceratium sp.*; *Noctiluca sp.*; and *Gymnodinium sp.*

The density of phytoplankton in the studied stations has been presented in Table 2. There were 12 diatoms and 3 dinoflagellates whose density could be determined from the collected samples of phytoplankton (Table 2). The genera *Eucampia* and *Rhizosolenia* were found to be present in all the stations. In this study, the density varied from 5-65 and 25-90 $\times 10^3$ ind/m^3, respectively (Table 2). From the data, it could be said that the density of *Rhizosolenia* was the highest. Except for these two, the third genus was *Climacodium* which was present in 4 stations (station 3-6) and the density ranged from 5-20 $\times$ 10^3 ind/m^3. The fourth most dominant species, belonging to the genus *Chaetoceros*, was found at three stations: stations 2, 4, and 5.

Among the Phytoplankton,the genera *Eucampia* and *Rhizosolenia* were found to be present in all the stations in this study conforming with (Temkar et al, 2015) however in this study the density varied from 5-65 and 25-90 $\times 10^3$ ind/m^3, respectively (Table 2).In the present investigation, the density of phytoplankton individuals recorded in different study stations ranged from 5-90 ind $\times$ 10^3/m^3 (Table 2); in same study area Jewel et al, (2002) found phytoplankton density in November (578.0 x 105 cells/L) and in June (37.5 x 105 cells/L). However in the SMI the phytoplankton density varied from 12.5-100.0 ind $\times$ 10^3/m^3 (Alam et al., 2021). Compared with these studies the density seems lower which can be explained by (Jewel et al, 2002) that found the relatively lower species number in winter months (December-February). Maximum species was recorded in November when salinity and $P0_4$-P concentration were found to be highest and $N0_3$-N was moderate.

Table 2: Quantitative Data on Phytoplankton (ind $\times$ 10^3/m^3)

Genus	st1	st2	st3	st4	st5	st6
Chaetoceros	-	15	-	20	30	-
Ceratium	-	5	-	-	-	-
Coscinodiscus	5	5	-	-	-	-
Climacodium	-	-	15	20	5	15
Ditylum	-	-	-	-	-	5
Eucampia	10	10	15	65	5	25
Gymnodinium	-	5	-	-	-	-
Melosira	40	-	-	-	-	5
Nitzschia	-	-	-	-	20	5
Noctiluca	5	-	-	-	-	-
Odontella	-	-	5	-	-	-
Planktoniella	-	20	-	-	-	-
Pseudo Guinardia	-	-	-	5	-	-
Rhizosolenia	25	90	60	40	25	45
Thalassiosira	-	-	-	15	-	5

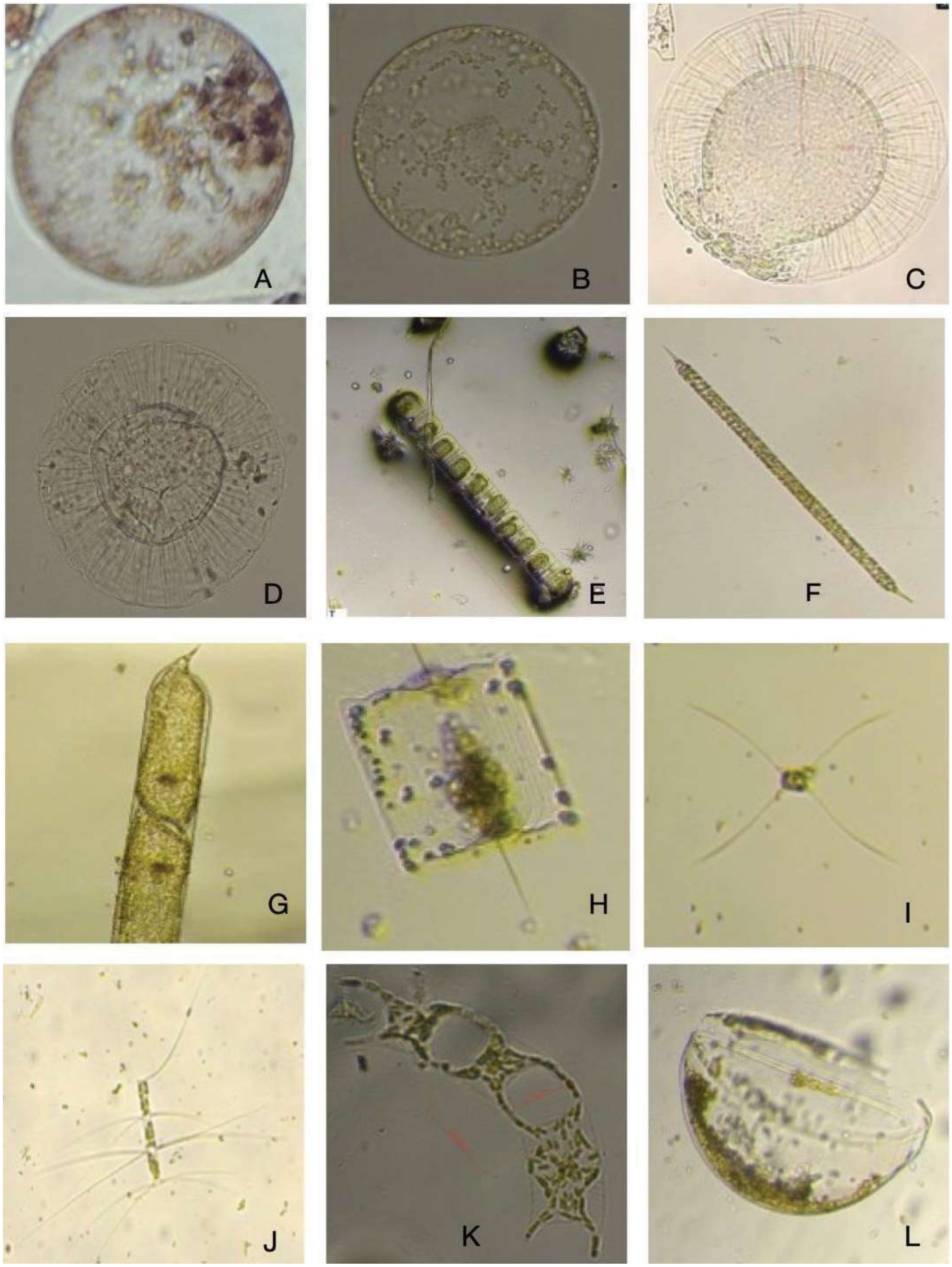

Figure 2: A-L. Photomicrographs of Phytoplankton. A-B, *Coscinodiscus sp.;* C-D, *Planktoniella sol*; E. *Thalassiosira sp*.; F, *Rhizosolenia sp.;* G, *Rhizosolenia imbricata; H, Lithodesmium undulatum;* I, *Chaetoceros danicus;* J, *Chaetoceros sp.;* K, *Climacodium frauenfeldianum*; L. *Palmeira hardmeniana*

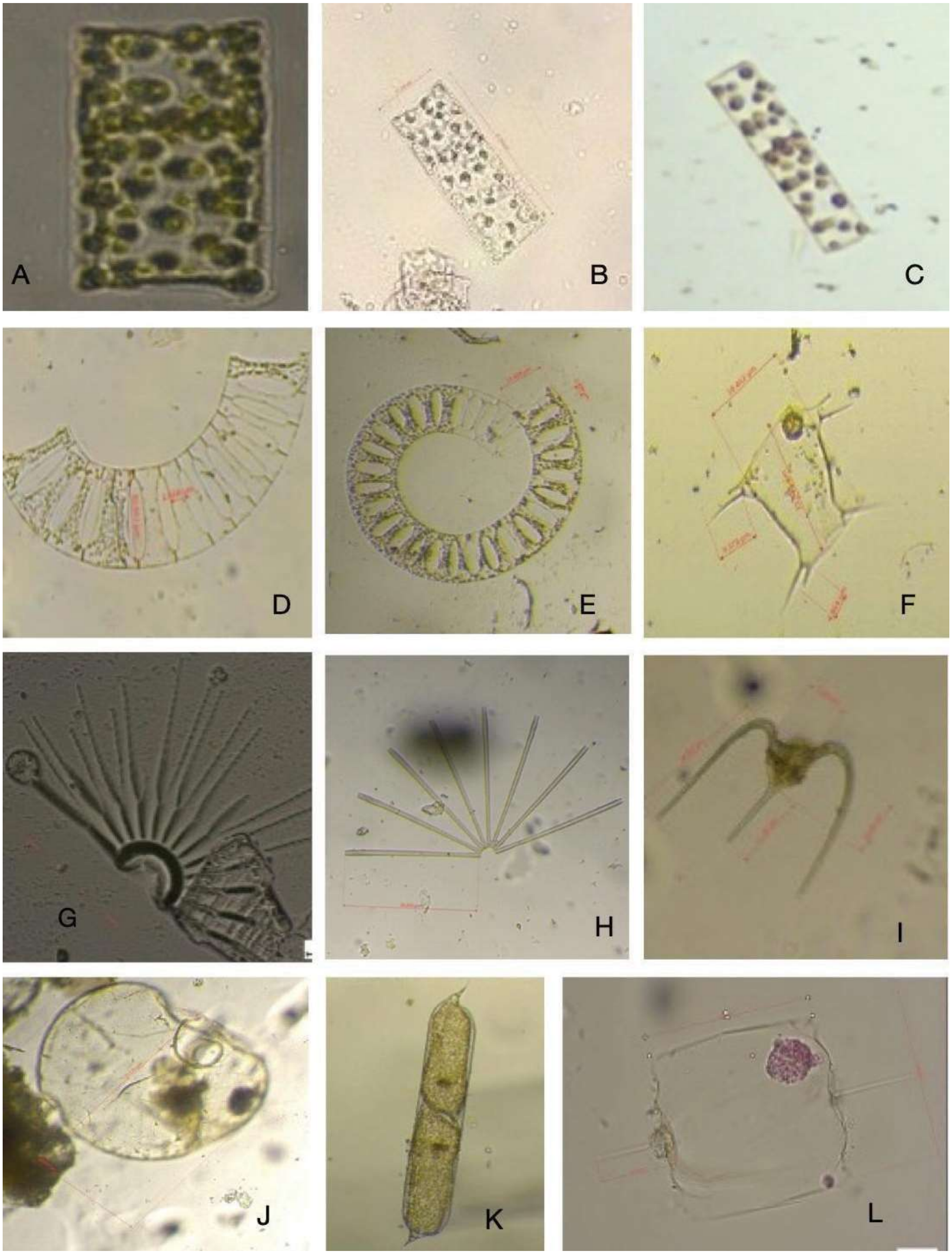

Figure 3: A-L. Photomicrographs of Phytoplankton. A-C, *Pseudoguinerdia sp.*; D-E*, Eucampia sp.;* F*, Odontella sp.;* G, *Lioloma sp.;* H*, Thalassionema bacillare;* I, *Ceratium sp*.; J, *Noctiluca sp.;* K, *Rhizosolenia imbricata;* L, *Odontella sp*

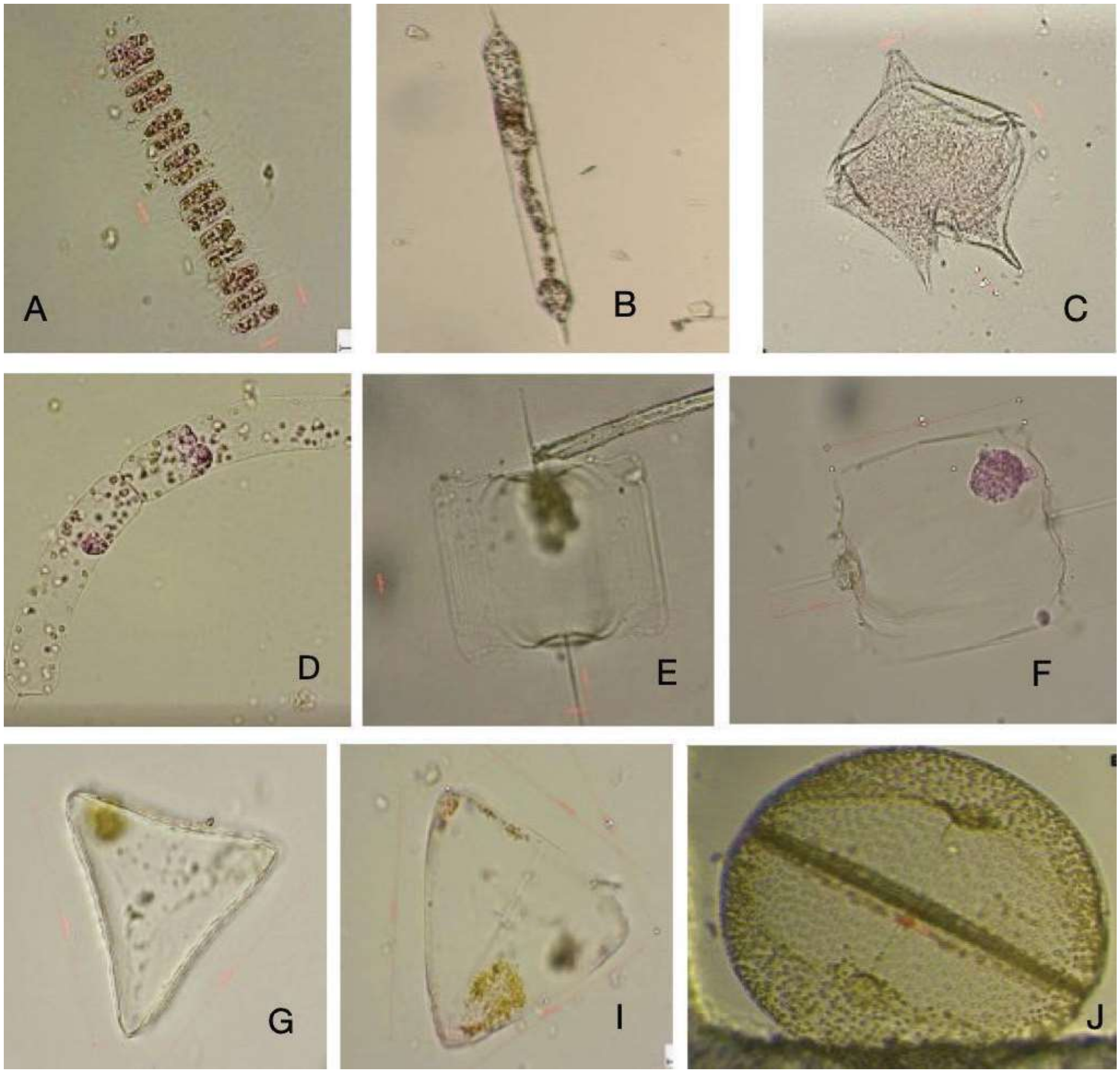

Figure 4: A-J. Photomicrographs of Phytoplankton. A, *Chaetoceros sp*.; B, *Rhizosolenia sp.;* C, *Gymnodinium sp.;* D, *Guinerdia sp.;* E*, Ditylum sp.; Odontella sp*.; G-I, *Lithodesmium sp*.; J, *Thalasiosirea oestrupii*

A total of 24 species of zooplankton was identified which is consistent with a previous study in the same region by Ayshi et al, (2024). Alam et al., (2021) found 34 species of zooplankton in SMI, Al et al, (2020) found 38 species; Copepods were prevalent in all these studies; however *Copepodite stage* was unique in this study. It indicates that the habitat is either favorable for the reproduction of copepod zooplankton or there might have occurred heavy predation pressure on the adult copepods in the ecosystem by fish. At a species level, Cirripede sp. *Acrocalamus sp*. and *Hyperia sp.* were unique to this study that were not even listed by Ayshi et al, (2024) in the same study area. That might be due to spatial heterogeneity or species rarity. However, the diverse group of zooplanktons identified in the Moheshkhali Channel in this study would be the baseline assessment to checklist the zooplankton species in the coastal waters that could further help in fisheries as well as aquatic resources management.

Microscopic analyses of the collected zooplankton samples from different study stations have revealed the presence of *copepod nauplii*; *copepodite stage*; *Cirripede nauplii*; *Oithona nana*; *Acrocalamus longicornis*; *Hyperia glaba*; *Acartia sp.*; *Evadne*; *Labidocera bengalensis*; and *Oithona sp.* The zooplankton individuals were photomicrographed and presented in figure 5.

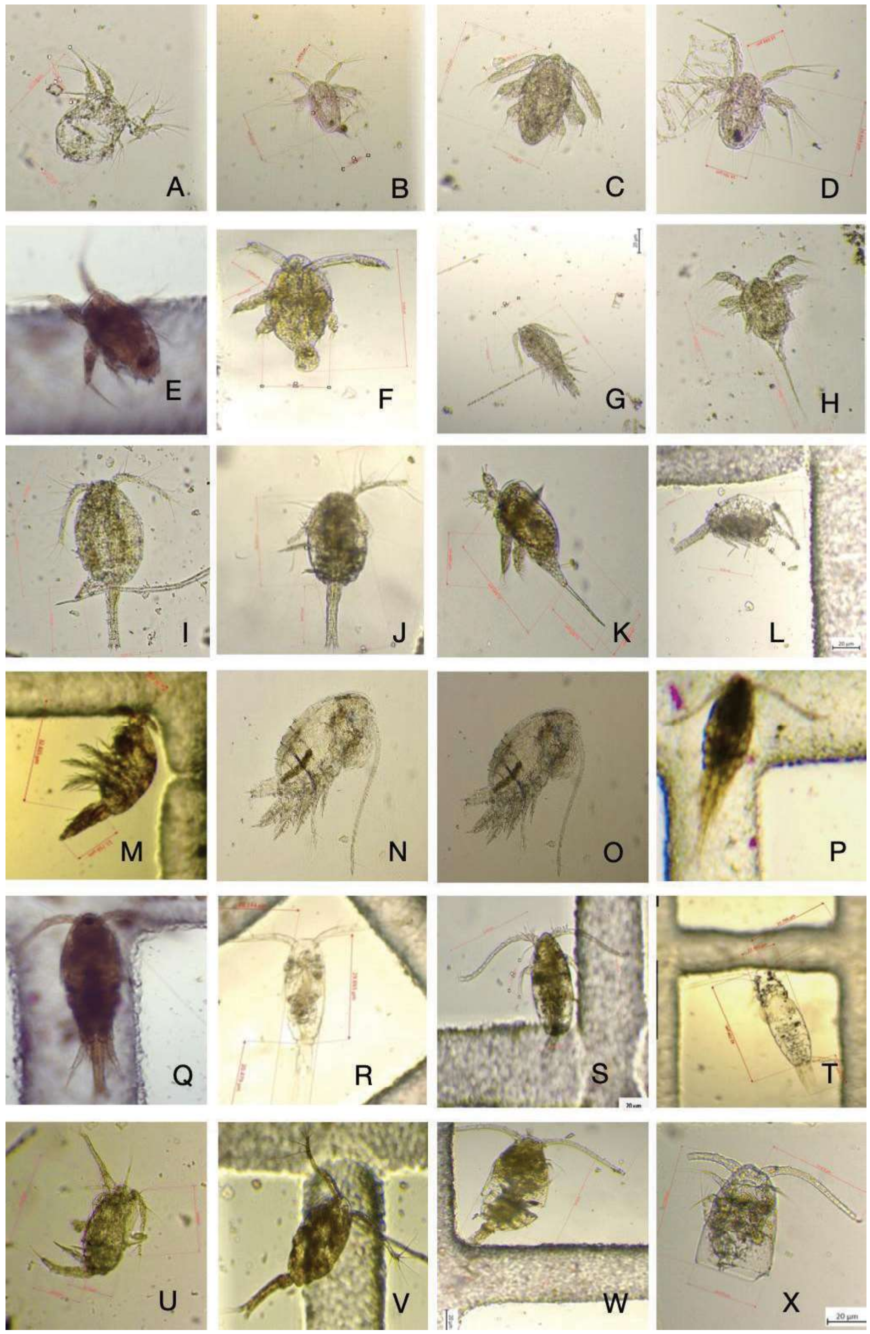

Figure 5: A-X. Photomicrographs of Zooplankton. A-F*, Copepod nauplii;* G, *Copepodite stage*; H, *Cirripede nauplii*; I-J, *Oithona nana;* K-L, Unidentified; M-O, *Acrocalamus longicornis*; P-S, *Hyperia glaba*; T, *Acartia sp.;* U, *Evadne*; V-W, *Labidocera bengalensis*; X*, Oithona sp*

Among zooplankton populations, the density of at least 4 genera and one reproductive stage could be counted (Table 3). Station 1 yielded a very low population of zooplankton where only copepod nauplii ($30 \times 10^2/m^3$) were recorded. *Calanus* population was the most dominant and its density ranged from 5-25 ind $\times 10^2/m^3$ (Table 3). Highest abundance of zooplankton was found at station 3 where the genera *Calanus, Copepod nauplii, Oithona*, and *Thysanoessa* were found to be present.

The findings of this study ranged between 5-30 ind $\times 10^2/m^3$ for zooplankton. In SMI it ranged from 450-1250 ind $\times 10^2/m^3$ (Alam et al., 2022). However, a much lower density of zooplankton was found in the Moheshkhali island ranging between 5-30$\times$ ind $\times 10^3/m^3$ compared to the SMI. In the Swatch-of-No Ground, Northern Bay of

Bengal, Bangladesh the density of surface zooplankton ranged from 0.015-22.5 ind × 10^2/m^3 (Sadia et al., 2022) which is lower compared to this study. Mozumder et al, (2023) found zooplankton density 10.72 ind/l in July and 5.6 ind/l in May in Sonadia island;111.2 ind/l in July but 20.8 ind/l in March in Teknaf Beach which is also higher compared to this study.

Table 3: Abundance of Zooplankton (ind × 10^2/m^3)

Genus	st1	st2	st3	st4	st5	st6
Calanus	-	5	5	25	15	10
Centropages	-	-	-	5	-	-
Copepod (Nauplius)	30	20	5	10	-	-
Oithona	-	-	20	10	5	-
Thysanoessa	-	-	20	-	-	-

The diversity indices of phytoplankton and zooplankton were calculated separately, and the data have been presented in Table 4. In the case of phytoplankton, no strong difference was observed among the Shannon-Wiener and Margalef's indices. They ranged from 1.03 to 1.56 and 1.02 to 1.97 for Shannon-Wiener and Margalef's indices, respectively (Table 4). The highest zooplankton diversity (1.30) was found at both station 3 and station 4. Pielou's index varied from 0.68 to 0.94 for phytoplankton, and for zooplankton, it was 0.72 to 1.08.

Table 4: Diversity Indices of Plankton at different Stations. (Data in parentheses represents zooplankton)

Stations	Shannon-Wiener	Margalef's	Pielou's
1	1.3	1.41	0.81
2	1.32 (0.50)	1.76 (0.62)	0.68 (0.72)
3	1.03 (1.19)	1.02 (1.30)	0.94 (1.08)
4	1.54 (1.22)	1.43 (1.30)	1.11 (0.88)
5	1.40 (0.56)	1.41 (0.72)	0.78 (0.81)
6	1.56	1.97	0.8

Biodiversity indices have been commonly used as biological parameters for community level investigation of environmental status, where higher index values represent the better quality status with lower expectation of pollution(Al et al., 2017).In the case of phytoplankton, the Shannon-Wiener indices ranged from 1.03 to 1.56 that's lower(1.46-2.41) than found by Alam et al., (2022);and Margalef's indices ranged from 1.02 to 1.97 that's also lower compared to the mentioned study(1.51-4.93), this indicates lower phytoplankton diversity and richness in Moheshkhali. The highest zooplankton diversity (1.30) was found at both station 3 and station 4 (Table 4) this implies that these stations have the most diverse zooplankton communities, with a greater variety of species present. Pielou's index varied from 0.68 to 0.94 for phytoplankton impling phytoplankton communities in this study are moderately even to relatively even.

Moheshkhali Channel is an estuarine coastal area of the Bay of Bengal, Bangladesh as evident from the salinity data Among the phytoplankton population, *Rhizosolenia*, *Eucampia*, and *Melosira* were the most dominating *Copepod nauplii* were highly abundant in the population of zooplankton in the Moheshkhali Channel, Together with these indices, the plankton composition and abundance and. From this study, it is evident that the biodiversity and density of plankton population are relatively lower compared to that of SMI and other euryhaline zones of the Bay of Bengal, Bangladesh.

CONCLUSIONS

The aim of this study was to conduct a thorough evaluation of the phytoplankton and zooplankton of the Moheshkhali channel. In the Moheshkhali Channel, the plankton community exhibits distinctive features. Diatoms, such as *Coscinodiscus*, *Planktoniella*, *Thalassiosira*, and *Rhizosolenia* dominate the phytoplankton group. Concurrently, the zooplankton community is characterized by the prevalence of genera like *Calanus*, *Centropages*, *Copepod (Nauplius)*, *Oithona*, and *Thysanoessa*. The standing crop, representing the density of phytoplankton individuals, ranges from 5 to 90 ind × 10^3/m^3, whereas zooplankton density spans 5 to 25 ind × 10^2/m^3. When compared to St Martin's Island (SMI) and other euryhaline zones in the Bay of Bengal, Moheshkhali Channel demonstrates lower plankton biodiversity and density. Water temperature, salinity, pH, and dissolved oxygen levels differ, shaping the unique ecological conditions of each station. Notably, the study focuses on the distinct characteristics of the Moheshkhali Channel in comparison to other regions. The diversity indices for both phytoplankton and zooplankton, such as the Shannon-Wiener and Margalef indices, further contribute to the characterization of the plankton community in the Moheshkhali Channel.

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