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# SEASONAL AND SPATIAL DISTRIBUTION OF ZOOPLANKTON COMMUNITIES WITH RELATION TO SOME PHYSICO-CHEMICAL PARAMETERS IN THE SOUTH EAST COAST OF BANGLADESH

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## ABSTRACT

Seasonal and spatial distribution of zooplankton communities in relation with some physico-chemical parameters in the south eastern coastal waters of Bangladesh was carried out from January 2016 to November 2016. Zooplankton samples were collected from seven different selected stations covering various ecosystems, viz.: Riverine (Bhola, Barishal & Chandpur), Offshore Island water (Sandwip & Hatia) and Nearshore (Cox's bazar & Naf River) regions. In total 33 genera were recorded during sampling periods and the highest abundance of zooplankton were recorded at Naf River (331.318 ind/$m^3$) and the lowest at Chandpur (22.6414ind/$m^3$) during post-monsoon. In pre-monsoon the highest abundance was recorded at Sandwip (31.49435ind/$m^3$) and the lowest at Bhola (8.239854ind/$m^3$). During monsoon the highest abundance was recorded at Cox's Bazar (51.64085ind/$m^3$) and the lowest at Barishal (4.389972ind/$m^3$). A total of 24, 22 and 32 individuals (genera) of zooplankton identified during monsoon, pre-monsoon and post-monsoon respectively from all sampling stations. *Calanoida*, *Cyclopoida*, Fish larvae, *Lucifer* and Shrimp Zoea were common in every sampling station. *Dictoyptera* was the only species found in marine water. The statistical analysis of water quality parameters as temperature, pH, salinity, transparency, DO, TDS and TSS indicated the substantial relationship with seasonal and spatial distribution, diversity and abundance of zooplankton. Diversity index also indicated seasonal and spatial variation of zooplankton communities in the south eastern coastal waters of Bangladesh.

***Keywords***

Zooplankton community, biodiversity, spatial variation, species richness & evenness

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## INTRODUCTION

Zooplankton are a multiple group of heterotrophic organisms that eat phytoplankton, revitalize nutrients through metabolism, and pass energy to higher trophic levels (Steinberg and Robert 2009). It is believed that zooplanktons play an excessive ecological role in the ecosystem, as they are second tropical level of food chain. Planktonic biomass and distribution are an index to the fertility of an area; it provides information of on the fishery potentiality. There lies an interrelationship among the different biotic elements of the marine estuarine ecosystem viz. phytoplankton, zooplankton, benthos and fishes. It is well known that the richest fisheries of the world are closely related to the plankton production (Fraser 1962), because the fisheries organisms are directly or indirectly dependent upon plankton for their nourishment. All consumer levels such as fisheries depend on zooplanktons for food during their larval phases, and some fishes continue to eat zooplankton in their entire lives (Madin *et al*., 2001). Planktonic biomass available in an ecosystem is of fundamental importance for fish production. Many studies have been conducted on the abundance, distribution and diversity of zooplankton from Bangladesh coastal waters. However, comprehensive studies on the spatio-temporal variation of zooplankton are meager. In addition, south eastern region of Bangladesh is highly diversified. Therefore, appropriate scientific investigation should be conducted on zooplankton to know the fisheries potentiality of the specific area. This study was mainly conducted i) to record the zooplankton genera of the south-east coastal area of Bangladesh ii) to describe the seasonal and spatial variation of zooplankton communities, and iii) to show the relation with some physico-chemical parameters in the south-eastern coastal waters of Bangladesh.

## MATERIALS AND METHODS

### Study Area

The major rivers those are outflow to the Bay of Bengal are Ganga, Padma, Meghna, Brahmaputra, Karnaphuli etc. Jamuna joins with Padma at north Faridpur and then flows as the Padma finally meets with the Meghna near Chandpur and then drains into the Bay of Bengal through the Meghna river estuary and ultimately it flows towards the Hatia channel. Large number of sediments with minerals is carrying through the water flow. Seven study sites were chosen for collected zooplankton and water samples (Fig. 1). Sampling stations were selected into three different zones/regions with respective stations

selected: Riverine (Bhola, Barishal and Chandpur), Offshore island (Sandwip and Hatia) and Nearshore (Cox's Bazar and Naf river) (Table 1).

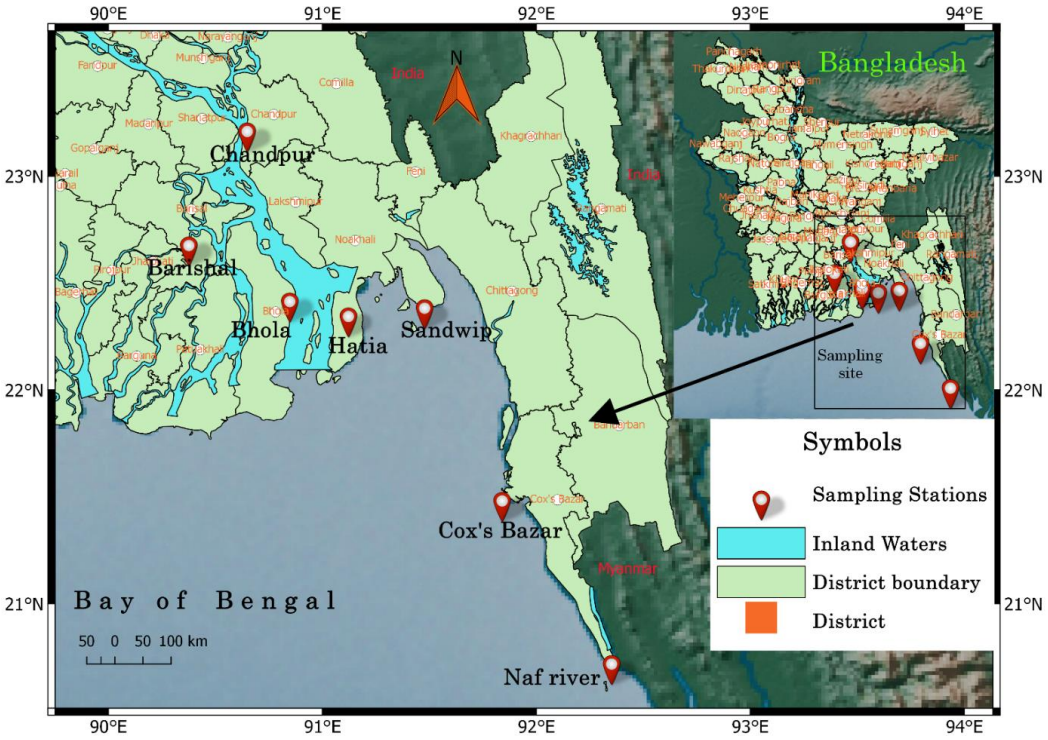



**FIG. 1. A MAP OF STUDY AREA WITH SAMPLING STATIONS**

**Sampling Periods**

Bangladesh has a subtropical monsoon with a wide seasonal variation. It has 3 major distinct seasons characterized by fog, high temperature, rainfall and humidity etc. These are Post-monsoon (Dry season) from December to January, Pre-monsoon (humid summer) from March-June and Monsoon (rainy monsoon season) from July- October. So, sampling was done following these three seasons to cover the temporal variation in the year.

**TABLE 1. SAMPLING ZONES AND STATIONS WITH GPS COORDINATES.**

| Sampling Zones | Sampling Stations | Latitude | Longitude | Short description of sampling stations |
|---|---|---|---|---|
| Off shore Islands | Sandwip | 22° 24'26.3"N | 91°28'40.3"E | Positioned approximately 200m off the shore of Bangla Bazar situated at the north western coast of the island |
| | Hatia | 22°22'07.3"N | 91°07'18.3"E | Nolchira ghat which is approximately 50m away from the coast line of the island |
| Riverine | Bhola | 22°26'18.5"N | 90°50'50.9"E | Located near Tajhimuddin ghat |
| | Barishal | 22°42'2.2"N | 90°22'32"E | Situated at Barishal launch terminal |
| | Chandpur | 23°14'03.2"N | 90°38'54.6"E | Situated at chandpur launch terminal |
| Nearshore | Cox's Bazar | 21°30'20"N | 91°50'25"E | 200m off the Cox's bazar coast and in between Sonadia island Island. |
| | Naf River | 20°44'31.8"N | 92°21'7.1"E | Approximately 600m far from the coast of Shah porir dwip, Teknaf |

**Collection and Preservation of Zooplankton**

Zooplankton sampling was carried out with the help of conical zooplankton net made of Nylon Silk of 325 micro meter mesh size and having 24 cm circular mouth opening fitted with a plastic bucket at the cod. A digital flow meter was set up at the mouth of the net to record the amount of water filtered through the net during sampling. Samples were collected at three sampling stations from the surface water for 10 to 15 min. After collecting sample were preserved in 5% formalin.

**Staining and Sorting**

For efficient sorting the samples were stained with eosin and left for overnight. All the zooplankton attained reddish color rendering easy identification. The stained plankton was sorted out from debris with fine brush, needle, forceps and low power microscope was used during sorting. The sorted organisms were preserved in 70% ethanol.

**Identification and Counting**

The sorted organisms were brought under microscope and identified following Davis (1955); Wickstead (1965), Yamazi (1974), Newell and Newell (1973); Mizuno (1976); Sterrer (1986); Zafar (1986); Santhanam and Srinivasan (1994); Belal (2001) and Islam (1982) etc. In each catch the total number of individual counts were done either by complete counting or by sub sampling.

**Zooplankton density calculation**

The Zooplankton concentration was calculated at individuals/$m^3$. Where, total volume of water ($m^3$) filtered through the net was calculated by using the following equation:

**Total volume of water (m) = {(FR-IR) × co-efficient} × $2\pi r^2$**

Where, FR= final reading; IR= Initial reading; Coefficient=0.3;
$\pi$=3.1416; r= Radius of ring of used at plankton net=12 cm;

Abundance of Zooplankton (individuals/$m^3$) = $\frac{\text{Number of Species in each groups}}{\text{Volume of water}}$

**Measurement of water quality parameters**

Water quality parameters such as surface water temperature, salinity and pH were recorded respectively using a Celsius thermometer, portable refractometer and

digital pH meter on the spot during sampling. A graduated mercury thermometer was used to determine the air and water temperature. One-third of the thermometer was immersed into the sample water for 1 minute and for the air temperature, the thermometer was exposed to the air for 1 minute. A Secchi disk was used to estimate the transparency of water (Pipkin et al., 1977). To determine the "in-situ" concentration of hydrogen ion (H+) a pen pH meter (Hanna Pocket pH meter) was used. The Atago hand refractometer was used to measure the salinity on the spot (ATAGO, S/Mill, salinity. 0-100 ‰, Japan). 86031 AZ Waterproof IP 67 Combo Water Quality Tester was used to determine the "in-situ" dissolved oxygen (DO), TSS and TDS content of the sampled water.

**Species diversity analysis**

Zooplankton assemblage data were analyzed with the Plymouth Routines in Multivariate Ecological Research (PRIMER) statistical package version 6 (Clarke and Gorley 2006). Diversity of the species assemblage was analyzed by the Shannon-wiener index (H') (Shannon 1949; Shannon and Weaver 1963; Ramos *et al*., 2006), species richness was measured by Margalef index (d) (Margalef 1968) and evenness was measured by Pielou's index (j) (Pielou 1966).

## RESULTS AND DISCUSSION:

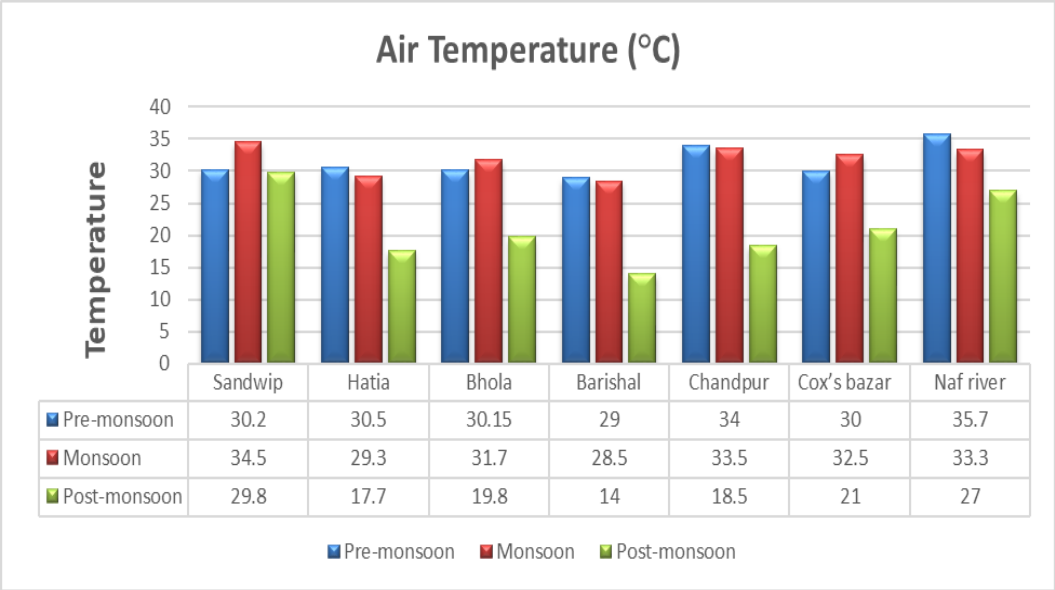
**Physio-Chemical Parameters**

Biochemical activity of both vertebrates and invertebrates are influenced by variations in physico-chemical parameters. These abiotic factors control the rate of metabolic changes, response patterns of zooplankton to environmental stressors and the efficacy of immune systems (Kinne 1964; Roddie *et al*., 1984), hence their occurrence and distribution of (Suresh *et al.*, 2011). Though, the occurrence of some species is restricted by some abiotic factors such as dissolved oxygen, pH, temperature, salinity, or other physico-chemical parameters (Ahmad *et al*., 2011). Zooplankton are available across an inclusive range of environmental conditions. Sleigh (1991) identified six vital environmental factors (water, temperature, pH, light, oxygen and salinity) for aquatic living organisms. Monitoring of these physico-chemical factors is very important to identify the probable influence of the variables on the distribution and abundance of zooplankton suggested by as Sharma *et al.,* (2007).

Water temperature is considered as one of the important factors in controlling the occurance and distribution of aquatic organisms (Wetzel 1983). Paturej *et al.*

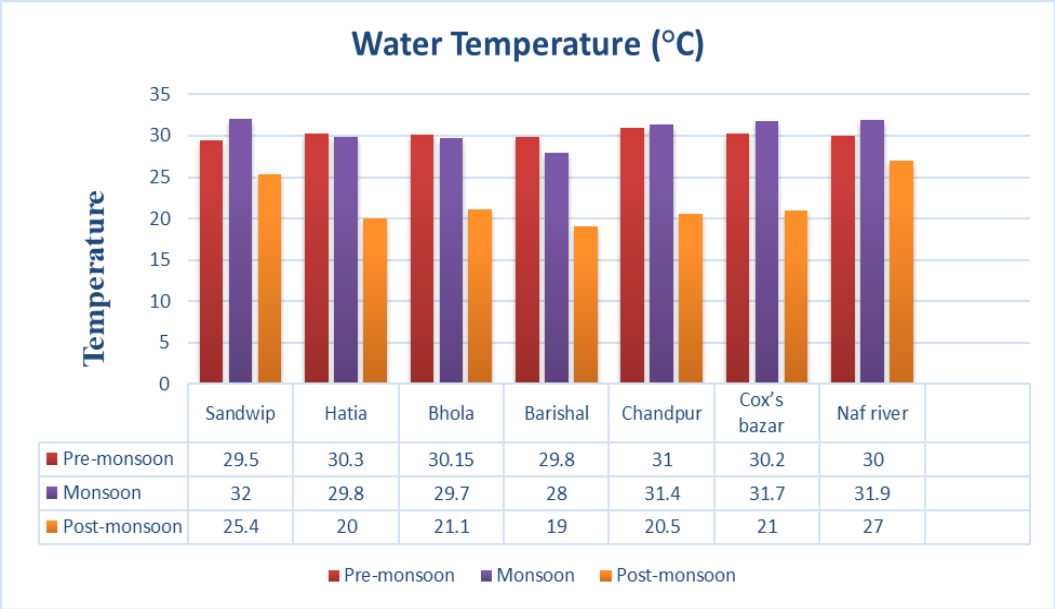
(2016) found that sudden change in water temperature causes unusual changes in composition and abundance of aquatic living organisms where as Hall and Burns (2001) reported that water temperature impacts the growth, development and mortality of living organisms. Adeniyi and Ovie (1982) revealed that optimum temperature range (22-31°C) for the survival and best growth of aquatic organisms in subtropical estuaries. Sharif *et al.,* (2017) recorded highest water temperature (31°C) at Sandwip and the lowest (21°C) at Bhola in monsoon. While in post-monsoon, maximum (22.5°C) was at Hatiya and the minimum (21°C) at Chandpur.

In the present study, during pre-monsoon, the highest air temperature was recorded at Naf River (35.7°C) and lowest at Barishal (29°C). In the time of monsoon season, highest air temperature (34.5°C) was observed at Sandwip and lowest (28.5°C) at Barishal. In post-monsoon, highest temperature (29.8°C) was found at Sandwip and the lowest (14°C) at Barishal (Fig 2). During pre-monsoon, the highest water temperature was recorded at Chandpur (31°C) and lowest at Sandwip (29.5°C). In monsoon, the maximum water temperature (32°C) was recorded at Sandwip and lowest (29.1°C) at Barishal. In the time of post-monsoon, highest temperature (27°C) was found at Sandwip and lowest (19°C) at Barishal (Fig 3). Water temperature was higher than the air temperature during post monsoon and in other seasons water temperature was lower than air comparatively. Sharif (2002), recorded the air temperature 26°C-33°C in monsoon period and 25°C-29°C in post-monsoon period at Meghna river estuary. Haque (1983) observed the water temperature in the Matamuhuri estuary as 28°C during October.




| | Sandwip | Hatia | Bhola | Barishal | Chandpur | Cox's bazar | Naf river |
|---|---|---|---|---|---|---|---|
| Pre-monsoon | 30.2 | 30.5 | 30.15 | 29 | 34 | 30 | 35.7 |
| Monsoon | 34.5 | 29.3 | 31.7 | 28.5 | 33.5 | 32.5 | 33.3 |
| Post-monsoon | 29.8 | 17.7 | 19.8 | 14 | 18.5 | 21 | 27 |

**FIG. 2. AIR TEMPERATURE VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**




| | Sandwip | Hatia | Bhola | Barishal | Chandpur | Cox's bazar | Naf river |
|---|---|---|---|---|---|---|---|
| Pre-monsoon | 29.5 | 30.3 | 30.15 | 29.8 | 31 | 30.2 | 30 |
| Monsoon | 32 | 29.8 | 29.7 | 28 | 31.4 | 31.7 | 31.9 |
| Post-monsoon | 25.4 | 20 | 21.1 | 19 | 20.5 | 21 | 27 |

**FIG. 3. WATER TEMPERATURE VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**

Many properties, processes and reaction are pH dependent, hence pH is commonly known as the controlling variable in water (Millero 1986). Studies (Dehui 1995; Ivanova and Kazantseva 2006; Yamada and Ikeda 1999) shown that low or high pH effects on zooplankton abundance reduction while low alkaline condition causes high primary production that influences the distribution and diversity of zooplankton (Bendnerz 2002; Mustapha MK. 2009). Sharif *et al.*, (2017) recorded slightly acidic in major part of the Meghna estuary and Sharif (2002), observed pH 6.5 to 7.2 during monsoon and 6.5-7.2 during post-monsoon. In the present investigation, maximum pH value was found at Barishal (8.5) and minimum at Sandwip (7.4) during pre-monsoon. The highest value of pH (7.7) recorded at Cox's bazar and Sandwip and the lowest at Chandpur (7.0) during monsoon, and during post-monsoon, highest pH was recorded at Barishal (8.5) and lowest pH was recorded at Cox's bazar (7.2) (Fig 4).

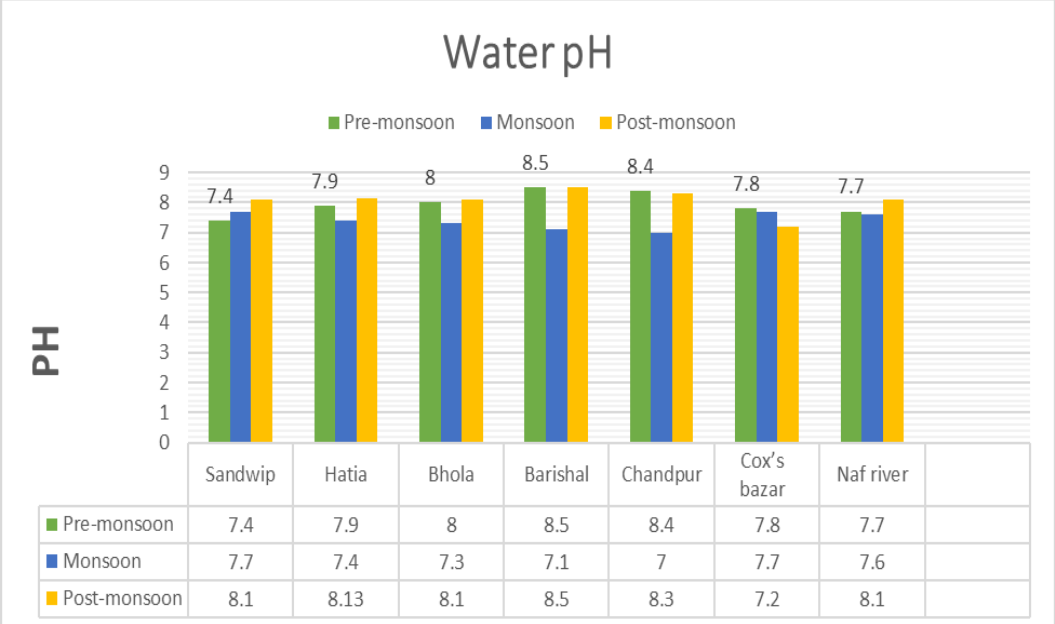
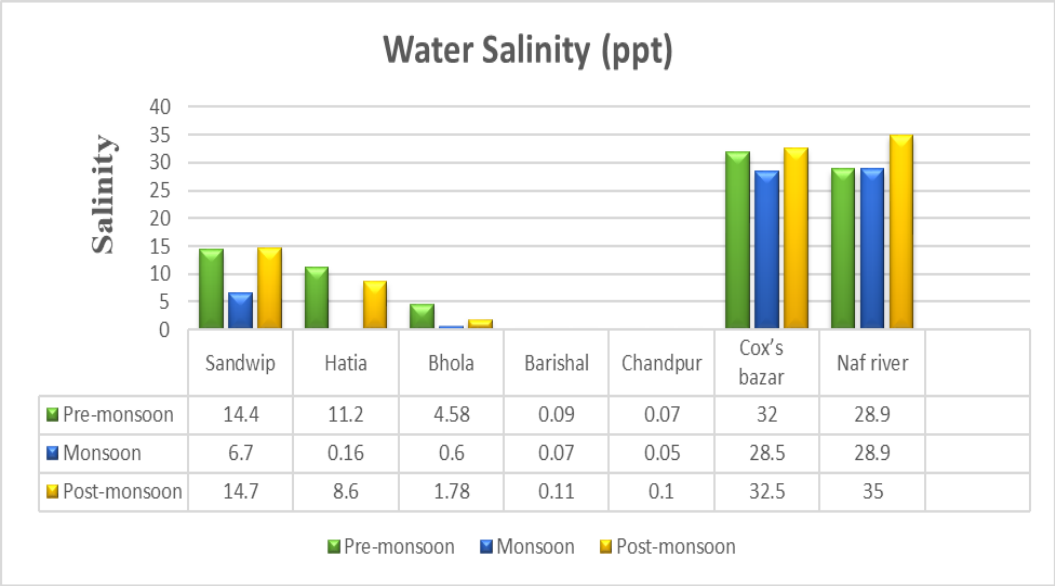



**FIG 4. WATER PH VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**

Salinity is regarded as limiting parameter as it influences the dispersal of plankton community (Sridhar *et al*., 2006). It acts as indicator of freshwater intrusion in the near shore coastal water as well as extrusion of tidal water in inland water bodies (George *et al.,* 2006). Excessively high or low salinity also effects organisms to migrate in order to escape unfavorable environmental conditions (Perumal *et al.,* 2009). They also mentioned that changes in salinity can also contribute indirectly to food shortages and thereby impact the zooplankton distribution and availability. During monsoon, only 1‰ salinity was recorded at Sandwip, while at all and during post-monsoon maximum salinity was 15‰ at Sandwip and minimum was 10‰ at Hatiya with zero in the riverine stations of Meghna as recorded by Sharif *et al.,* (2017).

During pre-monsoon, highest salinity was recorded at Cox's bazar (32 ppt) and lowest at Chandpur (0.07 ppt), maximum salinity (28.9 ppt) was found at Naf River and minimum (0.05 ppt) at Chandpur in monsoon and in post-monsoon, highest salinity was found at Naf River (35 ppt) and lowest value of salinity was recorded at Chandpur (0.11 ppt) (Fig 5) in the present study. At nearshore region, Naf River water was comparatively higher saline than cox's Bazar station. The highest salinity (35ppt) measured at Naf River during post-monsoon and the lowest salinity was 28.9 ppt during monsoon and pre-monsoon sampling period. At the Cox's Bazar sampling station salinity was measured as 28.5-32.5 ppt. At offshore island area, Sandwip had higher saline waters than Hatia. Salinity vary (6.7-14.7) ppt at Sandwip round the year. Chandpur, Barishal and Bhola are the riverine area where Salinity was measured 0.05-0.11 ppt at Chandpur, 0.07-0.13 at Barishal and 0.6-4.58 at Bhola sampling station (Fig 5).




| | Sandwip | Hatia | Bhola | Barishal | Chandpur | Cox's bazar | Naf river |
|---|---|---|---|---|---|---|---|
| Pre-monsoon | 14.4 | 11.2 | 4.58 | 0.09 | 0.07 | 32 | 28.9 |
| Monsoon | 6.7 | 0.16 | 0.6 | 0.07 | 0.05 | 28.5 | 28.9 |
| Post-monsoon | 14.7 | 8.6 | 1.78 | 0.11 | 0.1 | 32.5 | 35 |

**FIG. 5. WATER SALINITY VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**

Venkateswarlu and Reddy (2000) and Haruna *et al.*, (2006) confirmed that transparency increases the occurrence of zooplankton via the growth of phytoplankton. Sharif *et al.*, (2017) reported that the distribution and abundance of zooplankton hugely effected by transparency. In his study the highest secchi depth (55 cm) was at Chandpur and the lowest (4 cm) at Sandwip during monsoon whereas post-monsoon, maximum secchi depth (65 cm) was recorded at Bhola and the minimum (35 cm) at Sandwip. During this study, highest transparency was found (45 cm) in Barishal and lowest value was recorded at Sandwip which was only 2 cm in pre-monsoon. Maximum transparency was recorded (68 cm) at Naf River where as minimum value was found (11 cm) at Bhola, highest value was found as 120 cm at Naf River and lowest value was 16.5 cm at Hatia. (Fig 6) during post-monsoon. Light intensity of transparency and TSS are inversely related in an aquatic environment. Highest transparency was measured in Naf River at monsoon and post monsoon but in pre-monsoon the highest transparency was found in Barishal. Light penetration at Chandpur was also found in satisfactory level in comparison with other stations which is logical. The lowest transparency was at Bhola (monsoon), Sandwip (pre-monsoon) and Barishal (post-monsoon), where the maximum TSS were recorded (Fig 9).

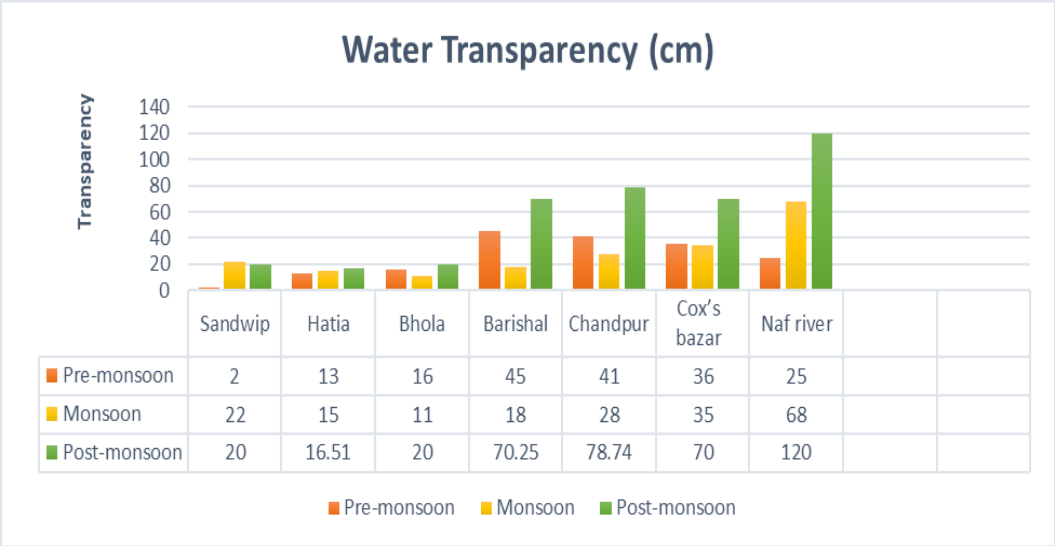



**FIG. 6. WATER TRANSPARENCY VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**

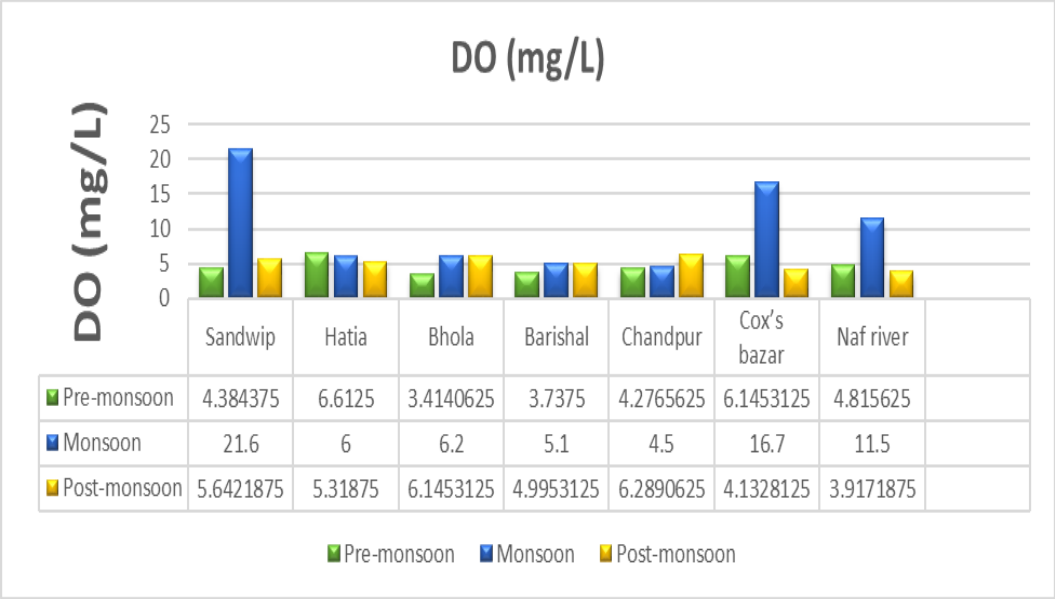
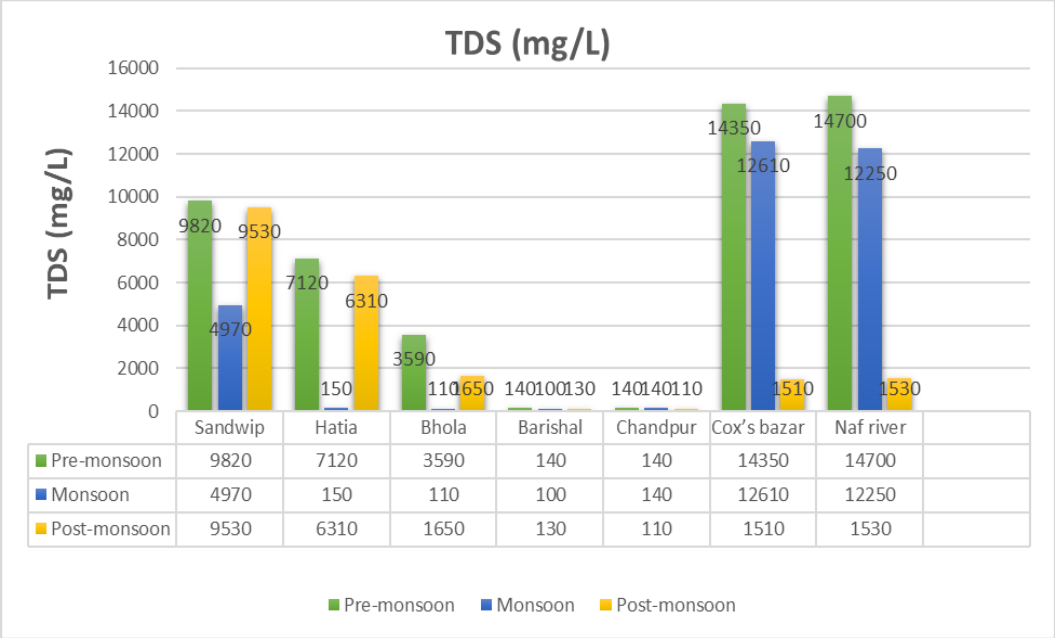
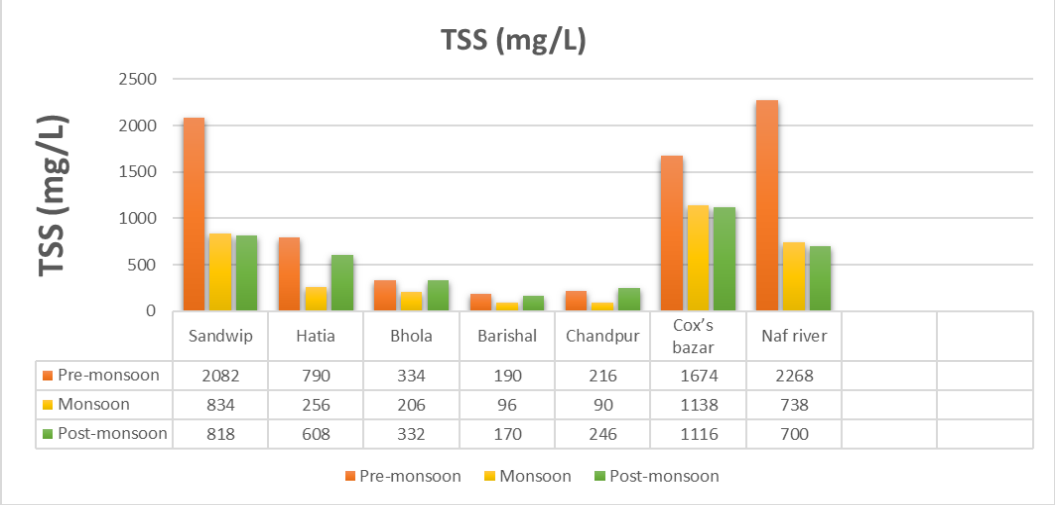



**FIG. 7. DISSOLVE OXYGEN VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**




| | Sandwip | Hatia | Bhola | Barishal | Chandpur | Cox's bazar | Naf river |
|---|---|---|---|---|---|---|---|
| Pre-monsoon | 9820 | 7120 | 3590 | 140 | 140 | 14350 | 14700 |
| Monsoon | 4970 | 150 | 110 | 100 | 140 | 12610 | 12250 |
| Post-monsoon | 9530 | 6310 | 1650 | 130 | 110 | 1510 | 1530 |

**FIG. 8. TOTAL DISSOLVED SOLID (TDS) VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS**




| | Sandwip | Hatia | Bhola | Barishal | Chandpur | Cox's bazar | Naf river |
|---|---|---|---|---|---|---|---|
| Pre-monsoon | 2082 | 790 | 334 | 190 | 216 | 1674 | 2268 |
| Monsoon | 834 | 256 | 206 | 96 | 90 | 1138 | 738 |
| Post-monsoon | 818 | 608 | 332 | 170 | 246 | 1116 | 700 |

**FIGURE 9: TOTAL SUSPENDED SOLID (TSS) VARIATION IN DIFFERENT STATIONS AND DIFFERENT SEASONS.**

Dissolved oxygen (DO) is one of the most important ecological factors that determines environmental health of water ecosystem and keep up a well-balanced aquatic living organism (George *et al.*, 2006; Chang H. 2005). The distribution and abundance of zooplankton are closely related to DO (Sharif et al. (2017) and zooplankton has a positive significant co-relation with DO (Edward and Ugwwnba, 2010). During pre-monsoon, highest DO was measured at Hatia (6.6 mg/L) and lowest was recorded at Bhola (3.4 mg/L), maximum DO (21.6 mg/L) was found at Sandwip and minimum (4.5 mg/L) was at Chandpur during monsoon and during post-monsoon the highest DO was found at Chandpur (6.29 mg/L) and lowest of that was recorded at Naf river (3.9 mg/L) (Fig 7) in the present study. This might due to the presence of atmospheric oxygen as a result of wave action or the DO pen meter had some problem while measuring the DO of this station. The lowest DO recorded in station 3 (Bhola) (3.4 mgO/L) might be due fish cages nearby. This is because the presence of cultured fishes competing with the oxygen content of the water used up the oxygen faster than the slow circulation of water can replace it (Felts *et al*., 1996). This low value is considered to be below the minimum 5 mg O/L DO concentration for fishery water favorable for growth and propagation of fish and other aquatic resources (DENR-DAO 34, 1990).

**Occurrence and Distribution of Zooplankton**

A total of 33 texa belonging two kingdoms (Protozoa and Animalia) of zooplankton were recorded during whole sampling periods in the present study. In total the highest 32 genera were identified during post-monsoon, 22 genera during pre-monsoon and 24 genera during monsoon. Highest number of zooplankton were found at Sandwip (2419.60 indivs/m3) and lowest at Bhola (29.90 indivs/m3) during monsoon (Table 3). Additionally, Copepoda (Calanoida and Cyclopoida) were common in all sites and seasons. Lucifer and Sagitta were restricted in Sandwip and Hatiya only in post monsoon (Sharif *et al.* 2017). The highest abundance of zooplankton was recorded at Naf River (331.318 ind/m3) and the lowest at Chandpur (22.6414 ind/m3) during post-monsoon. In pre-monsoon the highest amount of zooplankton was found at Sandwip (31.49435 ind/m3) and the lowest (8.239854 ind/m3) was recorded at Bhola. During monsoon, the highest abundance of zooplankton was found at Cox's bazar (51.64085 ind/m3) and the lowest at Barishal (4.389972 ind/m3) (Table 2-4).

**TABLE 2. ZOOPLANKTON ABUNDANCE (ind/m$^3$) IN DIFFERENT SAMPLING STATIONS DURING PRE-MONSOON**

| Name of the species | Sandwip (Ind/m$^3$) | Hatia (Ind/m$^3$) | Bhola (Ind/m$^3$) | Cox's Bazar (Ind/m$^3$) | Naf River (Ind/m$^3$) |
|---|---|---|---|---|---|
| ***Acetes*** | 4.3481 | 0.430893 | 0.366216 | 0 | 1.770746 |
| ***Amphipoda*** | 0.470065 | 0.861786 | 0.183108 | 0 | 0 |
| ***Calanoida*** | 9.753847 | 7.325177 | 0.640878 | 2.25477 | 3.049617 |
| ***Caridean shrimp*** | 0.352549 | 1.723571 | 1.190201 | 1.691077 | 2.754493 |
| ***Cladocera*** | 0.235032 | 2.154464 | 0.549324 | 0.724747 | 0.688623 |
| ***Crab larvae*** | 1.527711 | 0.430893 | 0 | 0.241582 | 0.491874 |
| ***Crab Zoea*** | 1.527711 | 0 | 0 | 0 | 0 |
| ***Cyclopoida*** | 3.407971 | 1.292678 | 0.274662 | 1.046857 | 1.672371 |
| ***Dictoyptera*** | 0 | 0 | 0 | 0 | 0.295124 |
| ***Fish egg*** | 0.352549 | 1.723571 | 0 | 0.563692 | 0 |
| ***Fish juvenaile*** | 1.057646 | 0 | 0 | 0.161055 | 0 |
| ***Fish larvae*** | 0.117516 | 0.861786 | 0 | 0.161055 | 0 |
| ***Hydromedusa*** | 0 | 0 | 0 | 0.161055 | 0.295124 |
| ***Isopoda*** | 0 | 0 | 0.091554 | 0.080527 | 0 |
| ***Jelly fish*** | 0 | 0 | 0.549324 | 0.161055 | 0.295124 |
| ***Lucifer*** | 0.94013 | 3.016249 | 0.45777 | 3.060045 | 4.328489 |
| ***Magalopa*** | 2.467841 | 0 | 0.366216 | 0.241582 | 1.672371 |
| ***Mysids*** | 0.822614 | 2.585357 | 0 | 0.64422 | 0.885373 |
| ***Mysis*** | 0.352549 | 0 | 0 | 0 | 0 |
| ***Penaeid shrimp*** | 2.232808 | 3.447142 | 1.556417 | 0.724747 | 0.590249 |
| ***Sagitta*** | 0 | 0 | 1.739525 | 0.402637 | 0 |
| ***Shrimp Zoea*** | 1.410195 | 0.861786 | 0.274662 | 0 | 0 |
| **Unidentified** | 0.117516 | 0.861786 | 0 | 0 | 0 |
| **Total** | **31.49435** | **27.57714** | **8.239854** | **12.32071** | **18.78958** |

**TABLE 3: ZOOPLANKTON ABUNDANCE (ind/m$^3$) IN DIFFERENT SAMPLING STATIONS DURING MONSOON**

| Name of the species | Sandwip (Ind/m$^3$) | Hatia (Ind/m$^3$) | Bhola (Ind/m$^3$) | Barishal (Ind/m$^3$) | Chandpur (Ind/m$^3$) | Cox's Bazar ( Ind/m$^3$) | Naf River (Ind/m$^3$) |
|---|---|---|---|---|---|---|---|
| ***Acetes*** | 0.556396 | 0 | 0.105563 | 0 | 0 | 0 | 0 |
| ***Amphipoda*** | 0 | 0 | 0 | 0 | 0 | 0 | 0.174397 |
| ***Calanoida*** | 0.397425 | 0.675988 | 0.42225 | 0.774701 | 0.319896 | 4.228432 | 0.784786 |
| ***Caridean shrimp*** | 1.033306 | 0.337994 | 0.633375 | 0.688623 | 2.825746 | 0 | 0.610389 |
| ***Cladocera*** | 0.15897 | 0.112665 | 0.105563 | 0 | 0 | 0.2699 | 0.174397 |
| ***Crab larvae*** | 0.15897 | 0 | 0.105563 | 0.172156 | 0.106632 | 2.069233 | 1.046381 |
| ***Crab Zoea*** | 0.15897 | 0 | 0 | 0 | 0 | 0 | 0.174397 |
| ***Ctenophores*** | 0 | 0 | 0 | 0 | 0 | 1.259533 | 0.261595 |
| ***Cyclopoida*** | 0.15897 | 0.450659 | 0.527813 | 0.688623 | 0.159948 | 1.529433 | 0.523191 |
| ***Fish egg*** | 0 | 0 | 0 | 0.602545 | 0 | 0 | 0 |
| ***Fish juvenaile*** | 0.715366 | 0.563323 | 0.844501 | 0.258234 | 0.053316 | 0 | 0 |
| ***Fish larvae*** | 0.079485 | 1.239311 | 0.738938 | 0.344312 | 0.159948 | 2.878932 | 0.435992 |
| ***Hydromedusa*** | 0.079485 | 0 | 0 | 0 | 0 | 0.719733 | 0.261595 |
| ***Isopoda*** | 0 | 0.112665 | 0 | 0 | 0 | 0 | 0 |
| ***Leptomedusae*** | 0 | 0 | 0 | 0 | 0 | 0.629766 | 0.087198 |
| ***Lucifer*** | 6.279322 | 0.225329 | 0.42225 | 0.430389 | 1.279583 | 11.8756 | 0 |
| ***Magalopa*** | 0 | 0 | 0 | 0.086078 | 0 | 1.529433 | 0 |
| ***Mysids*** | 0 | 0.112665 | 0 | 0 | 0.373212 | 0 | 0.261595 |
| ***Mysis*** | 0 | 0 | 0 | 0 | 0 | 0 | 0.174397 |
| ***Penaeid shrimp*** | 0.47691 | 0.450659 | 0.738938 | 0.258234 | 0.319896 | 0 | 1.65677 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Sagitta*** | 0 | 0 | 0 | 0 | 0 | 5.038131 | 0.610389 |
| ***Shrimp Zoea*** | 0.238455 | 0.112665 | 1.161188 | 0 | 0 | 18.62309 | 0.261595 |
| ***Siphonophores*** | 0 | 0 | 0 | 0 | 0 | 0.629766 | 0.261595 |
| ***Trachymedusae*** | 0 | 0 | 0 | 0 | 0 | 0.359867 | 0.174397 |
| **Unidentified** | 0.15897 | 0.225329 | 0.211125 | 0.086078 | 0 | 0 | 0.087198 |
| **Total** | **10.651** | **4.61925** | **6.017066** | **4.389972** | **5.598177** | **51.64085** | **8.022255** |

**TABLE 4. SEASONAL DIVERSITY INDEX**

| **Name of the season** | **S** | **N** | **J'** | **H' (*loge*)** | **D** |
|---|---|---|---|---|---|
| PRE-MONSOON | 10.14286 | 120 | 0.597832 | 1.5778589 | 1.866924 |
| MONSOON | 12.28571 | 149.4286 | 0.87276 | 2.0006297 | 2.502462 |
| POST-MONSOON | 15.28571 | 475.8571 | 0.688589 | 1.854269 | 2.557184 |

In Riverine area, there were 16 genera identified during monsoon. Calanoida (38.95257 ind/m3) was found maximum at Bhola and the lowest (0.161585 ind/m3) was *Acetes* at Barishal. In Bhola, total abundance of zooplankton was recorded 94.47846 ind/m3 and in Barishal total abundance of zooplankton was 35.54866 ind/m3 and in Chandpur it was recorded 22.6414 ind/m3. In Riverine area, there are 22 genera were identified during premonsoon. Sagitta (1.739525 ind/m3) is the maximum at Bhola and the lowest was *Isopods* (0.091554 ind/m3) at Bhola. In Bhola, total abundance of zooplankton was 8.239854 ind/m3 (Table 2, 3 and 4).

In offshore area, in total, 32 genera were identified. Calanoida (34.3338 ind/m3) was maximum at Sandwip and the lowest was Isopods (0.21897 ind/m3) at Hatia. In Sandwip, the total abundance of zooplankton was 37.0058 ind/m3 and in Hatia, the total abundance of zooplankton was 94.47846 ind/m3 (Table 1-2). In offshore area, 22 genera were identified during premonsoon. *Calanoida* (9.753847 ind/m3)

was maximum at Sandwip and the lowest Fish larvae (0.117516 ind/m3) was at Sandwip (Table 2-4).

In Nearshore area, there are 32 genera were identified. *Doliolum* (294.7307 ind/m3) is maximum at Naf River and lowest Isopods (0.179933ind/m3) at Cox's Bazar. In Naf River total abundance of zooplankton was recorded 331.318 ind/m3 and Cox's Bazar total abundance of zooplankton found 47.68232 ind/m3. In Nearshore area, there are 22 genera were identified during pre-monsoon. *Lucifer* (4.328489 ind/m3) was maximum at Naf River and the lowest was *Isopods* (0.080527ind/m3) at Cox's Bazar (Table 2-4).

Generally, species diversity is a function of species richness and evenness with which the individuals are distributed (Margalef, 1958). Shannon-Wiener diversity index (H'), evenness index (J') and species richness (d) were found a little bit variation in the present study in different stations both temporally and spatially. Spatially, the highest value of Shannon-Weiner (2.388), Species richness (0.853) and Evenness (3.50) were found at Naf River station and lowest value of Shannon-Weiner (1.06) at Chandpur, Species richness (1.302) and Evenness at (0.508) at Chandpur. Seasonally, Species richness was found highest in Monsoon (0.807) but lowest in pre-monsoon (0.597), Evenness was lowest in the pre-monsoon (1.866) but highest in the post-monsoon (2.55) and Shannon-Weiner was calculated highest in monsoon (2.00) but lowest in pre-monsoon (1.57) period in the study area (Table 4, 5; Fig 10, 11).

**TABLE 5: SPATIAL DIVERSITY INDEX**

| Sampling station | S | N | d | J' | H'(loge) |
|---|---|---|---|---|---|
| Sandwip | 15.66667 | 486.3333 | 2.539377 | 0.669576 | 1.842918 |
| Hatia | 12 | 154.3333 | 2.433574 | 0.821891 | 2.038648 |
| Bhola | 11 | 355 | 2.065682 | 0.824077 | 1.977704 |
| Barishal | 8.666667 | 90 | 1.693887 | 0.50863 | 1.264123 |
| Chandpur | 7.333333 | 115 | 1.302831 | 0.446845 | 1.06173 |
| Cox's Bazar | 16.33333 | 417.3333 | 2.619514 | 0.760793 | 2.117743 |
| Naf River | 17 | 121 | 3.507118 | 0.85348 | 2.388493 |

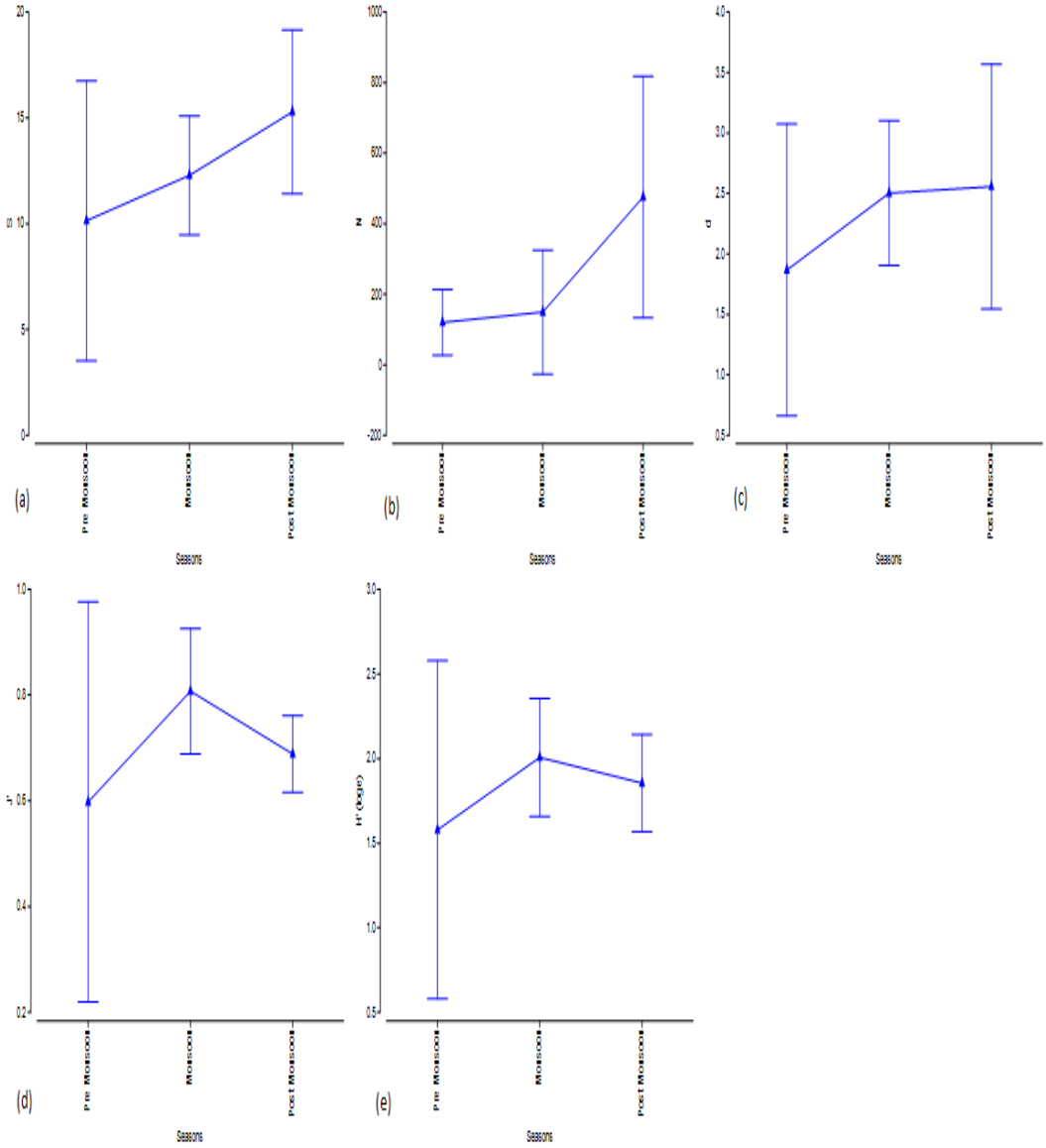



**FIGURE 10. SEASONAL DISTRIBUTION OF ZOOPLANKTON (A) NUMBER OF SPECIES (B) TOTAL INDIVIDUAL (C) SPECIES RICHNESS (D) EVENNESS (E) SHANNON-WEINER DIVERSITY**

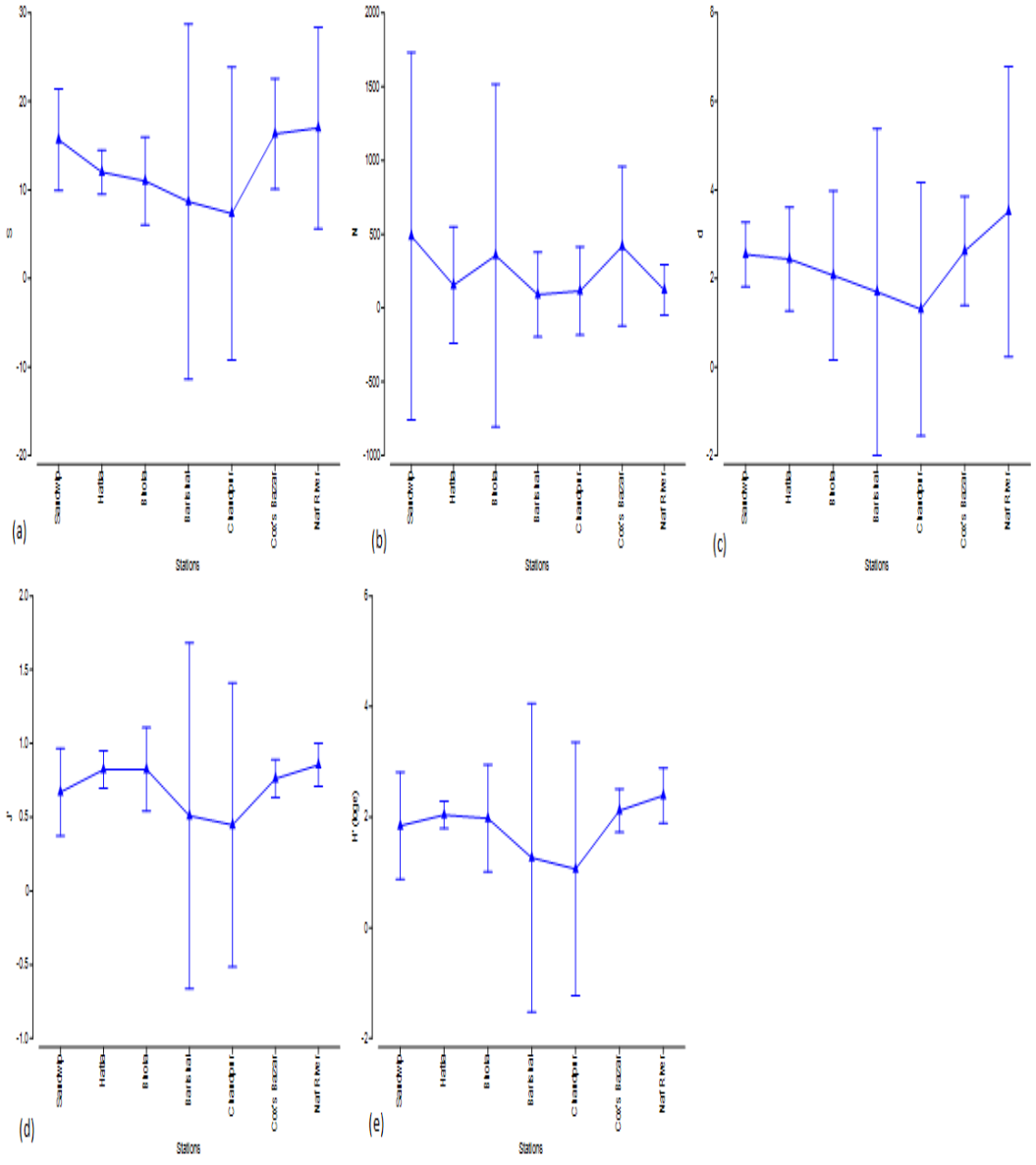



**FIGURE 11. SPATIAL DISTRIBUTION OF ZOOPLANKTON (A) NUMBER OF SPECIES (B) TOTAL INDIVIDUAL (C) SPECIES RICHNESS (D) EVENNESS (E) SHANNON-WEINER DIVERSITY**

## CONCLUSION

The findings of the present study are preliminary information of the effects of physio-chemical factors on the diversity, occurrence, distribution and abundance of zooplankton in the south east coast of Bangladesh covering various ecosystems, viz.: Riverine (Bhola, Barishal and Chandpur), Offshore Island water (Sandwip and Hatia) and Nearshore (Cox's bazar and Naf River) regions. This study identified 33 genera and some unidentified zooplankton in study stations. The values of different diversity index showed fluctuation within seasons rather than stations because it depends on different types of hydro-biological factors in the environment. The distribution patterns, abundance and composition of zooplankton also fluctuated with these parameters because water quality parameters were highly positively and negatively correlated with the zooplankton communities. In addition, zooplankton is very important for fisheries and shrimp in south eastern area of Bangladesh. So, more scientific investigation should be emphasized for doing further comprehensive research on hydro-biological resources in south eastern coastal waters of Bangladesh.

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