

Annual pattern of zooplankton communities and their environmental response in a subtropical maritime channel system in the northern Bay of Bengal, Bangladesh

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Abstract

Zooplankton plays an important role in aquatic food webs by fluxing of energy from primary producer to subsequent trophic levels in the food chain. The annual pattern of zooplankton communities and potential environmental drivers were studied in the Kohelia channel, Bangladesh from summer 2014 to spring 2015. Samples were collected using net at a depth of 1 m. A total of 32 species belonged to 18 orders, 27 families and 15 taxonomic groups were identified. Of these species, 22 distributed in all four seasons of which 8 were dominant and highly contributing to the total communities. Species number peaked in summer next to winter and fall in spring while maximum abundance was in summer and minimum in spring. Multivariate analyses showed that there was a clear annual pattern in the zooplankton communities. Species diversity and evenness peaked in spring but fall in autumn while the high value of species richness was found in winter. Biological-environmental best matching (BIO-ENV) analyses conformed that community pattern of zooplankton was mainly driven by transparency salinity, and temperature individually or combined with water nutrients. These results demonstrate that annual pattern of the zooplankton community shaped by channel environmental factors in subtropical channel ecosystems, thus might be used for community-based subtropical coastal water bioassessment.

Key words: zooplankton, trophic levels, subtropical channel, community structure, multivariate approach

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1 Introduction

Zooplankton are heterotrophic non motile/weak swimming aquatic animals living in all types of water bodies like fresh, coastal or marine ecosystems (Ferdous and Muktadir, 2009). They are key components in the aquatic ecosystems having effective role in the tropical food web and behave as a linker between the lower and higher levels (Liu et al., 2013; Sahu et al., 2013; Arashkevich et al., 2002). Most significantly they treat as intermediate nexus for fluxes of energy from primary producers like as phytoplankton and microbes to consumer levels of food chain (Iqbal et al., 2014; Madin et al., 2001), and also provide essential indication about the trophic condition of secondary production in the aquatic ecosystems (Abdullah Al et al., 2018). Moreover, the fertility of ecosystems depends on availability of zooplankton while eventually it provides information of fisheries potentiality and sustainability (Abu Hena et al., 2016; Srichandan et al., 2015). Furthermore, it is acquainted that the world richest fisheries directly or indirectly depend on zooplankton availability (Srichandan et al., 2013) because they lead the displacement of

the organisms that depended on them (Savari et al., 2013; Prabhakar et al., 2011). Studies have reported that variation in distribution, abundances and composition of zooplankton greatly influenced the existing aquatic habitats on depending communities like fishes, e.g., pelagic fishes feed on zooplankton for their entire life stages or early life stages (Abu Hena et al., 2016; Iqbal et al., 2014). Therefore, the relationship between zooplankton and physiochemical parameters directly/indirectly related to monsoonal activity of the bay water especially during monsoon period, e.g., May to July when effective rainfall and nutrients input from upland influence the community patterns like distribution, abundances and composition (Srichandan et al., 2014; Fernandes and Ramaiah, 2009). Moreover, it has been widely used as potential bioindicators for ecological succession of coastal waters, also discriminating environmental status due to short living and quick response to certain environmental changes (Ferdous and Muktadir, 2009; Bianchi et al., 2003; Ramaiah and Nair, 1997). Up to date, several studies have been carried out about zooplankton and related environmental paramet-

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ers in the coastal waters of the Bay of Bengal but very limited in the Bangladesh coastal waters especially northern part. Previous studies reported that the community patterns of zooplankton are governed by hydrological parameters of those ecosystems where transparency, salinity, temperature and nutrients are the significant influencing factors for variation of the community patterns (Abu Hena et al., 2016; Khan et al., 2015; Iqbal et al., 2014).

Bangladesh has the greatest significant of available resources both fauna and flora due to unbroken 710 km coast line and stable continental shelf also place in Genjatic delta region (Gonga-Brhamaputtra and Meghna) (Abu Hena and Khan, 2009), which carried out by several rivers, estuaries and open maritime channels systems, i.e., Moheshkhali, Kutubdia and Kohelia channels (Abu Hena et al., 2005). Their valuable economical contribution in the fisheries sectors and coastal carbon sequestration having massive growth of natural aquatic vegetation (e.g., mangroves, salt marshes and seagrasses) are noticeable. For example, Moheshkhali channel is habitat of around 35 fin-fish species and 10 shrimp species (Rashed-Un-Nabi et al., 2011) also seven species of cephalopods (Abu Hena et al., 2005). These fisheries species are fond of zooplanktons as their foodstuffs during foraging stages in the channels. In contrast, from the economical and geographical point of view, Kohelia channel has great contribution having massive growth of aquatic vegetation which provides feeding, spawning and nursery ground, also supply abundant food and relatively safe ecological niche for many valuable species like shrimp (e.g., *Penaeus monodon*) and other commercial fishes. Being as important wetland and aquatic ecosystem, the research on zooplankton along with limnology are still scarce in this area. The research on hydrological and biological properties are important of this channel system prior to take necessary steps on ecological health management and resource conservation.

In the present study, a one-year baseline survey was carried out in the channel from summer 2014 to spring 2015. Our objectives of this study were: (1) to document the species composition

and abundances of zooplankton; (2) to reveal the annual variation in zooplankton communities; and (3) to summarize the annual environmental response of zooplankton communities in such a subtropical channel system.

2 Materials and methods

2.1 Study area, data collection and sample processing

Three sampling stations were selected in the Kohelia channel: Sta. 1 was located at the mouth of the channel in the southeast part of the Dalghat (Monirtek); Sta. 2 was in the middle part of the channel near Zapua; and Sta. 3 was the joint of two channels of Kohelia and Moheshkhali near Materbari (Fig. 1). Samples were collected in summer (June 2014), autumn (September 2014), winter (December 2014) and spring (March 2015), respectively.

Zooplankton samples were collected using a conical shaped plankton net with a mesh size of 325 μm . 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 stations from the surface water at 1 m depth for 10–15 min.

After collection, all samples were preserved in 5% formalin solution (Goswami, 2004). For effective sorting, the samples were stained with rose bangle (coloring reagent) and left for 24 h in the laboratory. All zooplankton species attained pink color, which helped to sort out easily and identification was carried out using fine brush, needles, forceps and microscope.

Enumeration was done according to Goswami (2004) zooplankton abundance was expressed as individuals per liter (ind./L).

The sorted zooplanktons were preserved in 70% ethanol solution. Preserved samples were identified morphologically under the microscope according to the previous studies (Conway, 2012; Al-Yamani et al., 2011; Mulyadi, 2004; Conway et al., 2003; Buckland-Nicks et al., 2002; Goddard, 2001).

Environmental parameters such as water temperature ($^{\circ}\text{C}$), salinity, pH, and water transparency (cm) were estimated *in situ*

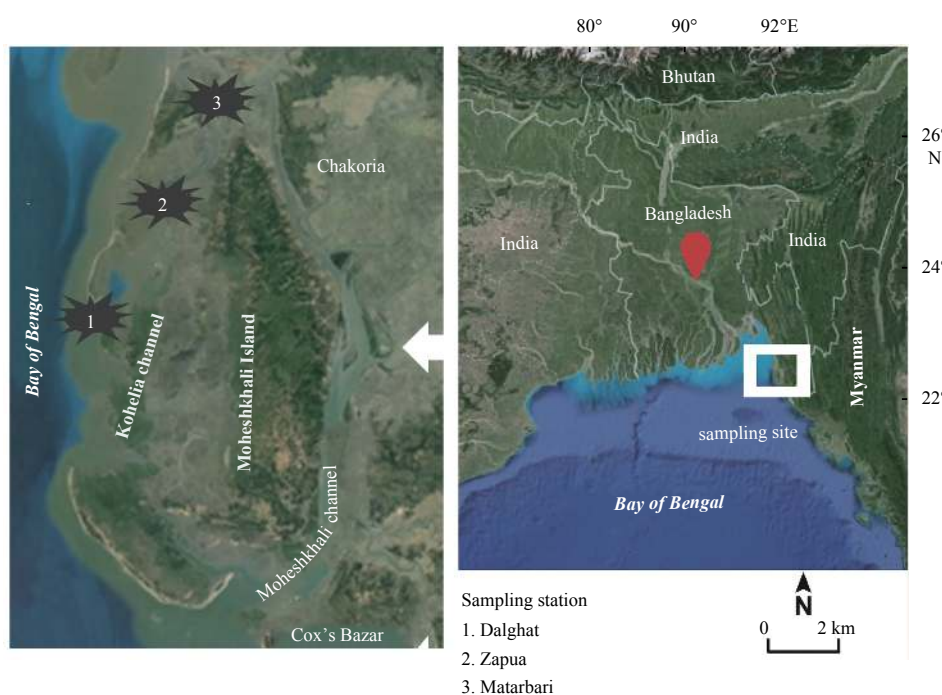


Fig. 1. Sampling stations (1–3) in the Kohelia Channel in the northern Bay of Bengal, Bangladesh.

using centigrade thermometer, refractometer (TANAKA New S-100, Japan), digital pen pH meter (HANNA instruments, model HI 98107) and secchi disk, respectively. Sub-subsurface (~1 m) water samples were collected for measuring dissolved oxygen (DO), total dissolved solid (TDS), total suspended solid (TSS), nitrite-nitrogen (NO₂-N) and soluble reactive phosphate-phosphorus (PO₄-P), following the standard method of APHA (1989).

2.2 Data analysis

Species diversity (H') (Shannon and Weaver, 1949), species richness (d) (Margalef, 1968) and species evenness (J') (Pielou, 1966) were used to summarize the biodiversity pattern of zooplankton. These three indices were calculated according to the following formula:

$$H' = - \sum_{i=1}^s P_i (\ln P_i),$$

$$J' = H' / \ln S,$$

$$d = (S - 1) / \ln N,$$

where H' is observed diversity index, P_i is proportion of the total count arising from the i th species, S is total number of species, and N is total number of individuals.

Multivariate analysis of annual variations in the zooplankton communities were analyzed using PRIMER v7.0.11 with the routine PREMANOVA (Abdullah Al et al., 2018; Clark and Gorley, 2015; Anderson et al., 2008). Bray-Curtis similarity and Euclidean distance matrices were computed on square root transformed species abundance data and on log-transformed/normalized environmental data, respectively. The species contribution as top rank contributors in each sampling period was conducted by SIMPER analysis. The species distribution among four sampling period was analyzed by the sub-module of CLUSTER on Bray-Curtis similarities from the standardized species abundance data. The annual variations in community patterns were coordinated using the sub-module of dbrDA (distance based redundancy analysis) of PREMANOVA in PRIMER (Anderson et al., 2008), while the annual pattern of environmental variables was coordinated using the routine PCA (principle component analysis) (Abdullah Al et al., 2018; Clark and Gorley, 2015).

Univariate analysis of Pearson correlation matrix was conducted using the IBM SPSS v.22 (Landau and Everitt, 2004) to identify any existences of variance between the environmental parameters and zooplankton communities.

3 Results

3.1 Environmental variables

The average values of nine environmental variables were: water temperature showed a clear annual variation, ranging from 23.67°C to 30.67°C from summer to spring; salinity ranged from 12.33 to 34.33, with minimum (12.33) in summer and maximum (34.33) in winter; transparency varied from 17.17 cm (summer) to 75.67 cm (spring); the average pH ranged from 7.24 to 7.54; DO fluctuated from 4.76 mg/L (summer) to 6.35 mg/L (autumn); TDS varied from 30.93 µg/L to 32.67 µg/L, maintaining relatively stable in all seasons; TSS varied from 0.58 µg/L to 1.00 µg/L with a peak in the winter; NO₂-N varied from 0.34 mg/L (summer) to 0.53 mg/L (peaked in autumn); and PO₄-P varied from 0.33 mg/L

to 0.55 mg/L (peaked in the spring).

3.2 Taxonomic composition and species distribution

The species composition, average abundances and the ranks of the top 8 contributors in each sampling period were given in Table 1. A total of 32 zooplankton species, belonging to 18 order, 27 families and 15 taxa were identified during the study period. Of these taxa, 22 species occurred in all seasons and were defined as “common” species, while eight species (*Ampelisca bocki*, *Acetes erythraeus*, *Americamysis bahia*, *Penaeus indicus*, *Tempra longicornis*, *Cyclops bicuspidatus*, *Mesopodopsis orientalis* and *Scylla serrata*) of the top 10 ranked contributors at each season defined as “dominant” species (Table 1). It was noteworthy that the other 10 species were occurred in specific seasons, and defined as endemic species with seasons. For example, *Amothenella longipes* was found only in summer; *Macrobrachium rosenbergii* and *Linuche unguiculata* were noted in winter and spring, respectively.

A dendrogram for species distribution in all the four seasons showed that 32 species formed seven groups at 60% Bray-Curtis similarity level based on their occurrences and abundances. Groups 1 and 2 consisted of 25 common/dominant species with higher composition and abundances in the total zooplankton communities. Of these 32 species, 26 occurred in summer, 30 in autumn and 28 species in winter and spring, respectively, which indicated a clear succession in the zooplankton communities from summer to spring (Fig. 2).

3.3 Seasonal variation of zooplankton communities

In terms of average values, species number peaked in summer, followed by winter and fall in spring while the maximum abundance occurred in the summer and gradually dropped in the spring (Fig. 3). The zooplankton communities represented clear annual variations in terms of both relative abundances and species composition (Fig. 4). It was noted that *Mesopodopsis orientalis*, *Acetes erythraeus*, *Americamysis bahia*, *Ampelisca bocki*, *Cyclops bicuspidatus*, *Penaeus indicus*, *Scylla serrata* and *Temora longicornis* were the primary contributors for the total composition of the communities in all the four seasons, e.g., *Americamysis bahia*, *Penaeus indicus*, *Scylla serrata* and *Ampelisca bocki* were contributors for summer; *Americamysis bahia*, *Mesopodopsis orientalis* and *Cyclops bicuspidatus* were for autumn; *Americamysis bahia*, *Mesopodopsis orientalis*, *Cyclops bicuspidatus*, *Temora longicornis*, *Ampelisca bocki* and *Penaeus indicus*; and *Mesopodopsis orientalis*, *Acetes erythraeus*, *Cyclops bicuspidatus*, *Temora longicornis*, *Ampelisca bocki* and *Penaeus indicus* for winter and spring, respectively.

Based on 12 data points, the distance-based redundancy analysis (dbrDA) demonstrated a clear annual pattern of the zooplankton communities (Fig. 5). For example, the first axis (dbrDA1, 60.1% of total variation) separated the zooplankton samples in spring and winter (on the left) from those in autumn and summer (on the right), while the second axis (dbrDA2, 23.7% of total variation) discriminated the samples in winter and autumn (upper) from those at the other two samples (lower) (Fig. 5a).

Vector overlay of Pearson correlations of the eight dominant species with the dbrDA axis was shown in Fig. 5b. Although these species were the top 8 ranked contributors in each samples, vector for 4 zooplankton species (*Americamysis bahia*, *Cyclops bicuspidatus*, *Penaeus monodon* and *Leucothoe spinicarpa*) pointed toward the sample cloud in autumn (upper in right), one species (*Mesopodopsis orientalis*) toward that in winter (upper left),

Table 1. Species list with average seasonal abundance (*N*, ind./L), and the top 10 ranks (Rk) by contribution of each species to the average Bray-Curtis similarity during the study period in the Kohelia channel, northern Bay of Bengal, Bangladesh

Species	Summer		Autumn		Winter		Spring	
	<i>N</i>	Rk	<i>N</i>	Rk	<i>N</i>	Rk	<i>N</i>	Rk
<i>Acetes erythraeus</i>	++	10	+	9	++	4	+++	1
<i>Acetes indicus</i>	++	8	+	...	+	10	+	7
<i>Americomysis bahia</i>	++++	1	+++	1	+++	1	+	5
<i>Ammothella longipes</i>	+	...	-	...	-	...	-	...
<i>Ampelisca bocki</i>	+++	3	+	8	+	8	+	6
<i>Canthocalanus pauper</i>	++	6	+	...	+	...	+	10
<i>Cheiriphotis megacheles</i>	+	...	+	...	+	...	+	5
<i>Cyclops bicuspidatus</i>	++	7	++	2	++	2	+	...
<i>Evadne tergestina</i>	+	...	+	...	+	...	-	...
<i>Gammarus roeseli</i>	+	...	+	...	+	...	+	...
<i>Leucothoe spinicarpa</i>	-	...	-	...	+	...	+	...
<i>Linuche unguiculata</i>	-	...	-	...	+	9	+	...
<i>Lucifer faxoni</i>	+	...	+	...	+	7	+	8
<i>Lucifer hansenii</i>	+	...	+	...	+	...	+	...
<i>Mactra chinensis</i>	+	...	+	...	+	...	+	...
<i>Mecrobrychium rossenbergi</i>	-	...	-	...	+	...	+	...
<i>Mesopodopsis orientalis</i>	+	...	++	3	++	2	+	...
<i>Micronephthys oligobranchia</i>	+	...	+	...	+	...	+	...
<i>Neptunus pelagicus</i>	+	...	+	...	-	...	-	...
<i>Nerocila phaioleura</i>	+	...	-	...	+	...	+	...
<i>Oniscus asellus</i>	+	...	+	...	+	...	-	...
<i>Penaeus indicus</i>	++	4	+	6	+	...	++	2
<i>Penaeus mergouiei</i>	+	...	++	4	++	3	+	4
<i>Penaeus monodon</i>	++	5	-	...	-	...	+	...
<i>Sagitta bedoti</i>	+	...	+	...	+	5	+	...
<i>Scylla serrata</i>	+++	2	+	10	-	...	-	...
<i>Solen brevis</i>	+	...	+	7	-	...	+	...
<i>Spadella cephaloptera</i>	+	...	+	...	+	...	+	...
<i>Tanaissus lilljeborgi</i>	+	...	+	...	+	...	+	9
<i>Temora longicornis</i>	++	9	+	5	+	6	++	3
<i>Trachycardium asiaticum</i>	+	...	+	...	+	...	+	...
<i>Umboonium vestiarium</i>	+	...	+	...	+	...	+	...

Note: Abundance: + is 0–1, ++ 1–50, +++ 50–100, and ++++ over 500 ind./L; contribution: ... means less contribution by SIMPER results. Text were bold for eight dominant species.

two species (*Acetes erythraeus* and *Cheiriphotis megacheles*) toward those in spring (lower left) and three (*Ampelisca bocki*, *Penaeus indicus* and *Scylla serrata*) toward those in summer (lower right).

The seasonal variation in species richness, evenness and diversity indices during study period was shown in Fig. 6. The species richness peaked in the winter but dropped in the autumn (Fig. 6a), while the species evenness and diversity represented the highest value in spring and lowest in autumn (Figs 6b and c).

3.4 Relationship between zooplankton and environmental parameters

The seasonal changes in environmental variables were summarized by principle component analysis (PCA) in Fig. 5. Vector overlay of these environmental variables with the PCA axis was shown in Figs 5c and d and coefficient of correlation (RELSTE) analysis showed that annual variations in zooplankton com-

munities were significantly correlated with the changes in environmental variables ($\rho=0.552$, $P<0.05$).

Biological-environmental best matching analyses (BIOENV) demonstrated that the seasonal shift in community structure of zooplankton was mainly driven by salinity, transparency, temperature and nutrients ($\rho=0.773$, $P<0.05$) individually or combined with other environmental parameters (Table 2).

Univariate statistical analysis of correlations between environmental parameters and abundances of eight dominant species of zooplankton was summarized in Table 3. Among the eight species, four (*Mesopodopsis orientalis*, *Ampelisca bocki*, *Cyclops bicuspidatus* and *Penaeus indicus*) were significantly correlated with TSS, pH and DO ($P<0.05$). For example, two species *Mesopodopsis orientalis* and *Cyclops bicuspidatus* were positively significant correlated with TSS but *Penaeus indicus* were significantly negative correlated with water pH (Table 3).

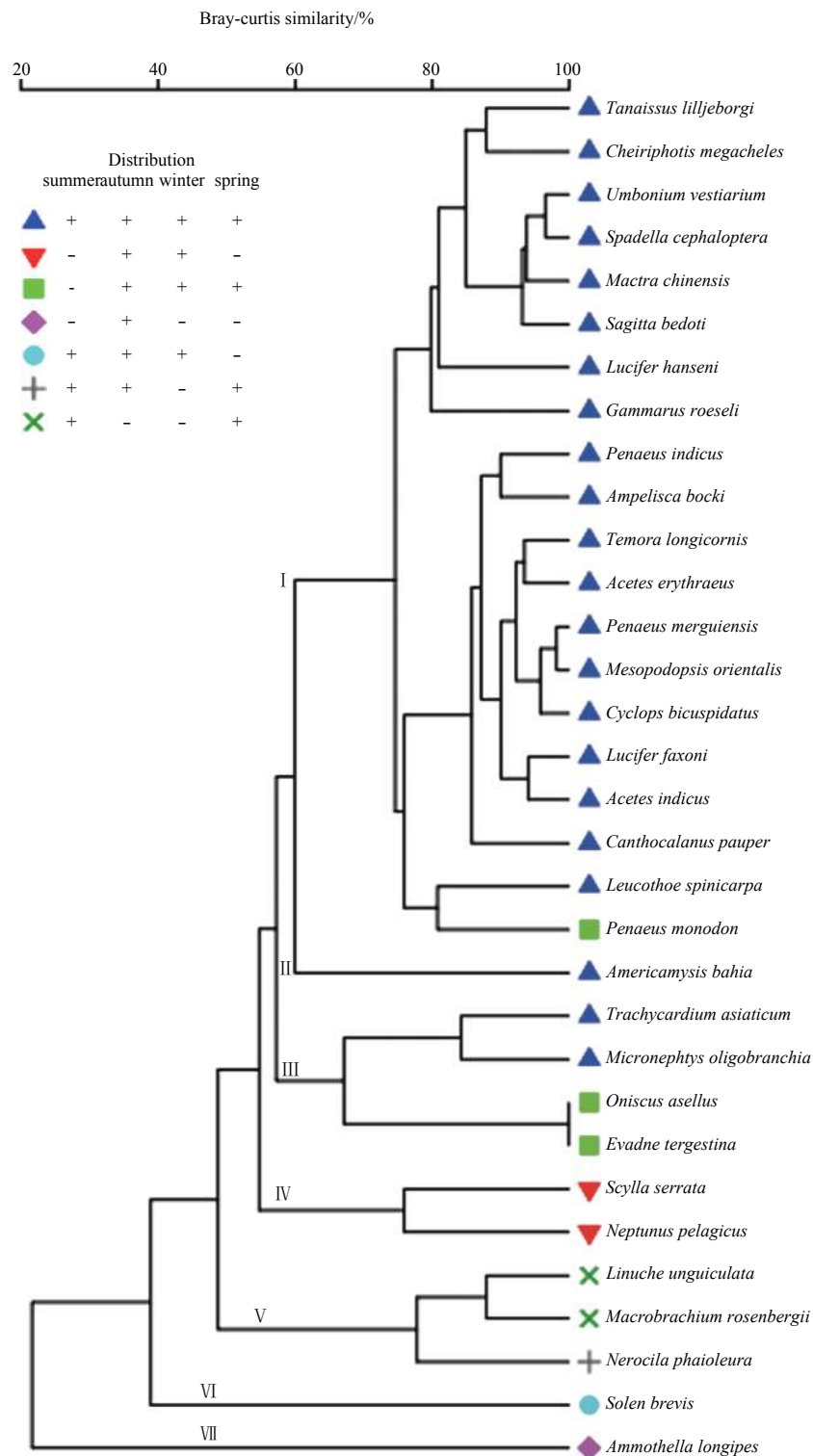


Fig. 2. Dendrogram of the species distribution during four seasons using group average clustering based on Bray-Curtis similarities from square root transformed species abundance data of each species of zooplankton of Kohelia Channel. + represents presence and - absence.

4 Discussion

In the present study, a total of 32 zooplankton species, belonging to 15 taxonomic groups, were identified during the all four seasons from the Kohelia channel, Bay of Bengal. This value is comparable with the reported values by [Abu Hena et al. \(2016\)](#), who reported 11 taxonomic groups including 33 species from

Bakkhali sub-tropical estuary, Cox’s Bazar, Bangladesh. The maximum species number and abundance was recorded in post monsoon and minimum was in monsoon period reported by [Abu Hena et al. \(2016\)](#), while [Sharif et al. \(2017\)](#) reported 37 major zooplankton groups with the maximum occurrences in monsoon from the Meghna River Estuary, Bangladesh. In our previous in-

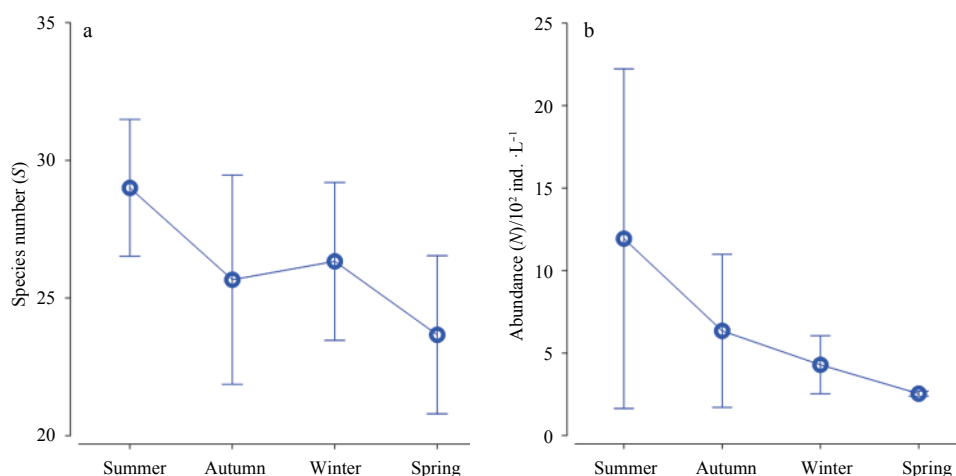


Fig. 3. Species number (a) and abundance of species (b) of zooplankton communities of Kohelia channel in the northern Bay of Bengal, Bangladesh.

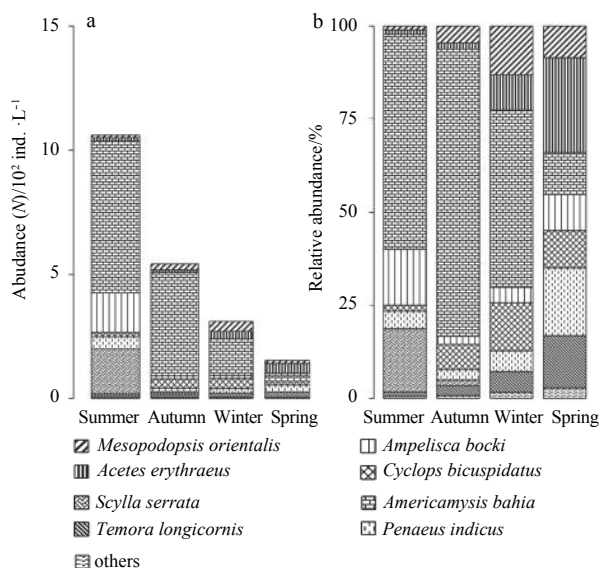


Fig. 4. Abundance of species (a) and relative abundance of species (b) of zooplankton communities of Kohelia Channel in the northern Bay of Bengal, Bangladesh.

investigation, we found 32 species from 15 taxonomic groups with maximum abundance in winter and minimum in summer, in same place with another channel system Kutubdia in Bangladesh (Abdullah Al et al., 2018), while Iqbal et al. (2014) reported 12 taxa with maximum abundance in winter and minimum in pre monsoon in southeastern coastal waters in Bangladesh. Furthermore, Khan et al. (2015) reported eight groups at Sitakunda coast in Bangladesh in the Bay of Bengal, while Savari et al. (2013) reported 15 groups of zooplankton in the Oman Sea with peak abundance which is observed in northeast monsoon period, who explained that water hydrographic condition could be led to variation of species composition and distribution. In contrast, present study was a little bit different from previous reports which might be due to the geographical location and ecological condition of the present study area. For example, most of the previous studies were conducted in estuarine environment, while the present study was in the open maritime channel which could probably had different ecological parameters, e.g., food availabil-

ity, transparency, salinity variation and nutrients of water, which directly or indirectly influenced the abundance and composition of zooplankton.

Based on the present data, 22 species were present in all the four seasons and others 10 species occurred in specific seasons. This implies that ecological conditions such as water parameters, food availability of the study area were different from one season to another throughout the year. Abdullah Al et al. (2018) and Sharif et al. (2017) stated that majority of the zooplankton groups in the northern Bay of Bengal driven coastal waters are shifted due to environmental condition, e.g., water temperature fluctuation, salinity variation, transparency and dissolved oxygen degradation, which was reflected in our present findings. Of these 32 species, *Americamysis bahia* was the most dominant species for three seasons while *Ampelisca bocki*, *Cyclops bicuspidatus*, *Mesopodopsis orientalis*, *Acetes erythraeus* and *Penaeus indicus* were dominant species in all seasons, although *Scylla serrata* was dominant only in summer. In terms of abundances of the dominant species, it should be noted that eight species belonging to groups of mysids, copepods, *Acetes*, shrimp larvae, crab larvae and amphipods were most dominated in this study area probably due to ecological parameters, e.g., salinity, transparency and pH of this channel system. In addition, the sustainability of mangroves and salt marshes habitats by providing shelter zone and adequate food supply for zooplankton were reported elsewhere (Abdullah Al et al., 2018; Abu Hena et al., 2016).

The species richness peaked in winter but dropped in autumn, while the species evenness and diversity showed similar patterns of changing whereas the highest in spring and the lowest in autumn. It is well recognized that estuary has dynamic environmental characteristics, which govern unique habitat for living organisms that is why abundance and composition of zooplankton was higher than other places (Abdullah Al et al., 2018; Abu Hena et al., 2016). Bearing these similarities, densely vegetation of mangroves and salt marsh, and estuarine habits in monsoon period of the Kohelia channel also provided favorable ecological niches for zooplankton communities. In the coastal waters, copepod density has reported to be highly related with salinity level during rainy season when freshwater added in water it turned to be declined (Abdullah Al et al., 2018; Abu Hena et al., 2016; Cook et al., 2007; Rakhesh et al., 2006; Hirst et al., 1999). Present study findings also reflected these arguments, and indic-

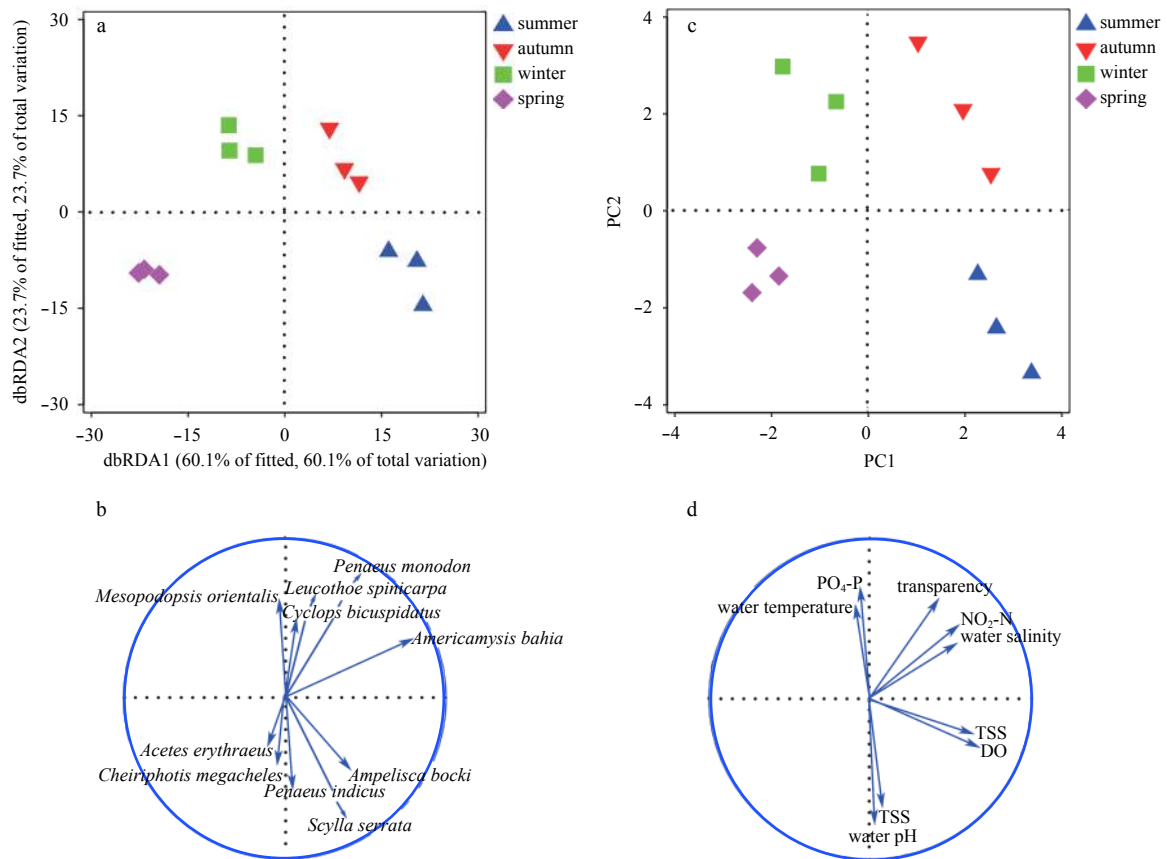


Fig. 5. Distance-based redundancy analysis (dbRDA) for the zooplankton communities with correlation of 10 dominant species with dbRDA axis (a, b) and principle component analysis (PCA) for the environmental parameters with correlations of zooplankton communities in PC axis (c, d) with required data transformed from four seasons.

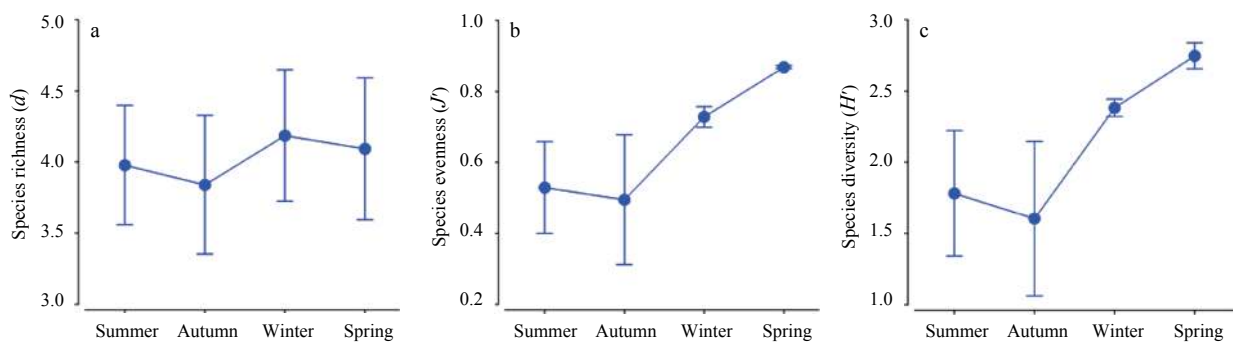


Fig. 6. Species richness (a), species evenness (b) and species diversity (c) of zooplankton communities of Kohelia channel in the northern Bay of Bengal, Bangladesh.

ating that copepods showed positive correlation with water temperature, salinity and transparency. Thus, these implies that with increasing salinity, temperature and transparency directly/indirectly influenced the composition and abundance of copepods than other zooplankton communities.

It has been increasingly recognized that multivariate analysis is more effective than univariate analysis for detecting the changing of community structure (Abdullah Al et al., 2018; Clark and Gorley, 2015). In this study, clustering analysis based on Bray-Curtis similarity, dbRDA and PCA of 32 species revealed a significant relationship between community variation in the zooplankton communities and the changes in the environmental parameters. Best matching analyses showed that temperature,

salinity and nutrients probably the main drivers to the annual patterns of the zooplankton communities in such a subtropical channel system. Seasonal cycle and situation of zooplankton species depend on water salinity, nutrients and transparency (Abdullah Al et al., 2018; Hwang et al., 2010; Mohanty et al., 2010; Osore et al., 2004). Based on present study, it has revealed that zooplankton communities of Kohelia channel in the northern Bay of Bengal governed by different hydrological factors of the channel environment where monsoonal activities of the Bay support very suitable ecological niche for mysids as well as other dominant zooplankton groups most prominently for copepods, amphipods and shrimps.

In conclusion, this is one of the pioneer research focusing on

Table 2. Summary of results from biota-environment (BIOENV) analysis showing the ten best matches of environmental variables with spatial variations in the zooplankton abundances during the study period

Rank	Environmental variables	ρ value	P value
1	Trans, NO ₂ -N	0.773	<0.05
2	T, Sal, Trans, TDS, NO ₂ -N	0.770	<0.05
3	T, Sal, Trans, PO ₄ -P, NO ₂ -N	0.767	<0.05
4	T, Sal, Trans, NO ₂ -N	0.762	<0.05
5	Sal, Trans, PO ₄ -P, NO ₂ -N	0.762	<0.05
6	T, Sal, Trans, NO ₂ -N	0.761	<0.05
7	Sal, Trans, NO ₂ -N	0.761	<0.05
8	Sal, Trans, TDS, PO ₄ -P, NO ₂ -N	0.759	<0.05
9	T, Trans, NO ₂ -N	0.756	<0.05
10	Sal, Trans, NO ₂ -N	0.753	<0.05

Note: ρ value is Spearman correlation coefficient and P value statistical significance level. T represents water temperature, Sal salinity, Trans transparency, TDS total dissolved solid, PO₄-P water soluble reactive phosphate-phosphorus, and NO₂-N water nitrite nitrogen.

Table 3. Pearson correlation between average values of the eight dominants zooplankton species with average environmental variables during the study period

Species	T	Trans	pH	Sal	TSS	TDS	DO	NO ₂ -N	PO ₄ -P
<i>Acetes erythraeus</i>	0.355	0.881	-0.842	0.786	0.210	-0.676	0.325	0.702	0.470
<i>Americamysis bahia</i>	-0.471	-0.860	0.906	-0.716	-0.122	0.846	-0.086	-0.677	-0.460
<i>Ampelisca bocki</i>	0.774	-0.427	-0.340	-0.636	-0.824	-0.489	-0.974*	-0.564	0.438
<i>Cyclops bicuspidatus</i>	-0.694	0.747	0.116	0.884	0.973*	0.057	0.774	0.889	-0.553
<i>Mesopodopsis orientalis</i>	-0.614	0.801	0.036	0.896	0.956*	-0.124	0.603	0.942	-0.583
<i>Penaeus indicus</i>	0.678	0.656	-0.973*	0.495	-0.175	-0.763	0.039	0.400	0.749
<i>Scylla serrata</i>	0.512	-0.714	0.049	-0.851	-0.782	-0.136	-0.943	-0.759	0.189
<i>Temora longicornis</i>	0.307	0.854	-0.797	0.783	0.223	-0.572	0.428	0.676	0.487

Note: * Correlation is significant at the $P < 0.05$ level. DO represents dissolved oxygen, TSS total suspended solid, and pH water hydrogen ion concentration. Significant values were in bold text. See Table 2 for other abbreviations.

annual variation in community patterns of zooplankton with response to environmental changes in the subtropical channel of Kohelia in the northern Bay of Bengal, southeastern coastal zone of Bangladesh. Of these 32 species, 22 distributed in all season of which eight species were found dominant with the highest abundances and composition in the zooplankton communities. Due to strategic location of the Kohelia channel, this place is highly suitable for most of the aquatic animals especially molluscs and shrimps. Besides, the existence of aquatic vegetation like mangroves and salt marshes could also provide the suitable habitats for the presence of pelagic mollusc and shrimp in this channel system. The changing of the salinity, transparency, temperature and nutrients drove the annual pattern in zooplankton community structures. Thus, this finding revealed that the zooplankton community represented structural variation shaped by the environmental drivers in tropical channel system, which might be used as bioassessment of monitoring program for assessing coastal ecosystems. We recommended that further more studies are needed to justify this statement.

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