INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 1, p. 271-282, 2017
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Spatio-temporal occurrence and distribution of copepod in the Karnaphuli river estuary, Bangladesh

Abu Sayeed Muhammad Sharif*[1], Md. Shafiqul Islam[2], Md. Simul Bhuyan[2]

[1]*National Oceanographic Research Institute, Bangladesh*

[2]*Institute of Marine Science and Fisheries, University of Chittagong, Bangladesh*

Article published on January 31, 2017

Key words: Spatio-temporal, Copepod, Occurrence, Distribution, Karnaphuli river

Abstract

A total of 25 major taxa of zooplankton were identified from the Karnaphuli River of which 23 taxa during monsoon, 20 taxa during post monsoon and 20 taxa during pre-monsoon. The sampling sites count started from the Karnaphuli River mouth towards the upstream. The seasonal highest peak of zooplankton recorded 423.54 indivs/m^3, 654.4 indivs/m^3 and 437.39 indivs/m^3 accordingly during monsoon, post-monsoon and pre-monsoon season at site-6, site-4 and site-6 respectively. Copepod occurred at all sites as a dominating species and contributed 40.18% annually. The seasonal highest peak of copepod was 83.02% at site-2 during monsoon, 89.39% at site-4 during post-monsoon and 36.82% at site-1 during pre-monsoon season. Copepod exhibited a weak positive linear relationship with dissolved oxygen; a moderate negative linear relationship with air temperature, water temperature, pH, salinity and a weak negative linear relationship with TDS. In this study copepod showed euryhaline nature. As a consequence, their abundance increased with decreasing salinity and maximum was found in the freshwater region.

***Corresponding Author:** Abu Sayeed Muhammad Sharif ✉ sharifimscu@gmail.com

Introduction

The Karnaphuli river originated from the Lusai hills (in Mizoram, India) enter into the eastern boundary of Chittagong and flows after a course of 194.73 km through Bangladesh and falls into the Bay of Bengal (O' Mallery, 1908). Very few or no remarkable study was conducted on the copepods of the Karnaphuli River. Copepods are one of the most dominant group in zooplankton communities (Castel and Feurtet, 1986; Soetaert and Van Rijswijk, 1993; Peitsch *et al.,* 2000; Bollens *et al.,* 2002; Lo *et al.,* 2004; Hooff and Bollens, 2004; Lopez-Ibarra and Palomares-Garcia, 2006; Bouley and Kimmerer, 2006; Cordell *et al.,* 2007; Cordell *et al.,* 2008; Devreker *et al.,* 2008; Bollens *et al.,* 2011) in terms of density and biomass (Froneman, 2002; Kibirige and Perissinotto, 2003).

Generally they are secondary producers (Islam *et al.,* 2006) in coastal and marine environment (Lo *et al.,* 2004; Magalhaes *et al.,* 2010) primarily feed on phytoplankton (Lo *et al.,* 2004). In tropical and subtropical estuaries, phytoplankton populations are limited by the zooplankton populations and zooplankton are limited by the accessibility of feeding resources (Rios-Jara, 1998; Ara, 2002; Marques *et al.,* 2007). The significant effects of planktonic copepods in food web are the contribution to organic matter fluxes as well as nutrient recycling (Parsons *et al.,* 1984; Miller *et al.,* 1991; Dam *et al.,* 1994; Landry *et al.,* 1994; Banse, 1995). They are also playing a paramount role in the energy transfer between producer and large heterotrophic organisms like fish (Parsons *et al.,* 1984; Banse, 1995). Moreover, they are well-known natural food source for fish larvae (Schipp *et al.,* 1999; Sommer *et al.,* 2002). The organic matter produced by phytoplankton is eaten by copepods thus energy in direct way transfers from autotrophic level to heterotrophic level- explains in classical food web.

The dynamics of fishery resources are also affected by the distribution of copepods as they are consumed by the fish and other organisms of higher levels directly or indirectly (Lo *et al.,* 2004; Payne and Rippingale, 2001; Evjemo *et al.,* 2003). Stimulatingly, copepods are playing crucial role in consuming carbon produced by the microbial loop (Champalbert and Pagano, 2002; Sommer and Stibor, 2002).

Composition, distribution, density and biomass of estuarine copepods varied spatially and temporally. The occurrence and distribution of copepods are influenced by ecological variables, especially in estuaries, bays, and lagoons (Castel and Courties, 1982; Ferrari *et al.,* 1985). These ecological variables include temperature (Degtereva, 1973; Timofeev, 1997), predation (Zelikman and Kamshilov, 1960; Hassel *et al.,* 1991), and advection of zooplankton (Skjoldal *et al.,* 1987; Loeng *et al.,* 1997; Helle, 2000). Revis (1988), Mckinnon and Klumpp (1998), Ara (2004) and Osore *et al.,* (2003) reported that salinity, turbidity, tidal regime, food availability, etc. Salinity plays vital role in the distribution and occurrence of copepods reported by (Ara, 2004; Froneman, 2004; Uriarte and Villate, 2005; Li *et al.,* 2006).

It is one of the main factors that control copepods development as because osmoregulation affects its ecological tolerances (Rippingale and Hodgkin, 1977; Cervetto *et al.,* 1999). Moreover, spatial variation is affected by local feeding (Zelikman and Kamshilov, 1960), grazing by planktophagous fish (Hassel *et al.,* 1991) and grazing (Zelikman and Kamshilov, 1960; Swanberg and Bamstedt, 1991).The relationship between dispersal of copepods and environmental factors have been studied in several estuaries (Hassel, 1986; Soetaert and Rijswijk van, 1993; Sarkar and Choudhury, 1998; Lawrence *et al.,* 2004; David *et al.,* 2007). Some ecological features of copepods have recently been studied, including behavior (Hwang and Turner, 1995), co-occurrence with ichthyoplankton (Cheng, 1998; Hsieh and Chiu, 2002), diversity and biomasses (Shih and Chiu, 1998), grazing rates (Hwang *et al.,* 1998; Wong *et al.,* 1998), in the estuarine and coastal distributions (Hsieh and Chiu, 1998; Lo *et al.,* 2001).

There is very few or no remarkable study on the copepods of the Karnaphuli River. The present study will uncover the abundance and seasonal distribution of copepods in the lower Karnaphuli River with reference to physico-chemical parameters.

Materials and methods

Study Area

Copepod occurrences and distribution was studied from six sampling sites in the Karnaphuli River (Table 1 & Fig. 1). The sampling sites count started from the Karnaphuli River mouth up to the Karnaphuli River above the Halda's (canal) Confluence. The salinity, temperature, pH, DO, TDS were recorded during the investigation.

Table 1. Sampling sites with respective geographical co-ordinates.

Sites No.	Name of the Sites	Geographical Location
Site-1	15 No. Jetty	22°14'28.2"N and 91°49'26.8"E
Site-2	Marine Fisheries Academy	22°17'49.5"N and 91°48'06.1"E
Site-3	Bridge Ghat	22°19'06.9" N and 91°50'30.6" E
Site-4	Nazirchar	22°21'44.7" N and 91°52' 33.8" E
Site-5	Halda Mouth	22°24'50.7" N and 91°53' 141.1" E
Site-6	Karnaphuli River above Halda's Confluence	22°24'27.6" N and 91°53' 58.7" E

Fig. 1. Map showing the sampling sites in the Karnaphuli River Estuary.

Sampling Duration

Considering the annual hydro-meteorological cycle of Bangladesh three sampling seasons were chosen to cover an annual cycle; Monsoon, Post-monsoon and Pre-monsoon.

Sampling and Preservation

Sub-surface water samples were drawn by Rutner water Sampler for hydrographic physic-chemical parameter determination.

Water temperatures were recorded using a centigrade thermometer; Hydrogen-ion-concentration (pH) was determined using a (Hanna digital HI98107 pHep® pH Tester) pen pH meter (after calibrating by buffer pH 4 and buffer pH 10); Dissolved Oxygen (DO) was determined following Winkler's titration method; Salinity were determined following the standard Mohr-Knudsen method (Barnes, 1959); Total Dissolved Solids (TDS) was measured by following the standard methods (APHA, 1975).

The working procedures also included zooplankton sampling, preservation and identification in the laboratory. Zooplankton samples were collected from the subsurface water using a zooplankton net of 300 µm. A flow meter was attached at the mouth of the net and a weight attached to keep the net at subsurface level while towing. After about 15 minutes towing the sample was kept in labeled bucket then preserved in 70% ethanol and transferred to the laboratory for further analysis. The stored samples were stained with Rose Bangle and left over night for efficient sorting. All the zooplankter's attained pink color rendering easy identification. The stained zooplankton was sorted out from debris and further preserved fresh in 70% ethanol. The sorted organisms were brought under microscope and identified following Mizuno (1976); Yamaji (1972, 1974,); Pennak (1978); Davis (1955); Santhanam and Srinivasan (1994); Newell and Newell (1973); Sterrer (1986); Parsons *et al.,* (1985); Mahmood *et al.,* (1976); Wickstead (1965); Zafar (1986); Mohi (1977); Edmondson (1959) etc.

Results and discussion

Hydrological Parameters

The hydrographic physico-chemical parameters were examined from the Karnaphuli are tabulated (Table 2). The air temperature of sampling sites varied between 15°C to 32.5°C. The water temperature ranged between 21°C to 32°C. The pH was recorded 6.5 to 7.6 during the investigation. The Dissolved Oxygen (DO) concentration in the surface water varied from 2.66ml/l to 5.37m1/l during the study period. The Total Dissolved Solids (TDS) ranged from 111mg/1 to 782.5mg/1 and the surface water salinity recorded from 0.2‰ to 24.5‰ (Table 2).

Table 2. Showing hydrological parameters recorded from the Karnaphuli River sampling sites during the study.

Parameters/ sites		Site-1	Site-2	Site-3	Site-4	Site-5	Site-6
Air Temperature (°C)	Monsoon	29	31	31	32	32	31.5
	Post-monsoon	21	22	26	20	15	16.5
	Pre-monsoon	32	30	31	32.5	32	32
Water Temperature (°C)	Monsoon	30	32	31	31.5	31.5	30
	Post-monsoon	21	21	21	21	22	22
	Pre-monsoon	30.5	32	32	31.5	30.5	30.5
pH	Monsoon	6.8	7.3	7.2	7.5	7.2	7
	Post-monsoon	6.5	6.7	6.5	7	6.6	6.5
	Pre-monsoon	7.5	7.4	7.3	7.5	7.6	7.2
DO (ml/l)	Monsoon	3.94	4.73	3.35	2.66	3.26	2.82
	Post-monsoon	4.11	4.12	3.89	4.35	4	5.37
	Pre-monsoon	4.43	3.29	4.15	4.57	4.15	4.72
Salinity (‰)	Monsoon	16.0	8.0	5.2	0.6	0.2	0.2
	Post-monsoon	24.5	17.0	11.6	3.5	0.3	0.3
	Pre-monsoon	19.0	9.4	3.0	0.3	0.2	0.2
TDS (mg/l)	Monsoon	432	602.5	780.5	231	114	143
	Post-monsoon	551.5	278	505.5	247.5	183.5	189
	Pre-monsoon	509	453.5	782.5	111	119.5	166.5

The relation between copepod abundance and hydrographic parameters (air temperature, surface water temperature, pH, DO, salinity and TDS) of monsoon, post-monsoon and pre-monsoon are shown in fig. 2. According to Rios-Jaha (1998), the abundance of copepod clearly go through seasonal changes in Phosphorescent Bay, Puerto Rico. Madhu *et al.,* (2007) reported that seasonal fluctuations in salinity have great influence on the distribution and abundance of micro and mesozooplankton in a tropical estuary. Magalhaes *et al.,* (2015) recorded significant relationship between the occurrence of copepods and salinity in tropical mangrove estuary (Amazon coast, Brazil). The present study results completely acquiesced with these results. It was recorded that copepod is euryhaline as its occurrence varied seasonally in different saline zone of the study area.

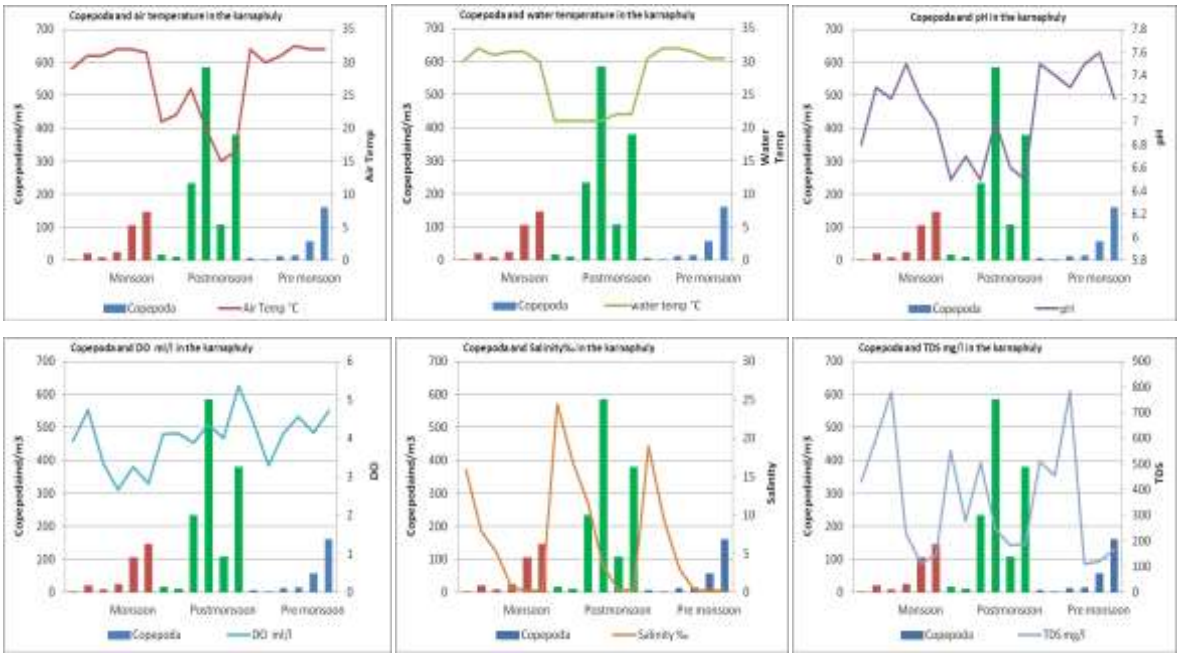

Fig. 2. Graphs showing physico-chemical parameters and copepod numerical abundance in the study area.

Copepod Abundance

A total of 29 zooplankton individual group were identified under microscopic observation. The zooplankton individual included 25 major taxonomic group viz; acetes, amphipoda, balanus, bivalvia, caridean, ciliophora, cladocera, copepod, megalopa (crab larvae) and crab zoea, cumacea, diptera, gastropoda, hydromedusae, hydroyda, isopoda, *lucifer*, mites (acari), mysidaceae (mysid), odonata, oligochaeta, ostracoda, penaidae/penaid, porifera, *sagitta*, shrimp zoea (Fig. 3). Besides these 25 taxonomic groups; egg (unidentified sp.), fish larvae (unidentified) and unidentified (may be broken or damaged organisms) were also recorded from study sites. The crab zoea and Megalopa (crab) were recorded as single taxonomic group.

Fig. 3. Photographs of zooplankton occurred in the Karnaphuli River during the study.

The composition and abundance of zooplankton and copepod (Table 3) varied with the sites as well as seasons. During monsoon, post-monsoon and pre-monsoon the maximum 13, 14 and 15 major zooplankton taxa and the minimum 8, 9 and 12 zooplankton taxa were recorded respectively.

Table 3. Seasonal no. of major taxa and zooplankton and copepod abundance /m^3 of each site.

Sampling sites & seasons	No. of major taxa (Zooplankton composition)			Zooplankton indivs/m^3			Copepod indivs/m^3		
	Mon	Pos	Pre	Mon	Pos	Pre	Mon	Pos	Pre
Site-1	11	10	12	15.00	19.86	15.27	12.16	17.69	5.62
Site-2	9	14	15	24.32	19.09	9.87	20.19	9.87	3.36
Site-3	11	11	13	34.01	262.78	40.92	8.87	233.08	13.14
Site-4	9	13	14	71.99	654.40	68.97	25.16	584.95	15.66
Site-5	8	10	13	73.20	141.93	219.11	106.96	108.02	58.15
Site-6	13	9	12	423.54	604.78	437.39	147.24	380.23	160.78

The seasonal highest peak of zooplanktons were 423.54 indivs/m³, 654.4 indivs/m³ and 437.39 indivs/m³ during monsoon, post-monsoon and pre-monsoon seasons at site-6, site-4 and site-6 respectively; and the lowest seasonal peak during monsoon, post-monsoon and pre-monsoon were 15 indivs/m³, 19.09 indivs/m³ and 9.87 indivs/m³ at site-1, site-2 and site-2 respectively. It is evidently observed that the abundance of copepod determine the profusion of zooplankton in the study area (Table 3). In case of copepod the maximum peak during monsoon, post-monsoon and pre-monsoon seasons were 147.24 indivs/m³, 584.95 indivs/m³ and 160.78 indivs/m³ at site-6, site-4 and site-6 respectively. Whereas the lowest peak during monsoon, post-monsoon and pre-monsoon seasons were 8.87, 9.87 and 3.36 at site-3, site-2 and site-2 respectively.

Copepod (fig. 4) showed a moderate negative relationship with air temperature and water temperature; weak negative linear relationship with the pH, salinity as well as TDS and a weak positive relationship with DO.

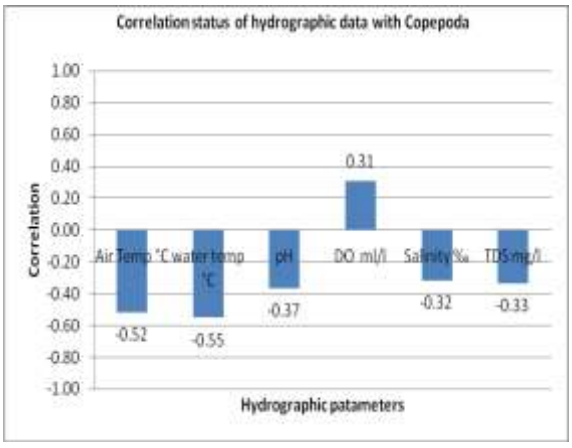

Fig. 4. The correlation between copepod and hydrographic data of the Karnaphuli River.

A total of 25 major taxa of zooplankton were identified from the Karnaphuli River of which 23 taxa during monsoon, 20 taxa during post monsoon and 20 taxa during pre-monsoon. Islam and Aziz (1975) identified 18 genera of zooplankton from the off shore coast of Bangladesh. The abundance of zooplankton occurred in the sampling sites are tabulated in the table 3. Das *et al.,* (1982) identified 21 groups of zooplankton from the continental shelf of the Bay of Bengal. Sharif (2002) identified 23 major taxa of zooplankton from the Meghna river-Estuary. Further 3 orders of copepod (counted in the same taxonomic group) were identified namely calanoida, cyclopoida, harpacticoida in the present study from the Karnaphuli river. The abundance of zooplankton individual groups from the Karnaphuli are shown in table 4.

In the present study it was observed that during monsoon and pre-monsoon season copepods numerical abundance and concentration was very low (>25 indiv/m³) near the estuary where salinity was recorded (>3‰). There was a little difference in copepod abundance at site-3 and site-4 considering the salinity during post-monsoon season. It was also observed that the concentration and numerical abundance of copepods were recorded (>100 indiv/m³) in the sites where salinity was recorded relatively less (<1‰) (fig. 5). Magalhaes *et al.,* (2010) also recorded higher abundance in low salinity zone of Caete Estuary. On the other hand it was also observed that the percentage frequency of copepod considering total zooplankton abundance was recorded higher near the estuary than that of the upstream sites (fig. 6) during monsoon and post-monsoon season and in case of pre-monsoon season it was relatively lower.

Table 4. The abundance of zooplankton at sampling sites during monsoon, post-monsoon and pre-monsoon seasons.

Sl	Zooplankton/ Sites (& seasons)	Monsoon						Post-monsoon						Pre-monsoon					
		St1	St2	St3	St4	St5	St6	St1	St2	St3	St4	St5	St6	St1	St2	St3	St4	St5	St6
1	Acetes	+	+	.	.	.	.	+	+	+	.	.	.	+	+	.	.	.	.
2	Amphipoda	.	.	+	+	.	.	+	+	+	+	+	.	+	+	+	+	+	+
3	Balanus	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
4	Bivalvia	.	.	+	+	.	.	.	+	.	+	+	.	.	+	+	+	+	+

Sl	Zooplankton/ Sites (& seasons)	Monsoon						Post-monsoon						Pre-monsoon					
		St1	St2	St3	St4	St5	St6	St1	St2	St3	St4	St5	St6	St1	St2	St3	St4	St5	St6
5	Caridean	+	+	+	+	+	+	.	+	+	+	+	.	+	+	+	+	+	+
6	Ciliophora	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	.	.
7	Cladocera	+	+	+	++	+++	+++++	+	+	+	+	.	.	+	+	+	++	+++++	+++++
8	Copepoda	+	+	+	++	+++++++++		+	+	+++++++++		+++++++++		+	+	+	+	+++	+++++
9	Crab megalopa	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	+	.	.
10	Crab zoea	+	+	+	+	+	+	+	.	+	++	+	+++++	+	+	+	+	++	+++
11	Cumacea	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.
12	Diptera	.	.	+	.	.	+	.	.	.	.	.	.	+	+	+	+	+	+
13	Egg	.	.	+	.	+	+	+	+	+	+	.	.	.	+	.	+	+	+
14	Fish larvae	+	.	+	+	+	++	+	+	+	+	.	+	+	+	+	+	+	+
15	Gastropoda	.	.	.	.	.	+	.	.	.	+	+	+++	.	.	.	+	+	+
16	Hydromedusae	+	.	+	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.
17	Hydroyda	.	.	.	.	+	+	.	+	.	.	+	.	.	+	.	+	.	.
18	Isopoda	+	+	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.
19	Lucifer	+	+	.	.	.	.	+	.	+	+	.	.	+	+	+	.	.	.
20	Mites	.	.	.	+	+	+	.	+	.	+	+	+	+	+	+	+	+	+
21	Mysidaceae/ Mysid	.	.	.	+	.	.	+	+	+	.	+	+	+	+	.	.	+	.
22	Odonata	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
23	Oligochaeta	.	.	+	.	.	+	.	+	+	.	.	+	.	.	.	.	.	.
24	Ostracoda	+	.	.	+	.	.	.	.	.	.	+	+	.	+	+	+	+	+
25	Penaidae /Penaid	+	+	+	.	.	.	+	+	+	+	.	.	.	+	+	+	+	+
26	Porifera	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.
27	Sagitta	+	+	.	.	.	.	+	+	+	+	.	.	+	.	.	.	.	.
28	Shrimp zoea	.	.	+	+	+	+	.	.	.	.	.	.	+	.	+	+	+	+
29	un-identified sp	.	+	+	.	.	.	.	+	.	+	+	.	.	+	+	.	+	.

Legends: · = absent, + = 0.001%-25%; ++ = >25%-50%; +++= >50%-75%; ++++= >75%-100% Crab megalopa, Crab zoea, Egg, Fish larvae and un-identified sp are not counted as taxonomic group rather zooplankton that occurred

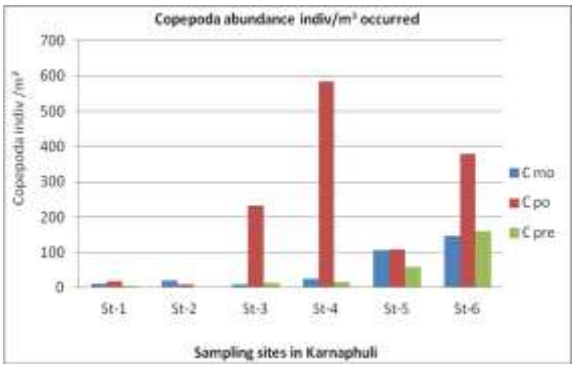

Fig. 5. Copepod abundance (indiv/m3) occurred in the Karnaphuli river.

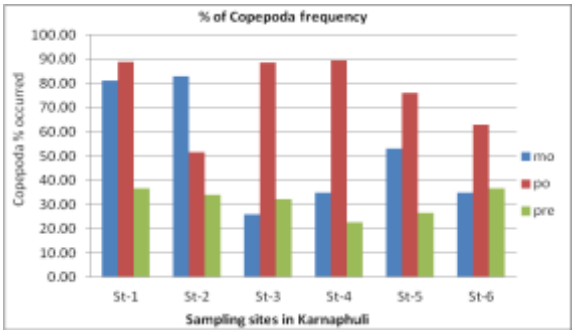

Fig. 6. Contribution % of copepod occurred in the Karnaphuli river.

References

APHA 1975. Standard Methods for the examination of water and waste water 14th (edi). American public health association American water works association USA. Water pollution control Federation/1193pp.

Ara K. 2004. Temporal variability and production of the planktonic copepod community in the Cananéia Lagoon estuarine system, São Paulo, Brazil. Zoological Studies **43**, 179-186.

Banse KI. 1995. Biomass and production measurements - Zooplankton: pivotal role in the control of ocean production. ICES Journal of Marine Science **52**, 265-277.

Barnes H. 1959. Apparatus and Methods of Oceanography.Part-1 Chemical. George Allen and Unwin Ltd. 216pp.

Bollens SM, Breckenridge JK, Cordell JR, Rollwagen-Bollens G, Kalata O. 2012. Invasive copepods in the Lower Columbia River Estuary: Seasonal abundance, co-occurrence and potential competition with native copepods. Aquatic Invasions **7**, 101–109.

Bollens SM, Breckenridge JK, vanden Hooff RC, Cordell JR. 2011. Mesozooplankton of the lower San Francisco Estuary: Spatio-temporal patterns, ENSO effects, and the prevalence of non-indigenous species. Journal of Plankton Research **33**, 1358–1377.

Bollens SM, Cordell JR, Avent S, Hooff R. 2002. Occurrences, causes and consequences of zooplankton invasions: a brief review, plus two case studies from the northeast Pacific Ocean. Hydrobiologia **480**, 87–110.

Bouley P, Kimmerer WJ. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology-Progress Series **324**, 219–228.

Castel J, Courties C. 1982. Composition and differential distribution of zooplankton in Arcachon Bay. Journal of Plankton Research **4**, 417-433.

Castel J, Feurtet A. 1986. Influence des matières en suspension sur la biologie d'un copepode estuarien: Eurytemora hirundoides (Nordquist, 1888). Colloque National du CNRS "Biologie des Populations", pp. 391-396.

Cervetto G, Gaudy R, Pagano M. 1999. Influence of salinity on the distribution of Acartia tonsa (Copepod, Calanoida). Journal of Experimental Marine Biology and Ecology **239**, 33–45.

Champalbert G, Pagano M. 2002. Copepod feeding in a tuna fishery area of the tropical Atlantic Ocean. Comptes Rendus Biologies **325**, 171–177.

Cheng CC. 1998. The distributional correlation between planktonic copepods and ichthyoplankton in the western North Pacific. Master's thesis, National Taiwan Univ., Taipei.

Chowdhury SR, Mahmood N, Uddin MM, Sharif ASM, Ullah MS. 2002. Material flux through the Karnaphuli River. Proceedings of the workshop on assessment of the material fluxes to the coastal zone in South Asia and their impacts. Pp.19-22.

Cordell JR, Bollens SM, Draheim R, Sytsma M. 2008. Asian copepods on the move: recent invasions in the Columbia–Snake River system, USA. ICES Journal of Marine Science **65**, 753–758.

Cordell JR, Rassmussen M, Bollens SM. 2007. Biology of the invasive copepod Pseudodiaptomus inopinus in a northeast Pacific estuary. Marine Ecology Progress Series **333**, 213–227.

Dam HG, Zhang X, Butler M, Roman MR. 1994. Mesozooplankton grazing and metabolism on the equator at 140Trans. Am. Geophys. Union ◦W during the JGOFS EQUPAC study. EOS 75, 50.

Das NG, Bhuiyan AL, Miah W. 1982. Taxonomy of Calanoid Copepod, *Candacia catula* (Giesbert) from North-eastern region of the Bay of Bengal. Mahasagar-Bull. National Ins. Ocean **15**, 53-54.

David V, Sautour B, Chardy P. 2007. Successful colonization of the calanoid copepod Acartia tonsa in the oligo-mesohaline area of the Gironde estuary (SWFrance) – Natural or anthropogenic forcing? Estuarine, Coastal and Shelf Science **71**, 429–442.

Davis CC. 1955. The marine and freshwater plankton. Michigan State University Press. Chicago USA. 562pp.

Degtereva AA. 1973. The relationship between abundance and biomass of plankton and the temperature in the south-western part of the Barents Sea. Trudy PINRO **33**, 13–23 (in Russian).

Devassy VP, Goswami SC. 1991. Seasonal fluctuations in the occurrence of cladocera in the Mandovi-Zoari estuarine waters of Goa. Indian Journal Marine Science **20**, 138-142.

Devreker D, Souissi S, Molinero JC, Nkubito F. 2008. Trade-offs of the copepod Eurytemora affinis in mega-tidal estuaries: insights from high frequency sampling in the Seine estuary. Journal of Plankton Research **30**, 1329-1342.

Dubischar CD, Lopes RM, Bathmann UV. 2002. High summer abundances of small pelagic copepods at the Antarctic Polar Front-implications for ecosystem dynamics, Deep Sea Research Part II: Topical Studies in Oceanography **49**, 3871–3887.

Edmondson WT. 1959. Fresh Water Biology. John Wiley & Sons, Inc. USA 1248pp.

Evjemo JO, Kjell IR, Olsen Y. 2003. Copepods as live food organisms in the larval rearing of halibut larvae (Hippoglossus hippoglossus L.) with special emphasis on the nutritional value. Aquaculture **227**, 191–210.

Ferrari I, Cantarelli MT, Mazzocchi MG, Tosi L. 1985. Analysis of a 24-hour cycle of zooplankton sampling in a lagoon of the Po River Delta. Journal of Plankton Research **7**, 849-865.

Froneman PW. 2002. Response of the biology to three different hydrological phases in the temporarily open/closed Kariega estuary. Estuarine, Coastal and Shelf Science **55**, 535-546.

Froneman PW. 2004. Zooplankton community structure and biomass in a southern African temporarily open/closed estuary. Estuarine, Coastal and Shelf Science **60**, 125–132.

Gain P. 2002. Bangladesh environmental facing 21st century. Society for environment and Human Development, Dhaka, Bangladesh. 340pp.

Goswami SC. 1985. Secondary production and zooplankton abundance in the coastal waters from vengurla to Malpe, west coast of India. Indian Journal Marine Science **14**, 85.

Hassel A, Skjoldal HR, Gjoaeter H, Loeng H, Omli L. 1991. Impact of grazing from capelin (*Mallets villosus*) on zooplankton: a case study in the northern Barents Sea in August 1985. Polar Research **10**, 371–388.

Hassel A. 1986. Seasonal changes in zooplankton composition in the Barents Sea, with special attention to Calanus spp. (Copepod). Journal of Plankton Research **8**, 329–339.

Helle K. 2000. Distribution of the copepodite stages of *Calanus finmarchicus* from Lofoten to the Barents Sea in July 1989. ICES Journal of Marine Science **57**, 1636–1644.

Hooff RC, Bollens SM. 2004. Functional response and potential predatory impact of *Tortanus dextrilobatus*, a recently introduced carnivorous copepod in the San Francisco Estuary. Marine Ecology Progress Series **277**, 167–179.

Hsieh CH, Chiu TS. 2002. Summer spatial distribution of copepods and fish larvae in relation to hydrography in the northern Taiwan Strait. Zoological Studies **41**, 85-98.

Hwang JS, Turner JT. 1995. Behavior of cyclopoid, harpacticoid and calanoid copepods from coastal waters of Taiwan. Marine Ecology **16**, 207-216.

Islam AKMN, Aziz A. 1975. A preliminary study on the zooplankton of the North-Eastern Bay of Bengal, Bangladesh. Bangladesh Journal of Zoology **3**, 125-138.

Islam MS, Ueda H, Tanaka M. 2006. Spatial and seasonal variations in copepod communities related to turbidity maximum along the Chikugo estuarine gradient in the upper Ariake Bay, Japan. Estuarine, Coastal and Shelf Science **68**, 113-126.

Khair SA, Bhuiyan AL, Das NG. 1979. Distribution of *Schmckeria lobipes* in the Karnafully River Estuary. Bangladesh Journal of Agriculture **6 & 17**, 36-42.

Khan RA. 1995. The structure and dynamics of planktonic copepods of Hugli Matla Estuarine systems. Zool. Surv. Ind. Estuarine Ecosustem Series pp.157-178.

Khan YSA, Talukder ABMA. 1993. Pollution in Coastal waters of Bangladesh. The Journal of NOAMI **10**, 1-11.

Kibirige I, Perissinotto R. 2003. The zooplankton community of the Mepanjati Estuary, a South African temporarily open/closed system. Estuarine, Coastal and Shelf Science **58**, 727-741.

Kumar RV, Sharma VV. 1988. Zooplankton studies in Vishakapatnam Harbor and near shore waters, East coast of India. Indian Journal Marine Science **10**, 258-261.

Landry MR, Lorenzen CJ, Peterson WK. 1994. Mesozooplankton grazing in the Southern California Bight. II. Grazing impact and particulate flux. Marine Ecology Progress Series **115**, 73-85.

Lawrence D, Valiela I, Tomasky G. 2004. Estuarine calanoid copepod abundance in relation to season, salinity, and land-derived nitrogen loading, Waquoit Bay, MA. Estuarine, Coastal and Shelf Science **61**, 547–557.

Li KZ, Yin JQ, Huang LM, Tan YH. 2006. Spatial and temporal variations of mesozooplankton in the Pearl River estuary, China. Estuarine, Coastal and Shelf Science **67**, 543–552.

Lo W, Chung C, Shih C. 2004. Seasonal Distribution of Copepods in Tapong Bay, Southwestern Taiwan, Zoological Studies **43**, 464-474.

Lo WT, Hwang JS, Chen QC. 2001. Identity and abundance of surface-dwelling, coastal copepods of southwestern Taiwan. Crustaceana **74**, 1139-1157.

Loeng H, Ozhigin VA, dlandsvik B. 1997. Water fluxes trough the Barents Sea. ICES Journal of Marine Science **54**, 310–317.

Lopez-Ibarra Ga, Palomares-Garcia R. 2006. Estructura de la comunidad de copépodos en Bahía Magdalena, México, durante El Niño 1997-1998. Rev Biol Mar Oceanogr **411**, 63–76.

Madhu NV, Jyothibabu R, Balachandran KK, Honey UK, Martin GD, Vijay JG, Shiyas CA, Gupta GVM, Achuthankutty CT. 2007. Monsoonal impact on planktonic standing stock and abundance in a tropical estuary (Cochin backwaters -India). Estuarine, Coastal and Shelf Science **73**, 54-64.

Madhupratup M, Nair SRS, Achuthankutty CT, Nai VR. 1981. Zooplankton abundance of around the Andaman-Nicober Island. Indian Journal Marine Science **17**, 75-77.

Magalhaes A, Pereira LCC, da Costa RM. 2015. Relationships between copepod community structure, rainfall regimes, and hydrological variables in a tropical mangrove estuary (Amazon coast, Brazil). Helgoland Marine Research **69**, 123–136.

Magalhaes A, Pereira LCC, Ribeiro MJS, Liang T. 2010. Populational Dynamics of *Pseudodiaptomus marshi* (CRUSTACEA: COPEPOD) In the Caeté Estuary (Brazil), Tropical Oceanography, Recife **38**, 165-174.

Magalhes A, Leite NDR, Silva JGS, Pereira LCC, Da Costa RM. 2009. Seasonal variation in the copepod community structure from a tropical Amazon estuary, Northern Brazil. Anais da Academia Brasileira de Ciencias **81**, 187-197.

Mahmood N, Khan YSA, Ahmed MK. 1976. Studies on the hydrology of the Karnafully Estuary, Journal of Asiatic Society of Bangladesh (Sc.) **2**, 88-99.

Margalef R. 1967. Some aspects relative to the organization of plankton. Oceanogr. Mar. Biol. Annu. Rev **5**, 257-289.

Marques SC, Pardal MA, Pereira MJ, Gonc¸alves F, Marques JC, Azeiteiro UM. 2007. Zooplankton distribution and dynamics in a temperate shallow estuary. Hydrobiologia **587**, 213–223.

Mckinnon AD, Klumpp DW. 1998. Mangrove zooplankton of North Queensland, Australia. Hydrobiologia **362**, 127-143.

Miller CB, Frost BW, Booth B, Wheeler PA, Landry MR, Welschmeyer N. 1991. Ecological processes in the Subarctic Pacific: Iron limitation cannot be the whole story. Oceanography **4**, 71-78.

Mizuno T. 1976. Illustrations of the fresh water plankton of Japan. Hoikusha publishing Co., Ltd. Osaka, Japan, (In Japanese 351pp).

Mohi SA. 1977. Distribution of Ichthyoplankton in the Karnafully River Estuary. M. Sc. Thesis (Unpublished) Inst. Mar. Sc. Univ. Ctg, 82 pp.

Newell GE, Newell RC. 1973. Marine Plankton-A practical guide. Hutchinson and Co. Ltd. London. 282pp.

O' Mallery LSS. 1908. E. B. Distric Gazetters, Chittagong. The Bengal Secretariat Book Depot, Calcutta.

Osore MKW, Fiers F, Daro MH. 2003. Copepod composition, abundance and diversity in Makupa Creek, Mombasa, Kenya. Western Indian Ocean Journal of Marine Science **2**, 65-73.

Parsons TR, Takahashi M, Hargrave B. 1984. Biological Oceanographic Processes, Oxford: Pergamon Press 332 p.

Parsons TR, Yoshaki M, Carol ML. 1985. Pergamon Press. Oxford. New York Toronto. Sydney. Frankfurt 173pp.

Patil GP, Taillie C. 1982. Biodiversity as a concept and its measurement. Journal of the American statistical Association 77, 548-567.

Payne MF, Rippingale RJ. 2001. Effects of salinity, cold storage and enrichment on the calanoid copepod Gladioferens imparipes. Aquaculture **201**, 251–262.

Peitsch A, Kopcke B, Bernat N. 2000. Long-term investigation of the distribution of *Eurytemora affinis* (Calanoida; -Copepod) in the Elbe estuary. Limnologica e Ecology and Management of Inland Waters **30**, 175-182.

Pennak RW. 1978. Fresh water invertebrates of the United States. 2nd (edi). A wiley-interscience publication John Wiley and Sons, Newyork. USA. 803pp.

Perkins EJ. 1976. The biology of Estuaries and Coastal waters. Academic press Inc. London NWI 678pp.

Pielou EC. 1966. The measurement of Diversity in Different types of Biological Collections. Journal of Theoretical Biology **13**, 131-144.

Pielou EC. 1975. Ecological Diversity. Jonh Willey, New York 63-69pp.

Pielou EC. 1975. Mathmatical Ecology. John wiely 269-375pp.

Ramaniah N, Nair VR. 1977. Distribution and abundance of copepods in the pollution gradients zones of copepods in the pollution gradients zones of Bombay Hourbour-Thana creek-Bassien creek, west coast of India, Indian Journal Marine Science **26**, 20-25.

Revis N. 1988. Preliminary observations on the copepods of Tudor Creek, Mombasa, Kenya. Hydrobiologia **167/168**, 343-350.

Rios-Jara E. 1998. Spatial and temporal variations in the zooplankton community of Phosphorescent Bay, Puerto Rico. Estuarine, Coastal and Shelf Science **46**, 797–809.

Rippingale RJ, Hodgkin EP. 1977. Food availability and salinity tolerance in a brackish water copepod. Australian Journal of Marine Freshwater Research **28**, 1-7.

Santhanam R, Srinivasan A. 1994. Manual of marine zooplankton. Oxford and IBH publishing Co. Pvt. Ltd. New Delhi, Bombay, Calcutta, India. 160pp.

Sarkar SK, Choudhury A. 1998. Distribution of inshore copepod of the Bay of Bengal off Sagar Island: A multivariate analysis. Tropical Ecology **29**, 146–158.

Schipp GR, Bosmans JMP, Marshall AJ. 1999. A method for hatchery culture of tropical calanoid copepods, Acartia spp. Aquaculture **174**, 81–88.

Sharif ASM. 2001. A comparative study on plankton and benthos of the Megna- River-Estuary during monsoon and post monsoon. M. Sc Thesis. Ins. Mar. Sc. Univ. Ctg, 103pp.

Shih CT, Chiu TS. 1998. Copepod diversity in the water masses of the southern East China Sea north of Taiwan. Journal of Marine Systems **15**, 533-542.

Skjoldal HR, Hassel A, Rey F. 1987. Spring phytoplankton development and zooplankton reproduction in the central Barents Sea in the period 1979–1984. In: Loeng, H. (Ed.), The Effect of Oceanographic Conditions on Distribution and Population Dynamics of Commercial Fish Stocks in the Barents Sea. Proceedings of the 3rd Soviet–Norwegian Symposium, Murmansk, May 26–28, 1986. Institute of Marine Research, Bergen pp. 59–89.

Soetaert K, Van Rijswijk, P. 1993. Spatial and temporal patterns of the zooplankton in the Westerschelde estuary. Marine Ecology Progress Series **97**, 47-59.

Sommer U, Stibor H, Katechakis A, Sommer F, Ansent H. 2002. Different levels of nutrient pelagic richness food web and their configurations implications at for the ratio fish production: primary production. Hydrobiologia **484**, 11–20.

Sommer U, Stibor, H. 2002. Copepod-Cladocera-Tunicata: the role of three major mesozooplankton groups in pelagic food webs. Ecological Research **17**, 161–174.

Sterrer W. 1986. Marine fauna and flora of Bermuda. A systematic guide to the identification of marine organism. A Wiley interscience publication. New York. 742pp.

Swanberg N, Bamstedt, U. 1991. Ctenophora in the Arctic- the abundance, distribution and predatory impact of the cydippid ctenophore Mertensia ovum (Fabricius) in the Barents Sea. Polar Research **10**, 2.

Timofeev SF. 1997. Zooplankton in the Barents Sea. In: Matishov, L.A. (Ed.), Plankton of the Sea of the Western Arctic. Kola Scientific Centre RAS, Apatity, pp. 266–295 (in Russian).

Uriarte I, Villate F. 2005. Differences in the abundance and distribution of copepods in two estuaries of the Basque coast (Bay of Biscay) in relation to pollution. Journal of Plankton Research **27**, 863–874.

Wickstead JH. 1965. An Introduction to the study of Tropical Plankton. Hutch inson and Co. Ltd. London. 160pp.

Yamaji I. 1972. Illustrations of the marine plankton of Japan. Hoikusha publishing Co. Ltd. Osaka Japan. 369pp.

Yamaji I. 1974. The plankton of Japanese coastal waters. Hoikusha publishing co.; Ltd. Osaka. Japan. 238pp.

Zafar M. 1986. Study on Zooplankton of Satkhira Estuarine system in the vicinity of Aquaculture Farms with special reference to Penaeid post larvae. M. Sc. Thesis. Ins. Mar. Sc. Univ. Ctg. 238pp.

Zelikman EA, Kamshilov MM. 1960. The long-term dynamics of plankton biomass in the southern part of the Barents Sea, and factors influencing it. Trudy Murmansk Mar. Biol. Inst **2**, 68–113.