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Distribution of Zooplankton Community in the River Nile at Esna Barrages, Egypt in relation to some ecological factors

Ahmad H. Obuid-Allah[1], Ahmed S. Moustafa[2], ElAmier H. M. Hussien[2], Azza M. Gaber[2], Wafaa A. Mohammad[3]

1- Zoology Department, Faculty of Science, Assiut University, Egypt.
2- Zoology Department, Faculty of Science, South Valley University, Qena, Egypt.
3- Zoology Department, Faculty of Science, New Valley University, Egypt

Corresponding author: elameer.hussien@sci.svu.edu.eg

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ABSTRACT

In riverine systems, zooplankton communities are usually thought to be driven by abiotic forces. This study was designed to assess the effect of ecological factors on the distribution of zooplankton community in the River Nile at Esna barrages which located 1.2 km downstream the old barrages. Monthly samples were collected during a period of one year from six sites situated in the River Nile, (upstream and downstream) of Esna Barrages. Seven physic-chemical parameters were measured during sampling using electronic portable instruments: air and water temperature, hydrogen ion concentration, dissolved oxygen, conductivity, total dissolved solids and turbidity. The collected zooplankton groups were Cladocera, Copepoda and Ostracoda where Cladocera exhibited the highest peak of density. The highest value of total abundance of zooplankton was recorded during winter 40% and the lowest value was recorded during summer 11%. The results indicated that Turbidity, pH and conductivity were the most affecting factors on abundance of all zooplankton groups during the study. Cladocera group correlated significantly with dissolved oxygen ($p>0.01$) and pH ($p<0.01$). Moreover, temperature and turbidity were the most affecting factors on Copepoda, while Ostracoda was affected by pH and conductivity.

INTRODUCTION

Among animal fauna, zooplanktons are important component of food web and their qualitative and quantitative studies play a key role in assessment of the water quality. Zooplankton community is an important component in aquatic freshwater ecosystems, whose main function is to act as direct link between primary producers and higher levels of food chain such as fish (Pradhan, 2014 and Aman *et al.*, 2016).

The relation between zooplankton and physico-chemical parameters in aquatic ecosystems is very important for the management planning processes (Edward and Ugwumba, 2010). In aquatic ecosystems, environmental factors including various physical properties and chemical characters of water are very important for growth and dispersal of phytoplankton on which zooplankton depend for their existence (Manickam *et al.*, 2018).

Zooplankton community fluctuates according to physico-chemical parameters of the environment; their density in any water is controlled by various water quality parameters such as light penetration, temperature, nutrient enrichment, herbivores and heterotrophic microorganisms (Reynolds, 1987). Accordingly, any change in abundance, species diversity, or community composition of zooplankton can provide important indications of environmental change or disturbance. Therefore, they are regarded as a potential bio-indicator species for water pollution (Jakhar, 2013 and Pradhan, 2014). Other reasons such as the shorter life span, short generation time and species sensitivity to different levels of physico-chemical parameters have made zooplankton an ideal biological indicator (Ferdous and Muktadir, 2009).

The present work was designed to determine the relationship between zooplankton community structure and some ecological variables from different sites in the River Nile at Esna barrages.

MATERIALS AND METHODS

Zooplankton Sampling

Random samples were collected monthly from six different locations in the River Nile at Esna barrages for a period of one year extended from October 2018 till September 2019. The barrage is situated at a distance of 1.1 km downstream of the old barrages, and located between 25°19'03.5"N and 32°33'19.5"E.

Zooplankton samples were collected vertically and horizontally by 153 µm mesh size, with 12.7 cm diameter and (38cm) in length. Each sample was immediately preserved in 95% ethanol. Zooplankton species were subjected to detailed examination and identification according to the following guides: Brooks (1959), Obuid-Allah (2001), Wilson and Yeatman (1959) and Fangary (2003)

Physico-chemical Parameters

Physico-chemical parameters were measured during sampling using electronic portable probes. Hydrogen ion concentration (pH) was determined in the same time of sampling using a pocket pH meter probe model SCHOTT. Dissolved oxygen was measured by a probe model HI 9146. Air temperature was recorded using GPS model magellan 2000, while water temperature was recorded using an ad 32(ADWA). Turbidity was expressed by TURBIDITY METER TU-2016 NTU. Water conductivity and TDS was measured with an electrode model Ad 32(ADWA).

Statistical analysis

The collected data were summarized and analyzed using SPSS software (Version 20). A two-way analysis of variance was calculated to find out the significance of the differences in density of the zooplankton groups at the studied sites during investigated seasons. Canonical corresponding analysis (CCA) and correlation analyses were used for explaining the relationship between the environmental parameters and zooplankton.

RESULTS

Physicochemical parameters:

The physico-chemical results during the period of study are presented in Tables (1) and (2). The recorded air temperature ranged from 12 ºC during February 2019 in site I to 41ºC during August 2019 in site III. It showed significant positive correlation with water temperature (r= 0.926) and dissolved oxygen (r=0.167), negatively correlated with turbidity (r= -0.056) and conductivity (r= -0.023). Also air temperature exhibited significant negative correlation with pH (r= -0.348) and TDS (r= -0.224). Water temperature ranged from 16.17ºC during January 2019 in site I to 29.67ºC in site III during August 2019. It showed significant negative correlation with pH (r= -0.384), conductivity (r= -0.150) and total dissolved solids (r= -0.224), positive correlation with dissolved oxygen (r=0.104) and turbidity (r=0.013). The recorded values of pH ranged from 7.07 during April 2019 in site I to 8.64 during March 2019 in site III.

Table 1: Minimum, maximum, mean and standard deviation of physicochemical parameters in the River Nile during the period of study.

sites / parameters		Site I	Site II	Site III	Site IV	Site V	Site VI
Air temp (ºC)	Min	12	13	17	17	16	17
	Max	32	34	41	39	39	39
	Mean ± SD	23.75±7.04 ^{a}	25.0±7.49 ^{a}	29.44±7.10 ^{c}	27.97±6.64 ^{bc}	27.33±6.81 ^{b}	28.69±6.95 ^{bc}
Water temp(ºC)	Min	16.17	16.27	17.3	17.3	17.6	16.67
	Max	26.77	28.07	29.67	28.2	28.67	28.27
	Mean ± SD	22.56±3.69 ^{a}	22.82±3.76^{b}	23.92±3.80 ^{c}	23.81±3.32 ^{c}	23.71±3.51^{bc}	23.16±3.32 ^{abc}
pH	Min	7.07	7.67	7.79	7.41	7.5	7.41
	Max	8.45	8.44	8.64	8.53	8.46	8.51
	Mean ± SD	8.01±0.43 ^{a}	8.15±0.27^{abc}	8.29±0.28 ^{c}	8.11±0.38 ^{ab}	8.19±0.30 ^{bc}	8.15±0.34^{abc}
DO (mg/l)	Min	4.03	3.99	4.23	3.68	4.1	4.1
	Max	7.6	6.87	7.47	7.43	7.39	7.15
	Mean ± SD	5.62±1.32^{b}	5.0±1.10 ^{a}	5.47±1.12 ^{ab}	5.24±1.26 ^{ab}	4.94±1.10 ^{a}	5.30±0.98 ^{ab}
Cond (µS/cm)	Min	285	288	282.67	282.33	274.67	257
	Max	423.33	393.33	393.33	396.67	396.67	390
	Mean ± SD	360.67±45.58 ^{a}	353.81±38.63 ^{a}	357.08±37.4 0^{a}	360.69±37.40 ^{a}	346.25±45.05 ^{a}	352 ±42.45 ^{a}
TDS (mg/l)	Min	170	170	170	169.33	153.33	171.67
	Max	226.67	236.67	233.33	236.67	233.33	230
	Mean ± SD	189.33±21.9 2^{a}	188.47±17.45 ^{a}	188.22±17.97 ^{a}	188.31±18.93 ^{a}	182.67±23.64 ^{a}	186.64±16.36^{a}
Turb (NTU)	Min	5.12	6.88	6.7	5.37	10.16	5.37
	Max	127.12	32.58	20.22	34.11	26.1	29.49
	Mean ± SD	26.04±50.69 ^{b}	14.67±9.64 ^{a}	13.56±6.22 ^{a}	15.62±8.26 ^{a}	15.28±5.44 ^{a}	14.41±9.46 ^{a}

Table 2: Correlation among the physico-chemical properties and of zooplankton groups in the study sites.

	water	pH	DO	Cond	TDS	Turb	Cladocera	Copepoda	Ostracoda
Air temp.	0.926**	-0.348**	0.167*	-0.023	-0.224**	-0.056	-0.444**	-0.178**	-0.133
Water temp.		-0.384**	0.104	-0.150*	-0.224**	0.013	-0.406**	-0.069	-0.103
pH			0.018	-0.092	-0.054	0.015	0.184**	-0.128	0.062
DO				-0.053	-0.117	0.151*	-0.165*	-0.140*	-0.051
Cond					0.521**	-0.264**	0.009	-0.140*	0.019
TDS						0.018	0.121	0.163*	0.204**
Turb							-0.040	0.105	0.038
Cladocera								0.182**	0.071
Copepoda									0.495**

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level.

It showed positive correlation with conductivity (r=0.018) and turbidity (r=0.015) and negative correlation with dissolved oxygen (r=-0.092) and total dissolved solids (r= -0.054). The recorded values of dissolved oxygen (DO) ranged from 3.68 mg/l in site IV during April 2019 to 7.6 mg/l in site I in October 2018. It showed negative correlation with conductivity (r= -0.053) and total dissolved solids (r= -0.117) and significant positive correlation with turbidity (r= 0.151). The electrical conductivity ranged from 257 µS/cm during November 2018 in site VI to 423.33 µS/cm in site I during January 2019. It showed significant positive correlation with total dissolved solids (r= 0.521) and negative correlation with turbidity (r= -0.264). The recorded values of TDS ranged from 153.33 mg/l in site IV during March 2019 to 236.67mg/l in site II, IV during December 2018. It showed significant positive correlation with turbidity (r= 0.018). Turbidity values ranged between 5.12 NTU during August 2019 to 127.12 NTU during October 2018.

Seasonally, low values of air and water temperature were observed during winter months; whereas high values were recorded in summer. The minimum values of pH were recorded in summer months and maximum value was in winter. Low values of conductivity were recorded in autumn months, while maximum values were in winter months. The high values of total dissolved solids were observed in winter and minimum values were in spring. Maximum values of turbidity were noticed in autumn months, while minimum values were in summer. Fig. (1).

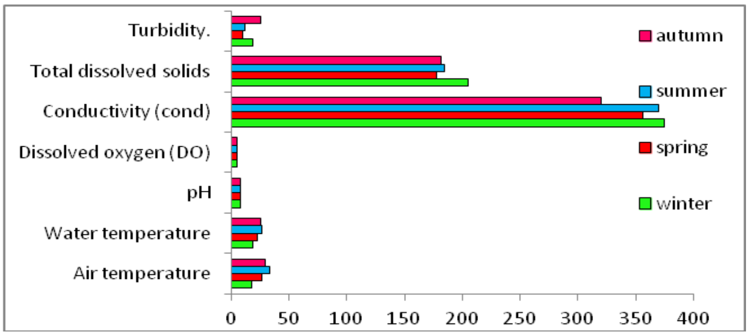

Fig. 1: seasonal variations in Air temperature, water temperature, Hydrogen ion concentration (pH), Dissolved oxygen (DO), Conductivity (cond), Total dissolved solids (TDS), and Turbidity (Turb) recorded at the study areas.

Zooplankton community

The data represented in Table (3) revealed that a total of 37 zooplankton taxa were identified. Cladocerans were the dominant group as numerically represented with 21 species. Copepods were represented by 11spp. in addition to copepodite stages and Nauplius larvae, ostracods were represented by 3 spp. throughout the sampling period. The greatest occurrence of zooplankton taxa were noted for 29 taxa at Site I and site II, followed by Site VI (25) and IV (24) and the lowest number was noticed at site III and V.

Cladocera formed the bulk of the zooplankton population in the six sites during the period of study. Copepoda formed the second group of zooplankton, while Ostracoda were poorly represented as it shown in Fig. (2).

Table 3: Occurrence of zooplankton taxa at the study sites during the period of investigation.

Taxa	Sites					
	Site I	**Site II**	**Site III**	**Site IV**	**Site V**	**Site VI**
Cladocera	**16**	**17**	**11**	**12**	**12**	**17**
Bosmina longirostris	+	+	+	+	+	+
Simocephalus expinosus	+	+	-	+	+	+
Simocephalus vetulus	+	+	+	+	+	+
Ceriodaphnia reticulata	+	+	+	+	+	+
Daphnia longispina	-	-	-	-	-	+
Ilyocryptus sordidus	+	+	+	+	+	+
Macrothrix laticornis	+	+	-	+	+	+
Alona bukobensis a	+	+	+	-	+	+
Alona bukobensis b	+	+	+	+	-	+
Alona bukobensis c	+	+	+	+	+	+
Alona rectangular	+	+	+	-	-	-
Alona sp.	-	+	-	-	-	-
Camptocercus australis	+	+	+	+	+	+
Leydigia quadrangularis	-	-	-	+	-	-
Oxyurella sp.	+	-	-	-	-	-
Chydorus sphaericus	+	+	+	+	+	+
Disparalona rostrata.	+	+	+	+	+	+
Pleuroxus aduncus	-	+	-	-	-	+
Pleuroxus letourneuxi	-	-	-	-	-	+
Dunhevedia crassa	+	+	-	-	+	+
Diaphanosoma birgei	+	+	-	-	-	+
Copepoda	**10**	**10**	**10**	**10**	**8**	**6**
Thermodiaptomus galebi	+	+	+	+	+	+
Mesocyclops ogunnus	+	+	+	+	+	+
Thermocyclops consimilis	+	+	+	+	+	+
Thermocyclops neglectus	-	+	-	+	+	-
Tropocyclops confinis	+	+	+	+	+	-
Macrocyclops albidus	+	-	-	+	-	-
Microcylops varicans	+	+	+	+	-	+
Microcylops linjanticus	+	+	+	+	+	-
Ectocyclops phaleratus	-	-	-	-	+	-
Afrocyclops gibsoni	+	-	+	-	-	-
Shizopera nilotica	+	+	+	+	-	+
Copepodite stage	+	+	+	+	+	+
Nauplius stage	-	+	+	-	-	-
Ostracoda	**3**	**2**	**1**	**2**	**2**	**2**
Cypridopsis vidua	+	+	+	+	+	+
Potamocypris variegate	+	-	-	+	+	-
Candona sp.	+	+	-	-	-	+
Total	**29**	**29**	**22**	**24**	**22**	**25**

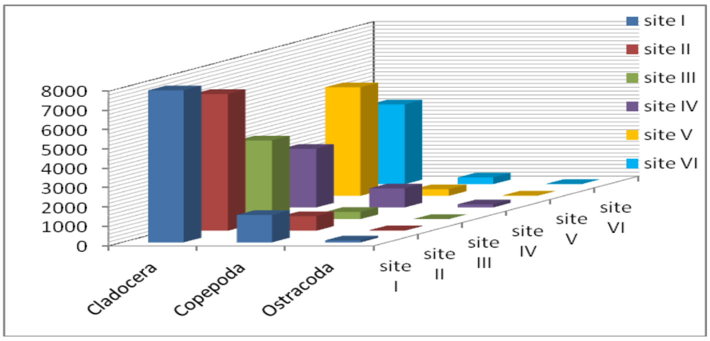

Fig. 2: Total zooplankton groups in the study areas during the period of investigation.

Table (4) shows the total density of zooplankton groups in the study sites during the period of investigation. The total density of Cladocera was highest at upstream sites than downstream sites, whereas site I (upstream) constituted the highest value (7873 indv/m^3) and site IV (downstream) constituted the lowest value (3034 indv/m^3). Site I recorded the highest density of Cladocera in March 2019 (2265 indv/m^3), while the lowest density was in June 2019 (25 indv/m^3). Site IV recorded the highest density of Cladocera in February 2019 (877 indv/m^3), while the lowest density was in July 2019 (52 indv/m^3).

The highest density of Copepoda was recorded in site I (1419 indv/m^3) and the lowest was in site III (374 indv/m^3). In site I there were no copepods recorded in May 2019, while the highest value was recorded in December 2018 (378 indv/m^3) and the lowest density was in June 2019 (4 indv/m^3). In site IV there were no copepods recorded in January, April, May and August 2019, while the highest value was recorded in September 2018 (88 indv/m^3) and the lowest density was in March and June 2019 (4 indv/m^3).

Ostracoda was recorded poorly during the year of the study, its highest density was in site IV (165 indv/m^3) and the lowest was in site III (8 indv/m^3).

Table 4: Monthly abundance (indv/m^3) of different zooplankton groups at all study sites from October, 2018-September 2019.

	Sites	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
Cladocera	Site I	100	905	1534	602	1134	2265	324	147	25	244	414	179	7873
	Site II	177	513	1117	653	1483	2287	94	270	102	21	146	213	7076
	Site III	167	801	889	260	1216	481	0	11	97	24	22	105	4073
	Site IV	146	232	196	99	877	346	133	78	484	52	161	230	3034
	Site V	110	107	866	580	407	834	1826	56	648	51	36	101	5622
	Site VI	90	143	67	175	743	655	642	0	888	94	48	583	4128
Copepoda	Site I	73	302	378	40	129	104	78	0	4	154	51	106	1419
	Site II	57	312	47	20	7	73	52	33	15	0	0	139	755
	Site III	49	79	80	0	5	8	0	0	8	57	0	88	374
	Site IV	54	259	251	33	56	7	112	0	24	99	27	65	987
	Site V	24	47	7	85	29	35	13	0	17	36	7	44	344
	Site VI	21	62	14	19	8	9	20	0	20	7	0	169	349
Ostracoda	Site I	0	0	22	0	47	13	0	22	0	0	0	0	104
	Site II	0	0	20	0	0	0	0	0	4	0	0	4	28
	Site III	0	0	0	0	0	8	0	0	0	0	0	0	8
	Site IV	0	27	120	0	0	0	0	0	13	5	0	0	165
	Site V	0	0	0	0	7	0	4	0	0	0	0	0	11
	Site VI	0	0	0	0	0	0	0	0	13	0	0	4	17

Seasonal fluctuations of zooplanktonic groups during the period of investigation indicated that: the highest total density of Cladocera was recorded during winter months 40.5%, while the lowest density was recorded during summer months 11.2%. Copepoda showed the maximal total density during autumn 46% and the minimal total density was during summer 12.4%. Ostracoda recorded the highest density values during winter 64.9% and the lowest was during summer and autumn 10.5%. The highest value of total zooplankton density was recorded during winter months, represented by 40%, and the lowest density was recorded during summer months 11%. Fig. (3).

Canonical Correspondence Analysis (CCA):

CCA was performed to conclude the most important factors affecting the abundance of zooplankton groups. The results indicated that, turbidity, pH and conductivity were the most effective ecological factors on zooplankton groups during the period of study. Total zooplankton correlated positively with dissolved oxygen and total dissolved solids. Cladocera correlated with dissolved oxygen, total dissolved solids and pH. Each of them was correlated negatively with water temperature.

Copepoda was correlated with water temperature and turbidity and the last was the most controlling factor for Copepoda. However, Ostracoda was correlated positively with conductivity and pH and the later was the most controlling factor for it. Fig. (4).

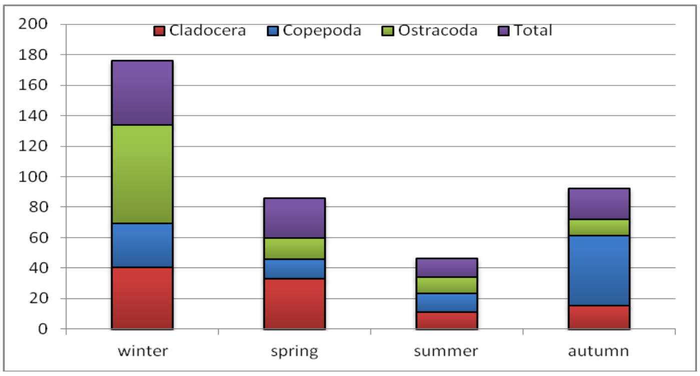

Fig. 3: Seasonal fluctuations of different zooplanktonic groups observed during the study period.

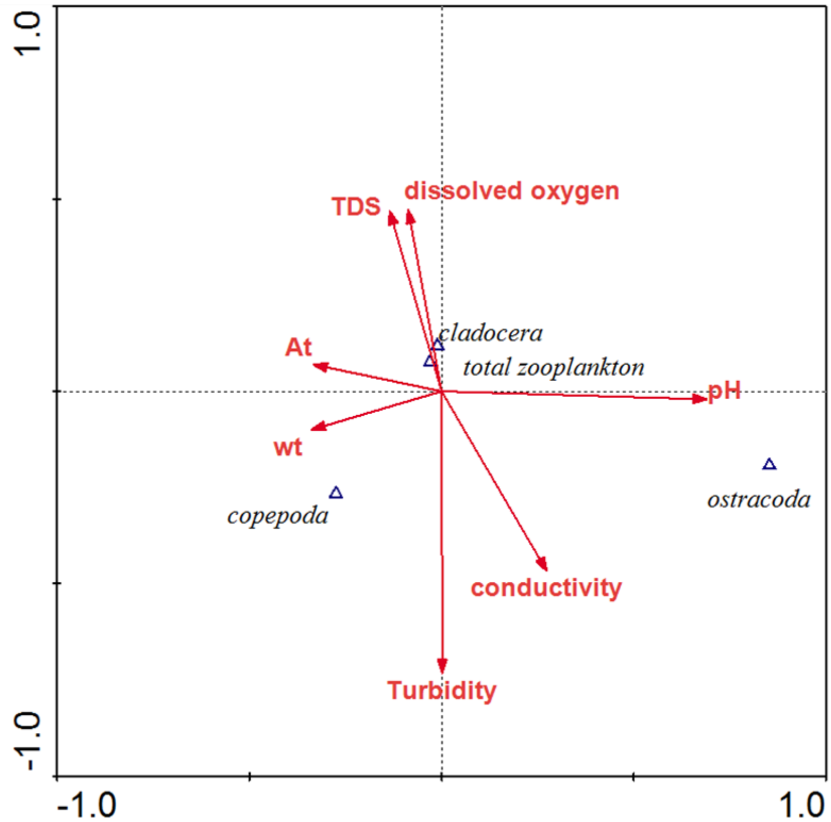

Fig. 4: Canonical Corresponding Analysis (CCA) of Zooplankton groups for abundance; data collected from all sites and corresponding ecological factors, Cladocera, Copepoda and (Ostracoda). At: air temperature. wt: water temperature. TDS: Total Dissolved Solids.

DISCUSSION

Physico-chemical parameters may change by numerous environmental incid-ences and it can affect the biota including zooplankton community and may seem to issues related to food supply for customers in the higher trophic levels (Manikarachchi *et al.*, 2013). Varied distribution of zooplankton groups during different seasons looked to be greatly influenced by several environmental factors like water temperature, presence of nutrients and physico-chemical factors (Ahmed *et al.*, 2011).

During the period of study lowest values of water temperature were observed during winter, while high temperature was observed in summer. High temperature during summer may be due to clear atmosphere and great solar radiation. This result agreed with previous studies such as Mola, (2015), El-Tohamy (2018) and Fishar *et al*. (2019). Minimum values of pH were recorded in summer months and maximum value was in winter. This result agrees with Mola, (2015) and Fishar *et al*. (2019). High values of dissolved oxygen were recorded during spring and low values were during summer. High values of DO during spring could be attributed to the flourishing of phytoplankton and high movement of water. This result is in accordance with Sharma (2019) who recorded that level of dissolved oxygen is high in spring and winter, while it was low during summer and autumn. The high values of total dissolved solids were observed in winter and minimum values were in spring, however maximum values of turbidity were noticed in autumn months and minimum values were in summer. Singh and Gupta (2010) and Chowdhary (2011) observed increased solubility of calcium and magnesium ions at low temperature. Welcomme, (1979) recorded high turbidity during winter months which may attributed to the high concentrations of total dissolved substances in water, which come from rains and soil drift.

During the year of the study, maximum abundance of zooplankton assemblage was recorded during winter season which may be due to favorable environmental conditions and minimum abundance was recorded in summer. Zooplankton groups were primarily contributed by Cladocera, Copepoda and Ostracoda, The highest population density of Cladocera was recorded in winter while the lowest population density was observed during summer. This result is in agreement with Mohammad *et al*., 2016 and Fishar *et al*., (2019). The peak of Cladocera population during winter months showed that they may be linked to favorable temperature and availability of abundant food in the form of bacteria and suspended detritus. Moreover, decreasing abundance of Cladocera during summer may be attributed to fish predation and the active competition with other groups as notified by Pandey *et al*. (2009).

Canonical corresponding analysis showed that turbidity was the most controlling factor for all zooplankton groups, followed by pH. Previous studies, such as Viroux (2002) and Kumar *et al*. (2011) indicated that high turbidity interferes with the photosynthesis of phytoplankton thus inhibiting their multiplication and ultimately reducing zooplankton population due to food scarcity. Dejen *et al*. (2004) established that turbidity may have played a role in the distribution of zooplankton taxa in a large tropical lake. Guo *et al*. (2003) indicated that low turbidity and high transparency favor phytoplankton growth, improving zooplankton grazing conditions and consequently increasing zooplankton diversity.

From the result of CCA test, both Cladocera and total zooplankton were correlated positively with total dissolved oxygen, dissolved solids, and pH. Stahl and Ramadan (2008) stated that oxygen in the water is the most important factor for most aquatic plants and animals to survive and plays an important role in the occurrence and abundance of plankton. Sharma (2019) informed that variations between the levels of dissolved oxygen during different seasons affect the activity and standing stock of zooplankton. Wang (2007) pointed that as the biological metabolism level and oxygen utilization rate of organisms increase with water temperature, and the dissolved oxygen level in water directly determines the biological abundance under high temperature.

Cladocera showed significant negative correlation with temperature. Accretion of Cladocera was inherent to high values of dissolved oxygen and low values of water temperature, this result agrees with Zaghloul (1985) and Mohammad *et al*. (2016). Sommer *et al.* (2012) and Strecker *et al.* (2014) reported that warmer temperature could negatively affect zooplankton in unproductive ecosystem; this may be due to the influence of strong synergetic interactions between thermal stress and food limitation on the growth of reproduction of the cladocera. El-Bassat (2002) indicated that temperature plays a key role in the distribution of Cladocera and most cladoceran species prefer low temperature. Also, Abd El-Karim (1999) and Bedair (2006) suggested that, decreasing the density of Cladocera population during summer may be due to flourish of Blue green algae and dinoflagellates which lead to decreasing the Cladocera filtering. Manickam *et al.* (2018) observed an increase in the total abundance of zooplankton during summer season, and decreased during rainy season.

Besides, both total zooplankton and Cladocera showed significant positive correlation with total dissolved solids (TDS). The increase in suspended solids will cause rapid growth of algae, which is a very important food source for many zooplanktons. Contrarily, Abdulwahab (2015) indicated that extremely increment levels of total dissolved solids in water will deteriorate the conditions of macrozooplankton, especially cladocerans, where they will die due to the clogging of the filter.

The result showed significant positive correlation between Cladocera and pH, this finding agrees with Karuthapandi *et al*. (2012) and deepthi *et al*. (2014) who observed positive correlation between Cladocera and alkalinity. Mohideen *et al*. (2008) established that the variation in pH is always associated with species composition of plankton inhibiting them. Paulose and Meheswari (2008) inferred that there is an inverse relation between the crustaceans (particularly Copepoda) and the total alkalinity.

During the period of study, Copepoda constituted the second abundant group which showed its maximum peak during autumn and the minimum was during summer. El-Bassat (2002) noticed that the maximum abundance of this group was attributed to the high concentration of nutrients and high transparency. The strong significant correlation between Copepoda and Cladocera may illustrate predation effect from copepods on adult cladocerans or their eggs; this result is in agreement with Wolfnbarger (1999); Forneman *et al*. (2002) and Gaudy *et al*. (2004). Williamson and Bulter (1986) indicated that, copepods were feeding on the cladoceran eggs inside their brood pouches.

Turbidity and Temperature are the most controlling factors for abundance of Copepoda. The correlation between temperature and Copepoda agreed with previous studies such as Halsband-Lenk *et al*. (2002); Yang and Rudolf, (2010); Forster and Hirst, (2012) who concluded that the influence of temperature on individual copepods and populations is a critical. Bonnet *et al*. (2009) and Dam (2013) revealed that temperature effects on the reproduction and developmental rate of copepods are widely recognized as a key issue for understanding population dynamics.

The correlation between turbidity and Copepoda agreed with Hart (1990) who points out that the abundance of copepod and cladoceran increased down the lake along with decreasing turbidity and suspended solids.

The pH is a major environmental factor of aquatic ecosystems and is impacted by biological processes such as photosynthesis and respiration. In the present study pH was the most controlling factor for Ostracoda. This result agreed with the finding of Mohammad *et al*. (2017) who studied the effect of ecological factors on fresh water zooplankton in the River Nile. Basu *et al*. (2010) and shah and pandit, (2013) observed a direct relation between the pH and the crustaceans.

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