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Zooplankton Community Structure and Diversity Relative to Environmental Variables in the River Nile from Helwan to El-Qanater El-Khayria, Egypt.

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ABSTRACT

Zooplankton and water samples were collected from five Stations of River Nile from Helwan to El-Qanater El-Khayria during the period from May, 2013 to February, 2014. Water Physico-chemical characteristics were analyzed. Rotifera formed the highest percentage of zooplankton (93.66 %), followed by Cladocera (1.86 %) and Copepoda (1.79 %), while Meroplankton and Protozoa formed the lowest dominant groups. Thirty seven species were identified belonging to Rotifera (30 species), Cladocera (2 species), Copepoda (1 species), Protozoa (2 species) and Meroplankton (2 species).The principal component analysis (PCA) showed that negative correlations between nutrient, major salts and the dominant zooplankton due to the increasing of wastewater discharged. So we recommended treatment of wastewater from Iron and Steel Factory and Starch and glucose Company before discharging to enhance water quality. Canonical corresponding analysis (CCA) was confirmed our results.

Key words: Zooplankton, nutrient salts, physico-chemical characteristics, River Nile, PCA, CCA.

Introduction

Nile River, with an estimated length of over 6800 km, is the longest river flowing from south to north over 35 degrees of latitude (FAO, 1997). The Nile basin covers the whole of Egypt, north and south Sudan, one third of Ethiopia, the whole of Uganda, and part of Kenya, Tanzania, Congo, Rwanda and Burundi. Conventionally, the Nile is divided into a number of sub-basins: the White or Equatorial Nile and its source lakes, the Blue Nile and Lake Tana, and the Main Nile. The River Atbara is often considered a separate, although small, sub-basin (Tudorancea & Taylor, 2002). Before the construction of the Aswan High Dam; the Nile rolled through a series of six rapids, called cataracts, between northern Sudan and southern Egypt. Since the construction of the dam, the river has gradually changed its course. The characteristic of the Nile downstream from Aswan has changed dramatically as the Nile water became silt-free, less turbid and with considerably less velocity (Saad and Goma, 1994). According to the National Water Research Center (NWRC, 2000), the River Nile from Aswan to El-Kanater Barrage receives wastewater discharge from 124 point sources, of which 67 are agricultural drains and the remainders are industrial sources. Now, the changes in water quality are primarily due to a combination of land and water use, as well as water management interventions such as; (a) different hydrodynamic regimes regulated by the Nile barrages, (b) agricultural return flows, and (c) domestic and industrial waste discharges including oil and wastes from passenger and riverboats. These changes are more pronounced as the river flows through the densely populated urban and industrial centers of Cairo and the Delta region (Agricultural Policy Reform Program, 2002). The River Nile may be considered mostly as a moderately clean river, but with localized pollution problems. Due to the highly decreased of swept-out effluents property of the River Nile to the sea and rather extensive water use and contamination, the river is in great danger of becoming a waste collecting system. Although the impact of the wastes discharged on ambient water quality of the Nile has not been significant in recent years due to the high self-assimilation capacity of the Nile water (Abdel-Satar, 2005).

The composition of river plankton (potamoplankton) is quite different from that of lakes (Limnoplankton). In rivers, zooplankton typically is dominated by rotifers (e.g. *Brachinous, Keratella, Filinia* and *Synchaeta*), with relatively few cladocerans and copepods. In comparison, zooplankton of lakes tends to be dominated by Copepoda and Cladocera (Shiel *et al.*, 1982). Regarding aquatic food webs, zooplankton plays a vital role in them, because they consume the primary producers (phytoplankton) and form a major food source for tertiary producers. Zooplankton considered as the basic principal of natural fish feeding for the young and some adults of many fishes which support fish production. The communities of zooplankton are highly sensitive to environmental variation. The changes in their abundance, species diversity, or composition can provide important indications of environmental change or disturbance. Zooplankton communities often respond quickly to environmental change because most species have short generation times (usually days to weeks). The

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variation of their spatial distribution based on different physical factors (Epifanio & Garvine, 2001and Kimmel *et al*., 2006). Zooplankton diversity responds rapidly to changes in the aquatic environment. Several zooplankton species have served as a bioindicators (Mola, 2011 and Ahmad *et al*., 2012). Some species flourish in highly eutrophic waters, while others are very sensitive to organic or chemical wastes (Mola, 2011). Rotifers constituted the main food of Cichlid species (Hegab, 2010). Rotifers, especially *Brachionus*, constitute an important link in the food chains of inland waters. They are considered preferred food for many fish larvae (Guerguess, 1993). Studies on planktonic composition and morphometric, physical and chemical characteristics of water bodies are necessary to obtain basic knowledge on the biodiversity (Rajagopal *et al*., 2010).

The present study was mainly aimed at analysing the impact of some physical and chemical variables on zooplankton in this area of the Nile by evaluating its effect in terms of abundance, size structure and species composition of the zooplankton community.

Material and methods

A-Study Area

The River Nile is considered as one of the longest rivers in the world; it runs about 6,650 km through eleven countries from Burundi to Egypt. The last 1,600 km of this journey goes through Egypt. The main part of water resources come from the Blue Nile in Ethiopia and the rest from the White Nile in Uganda (El Gohary, 1994). The River Nile is the artery of Egypt, as it provides for more than 96% of the municipal, industrial and irrigation requirements of Egypt (Abdel-Satar, 2005).The selected stations along River Nile from Helwan to El-Qanater El-Khayria (Figure 1) were described as the following:

1-Helwan (Front of Iron and steel company, Latitude 29°48'0"N and Longitude31°17'45"E).
2-El-Hawamdiya (Starch and glucose Company, Latitude 29°52'31"N and Longitude 31°17'3"E).
3-Rod El-Farage (Tourism activity, Latitude 30° 5'27 " N and Longitude 31°14'1"E).
4-Shobra (Front of Electrical power Station, Latitude 30° 7'29"N and Longitude 31°14'4" E).
5-El-Qanater El-Khayria (Front of water purification Station, Latitude 30°11'1"N and Longitude 31° 8'20 "E).

Fig.1: Map of River Nile at Great Cairo showing the selected stations during the study.

B-Collection and analysis of samples

Water samples were seasonally collected from the selected stations during the period from April, 2013 to February, 2014. Some parameters were measured in the field e.g. water temperature, pH, electrical conductivity and total solids using multi-probe portable meter (Model CRISON-Spain.) and water transparency using secchi disc. All the chemical parameters and nutrient salts were determined according to APHA (2005).

Zooplankton was collected by filtration of 30 Litters from the water column with plankton net (mesh size 55 µm). All samples were fixed in 4 % formalin. In the laboratory, the samples were examined, counted, classified, identified and described according to description and keys constructed by Edmondson (1966), Pennak (1978) and Shehata *et al*. (1998 a & b).

C- Statistical analysis

Principal component analysis (PCA):

Principal component analysis (PCA) was conducted to correlate physico-chemical parameters, nutrient and major satts in water with the dominant zooplankton species and groups. It was carried out by XL STAT program, 2015.

Canonical Correspondence Analysis (CCA):

The data of zooplankton and water quality variables were drawn up in the form of one matrix and were analyzed by canonical correspondence analysis (CCA) using Brodgar Program, version 2.4.8 (Highland Statistics, 2005). CCA diagram was performed to determine relationships between the environmental variables and zooplankton groups and species. CCA is a non-linear technique used to relate variation in biotic properties to measured variation of the environment. Biological data were log transformed to approach the assumed conditions of normality and homocedasticity of the data to standardize the datasets. The constrained ordination axes correspond to the directions of the greatest variability of the data set that can be explained by the variables (Leps & Smilauer, 1999).

Results and Discussion

1-Physico-chemical parameters in water

Water temperature recorded its highest reading during summer (32.7 ^{0}C) and the lowest during winter (18.5 ^{0}C). The highest reading of transparency was recorded at El-Qanater El-Khayria station during Autumn (120 cm) this might be due to settlement of sediment. The lowest reading was recorded at Helwan Station during summer and winter (50 cm in June) which might be due to evaporation of water, which causes concentration of dissolved solids and increasing of temperature and production of plankton. Similar observations were recorded by Mola and Parveen (2014). The lowest values of pH (7.86 and 7.89) were recorded At El-Hawamdiya and Helwan station during summer. The relative decrease of pH values in these stations might be due to the effect of inflowing industrial wastewater and the highest value of pH (8.92) was recorded at Helwan during winter.

The lowest value of dissolved oxygen (DO) was recorded At El-Hawamdiya station during spring and autumn (7 mg/l). The relative decrease of DO values in this station might be due to the effect of inflowing wastewater from El-Hawamdiya factory which consuming the DO during the oxidation processes. Also, this might be attributed to the input of industrial wastes, as biochemical decomposition of organic matter leads to increasing ammonia and sulphids production during mineralization of organic matter which lead to enormous oxygen depletion. Similar observations were given by Emam (2006). The highest value of DO (9.6 mg/l) was recorded at Helwan during spring. This may be due to the abundance of phytoplankton which enriched water with oxygen during photosynthesis activity (Mola and Parveen, 2014). The highest value of chemical oxygen demand (COD) was recorded at El-Hawamdiya during spring (22.3 mg/l) this might be due to the effect of inflowing organic wastewater from El-Hawamdiya factory. The highest value of electrical conductivity (EC) was recorded at El-Qanater El-Khayria Station during winter (538 µmhohs/cm**)**. This may attributed to the effect of discharged washable water from El-Qanater Water Station. Bicarbonate concentrations observed its highest values during summer due to the effect of evaporation (Figure 2 and 3).

2-Nutrient and major salts in water:

Nutrient salts were high in the Nile. Nitrite, nitrate, ammonia and sulphate were analyzed at the selected stations. The discharging points recorded the highest values of nutrients especially at Helwan and El-Hawamdia. This may be due to the highly polluted wastes, which discharged at these stations. It was fluctuated between 13.2-23.5µg/l, 18.7-58.5 µg/l, 79.7-1174.5 µg/l and 35-41.5 mg/l for nitrite, nitrate, ammonia and sulphate respectively. Major salts were showed fluctuated between 26-45 mg/l, 25.4-44.5 mg/l and 2.2-35.5 mg/l for chloride, calcium and magnesium respectively. Major salts recorded were increasing with increasing of nutrient salts (Tables 1). The present study agrees with Abdel Satar (2005) and Mola and Abdel Rashid (2012) which recorded high positive correlation between major salts and nutrient salts.

3-Zooplankton abundance and distribution

The lowest average abundance of zooplankton was observed during autumn (45000 Org./m^3) while the highest average one was observed during spring (60000 Org./m^3). Mageed (2008) claimed that certain deaths occurred due to stresses by high pH, which had also a synergistic action upon zooplankton together with ammonia and that there was a direct relationship between temperature increase in water and the increase in zooplankton. Rotifera formed the highest percentage of zooplankton (93.66 %), it was followed by Cladocera

(1.86 %) and Copepoda (1.79 %) while Ostracoda, Nematoda and protozoa formed the lowest dominant groups being collectivity 2.69 % respectively (Figure, 2). Six groups of zooplankton were recorded in the present study. These results are in conformity with the findings of Khalifa (2000), Bedair (2003), Emam (2006), Hegab (2010) and Mola *et al*. (2011) and in confrontation with the findings of Amer (2007) who found that Protozoa was the main bulk of zooplankton community in River Nile. This may be due to the later one focusing on the effect of different type pollutants on bactria zooplankton interaction. Many authors (Basu and Pick, 1996 and Viroux, 1997) mentioned that zooplankton in fresh water rivers are often dominated by small forms such as rotifers and ciliated, bosminids and juvenile of copepods throughout the year. The lowest average number was recorded at Shobra Station (33332 Org./m^3) while the highest number was recorded at Helwan (717858 Org./m^3). The dominance of Rotifera at the River Nile may be due to their relatively short generation time compared to the larger crustacean zooplankton (Van Dijk and Van Zanten, 1995) or due to their ability to reproduction over a wide range of temperature (Galkovskaja, 1987).

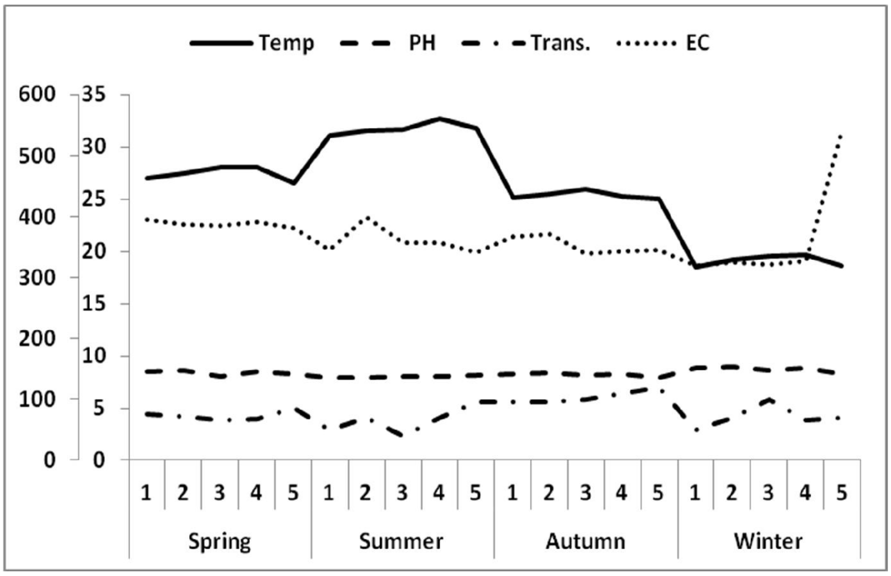

Fig. 2. Seasonal variations of physical parameters.

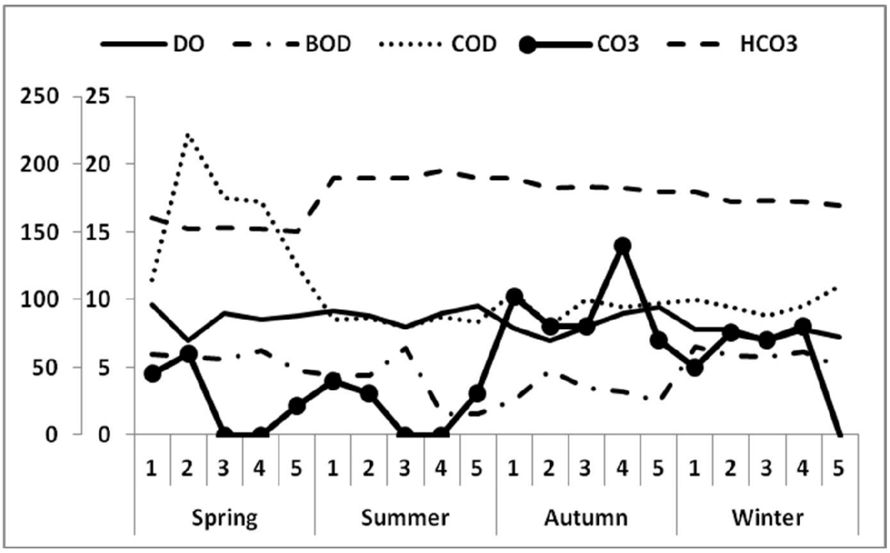

Fig. 3. Seasonal variations of some chemical parameters.

Table 1: Nutrient and major salts in water (µg/l) in water at the selected stations during the study.

Season	Station	NH_4 (µg/l)	NO_3 (µg/l)	NO_2 (µg/l)	SO_4^{--} (mg/l)	Cl^{-} (mg/l)	Ca^{++} (mg/l)	Mg^{++} (mg/l)
Spring	1	256.8	49.8	17.3	38.1	32	33	13.1
	2	249.3	52.4	17.6	38.1	27	37.2	11.6
	3	292.9	46.4	16.7	35.6	34	34.8	12.5
	4	270.1	47.1	13.8	35.5	29	32.7	12.8
	5	307.9	41.8	13.5	35	28.5	31.5	13.5
Summer	1	327.7	40.4	12.5	39	30	28.2	11.2
	2	1174.5	39.1	18	39.2	26	31.3	10.3
	3	314.5	33.7	13.2	36.1	32	28.7	11.1
	4	329.5	34.5	13.2	36	28.2	25.8	11
	5	329.5	27.9	13.4	35.5	24.5	25.4	12.2
Autumn	1	250	58.5	23.4	35.7	42	37.3	19.6
	2	479.2	74.3	21.3	38.2	42.5	47	2.2
	3	193.2	52.5	18.5	35.2	44	22.4	35.5
	4	111.8	77.6	19.7	33.5	37.5	40	23.3
	5	79.7	73.6	14.6	32.9	34.3	39	20.2
Winter	1	691.3	18.7	15.6	41.5	45	44.5	23.8
	2	408.7	96.5	18.5	39.9	39	43	28.1
	3	443.9	133.5	17.5	39.1	45	42.9	25.3
	4	370.5	81.3	17.9	38.2	43	43.5	19.5
	5	365.5	192.3	23.5	38.5	40	42.5	20.2

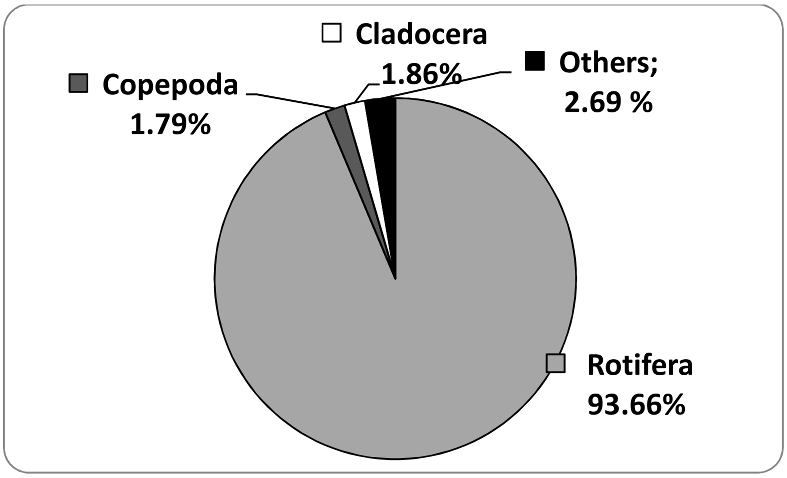

Fig. 4: Percentage frequency of the dominant zooplankton groups.

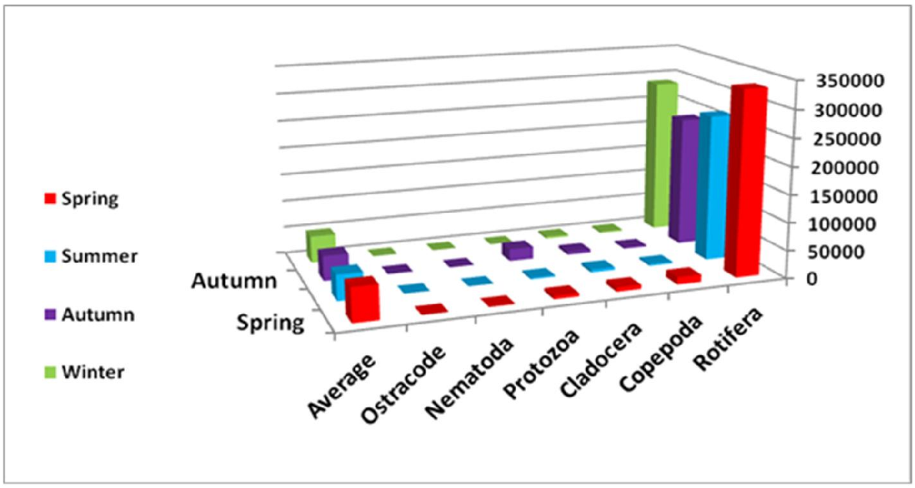

Fig. 5. Seasonal variations of zooplankton groups from May, 2013 to February, 2014.

In the present study, thirty five species were identified belonging to Rotifera (30 species), Cladocera (2 species), Copepoda (1 species) and Protozoa (2 species). The most dominant species of Rotifera were *Collothica* sp., *keratella cochlearis* and *Brachionus calciflorus* which formed 21.61, 21.14 and 11.83 % of the total zooplankton and 23.07, 22.57 and 12.63 % of the total Rotifera. *Branchionus* sp. is one of the major components of zooplankton in this river. It was represented by 8 species which are; *Branchionus angularis, B. budapestinensis, B. calyciflorus, B. caudatus, B. Plicatilis, B. urceolaris, B. falcatus* and *B. quadridentatus*. The presences of *B. calyciflorus* and *B. angularis* with high composition indicate eutrophication of River Nile (Mageed, 2008 & Mola, 2011). The presence of these species indicates the higher trophic status of water (Sharma *et al.*, 2015).

All the previous studies mentioned that, genus *Brachionus* spp. form the most dominant rotiferan species in River Nile and has the ability to tolerate the pollution. Sladeček (1983) mentioned that this species is cosmopolitan with a broad distribution in the most strongly eutrophic waters.The highest number of *P. vulgaris* was recorded during spring (59800 Org./m^3) and the lowest was observed during summer (4513 Org./m^3). El Shabrawy and Khalifa (2002) mentioned that the presence of Rotifers such as (*Brachious calcifloris, Polyarthra vulgaris* and *Keratella cochlearis*) indicate the eutrophic nature of water bodies.

Protozoa is the second dominant (2.64 % of the total zooplankton with average 7600 Org./m3). The highest number of protozoa was recorded at Helwan being 45333 Org./m^3 and Rod El-Farage (40000 Org./m^3) which may be attributed to the effect of swage dumping from Iron and steel factory and the tourism ships in Rod El-Farage. This indicates that it have the ability to tolerate high pollution. Ibrahiem (2013) recorded similar observation in the Nile River.

Cladocera formed the Third dominant zooplankton group with average number 5586 Org./m^3. It formed only 1.89 % of the total zooplankton. The lowest occurrence of Cladocera could be related to the high temperature as samples were collected during summer (5160 Org./m^3). The findings are in line with the findings of Hegab (2010) and Mola *et al.* (2011) they mentioned that the lowest average numbers of Cladocera was recorded during summer due to the effect of water temperature. Cladocera was represented by 2 species (*Bosmina longiroisris*, *Daphnia* sp.). *B. longiroisris* formed the highest bulk of Cladocerans (83.77 %).

Copepoda formed the fourth dominant zooplankton group with average number 5390 Org./m^3. Cyclopoid was represented by *Mesocyclops* sp. being 1010 Org./m^3 respectively. Nauplius larvae recorded the highest bulk of copepods in the River forming 64.37 % of the total Copepoda and 1.15 % of the total zooplankton. The presence of this larvae in most stations indicate that it have the ability to tolerate pollution (Emam, 2006). Copepodite stages (Cyclopoid and calanoid) constituted collectively 22.58 % of total copepods. The low numbers of copepoda might be attributed to the effect of pollution (Mola *et al*., 2011). El-Enany (2009) mentioned that Copepoda was the most dominant group in Lake Nasser which attributed to the good environmental conditions of the lake.

The highest number of Nematoda was recorded at El-Qanater El-Khayria (Station 5) being 3500 Org./m^3.This may be due to the effect of water discharged water from water purification Station. Hegab (2010) mentioned that Nematoda can live in the deficiency of dissolved oxygen and in the presence of organic pollutants. Ostracoda recorded the lowest dominant group (0.06 % of the total zooplankton) and recorded similar pattern of distribution for Nematoda.

Statistical analysis

Principal component analysis (PCA)

Principal component analysis (PCA) was conducted between physic-chemical parameters and zooplankton (Figure 4). The highest positive correlation was observed between pH and *Keratella cochlearis* (0.68). It also recorded a positive correlation with the most dominant groups of zooplankton e.g. Total rotifer and total cladocera being 0.54 and 0.61 respectively. The lowest numbers of zooplankton species might be due to the fluctuations of pH values and the deficiency of dissolved oxygen (Mola and Parveen, 2014). Temperature recorded high positive correlation with *Collothicca* sp. (0.63) while transparency recorded a negative correlation with *B. quadridentatus* (-0.66).

Principal component analysis (PCA) was conducted also between Nutrient & major salts and zooplankton (Figure 5). PCA showed that the highest positive correlation was observed between SO4 and between *B. calyciflorus* (0. 66) while nitrite and nitrate showed a negative correlation with *B. quadridentatus* being -0.49 and -0.48 respectively. Calcium recorded a positive correlation *B. angularis* and *Conochilus* sp. being 0.53 and 0.45 respectively while magnesium recorded negative correlations with *B. angularis*, *Colothica* sp., *Philodina* spp. and *Bosmina longirostris*. Ahmad *et al.*, (2012) founded a high negative correlation between total zooplankton which dominated with rotifer and nitrate.

Bicarbonate showed a positive correlation (0.58) with *B. falcatus*. This may be due to the highest concentration of bicarbonate during summer and appearance of this species during summer only. On the other hand, bicarbonate showed a negative correlation with total copepod (-0.53), copepodite stages (-0.50) and *polyarthra* sp. (-0.59). This might be due to the negative of waste water on this species which considered an indicator to clean water. El-serfy *et al.* (2009) and Hegab (2010).

Table 3: Seasonal variations of the recorded species during the period from May, 2013 to February, 2014.

Species	Spring	Summer	Autumn	Winter	Average
Rotifera					
Asplanchna priodonta	600	533	1233	1333	925
Brachionus angularis	667	1067	533	4857	1781
B. caudatus	0	0	0	6190	1548
B. falcatus	0	4113	0	0	1028
B. plicatilis	0	0	700	0	175
B. quadridentatus	6133	7047	1200	3048	4357
B. urceolaris	0	533	0	0	133
B. budapestanes	3233	1600	0	952	1446
B. calyciflorus	53600	22413	5800	65524	36834
Cephalodella sp.	0	1333	1600	1143	1019
Collothica sp.	48200	116600	79633	5667	62525
Conochilus Sp.	0	0	1233	6667	1975
Epiphenus sp.	0	400	0	0	100
Euclanis sp.	0	0	0	6952	1738
Filina longiseta	0	1600	0	0	400
F. opoliensis	333	533	0	0	217
Keratella cochlearis	101767	37727	20834	91524	62963
K. quadrata	0	0	0	5714	1429
k. serrulata	0	0	533	0	133
K. tropica	19500	19300	64733	25619	32288
Lecan luna	0	1713	0	0	428
Lecan sp.	2600	0	700	0	825
Lepadella ovalis	1567	513	0	667	687
Philodina spp.	20600	36893	12967	9333	19948
platyias patulus	0	400	0	0	100
Pluoroxus sp.	0	0	700	0	175
Polyarthra vulgaris	59800	4513	10200	45333	29962
Proales similis	0	0	533	0	133
Synchaeta sp.	883	533	1400	952	942
Trichocerca spp.	15067	6633	38100	6381	16545
Copepoda					
Naupilus larve	8067	3047	1233	1143	3372
Calanoid copepodit	0	0	0	952	238
Cyclopoid copepodit	2433	0	700	0	783
Mesocyclops sp.	2617	0	700	667	996
Clodecera					
Daphnia sp.	1900	0	0	2286	1046
Bosmina longrostris	5767	5160	5900	1333	4540
Protozoa					
Vortecella sp.	0	533	0	0	133
Ciliated protozoa	5600	2000	22267	0	7467

Canonical corresponding analysis (CCA):

Canonical Correspondence Analysis (CCA) is carried out for analyzing 9 environmental variables and 17 dominant zooplankton as in Figure 6. Analysis indicated that, the most important factors affecting on zooplankton distribution are NO_2, NO_3, Ca, Mg, CO_3 and HCO_3. CCA declared that Ca recorded a positive correlation with *Brachionus angularis* and *Conochilus* Sp. while Mg showed a negative correlation with *B. angularis*, *Colothica* sp. *Philodina* spp. and *Bosmina longirostris.* This agree with krzyzanek (1986) who stated that the great amount of organic matter rich in Ca and Mg increases development of some invertebrates.

Rotifers species was located at the center of the CCA ordination diagram because they were recorded in high abundance in all the stations sampled. Similar observation was recorded by Ali *et al.*, (2007). El-Enany (2009) stated that, Insecta, Protozoa, Cladocera and Copepoda were situated close to the center of CCA diagram. However, they were abundant in the Stations characterized by high TS, EC, PO_4 and Ca. The high numbers of drains on the River Nile which carrying high amount of nutrient, salts lead to eutrophication of water. This eutrophication is in turn effect zooplankton composition, shifting the dominance from large species (Copepoda) to smaller species (Rotifera) (El-Shabrawy, 2000; Emam, 2006 and Mola *et al.*, 2011).

In conclusion, the negative correlation was observed between nutrient, major salts and the dominant zooplankton due to the increasing of wastewater discharged. So we recommend the treatment of wastewater from Helwan (Iron and Steel Factory) and El-Hawamdia (Starch and glucose Company) before discharging to enhance water quality.

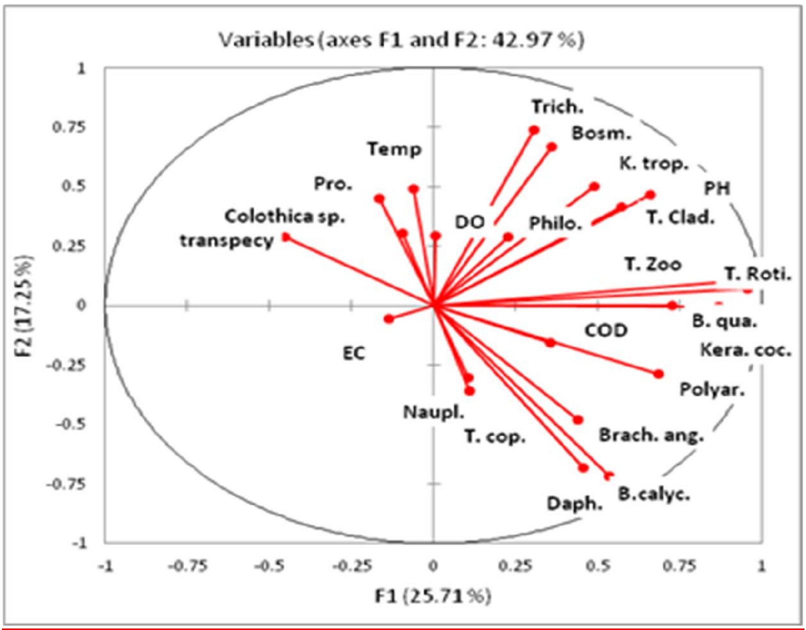

Fig. 6: Principal component analysis (PCA) was conducted for physico-chemical parameters and the dominant zooplankton.

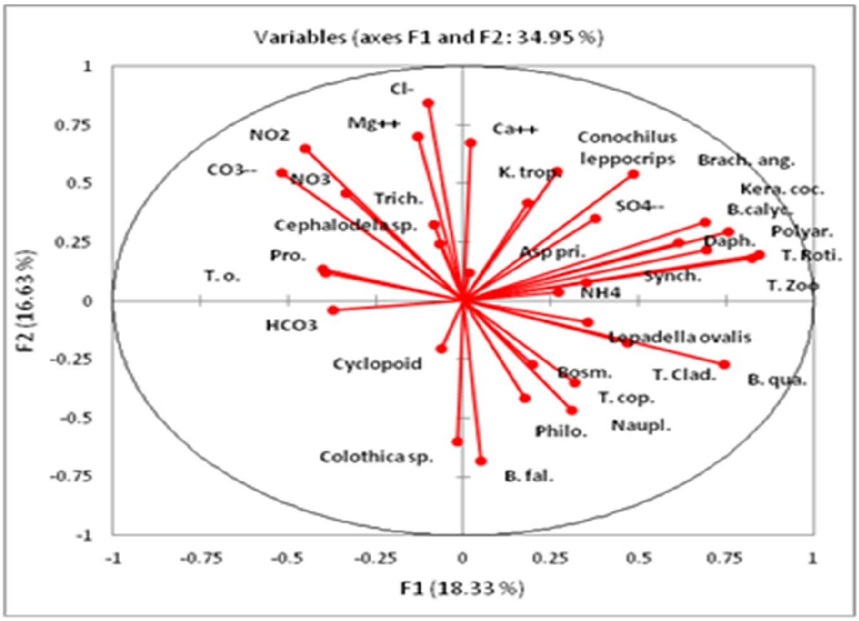

Fig. 7: Principal component analysis (PCA) was conducted for nutrient and major salts with zooplankton taxa.

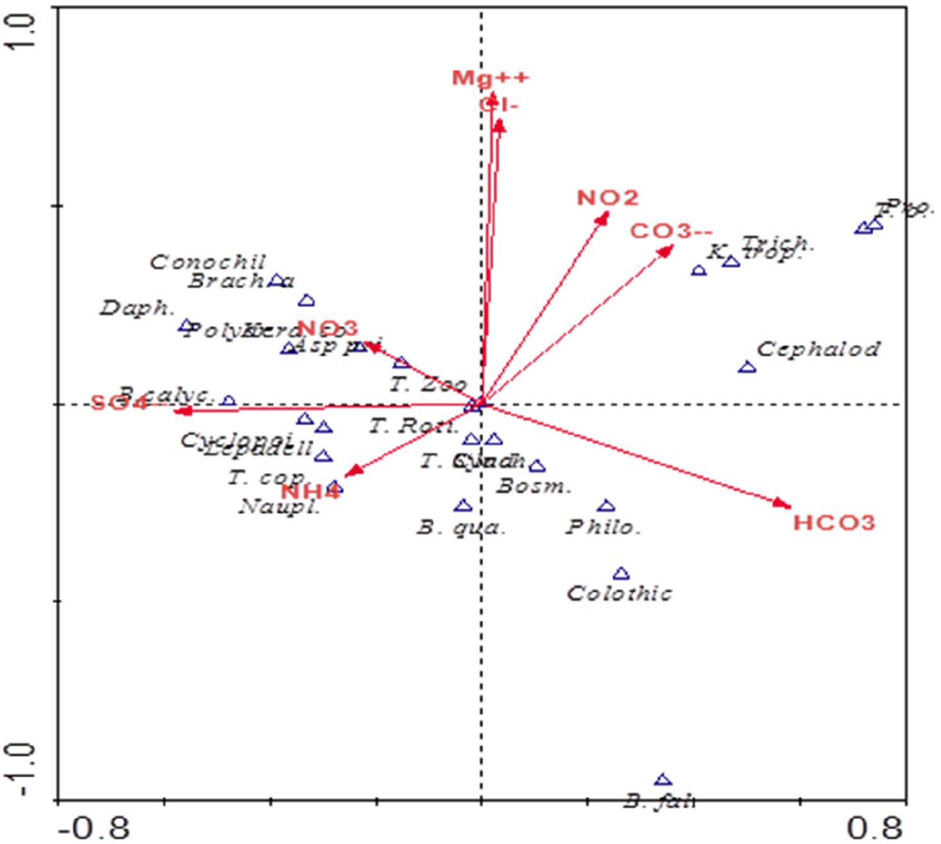

Fig. 8. Canonical Correspondence Analysis (CCA) diagram of 9 environmental parameters (NH4, Nitrate-NO_3 nitrite-NO_2, carbonate alkalinity- Co_3, bicarbonate alkalinity- HCo_3, calcium-Ca, magnesium-Mg, chloride-Cl, Sulphate-So_4,) and 17 dominant zooplankters (total zooplankton-TZ, *Keratella cochlearis*-Kera.coc., *K. tropica*-K. trop., *B. angularis*- Brach. ang., *B. quadridentatus*-B.qua.*, B. calyciflorus-B.calyc., Polyarthra* sp.-Polyar.*, Trich.- Trichocerca* spp.*, Colothica* sp., *Philodina* spp.-Philo., *Daphnia longispina* - Daph.*, Bosmina longirostris*-Bos, Total Copepoda- T. cop., Naupl.-Nauplis larvae total Cladocera-T. Clad., total Rotifera- T. Roti. and Protozoa-Pro.).

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