INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND ENGINEERING (IJESE)
Vol. 4: 29-45 (2013)
http://www.pvamu.edu/texged **Prairie View A&M University, Texas, USA**

Sewage pollution and zooplankton assemblages along the Rosetta Nile branch at El Rahawy area, Egypt.

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ARTICLE INFO
Article History:
Received: Dec.15, 2012
Accepted: Jan18, 2013
Available online: July 2013

***Keywords*:**
Zooplankton
River Nile
Rosetta Branch
Sewage pollution
El Rahawy Drain.

ABSTRACT

The abundance and diversity of zooplankton has been studied in relation to sewage pollution in Rosetta Nile branch. Twenty physical and chemical parameters and six heavy metals were investigated for water quality assessment during the period from winter to autumn 2010. The results revealed the negative impact of sewage wastewater effluent of El-Rahawy drain on abiotic variables of Rosetta Nile branch. There was an increase in electric conductivity, total dissolved solids, ammonia, H_2S, NO_2, PO_4, BOD and great depletion of dissolved oxygen at the discharged point of the drain effluent (station 2) , with an improvement away from the drain outlet. Seventy seven species and taxa of zooplankton had been identified during the present survey (48 Rotifera, 8 Copepoda, 11 Cladocera, 7 Protozoa and 3 Meroplankton). Rotifera dominated the other zooplanktonic groups, forming 72.4% of total zooplankton crop. Cladocera came next, with 11.9 %, while Copepoda, Protozoa and meroplankton were only represented by 7.2, 4.9 and 3.7 % respectively. The total zooplankton density has been decreased with increasing the sewage waste water concentration of El Rahawy effluent. The lowest species number and diversity index (18 species and 2.55) have been recorded at the discharged point of the drain effluent (Station 2) and it was gradually increased with decreasing the effluent concentration. Rotifers were the most tolerant species; copepods followed rotifers, while cladocerans only contributed significantly to the community at the surveyed area. Cladocerans showed very low tolerance to the toxic action of the sewage pollution. The results of this study showed that zooplankton responds as a good descriptor of water quality, constituting an efficient tool to assess the sewage pollution, eutrophication and heavy metal contamination

1. INTRODUCTION

The River Nile is the primary source of water in Egypt; used for drinking, fishing, industrial use, livestock and irrigation. The Nile water in Egypt is intricately managed through an extensive system of dams, barrages and canals. The water from the Nile is conveyed to the users through a vast network of canals.

ISSN 2156-7530

Wastewater and agricultural drainage water from these uses are collected by drains and are often returned to the River Nile as inflows. The Nile water is of high quality as the river reaches Cairo. Deterioration in water quality occurs when the Nile splits into the Damietta and Rosetta branches in a northward direction due to disposal of municipal and industrial effluents and agricultural drainage with decreasing flows (World Bank, 2005). Increase in sewage volume is one of the negative consequences derived from urban growth, constituting the main cause of eutrophication and associated pollution in aquatic ecosystem. Wastewaters contain large amounts of organic matter which are used by bacteria, thus reducing the dissolved oxygen levels in aquatic environments (Curds 1982). Also, these are the major source of inorganic nutrients, particularly nitrogen and phosphate, which can produce eutrophication (Wolf 1990). Furthermore, effluents transport large volumes of polluting chemical compounds such as heavy metals, hydrocarbons, pesticides and other toxic organic compounds (Fleeger *et al.* 2003; Caulleaud *et al.* 2009). Among aquatic indicator organisms a significant role is assigned to zooplankton assemblages due to their significant capacity to accumulate heavy metals, and their essential role in the enrichment of anthropogenic compounds in food chains (Stemberger & Chen, 1998). Also zooplankton communities respond to a wide variety of disturbances including nutrient loading (Dodson 1992), acidification (Armorek and Kormann 1993), contamination (Yan *et al.*, 1996), fish densities (Carpenter and Kitchell 1993), and sediment inputs (Cuker 1997).

Many studies had been carried out on the River Nile, and its branches. Most of these studies concerned with the state of the River Nile after the changes caused by many of industrial, domestic wastes and agriculture runoff. Chemical (El-Gohary, 1983, Abdel-Hameid et al, 1992; Abdo 1998; Ghallab, 2000 ; Abdel-Aziz, 2005; El Bouraie *et al*., 2011) heavy metals in water (Masoud *et al*., 1994; Soltan and Awadallah 1995; Issa *et al*., 1997; Mahmoud, 2002; Al-Afify 2006; El Bouraie *et al*., 2010; Ali *et al*., 2011), zooplankton (Helal 1981; Aboul Ezz *et al*., 1996; El-Bassat, 2002; El-Shabrawy & Ahmad, 2002; El-Shabrawy *et al* 2005; Amer, 2007; Hegab, 2010; Ahmed, 2012).

The objective of this study is to determine some physico-chemical variables of the sewage water of El Rahawy drain water as well as, its effect on Rosetta Nile branch. Clarify the regional and temporal variation in heavy metal concentrations in surface water of the drain and Rosetta branch. Characterize and attribute differences in zooplankton, to conditions resulting from the discharges of the raw sewage of El Rahawy drain into Rosetta Nile branch, where comparable conditions and impacts would be expected.

2. MATERIALS AND METHODS

2.1. Area of study: El-Rahawy drain

El-Rahawy drain is one of the main drains, which outlet into Rosetta branch of the River Nile, and receives considerable waste waters from Greater Cairo area (El Bourie 2008). There are two main sources of pollutions, which potentially affect and deteriorate the water quality of El Rahawy drain; agricultural and sewage wastes. The drain is located at about 963 Km from Aswan High Dam and surrounded by high density of population area and wide agricultural lands (Fig. 1).

El Rahawy drain receives about 400,000 m^3/day primary treated wastewater from Abo Rawash, besides 600,000 m^3/day untreated wastewater as a bypass from this planet. It also receives 430,000 m^3/day of secondary treated wastewater from Zeinen (El Bourie 2008).

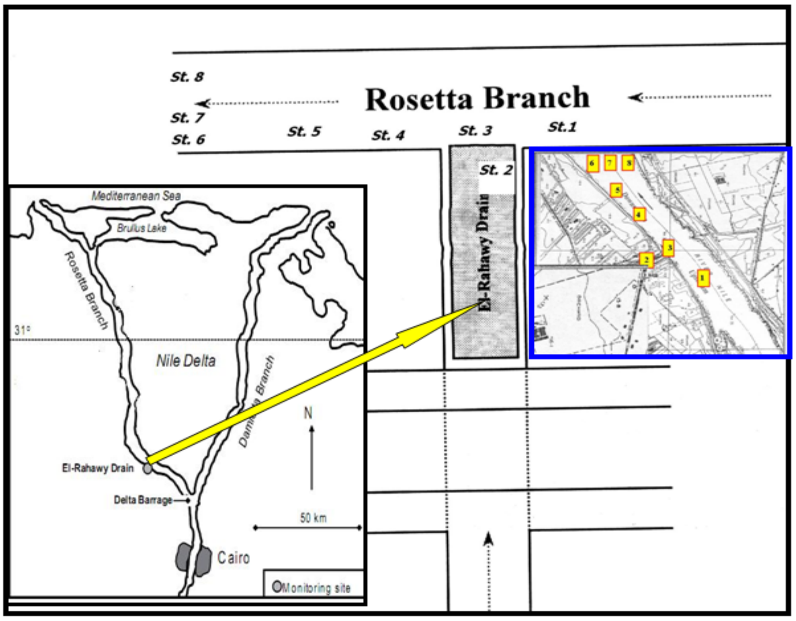


Fig. 1: The surveyed area map showing the selected stations.

2.2. Sampling stations:

Eight stations were selected to represent the different habitats at the surveyed area (Table 1)

Table 1: Location of the selected stations

Location	Station	Features of station
2 Km upstream of El Rahawy Drain	**1**	At left bank of Rosetta branch
Inside El Rahawy Drain and the mixing point to Rosetta branch	**2**	Inside El Rahawy drain before input into Rosetta branch
	3	At the discharge point of El Rahawy Drain into Rosetta branch.
Downstream of El Rahawy Drain	**4**	2Km. downstream the mixing point (at left bank)
	5	4Km. downstream the mixing point (at left bank)
	6	6Km. downstream the mixing point (at left bank)
	7	6Km. downstream the drain (in main Channle)
	8	6Km. downstream the drain (at right bank)

2.3. Sampling procedure

Subsurface water samples were collected seasonally from sampling stations during the period from winter to autumn 2010, using a Van Dorn Water Sampler bottle with capacity of 2L. Water samples for heavy metals were taken and kept in cleaned plastic bottle of 1L capacity, and preserved with 5 ml concentrated nitric acid on the spots and stored in refrigerator. Zooplankton samples for quantitative analysis were collected from the surveyed stations. 50 liters of subsurface water were filtered through plankton net 55 µm mesh size. Samples were preserved immediately after collection in 4 % neutral formalin.

2.4. Methods of Analysis

The methods discussed in the American Public Health Association (APHA, 1992) were used for the determination of the chemical parameters. pH were measured using Hydrolab (model WTW Multiset 430i), dissolved oxygen was carried out using modified Winkler method, Biological Oxygen Demand (BOD) was determined using 5 days incubation method. Chemical Oxygen Demand (COD) was carried out using potassium permanganate method. Water alkalinity was determined immediately after sampling collection using phenol-phthalein and methyl orange indicators. Sulphate was determined using turbidimetric method. Calcium and magnesium were detected using complexemetry method by direct titration using EDTA solution. Ammonia was determined by phenate method. Nitrite was determined using colorimetric method. Nitrate was measured by cadmium reduction method. Orthophosphate was estimated by using ascorbic acid molybdate method. Reactive silicate was heavy metals determined using molybdate methods as described in (APHA, 1992).

Six heavy metals included Fe, Mn, Cu, Zn, Pb and Cd were measured in water samples after digestion by adding 10 ml nitric acid to 500 ml of mixed sample in a beaker (APHA, 1995).

In the laboratory, samples were made up to a standard volume (100 ml). 1-3 ml was used for counting by using a binocular microscope. Zooplankton species were identified according to Shiel and Koste (1992), Einsle (1996) and Smirnov (1996).

Shannon-Winner diversity, species richness, evenness and similarity index were calculated for zooplankton assemblages, using Primer program.

3. RESULTS

3.1. Physical and chemical parameters:

The results of physical, chemical and Heavy metals parameters of water samples from the surveyed area are present in Table (2). Air temperature reached its maximum of 34.4 °C in station 7 during summer and decreased abruptly to 18.2°C at stations 1 & 2 during winter, with overall mean value of 26.3°C. Water temperature followed more or less the corresponding value of air temperature. Its values fluctuated between 29.5°C in station 8 (downstream El Rahawy drain) during summer and 16.1°C in station 2 (inside the drain) during winter, with an overall average value of 23.2°C. Due to the shallowness of water in the studied area, there is no thermal stratification. Results of Secchi-disc measurements showed low transparency values particularly at El-Rahawy drain and mixing stations. Transparency (Secchi-depth) was ranging between 10 cm at Station 2 and 110 cm at Stations 1 and 8 (Table 2). The conductivity readings in the studied localities ranged between 1143µS/cm in station 2 (El-Rahawy drain) during autumn and 359µS/cm in station 1 in spring. The level of TDS reached its highest value of 692 mg L-1 at Station 2 in autumn, while it decreased at the upstream of El Rahawy drain in Rosetta branch (St. 1) with a lowest content of 237 mg L^{-1} in spring. As shown in Table (2), the pH values of the selected localities were always on the alkaline side. It ranged between 8.27 in station 1 during winter and 7.2 in station 2 in autumn, with an average value of 7.75. The amount of dissolved oxygen was undetected in El Rahawy drain (St. 2), which was greatly affected by pollution load of the untreated wastewater. The water of the upstream station (St. 1) and the down most stream (station 8) were characterized by a well oxygenated water with an average of 7.5 mg L^{-1}. The highest BOD values were found at station 2 (El Rahawy drain) with a pinnacle of 37.4 mg L^{-1} in summer. There was a gradual decrease in BOD values from the input point of El Rahawy drain until reached minimum average value of 5.9 mg L^{-1} at station 8 (Table 2). The values of COD showed great fluctuations between different localities. Station 2 (El Rahawy drain) maintained the highest average value of 39 mg L^{-1} (range 34.8: 42.6 mg L^{-1}), while the lowest average concentration values of 7.8 and 8.8 mg L^{-1} were recorded at the upstream (Station 1) and the most downstream stations of Rosetta Nile branch (Station 8).

3.2. Major Anions

There was no sign of carbonate at the polluted stations from station 2 to station 7, however the unpolluted stations 1 and 8 had a low concentration value of 3.2 mg L^{-1}. The values of bicarbonate in the water of El Rahawy drain (Station 2) were obviously higher than the corresponding values of Rosetta Nile branch, with a mean value of 255.2 mg L^{-1}. It was varied from 185.4 to 302 mg L^{-1} during summer and winter, respectively. Bicarbonate values showed a gradual decrease from the discharging point of the drain in Rosetta Nile branch, station 3 (204 mg L^{-1}) till reached its lowest concentration at the down most station 8 (128 mg L^{-1}). The chlorosity level was always high at El Rahawy drain (Station 2) with a maximum value of 170.2 mg L^{-1} in autumn (Table 2). Sulphate concentrations were following the same basic trends as chlorosity.

3.3. Major Cations

Calcium content in the water of studied area was obviously high (average 47.9 mg L^{-1}) at station 2 (El Rahawy drain), while the lowest average concentration of 26.9 mg L^{-1} was recorded at station 8 (down most station). As in case of Calcium, Magnesium content were always much higher (36.5 mg L^{-1}) in station 2 (El Rahawy drain) than the corresponding values at the rest of stations. A severe drop in magnesium level was observed at the upstream station 1 with an average of 12 mg L^{-1}.

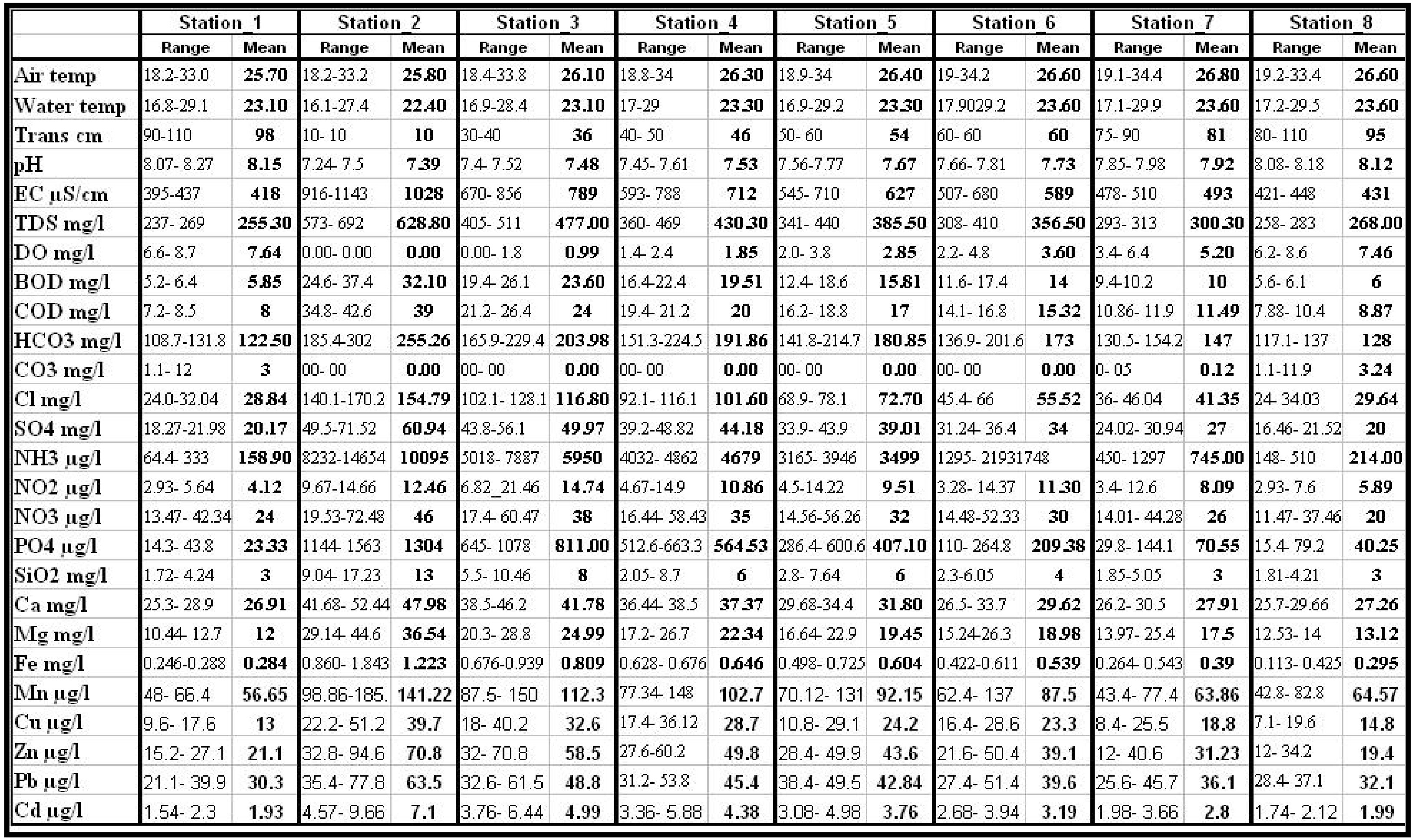
3.4. Basic nutrient salts

The maximum nitrite concentrations were recorded at station 3 (Discharging point of El Rahawy drain to Rosetta Nile branch) with a mean value of 14.7 µg. L^{-1}. Contrarily, the minimum concentrations of nitrite were recorded as approximately 4.1 µg L^{-1} at the upstream station1 (Table 2). The present results show a narrow variation in nitrate distribution patterns at the surveyed area Winter maintained the highest nitrate level at all station with a peak of 72.5 µg L^{-1}at station 2 (El Rahawy drain). The concentration of ammonia was much higher (average 10.1 mg L^{-1}) at station 2 (El Rahawy drain), while Station 1 had the lowest average level of 0.16 mg L^{-1}. The orthophosphorus content of the surface water was lower at upsteam station 1 (average 23.3 µg L^{-1}) than the rest of stations. On the contrary, the maximum values were recorded at station 2 (El Rahawy drain) with an average value of 1304 µg L^{-1}. The concentration of silicate has been found much higher (13.1 mg L^{-1}) at station 2 (El Rahawy drain) than the other stations. Stations 1 and 8 sustained the lowest silicate mean value of 2.9 mg L^{-1}.

3.5. Heavy Metals

The recorded concentration values of some heavy metals in water from the studied area are presented in Table (2). Overall results of water samples showed variations in the distributions of Fe, along the surveyed localities. Obviously high concentrations, up to 1.2 mg L^{-1} has been found at station 2 with a maximum value of 1.84 mg L^{-1} in summer. On the other hand, the lowest concentration was recorded at stations 1 and 8 with mean values of 0.28 and 0.3 mg L^{-1}, respectively. The maximum manganese concentrations were always recorded at station 2 with an average of 141 µg L^{-1}, while its minimum concentrations were detected at station 1 (Upstream station). The obtained results of zinc values showed a maximum average concentration of 70.7 µg L^{-1} at station 2, with a major peak of 94.6 µg L^{-1} in autumn (Table 2). The obtained results of Copper showed an obvious increase to an average value of 39.7 µg L^{-1} at station 2, while the minimum mean value of 13 µg L^{-1} was measured at station 1.

Table 2: Some physical and chemical properties and heavy metals contents of the water of the surveyed areas.



	Station_1		Station_2		Station_3		Station_4		Station_5		Station_6		Station_7		Station_8	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Air temp	18.2-33.0	**25.70**	18.2-33.2	**25.80**	18.4-33.8	**26.10**	18.8-34	**26.30**	18.9-34	**26.40**	19-34.2	**26.60**	19.1-34.4	**26.80**	19.2-33.4	**26.60**
Water temp	16.8-29.1	**23.10**	16.1-27.4	**22.40**	16.9-28.4	**23.10**	17-29	**23.30**	16.9-29.2	**23.30**	17.9029.2	**23.60**	17.1-29.9	**23.60**	17.2-29.5	**23.60**
Trans cm	90-110	**98**	10- 10	**10**	30-40	**36**	40- 50	**46**	50- 60	**54**	60- 60	**60**	75- 90	**81**	80- 110	**95**
pH	8.07- 8.27	**8.15**	7.24- 7.5	**7.39**	7.4- 7.52	**7.48**	7.45- 7.61	**7.53**	7.56-7.77	**7.67**	7.66- 7.81	**7.73**	7.85- 7.98	**7.92**	8.08- 8.18	**8.12**
EC µS/cm	395-437	**418**	916-1143	**1028**	670- 856	**789**	593- 788	**712**	545- 710	**627**	507- 680	**589**	478- 510	**493**	421- 448	**431**
TDS mg/l	237- 269	**255.30**	573- 692	**628.80**	405- 511	**477.00**	360- 469	**430.30**	341- 440	**385.50**	308- 410	**356.50**	293- 313	**300.30**	258- 283	**268.00**
DO mg/l	6.6- 8.7	**7.64**	0.00- 0.00	**0.00**	0.00- 1.8	**0.99**	1.4- 2.4	**1.85**	2.0- 3.8	**2.85**	2.2- 4.8	**3.60**	3.4- 6.4	**5.20**	6.2- 8.6	**7.46**
BOD mg/l	5.2- 6.4	**5.85**	24.6- 37.4	**32.10**	19.4- 26.1	**23.60**	16.4-22.4	**19.51**	12.4- 18.6	**15.81**	11.6- 17.4	**14**	9.4-10.2	**10**	5.6- 6.1	**6**
COD mg/l	7.2- 8.5	**8**	34.8- 42.6	**39**	21.2- 26.4	**24**	19.4- 21.2	**20**	16.2- 18.8	**17**	14.1- 16.8	**15.32**	10.86- 11.9	**11.49**	7.88- 10.4	**8.87**
HCO3 mg/l	108.7-131.8	**122.50**	185.4-302	**255.26**	165.9-229.4	**203.98**	151.3-224.5	**191.86**	141.8-214.7	**180.85**	136.9- 201.6	**173**	130.5- 154.2	**147**	117.1- 137	**128**
CO3 mg/l	1.1- 12	**3**	00- 00	**0.00**	00- 00	**0.00**	00- 00	**0.00**	00- 00	**0.00**	00- 00	**0.00**	0- 05	**0.12**	1.1-11.9	**3.24**
Cl mg/l	24.0-32.04	**28.84**	140.1-170.2	**154.79**	102.1- 128.1	**116.80**	92.1- 116.1	**101.60**	68.9- 78.1	**72.70**	45.4- 66	**55.52**	36- 46.04	**41.35**	24- 34.03	**29.64**
SO4 mg/l	18.27-21.98	**20.17**	49.5-71.52	**60.94**	43.8-56.1	**49.97**	39.2-48.82	**44.18**	33.9- 43.9	**39.01**	31.24- 36.4	**34**	24.02- 30.94	**27**	16.46- 21.52	**20**
NH3 µg/l	64.4- 333	**158.90**	8232-14654	**10095**	5018- 7887	**5950**	4032- 4862	**4679**	3165- 3946	**3499**	1295- 21931748		450- 1297	**745.00**	148- 510	**214.00**
NO2 µg/l	2.93- 5.64	**4.12**	9.67-14.66	**12.46**	6.82_21.46	**14.74**	4.67-14.9	**10.86**	4.5-14.22	**9.51**	3.28- 14.37	**11.30**	3.4- 12.6	**8.09**	2.93- 7.6	**5.89**
NO3 µg/l	13.47- 42.34	**24**	19.53-72.48	**46**	17.4- 60.47	**38**	16.44- 58.43	**35**	14.56-56.26	**32**	14.48-52.33	**30**	14.01- 44.28	**26**	11.47- 37.46	**20**
PO4 µg/l	14.3- 43.8	**23.33**	1144- 1563	**1304**	645- 1078	**811.00**	512.6-663.3	**564.53**	286.4- 600.6	**407.10**	110- 264.8	**209.38**	29.8- 144.1	**70.55**	15.4- 79.2	**40.25**
SiO2 mg/l	1.72- 4.24	**3**	9.04- 17.23	**13**	5.5- 10.46	**8**	2.05- 8.7	**6**	2.8- 7.64	**6**	2.3-6.05	**4**	1.85-5.05	**3**	1.81-4.21	**3**
Ca mg/l	25.3- 28.9	**26.91**	41.68- 52.44	**47.98**	38.5-46.2	**41.78**	36.44- 38.5	**37.37**	29.68-34.4	**31.80**	26.5- 33.7	**29.62**	26.2- 30.5	**27.91**	25.7-29.66	**27.26**
Mg mg/l	10.44- 12.7	**12**	29.14- 44.6	**36.54**	20.3- 28.8	**24.99**	17.2- 26.7	**22.34**	16.64- 22.9	**19.45**	15.24-26.3	**18.98**	13.97- 25.4	**17.5**	12.53- 14	**13.12**
Fe mg/l	0.246-0.288	**0.284**	0.860- 1.843	**1.223**	0.676-0.939	**0.809**	0.628- 0.676	**0.646**	0.498- 0.725	**0.604**	0.422-0.611	**0.539**	0.264- 0.543	**0.39**	0.113- 0.425	**0.295**
Mn µg/l	48- 66.4	**56.65**	98.86-185.	**141.22**	87.5- 150	**112.3**	77.34- 148	**102.7**	70.12- 131	**92.15**	62.4- 137	**87.5**	43.4- 77.4	**63.86**	42.8- 82.8	**64.57**
Cu µg/l	9.6- 17.6	**13**	22.2- 51.2	**39.7**	18- 40.2	**32.6**	17.4- 36.12	**28.7**	10.8- 29.1	**24.2**	16.4- 28.6	**23.3**	8.4- 25.5	**18.8**	7.1- 19.6	**14.8**
Zn µg/l	15.2- 27.1	**21.1**	32.8- 94.6	**70.8**	32- 70.8	**58.5**	27.6-60.2	**49.8**	28.4- 49.9	**43.6**	21.6- 50.4	**39.1**	12- 40.6	**31.23**	12- 34.2	**19.4**
Pb µg/l	21.1- 39.9	**30.3**	35.4- 77.8	**63.5**	32.6- 61.5	**48.8**	31.2- 53.8	**45.4**	38.4- 49.5	**42.84**	27.4- 51.4	**39.6**	25.6- 45.7	**36.1**	28.4- 37.1	**32.1**
Cd µg/l	1.54- 2.3	**1.93**	4.57- 9.66	**7.1**	3.76- 6.44	**4.99**	3.36- 5.88	**4.38**	3.08- 4.98	**3.76**	2.68- 3.94	**3.19**	1.98- 3.66	**2.8**	1.74- 2.12	**1.99**

There was a gradual decrease in Copper concentration from the drain input point (Station 3) downward. The concentration of lead at the investigated area reached its maximum of an average of 63.5 µg L^{-1} at station 2 with a peak of 77.8 µg L^{-1} in winter. The lead content showed a gradual decrease from 48.8 µg L^{-1} at station 3 (Drain input point) to 32.1 µg L^{-1}at station 8 (Down most station). The mean Cd concentrations in this study varied from 9.4 µg L^{-1} at station 2 in autumn to 1.5 µg L^{-1}at station 1 in summer

3.6. Zooplankton

Generally, the population density of zooplankton was obviously higher at station 1, with a major peak of 292,500 Ind. m^{-3} in winter. On the other hand, station 2 (El Rahawy drain) sustained the lowest crop, with an average of 11750 Ind. m^{-3} (Fig 2). As shown in Table (3) Seventy seven species and taxa of zooplankton had been identified during the present survey (48 Rotifera, 8 Copepoda, 11 Cladocera, 7 Protozoa and 3 meroplankton). Rotifera dominated the other zooplanktonic groups, forming 72.4% (range 36.2-79.3%) of total zooplankton standing crop at stations 2 and 1, respectively. Cladocera came next, contributed 11.9 % (range 9.9-23.4%), while Copepoda, Protozoa and meroplankton were only represented by 7.2, 4.9 and 3.7 % respectively (Fig. 2).

Table 3: A list of zooplankton species recorded at the surveyed area.

Species
Rotifera
Anuraeopsis fissa
Asplanchna girodi
Ascomorpha ecaudis
Brachionus angularis
Brachionus caudatus
Brachionus budapestinensis
Brachionus calyciflorus
Brachionus quadridentatus
Brachionus rubens
Brachionus urceolaris
Brachionus falcutus
Brachionus plicatilis
Cephalodella gibba
Collotheca pelagica
Colurella obtusa
Colurella adriatica
Epiphanes brachionus
Epiphanes senta
Euchlanis dilatata
Euchlanis triquetra
Filinia longiseta
Keratella cochlearis
Keratella tropica
Lecane bulla
Lecane closterocerca
Lecane hamata
Lecane grandis
Lecane leontina
Lecane luna
Lepadella patella
Lepadella ovalis
Monommata aequalis
Philodina roseala
Pompholyx complanata
Polyarthra ramata
Polyarthra vulgaris
Proales decipiens
Proalides sp.
Rotatoria sp.
Squatinella mutica
Syncheata pectenata
Syncheata oblonga
Testudinella patina
Trichotria tetructis
Trichocerca porcellus
Trichocerca elongata
Trichocenca cylindrica
Trichocerca pusilla
Copepoda
Nauplius larva
Cyclopoid copepodid
Paracyclops chiltoni
Acanthocyclops trajani
Thermocyclops neglectus
Thermodiaptomus galebi
Mesocyclops ougunnus
Schizopra nilotica
Cladocera
Daphnia longispina
Coronatella rectangula
Bosmina longirostris
Ceriodaphnia quadrangula
Ceriodaphria reticulata
Chydorus sphaericus
Ilyocryptus agilis
Leydgia acanthocercoides
Macrothrix laticornis
Moina micrura
Simocephalus vetulus
Protozoa
Arcella discoides
Centropayx acoelata
Dileptus anser
Euplotes affinis
Paramecium caudatum
Textularia sp.
Tokophrya sp.
Meroplankton
Free living nematoda
Chironomus larvae
Mollusc larvae

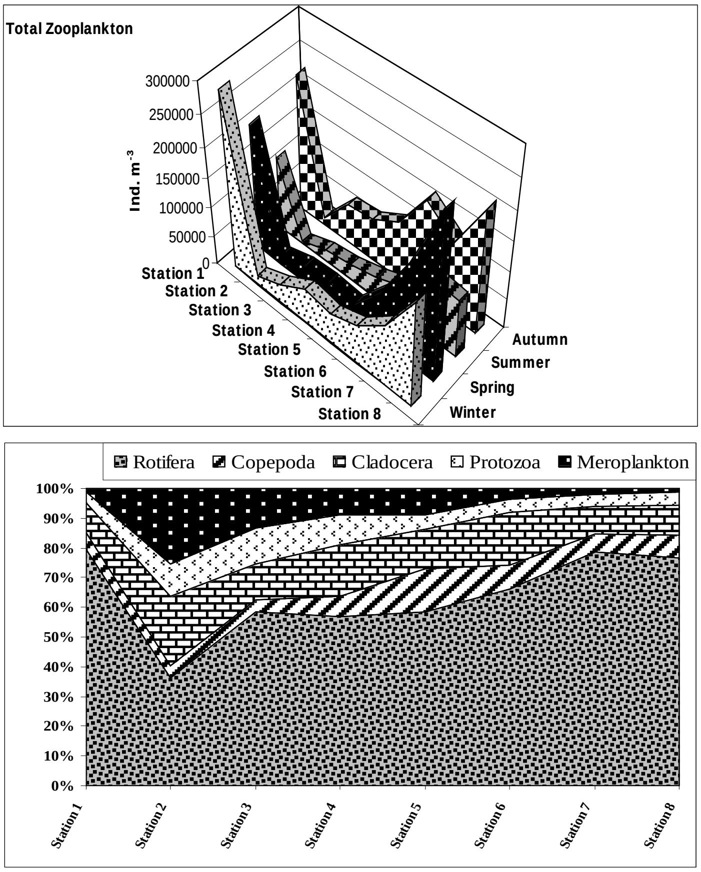


Fig. 2: Regional distribution and community composition of total zooplankton and its main groups at the surveyed area

3.7. Rotifera

The distribution of rotifers followed the same general trends observed for total zooplankton. Rotifers community consisted of 48 species. The dominant rotifers genera in the surveyed area were *Keratella, Brachionus, Trichocerca, Polyarthra, Lecane* and *Proalides*. They formed about 90 % of the total rotifers. The other genera of rotifers were rarely appeared in this section of the River Nile. *K. cochlearis* was the most dominant rotifer species in El Rahawy area of Rosetta Nile branch, contributed about 88.9 and 43.2 % of the total genus and rotifer counts. The highest population density of 140,000 Ind. m^{-3}) was recorded at station 1 in winter, while the lowest ones were recorded at station 2 during winter and spring and disappeared completely from zooplankton hauls at station 2 in summer and autumn (Fig. 3). The highest population density of *K. tropica* (9,000 Ind. m^{-3},) was recorded at station 8 with a pinnacle of 14000 Ind. m^{-3} in spring, while the lowest average standing crop of 250 Ind. m^{-3}, was appeared at station 2. *Brachionus calyciflorus* was one of the dominant rotifers species, contributing about 9.7% among total rotifera species and 56.8% of the genus counts, with an average of 6,800 Ind. m^{-3}.

The species highest density of 29,000 Ind. m^{-3} was recorded at station 1 during spring, while the lowest crop of 1000 Ind. m^{-3} was recorded at station 2 in summer and station 3 in autumn. *Brachionus calyciflorus* disappeared completely from zooplankton hauls at station 2 in winter, summer & autumn (Fig. 3). *Brachionus angularis* was one of the perennial plankters in the studied area.

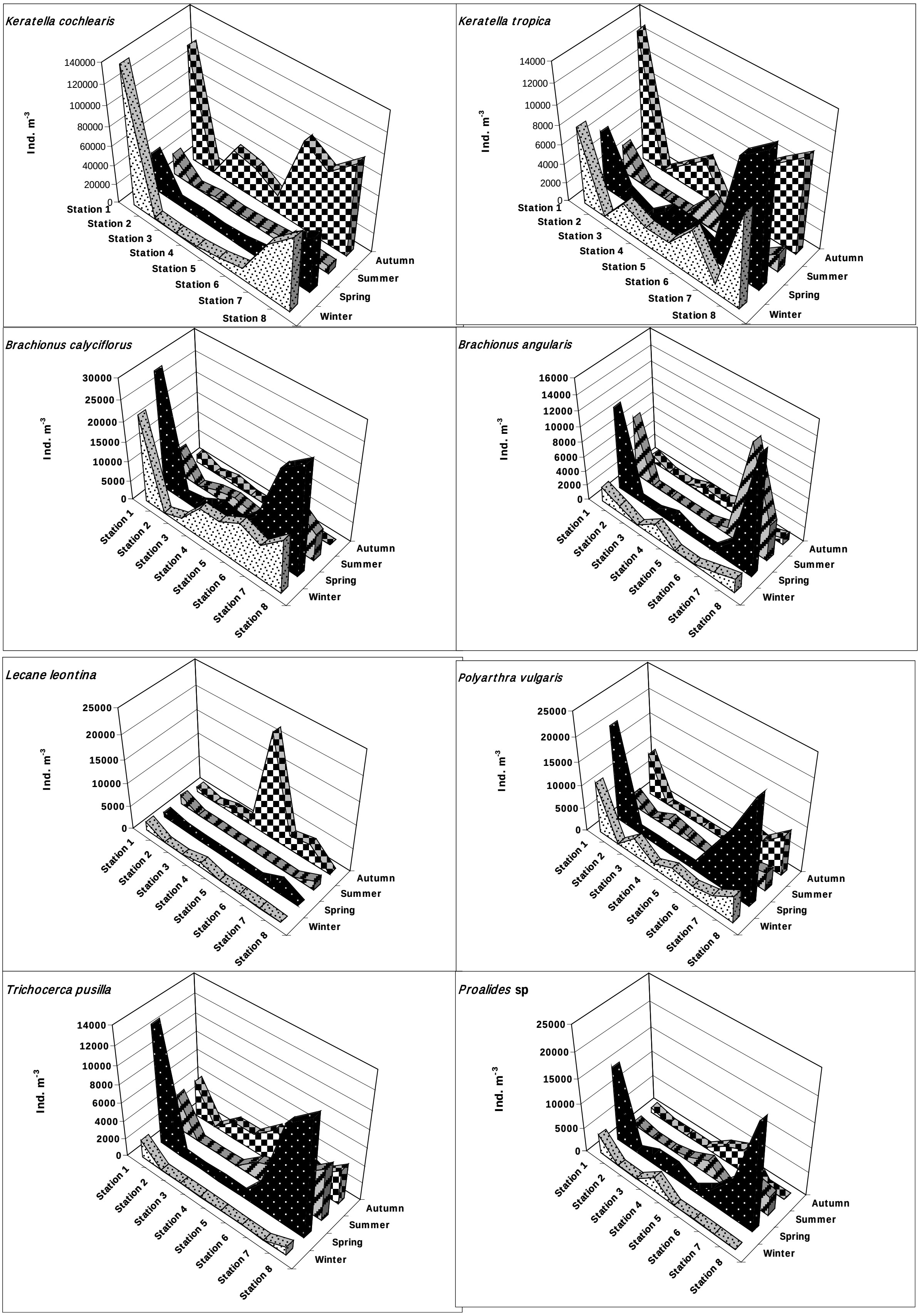


Fig. 3: Regional distribution of the dominant rotifer species in the studied area.

Two density peaks of this species (3900 and 3500 Ind. m^{-3}) were recorded in spring and summer respectively, while the lowest density (750 Ind.m^{-3}) was occurred in autumn. *Polyarthra vulgaris* appeared with a standing crop fluctuated between 23,000 Ind. m^{-3} at station 8 in spring and 1,000 Ind. m^{-3} at station 4 in winter and summer. The highest density of *Trichocerca pusilla* of 13000 Ind. m^{-3} was recorded at stations 1 and 8 during spring, while the lowest crop of 1000 Ind. m^{-3} was recorded at station 8 in winter. *T. pusilla* disappeared completely from zooplankton hauls at station 2, missed at stations 3. 4 in winter, spring and summer (Fig. 3). *Lecane leontina* was widely distributed at the majority of stations in autumn, while it was very sporadic and recoded at only two stations during each of the reset of seasons. *Proalides* sp. showed a highest mean density of 6500 and 5250 Ind. m^{-3} at stations 8 and 1 respectively, while the least mean of 500 Ind. m^{-3} was recorded at station 3 and completely missed from zooplankton hauls at the heavy polluted station 2 (El Rahawy drain).

3.9. Cladocera

The highest averages densities of Cladocera (21,000 and 19,750 Ind. m^{-3}) were observed at station 1 and 8, respectively, while the lowest standing crop of 2,750 Ind. m^{-3} was noticed at stations 2. On a seasonal basis, winter had the highest mean standing crop of 19,500 Ind.m^{-3}, while it was poorly represented in summer and autumn (average 6,200 Ind. m^{-3}). Numerically Cladocera occupied the second predominant position comprising about 11.9% of the total zooplankton crop at the surveyed area. Eleven species, dominated mainly by *Bosmina longirostris*, *Chydorus sphaericus* and *Coronatella rectangula* were represented the community of Cladocera in the area under study. *B. longirostris* was widely distributed with a highest density of 25,000 Ind. m^{-3} at station 1. Winter proved to be the most productive season for this species (mean 12500 Ind. m^{-3}), while it was faintly represented or even absent in summer (Fig. 4). The regional distribution of *Chydorus sphaericus* showed a highest mean density of 5000 Ind. m^{-3} at station 6, while the lowest yield of 250 Ind. m^{-3} was recorded at station 4.

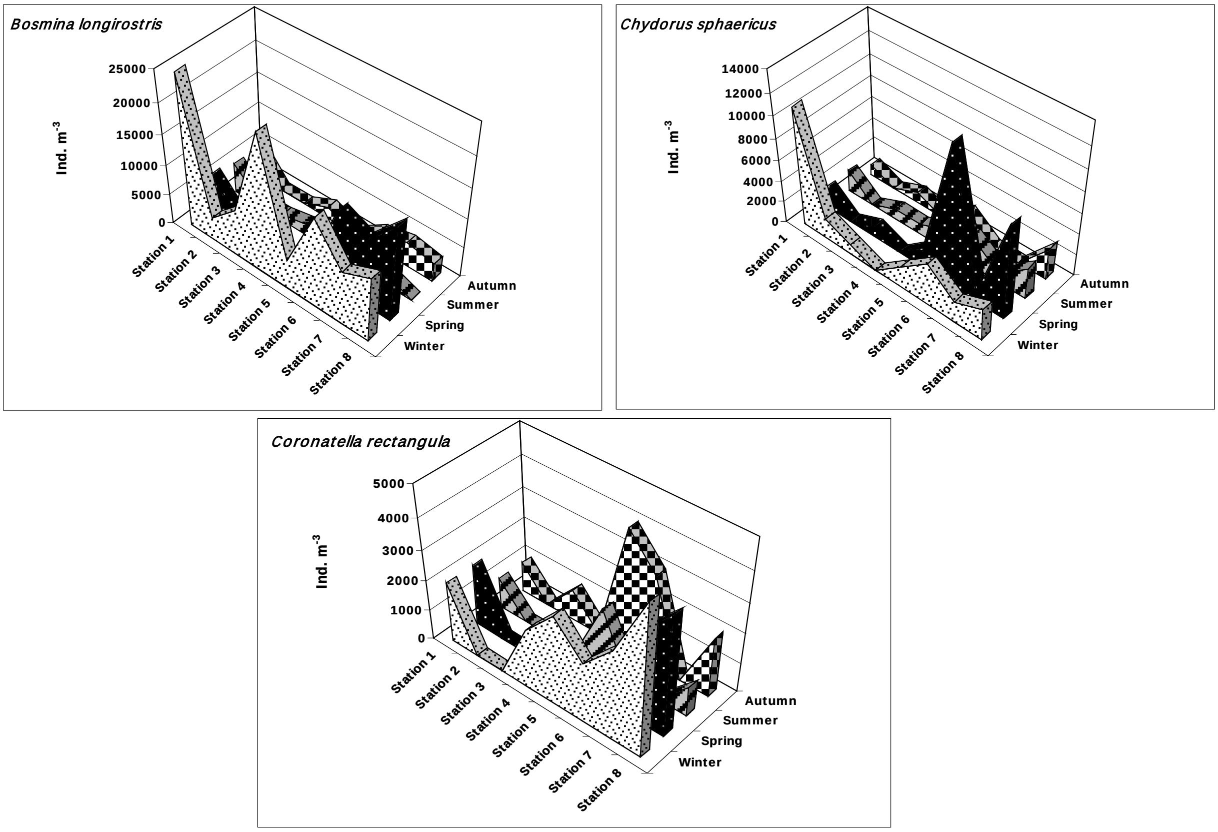


Fig. 4: Regional distribution of the dominant caladoceran species

Regarding seasonal variation, spring maintained the maximum average density value of 3500 Ind. m^{-3}, while it was poorly represented in autumn with an average of 875 org.m^{-3}. The permanent occurrence of *Coronatella rectangular* was highly confined to stations 1 and 8 with an average values of 3000 and 1500 Ind. m^{3}respectively, while it was sporadically occurred along the rest of the stations.

3.10. Copepoda

Copepoda was abundant at stations 1 and 8 reaching a mean density of 12500 and 14750 Ind. m^{-3}, respectively. The standing crop of Copepoda had been reduced a lot at station 2 (500 Ind. m^{-3}). Autumn maintained the highest density of these organisms, with an average standing crop of 9250 Ind. m^{-3}, while winter was the poorest season. Eight copepod taxa, dominated mainly by *Schizopra nilotica*, *Thermocyclops neglectus* and *Mesocyclops ougunnus* were recorded during the present study. The highest density peak of *Schizopra nilotica* (14.000 Ind. m^{-3}) had been recorded at station 5 in autumn, while it was appeared as scattered individuals in other sites, except for stations 2 and 3, where it was totally missed.

The permanent occurrence of *Thermocyclops neglectus* was highly restricted to station 1 with a highest mean of 1750 Ind. m^{-3}, while the lowest average of 250 Ind. m^{-3} was noticed at station 7. *T. neglectus* has been missed at station 2 (Fig. 5). *M. ougunnus* was widely distributed at the surveyed area in spring and it was infrequently occurred during the rest of the seasons. There was no sign for the occurrence of this species at the polluted sites (stations 2, 3 and 4).

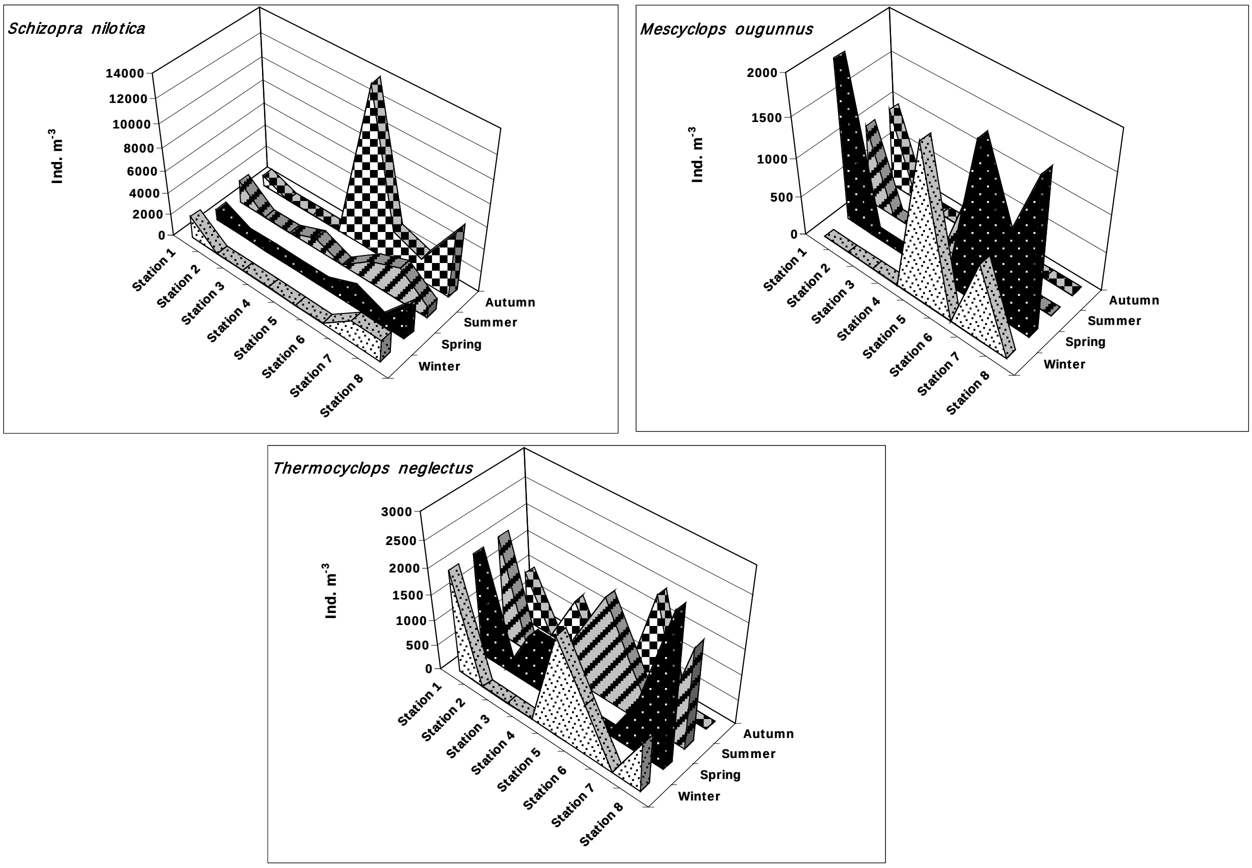


Fig. 5: Regional distribution of the dominant copepod species in the studied area.

4. DISCUSSION

Rivers, lakes and other water bodies are frequently located in urbanized areas. Such waters are not only used with recreational purposes, but usually act as collectors of diverse types of effluents. However, it is a well-known fact that urbanization originates great changes in the hydrology, geomorphology and water quality (Baer and Pringle, 2000), which can be stronger than the impacts caused by other uses of the land such as agriculture and forestation (Paul and Meyer, 2001). The natural aquatic systems may extensively be contaminated with heavy metals released form domestic, industrial and other man-made activities (Velez and Montoro, 1998). Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms (Farombi *et al.*, 2007).

Zooplankton represent the link between primary producers and secondary consumer, so it significantly influencing the food web structure (Marazzo and Valentin 2001). Zooplankton occurrence, distribution and abundance are of extreme importance in aquatic systems since they are sensitive to disturbances including eutrophication due to anthropogenic impacts such as heavy urbanization, domestic, and industrial pollutants and sewage disposal which can alter ecosystem components (Vidjak *et al.* 2006). In the present study, zooplankton communities tend to show a noticeable decrease in their abundance and diversity at the sewage waste discharge. Among the toxicological factors, metals in water (Fe, Cr, Pb, Mn, Zn) as well as, the composite indices of metal and organic contamination were the most important in explaining variance in zooplankton abundance and composition. The total zooplankton density have been decreased with increasing the wastewater concentration of El Rahawy effluent, zooplankton and its main groups and species showed a negative correlation with heavy metal concentration. The reduction may be referred to the direct toxic effects of the heavy metals in sewage water. This result coincides with Verbiskij *et al.* (1991), who found that the presence of heavy metals resulted in the decrease of the total zooplankton density by 4-times during 7-10 days of exposure. Also, Konar and Mullick (1993) found that heavy metals such as zinc, iron, and lead, when discharged in mixtures into water, produce an entirely different lethal impact on aquatic life than when they were discharged separately. There was an inverse relationship between stress situations and zooplankton body size. The results of this study showed that zooplankton responds as a good descriptor of water quality, constituting an efficient tool to assess eutrophication and heavy metal contamination. The field study showed the inhibitory effects of sewage and industrial effluent on zooplankton diversity; the lowest species number and richness have been recorded at the discharged point of plants or drain effluent. The same phenomenon was recorded by Ahmed (2000) and Mostafa (2002).

Rotifers have widely served as biological indicators and the relationship between toxins and rotifer predator-prey interactions and composition has been explored (Lagadic and Caquet, 1998; Wallace and Snell, 2010). Such toxicity tests included exposing the rotifers to insecticides, crude oil, heavy metals, and petrochemicals (Radix *et al.* 2000). Previous studies have found rotifers to be good indicators of water quality. Rotifers were the most tolerant species; copepods followed rotifers, while cladocerans only contributed significantly to the community at the surveyed area. Cladocerans showed very low tolerance to the toxic action of heavy metals. The clustering of the studied localities according to zooplankton density showed three groups of environments (Fig. 6); the first one was Elrahawy drain (Station 2), with a heavy contamination by heavy metals and lower density, and the diversity S, which separated clearly from the other two groups. The second group was the mixed point of the drain with Rosetta Nile branch (Station 3) and its closed localities (Stations 4 & 5). The third group represented by the upstream station 1 and the farmost stations to the drain (stations 6, 7 and 8) with a lower contamination by heavy metals and higher density, and S. Species diversity values (H) allowed differentiating between pollution levels.

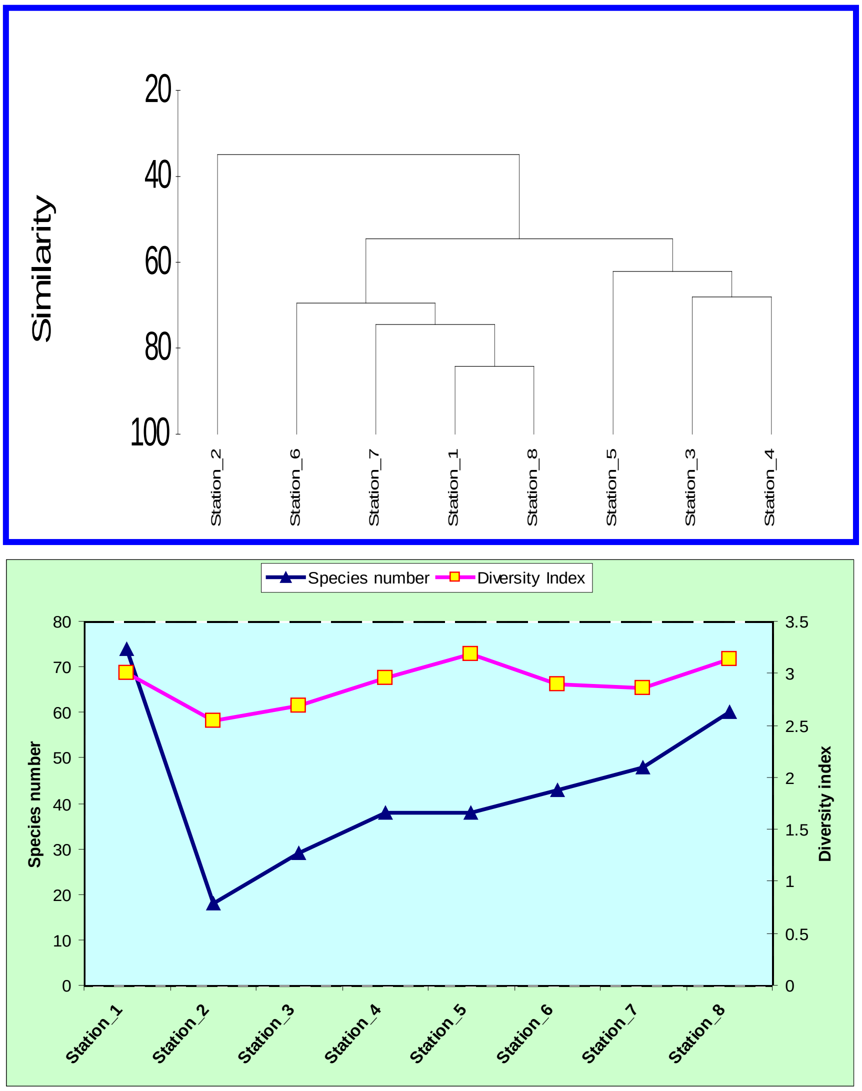


Fig. 6: The clustering analysis of the studied localities according to zooplankton density (Upper) and zooplankton density and diversity (Lower)

During the present study, Cladocera was highly sensitive to the sewage wastes. There was a severe drop in its density as concentration of effluent increased. Walia and Mehra (1998) found that *Moina* and *Ceriodaphria* were the only two cladoceran forms in the polluted site on River Yamuna (India). *Leydgia acanthocercoides*, *Bosmina longirostris*, *Coronatella rectangula* and *Chydorus sphaericus* were common among cladocera at the studied site. *Bosmina longirostris*, *Moina micrura* and *Chydorus sphaericus* were more tolerant to sewage waste concentration in the surveyed area. This was contrarily to the finding of Ahmed (2000) in the River Nile At Helwan area.

According to sensitivity of organisms to water pollution, zooplankton has been classified into two categories namely; sensitive and tolerant species. *Brachionus angularis*, *B. calyciflorus*, *Keratella cochlearis*, *Lecane bulla*, *Philodina roseala*, *Rotatoria* sp, *Syncheata oblonga* (Rotifera), nauplius larvae (Copepoda), *Bosmina longirotris*, *Miona micrura Chydorus sphearicus* (Cladocera), *Chironomus* larvae

(Arthropoda), free living nematods and Protozoa are pollution tolerant species and groups of zooplankton., While *Brachionus budapestinensis*, *Euchlanis triquetra*, *Filinia longiseta*, *Lecane hamata*, *Monommata aequalis*, *Polyarthra ramata*, *Syncheata pectenata*, (Rotifera), *Thermodiaptomus galebi* (Copepoda), *Daphnia longispina* (Cladocera), were the most sensitive zooplankton species.

When contamination by heavy metals is added to an eutrophication process it can turn out to be a very complex situation. As Clements and Newman (2002) pointed out, the studies of community-level impacts are a very useful tool for understanding pollution effects on the ecosystems. In this sense, responses of zooplanktonic species assemblage are a possible and reliable approach. This community, as it is constituted by organisms of different sizes and trophic habitats and complex life cycles (parthenogenesis, sexual reproduction with larval and juvenile stages), is a valuable tool to characterize the environment biologically in areas with different degrees of anthropogenic impact.

5. RECOMMENDATIONS

- El-Rahawy drain is mainly sewage in nature and mixed with agricultural wastes. The results of the present work indicated that El-Rahawy drain is suffering from extreme pollution concerning its physico-chemical properties due to inadequate treatment. Also, the discharge of this untreated wastewater to Rosetta Nile branch could have an adverse impact on its water quality as well as on the communities of zooplankton.
- According to sensitivity of organisms to water sewage pollution, zooplankton have been classified into two categories namely; sensitive and tolerant species. *Brachionus angularis, B. calyciflorus, Keratella cochlearis, Lecane bulla, Philodina roseala, Rotatoria sp, Syncheata oblonga* (Rotifera), nauplius larvae (Copepoda), *Bosmina longirotris, Miona micrura Chydorus sphearicus* (Cladocera), free living nematods and protozoans are pollution tolerant groups of zooplankton., While *Brachionus budapestinensis, Euchlanis triquetra, Filinia longiseta, Lecane hamata, Monommata aequalis, Polyarthra ramata, Syncheata pectenata,* (Rotifera), Thermodiaptomus galebi (Copepoda), *Daphnia longispina* (Cladocera), were the most sensitive zooplankton species.
- The present study recommended using these invertebrate animals as a bioindicators for water quality to provide early warning mechanisms of possible environmental damage and the impacts of effluents can also be tested and predicted before their discharge.
- Environmental degradation can be assessed by studying the communities of invertebrate organisms present in the water body, thus giving an indication of effects on the aquatic ecosystem.
- Drainage wastewater should be treated using more advanced methods prior to discharge into River Nile and its branches.
- Enforcement of all articles of laws 48/1982 and 4/1994 regarding protection of River Nile and the environment.
- The simplicity and low-cost of many methods enables monitoring to be carried out in many situations where the financial resources cannot support the sophisticated equipment required for chemical analysis of water quality. Using invertebrates as bioindicator for water pollution is strongly is strongly recommended in conjunction with chemical and hydro-logical monitoring and assessment programmes.

6. CONCLUSION

Increase in sewage volume is one of the negative consequences derived from urban growth, constituting the main cause of eutrophication and associated pollution in rivers. Wastewaters contain large amounts of organic matter which are used by bacteria, thus reducing the dissolved oxygen levels in aquatic environments. Also, these are the major source of inorganic nutrients, particularly nitrogen and phosphate, which can produce eutrophication. Furthermore, effluents transport large volumes of polluting chemical compounds such as heavy metals, hydrocarbons, pesticides and other toxic organic compounds. The present study shows that sewage discharge affects the physical and chemical water composition in the discharge zone of El Rahawy drain to Rosetta Nile branch, affects both directly and indirectly the composition, diversity and abundance of zooplankton, in the area of highest impact. This is why marked differences were observed in the composition, abundance and diversity of these organisms between the highest impact area. Furthermore, the high organic and inorganic nutrients and the alleged presence of toxic substances in the discharge area seem to induce a low overall abundance of these invertebrate. These phenomena explain the low species diversity recorded in this area with respect to those recorded at the reference station (Station 1). Heavy metal levels in the surveyed area sediments were remarkably high, but varied among sampling stations. Our results suggest that special attention must be given to the issue of metal re-mobilization, because a large portion of metals in sediments are likely to release back into the water column. Finally, this work not only emphasis the importance of an environmental monitoring study in this part of Rosetta Nile branch but also highlight the importance of ecological analyses as an essential tool for the evaluation of anthropogenic effects on ecosystems.

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