INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 4, No. 2, p. 58-67, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Population dynamics of Rotifera in Ismailia Canal, Egypt

Nehad Khalifa

National Institute of Oceanography and Fisheries, 101 Kasr Al Ainy, P.C. 11694, Cairo, Egypt

Article published on February 03, 2014

Key words: Egypt, Ismailia Canal, Rotifera, population dynamics.

Abstract

Ismailia Canal is one of the most important tributaries of the River Nile in Egypt. The population dynamics of rotifers in three zones of Ismailia Canal were studied in spring and autumn 2011, in relation to some physical and chemical characteristics of water. A total of 40 rotifers' species were identified, the dominant were *Keratella cochlearis, Collotheca pelagica* and *Polyarthra vulgaris*. *Keratella cochlearis* dominated in all the sampling sites and contributed 57.1% and 25.4 % of the total rotifers in spring and autumn. *Brachionus* was the most taxon-rich genus being represented by eight species. In autumn, rotifers population density and species richness were positively correlated with water temperature and transparency and a negative relation detected with electric conductivity in both seasons. But, in spring no clear relation was observed in response to the water physical and chemical characteristics and rotifers population dynamics which may be its occurrence in this season depend on algal abundance. The dominant rotifer species in Ismailia Canal and its two branches Suez and Port Said are eutrophic indicator species. Thus, the community composition of the rotifers indicate that, Ismailia Canal and its two branches are highly eutrophic and shows signs of partial pollution.

***Corresponding Author:** Nehad Khalifa ✉ nehadkhalifa@hotmail.com

Introduction

Ismailia Canal is one of the most important tributaries of the River Nile in Egypt. Along the canal there are several sources of pollution industries in the region of Cairo as well as agricultural run-offs in the eastern part. Measuring of a specific physic-chemical parameter in the contaminated aquatic ecosystem is important in determining the potential toxicity and its effects on the living organisms inhabiting that environment (Wrona and Cash, 1996). Bedair (2006) compared the seasonal variations of zooplankton in the River Nile at Shoubra El-Khema, Sharkawia Canal and Ismailia Canal. The variation in temperature and type of pollution affected the presence of zooplankton species at Great Cairo region of River Nile (Amer, 2007). Study of zooplankton and macrobenthos communities in Ismailia Canal revealed that pollution had affected their biodiversity and increased the population density of zooplankton indicators (Nassif, 2012).

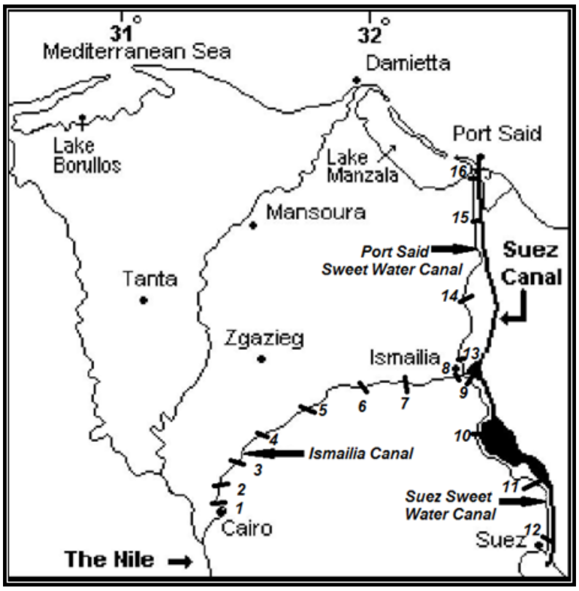

Fig. 1. Map of the selected sampling sites in Ismailia Canal, Egypt.

Rotifers perform an important link in the food chain and constitute the main food items for a great variety of aquatic organisms. They share also in the transfer of energy from primary producers to higher trophic levels (Stemberger, 1990). Rotifers are amongst some of the most abundant and important members of the freshwater fauna, along with Protozoa and Crustaceans. Rotifer populations are very useful in indicating water quality particularly in pollution studies (Sladecek, 1983). Seasonal occurrence of planktonic rotifer and their relationships with physico-chemical parameters have been studied from different water bodies in the world (Hoffman, 1977; Shayestehfar *et al.*, 2008; Casanova *et al.*, 2009; Kaya *et al.*, 2010; Sulehria and Malik, 2012).

The purpose of the present work was to identify rotifer community in Ismailia Canal and its two branches and to determine variations in its density and diversity in spring and autumn seasons in relation to physic-chemical variations of water.

Material and methods

Study site

Ismailia Canal was constructed in 1862 by virtue of two agreements between the Egyptian government and the Suez Canal Company for creating a navigable waterway between the Nile and the Suez Canal. Today its water is only used for irrigation and to provide drinking water for towns along its course. The canal has its inlet from the Nile at Cairo and runs directly to the east to the town of Ismailia passing the governorates of Cairo – Kalioubeya – Sharkeya and Ismailia. At Ismailia it bifurcates into two arms: one to the north to supply the town of Port Said and the second to the south to the town of Suez (Fig. 1). A short part without current directly connects the canal to the Suez Canal (Stahl and Ramadan, 2008). Sixteen stations were studied in spring and autumn 2011. Eight sampling sites were selected along the area extended from the mouth of the canal at Al-Mazalat region to Ismailia city (1-8) and four sites to cover each of the Suez Branch (9-12) and Port-Said Branch (13-16) as shown in figure 1.

Field and laboratory methods

At every sampling site, some physical and chemical parameters (temperature, oxygen, conductivity, pH and Secchi disk depth) were measured. Water temperature was measured by an ordinary thermometer, pH by Orion Research Ion Analyzer 399A pH meter and transparency by Secchi disc.

Electrical conductivity (EC) was measured using Hydro-Lab., "Multi 340 II SET". Dissolved oxygen (DO) was determined by azide modification method as specified in APHA (1998).

Rotifer samples for quantitative analysis taken from each sampling sites by filtering 30 liters from surface water through a zooplankton net of 55 µm mesh diameter. Collected samples were kept in plastic bottles with some lake water to which 4% formalin was added as a preservative. Rotifers were counted in a Sedwick-Rafter cell (APHA, 1998) at 100x using compound microscope and specimens identified at the species level when possible. Rotifers numbers were expressed as number of organisms per cubic liters. Identification of rotifers was mainly based on Kost (1978).

Statistical analysis

For statistical analysis, Pearson's correlation analysis was performed to evaluate the relationships between physico-chemical variables, rotifers densities and species numbers using XL stat software version 2012. Shannon-Winner diversity, species richness, evenness and similarity index were calculated using Primer 5 program.

Result and discussion

The three studied areas expressed nearly similar trend in variation of physic-chemical parameters in spring and autumn as shown in table (1). Temperature is one of the major factors which directly affects animal and plant life in fresh water (Nassif, 2012). Water temperature was higher in autumn with maximum value of 28.1°C at site 2, it revealed a positive correlation with both rotifers population density and species richness ($r = 0.755$ and $r = 0.724$) in autumn, while in spring no relation detected. A positive correlation between temperature and rotifer density was detected in Balloki Headworks, Pakistan (Sulehria and Malik, 2012). Temperature seems to be the main factor affecting population density, species composition and richness of rotifers in freshwaters (Shayestehfar *et al.*, 2008 and Kaya *et al.*, 2010).

The area under study attained a relatively low visibility of an average of about 50 cm in both seasons. Transparency showed that the Secchi disc readings attained its lowest values at sites of Suez and Port Said branches, while in Ismailia Canal it increased and the highest value of 100 cm was detected at site 8 in autumn season (Table 1), this may be attributed to the shallowness of water and increase of suspended particles at most sites especially at the end of Port-Said branch (Abdo *et al.*, 2012). Rotifers population density and its species richness attained positive correlation ($r = 0.451$ and $r = 0.670$) with transparency in autumn season and a weak relation was detected in spring. The influence of turbidity on biotic factors affecting rotifer densities has been observed in some large rivers (Lair, 2005), but several conditions are responsible for the reduction of rotifer population in areas of high turbidity (Sulehria and Malik, 2012). Lowest secchi depths in Cle Elum Lake were typically recorded during spring runoff in May and in September perhaps from increased algal abundance (Lieberman and Grabowski, 2007).

Electrical conductivity of the investigated sites water was higher at site 12 at the end of Suez Canal branch with maximum value of 649µS cm^{-1} in autumn, but dropped to a minimum level of 386µS cm^{-1} in spring at site 1 (Table 1). The highest value of electrical conductivity could be attributed mainly to the high pollution levels in water, resulted from the high nutrient loads of wastewater (Kobbia *et al.*, 1995; Fathi and Al-Kahtani, 2009). Abdo *et al.*, (2012) refereed the increase in EC in downstream sites of each branch to the effect of organic and inorganic pollutants discharged there. Nassif (2012) recorded the highest EC average during autumn after Misr Petroleum Company in Ismailia Canal, which may be attributed to the effluents of the company. In the present study EC revealed a moderate negative relation with rotifers population density in spring and autumn (r =- 0.609 and r = -0.480).

Table 1. Values of physic-chemical parameters of Ismailia Canal and its branches in spring and autumn 2011.

		Temperature (^oC)		Transparency (cm)		EC (µS cm^{-1})		pH		DO (mgl^{-1})	
		S	A	S	A	S	A	S	A	S	A
Ismailia Canal	**1**	21.9	25.9	80	70	386	425	8.32	8.24	11.1	6.2
	2	22.2	28.1	60	60	390	439	8.40	8.17	10.3	6.6
	3	22.7	27.0	70	65	390	435	8.44	8.16	8.2	7.6
	4	22.9	27.2	40	60	390	427	8.41	8.08	8.5	8.8
	5	22.8	27.1	50	70	404	416	8.40	8.12	10.0	8.2
	6	22.7	27.1	60	50	406	419	8.44	8.17	9.6	11.4
	7	23.2	27.3	50	50	408	458	8.32	8.26	10.6	7.3
	8	23.6	27.2	50	100	412	423	8.38	8.35	8.5	7.6
Suez Canal Branch	**9**	23.4	27.1	35	40	410	422	8.42	8.28	10.4	7.4
	10	23.1	27.4	40	50	410	455	8.46	8.35	8.8	11.2
	11	24.0	27.1	50	30	504	537	8.42	8.31	10.7	7.2
	12	23.5	25.3	50	30	604	649	8.37	8.38	6.8	6.3
Port Said Canal	**13**	23.5	25.5	40	20	438	496	8.28	7.76	7.8	10.0
	14	22.4	25.1	70	40	445	478	8.35	8.27	8.4	10.9
	15	22.0	25.4	25	30	449	466	8.40	8.18	11.2	8.4
	16	21.4	25.5	40	20	450	513	8.34	8.25	8.0	9.4

S: summer A: autumn

Change in pH value was always in the alkaline side. It fluctuated between 7.76 in autumn at site 13 and 8.46 in spring at site 10 (Table 1). This tendency to the alkaline side may be due to the increased photosynthetic activity of planktonic algae, or to the chemicals nature of water (Kobbia *et al.*, 1995; Fathi and Kobbia, 2000).

The presence of oxygen in water is a positive sign since most aquatic plants and animals need oxygen to survive (Stahl and Ramadan, 2008). The oxygen content at the investigated area tended to be higher in spring in most sites (mean 9.3 mg l^{-1}) and lower in autumn (mean 8.4 mg l^{-1}). The relatively high concentrations of dissolved oxygen recorded in spring could be mainly attributed to the increased photosynthetic activity of phytoplankton populations. Abd El-Hady and Hussian (2012) detected the highest population density of phytoplankton, at the selected sampling sites during the same study period, in spring with a maximum density of 1450 x 104 cells/l at station 7 with high oxygen content (10.6 mg l^{-1}). While the lowest phytoplankton crop was observed in autumn with a minimum value of 110 x 104 cells/l at station 12 which attained least oxygen content (6.3 mg l^{-1}). According to Hoffman (1977), dissolved oxygen plays an important role in the occurrence and abundance of rotifer species.

Rotifers were abundant in spring and its density was higher in Ismailia Canal sites than in Suez and Port-Said sites and its abundance peaks was detected at site 6 in spring (1938 000 Ind. m^{-3}) and at site 2 in autumn (894 000 Ind. m^{-3}). The noticeable drop in rotifers' population density in Suez and Port-Said branches (Fig. 2A) may be due to the effect of agricultural effluents which considered the major contamination source at two branches (Abdo *et al.*, 2012). The dominance of rotifers in spring may be attributed to the favorable conditions as suitable temperature, stable water condition and abundance of food (Abdel Aziz, 2005). Nassif (2012) declared the highest rotifers' crop in spring at Ismailia Canal due to lowest BOD values and highest orthophosphate concentrations.

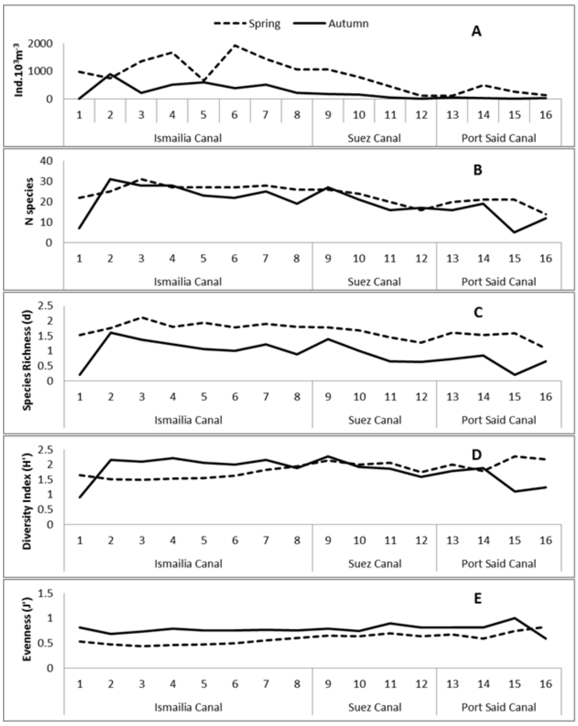

Fig. 2A. Population density, B: Species number, C: Species richness, D: diversity index and E: Evenness of rotifers at Ismailia Canal and its two branches in spring and autumn 2011.

Cluster analysis (Fig. 3) of the rotifer communities in each studied season revealed two clusters at about 50% and 30% similarity level for spring and autumn respectively. In spring, the first cluster formed four cluster groupings from sampling site 1 to 11 in addition to site 14 and 15. The highest similarity of about 90 % within this group was between site8 and 9, which may be attributed to that the rotifers' standing crop at both sites are nearly similar as they attained the same number of species and species richness (Fig. 2B&C). In autumn, each main cluster contained three groupings, the first cluster comprised sites of Ismailia Canal (2-8) in addition to sites 9 and 10. The second cluster contained sites of Port Said Canal (13-16) beside sites 1, 11 and 12. The highest similarity (82.3%) was recorded between sites 4 and 6 in the first group, followed by sites 11 and 14 within the second group. It seems that nearby sampling sites attained similar rotifers communities.

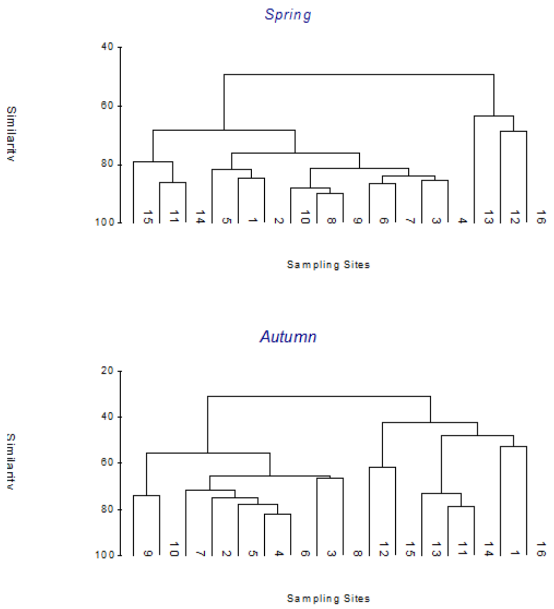

Fig. 3. Dendrogram showing similarity among different sampling sites of Ismailia canal and its two branches according to rotifers community structure in spring and autumn 2011.

A total of 40 species were identified (Table 2), of which 23 were ubiquitous appeared in both seasons. The greatest number of species was observed in autumn (34 species), In in central Spain, zooplankton diversity was higher in autumn than in spring and it was positively correlated with lake size (area and depth) in spring, but not in early autumn (Armengol and Miracle, 1999). Sampling sites 1 and 15 contained the lowest diversities in autumn with seven and five species, respectively and in turn the lowest species richness. Sites 3 and 2 attained the greatest number of species (31 species) in spring and autumn, and consequently the highest species richness of 2.117 and 1.605 respectively (Fig.2 B&C). Diversity index was higher at most sites of Ismailia branch in autumn; on the contrary, the species diversity in Suez and Port-Said sites was slightly higher in spring (Fig. 2D). Evenness had higher values in autumn along the study area except at sampling site 16 (Fig. 2E).

Table 2. Population density (Ind. m-3) of Rotifera species (in alphabetical order) collected from Ismailia Canal and its branches in spring and autumn 2011.

	Spring	Autumn
Asplanchna sp.	-	188
Anuraeopsis fissa (Gosse, 1851)	7688	11000
Brachionus angularis Gosse, 1851	9563	1313
B. budapestinensis (Daday, 1885)	625	-
B. calyciflorus Pallas, 1766	9688	1063
B. caudatus Barrois &Daday,1894	15188	375
B. falcatus Zacharias, 1898	750	188
B. patulus (O.F. Müller, 1786)	-	1250
B. quadridentatus Hermann, 1783	375	1938
B. urceolaris Müller, 1773	1125	875
Cephalodella gibba (Ehrenberg, 1830)	125	313
Cephalodella sp.	438	1750
Collotheca pelegica (Rousselet, 1893)	126000	39125
Conochilus unicornis Rousselet, 1892	16438	313
Colurella uncinata (Müller, 1773)	313	1375
Epiphanes macroura (Barrois and Daday, 1894)	375	375
Euchlanis dilatata Ehrenberg, 1832	-	750
Filinia longisetea (Ehrenberg, 1834)	125	938
Hexarthra sp.	-	2938
Keratella cochlearis (Gosse, 1851)	475938	63563
K. tropica (Apstein, 1907*)*	35063	42000
K. quadrata (Müller, 1786)	125	-
Lecane bulla (Gosse, 1851)	438	1938
L. closterocerca (Schmarda, 1859)	125	-
L. hamata (Stokes,1896)	-	188
L. leontina (Turner,1892)	-	938
L. luna (Müller, 1776)	-	188
L. ungulata (Gosse, 1887)	-	125
Lecane sp.	-	188
Lepadella patella (O.F. Müller, 1786)	188	-
Philodina roseola (Ehrenberg,)	12813	32250
Polyarthra vulgaris Carlin, 1943	70625	25625
Scaridium longicaudum (Müller, 1786)	250	63
Synchaeta oblonga Ehrenberg, 1832	1250	125
Trichotria tetractis (Ehrenberg, 1830)	188	5438
Trichocerca longiseta Schrank, 1802	313	-
T. porcellus (Gosse, 1851)	-	813
T. pusilla (Jennings, 1903)	31938	5938
Trichocerca sp.	-	4438
Unidentified bdelloid	15125	-

Genus *Keratella* was represented by three species, only *Keratella cochlearis* dominated in all the sampling sites in the two examined seasons. It contributed 57.1% and 25.4 % of the total rotifers in spring and autumn. *Keratella cochlearis*, which is one of the most common representatives of the family Brachionidae and is known to inhabit a diverse range of waters (Pejler and Bērziņš 1989), is also believed to be the most common freshwater metazoan in the world (Koste 1978). *Keratella cochlearis* listed among the most dominant taxa in large rivers and lakes systems worldwide (Egborge and Tawari, 1987; Pace *et al*., 1992; Van Dijk and Van Zanten, 1995; May and Bass, 1998; Burger *et al*., 2002). *Keratella tropica* formed only 4.2 % of the total rotifers in spring and increased to constitute more than 16% in autumn. *Keratella* species has been indicated as an indicator of pollution (Bahura *et al.,* 1993).

Collotheca pelgica nearly contributed about 15% of the total rotifers in both seasons, although it attained its highest population density in spring (Table 2). In

Ismaillia Canal and different areas of River Nile *Collotheca* flourished in spring season (Helal, 1981; Bedair, 2006; Nassif, 2012). The population density of *Polyarthra vulgaris* increased in spring season to form about 8.5% of the total rotifers and its crop decreased in autumn but it constituted 10.3% of total rotifers. The species flourish in Ismailia Canal sites and gradually deceased in Suez Canal branch and attained its lowest occurrence in Port-Said branch. Nassif (2012) recognized *P. vulgaris* as the most dominant rotifer in Ismailia Canal and it highly flourished in organic matter enrichment area in front of petroleum companies. Stemberger (1990) reported *P. vulgaris* as a cosmopolitan truly planktonic rotifer and regarded as a good indicator of eutrophication. Also, *K. tropica*, *Filinia* and *Polyarthra* reported in polluted waters (Unni, 1986); on the contrary, *Polyarthra* spp. has been recorded as indicator of clean water with low temperature (Bahura *et al.* 1993). *Philodina roseola* peaked in autumn and formed about 13% of the total rotifers density and decreased in spring to form only 1.5 % of the total rotifers counts. Monterio *et al.*, (1995) recorded *Philodina sp.* in the most tolerant taxa to metal concentrations in the most contaminated zone in Soda River (Portugal). This species appeared more tolerant to the industrial waste in River Nile and might be used as indicators of industrial waste pollution (Khalifa, 2000).

At the studied area *Brachionus* was the most taxon-rich genus being represented by eight species; however their densities were very low throughout the study period, *B. caudatus*, *B. calyciflorus* and *B. angularis* dominated in spring. In River Nile and Ismailia Canal seven species of genus *Brachionus* (*B. angularis*, *B. calyciflorus*, *B. capsuliflorus*, B. *caudatus, B.falcatus, B. forficula and B. plicatlis*) have been described (Amer, 2007 and Nassif, 2012). The occurrence of *Brachionus* is related to water eutrophic conditions (Gannon and Stemberger, 1978and Sladecek, 1983). In Brazil, Sendacz *et al.*, (1985) associated the abundance of *Brachionus* to more eutrophic environments in reservoirs in South east of São Paulo State. Abdel Aziz and Aboul Ezz (2004) mentioned that *B. calyciflorus* prefers mixotrophic environments rich in nutrients.

Trichocerca represented by four species, among which *T. pusilla* dominated and detected in both seasons and it peaked in spring. *Anuraeopsis fissa* exhibited the maximum population density of 11 000 Ind. m^{-3} in autumn, this result was on the contrary with the study of Nassif (2012) which detected the peak of occurrence of *A. fissa* in spring. This species was considered among pollution indicators in Lake Maryout (Abdel Aziz and Aboul Ezz, 2004). *Lecane* was represented by seven species, they had low density throughout the period of study, all of which were present in autumn, except *L. closterocerca* which appeared in spring and the dominant form *L. bulla* detected in both seasons. Sulehria and Malik (2012) found the population density and species diversity of *Lecane*, *Lepadella* and *Synchaeta* increased in the cold months and decreased in the warm months. Other rotifers' species detected in the study area were present in low densities in one season or both (Table 2). Sulehria and Malik (2012) recorded *Lecane*, *Epiphanus*, *Lepadella* and *Synchaeta* became more abundant with increase in eutrophication and other genera such as *Brachionus*, *Cephalodella*, *Filinia*, *Philodina*, *Polyarthra* and *Trichocerca* were also present with low density.

Conclusion

In autumn, rotifers population density and species richness were positively correlated with water temperature and transparency, while a negative relation was detected with electric conductivity in both seasons. In spring no clear relation was observed in response to the water physical and chemical characteristics and rotifers population dynamics, so its occurrence in this season may depend on algal abundance. The dominant rotifer species in Ismailia Canal and its two branches Suez and Port Said *Keratella cochlearis, Collotheca pelagica*, *Polyarthra vulgaris and Brachionus* spp. are eutrophic indicator species. Thus, the community composition of the rotifers indicates that Ismailia Canal and its two branches are highly eutrophic and shows signs of partial pollution.

Acknowledgments
The author is most grateful to Inland Water and Aquaculture Branch, National Institute of Oceanography and Fisheries, Cairo, Egypt, which funded this work through a project entitled "Environmental and chemical studies on Ismailia Canal, River Nile, Egypt". The author also wishes to express her sincere thanks to the chemistry laboratory for providing some chemical data.

References

Abd El-Hady HH, Hussian AM. 2012. Regional and Seasonal Variation of Phytoplankton Assemblages and its Biochemical Analysis in Ismailia Canal, River Nile, Egypt. Journal of Applied Sciences Research **8(7)**, 3433-3447.

Abdel Aziz NE. 2005. Short-term variations of zooplankton community in the west Naubaria Canal, Alexandria, Egypt. Egyptian Journal of Aquatic Research **31,** 119-131.

Abdel Aziz NE, and Aboul Ezz SM. 2004. The structure of zooplankton community in Lake Maryout, Alexandria, Egypt. Egyptian Journal of Aquatic Research **30,** 160-170.

Abdo MH, Goher ME, Sayed MF. 2012. Environmental evaluation of Ismailia Canal water and sediment, Egypt. Journal of Egyptian Academic Society for Environmental Development **13(2),** 61-78.

Amer AS. 2007. Effect of different types of pollutants o Bacteria-zooplankton interaction in the Nile water. PhD Thesis, Faculty of science, zoology department, Girls College, Ain Shams University.

APHA. 1998. *Standard Methods for the Examination of water and waste water,* 20th edn., Lenore, S. C., Arnold, E.G. and Andrew, E. E. (Eds.), Washington, 543.

Armengol X, Miracle MR. 1999. Zooplankton communities in doline lakes and pools, in relation to some bathymetric parameters and physical and chemical variables. Journal of Plankton Research **21 (12),** 2245–2261.

Bahura CK, Bahura P, Saxena MM. 1993. Zooplankton community of Shivbari temple tank, Bikaner. Journal of Ecology **5,** 5-8.

Bedair SM. 2006. Environmental studies on zooplankton and phytoplankton in some polluted areas of the River Nile and their relation with feeding habit of fish. PhD Thesis, Faculty of science, Zagazig University, Egypt.

Burger DF, Hogg ID, Green JD. 2002. Distribution and abundance of zooplankton in the Waikato River, New Zealand. Hydrobiologia **479,** 31-38.

Casanova SMC, Panarelli EA, Henry R. 2009. Rotifer abundance, biomass, and secondary production after the recovery of hydrologic connectivity between a river and two marginal lakes (São Paulo, Brazil). Limnologica **39,** 292–301.

Egborge ABM, Tawari P. 1987. The rotifers of WarriRiver, Nigeria. Journal of Plankton Research **9,**1-14.

Fathi AA, Al-Kahtani M A. 2009. Water Quality and Planktonic Communities in Al-Khadoud Spring, Al-Hassa, Saudi Arabia. *American Journal of Environmental* Sciences **5 (3),** 434-443.

Fathi AA, Kobbia IA. 2000. Hydrobiological investigation of Abou-Median lake, El-Minia, Egypt. Bullten of Faculty of Science of Assiut University **29,** 77-91.

Gannon JE, Stemberger RS. 1978. Zooplankton especially crustaceans and rotifers as indicators of water quality. Transactions of the American Microscopical Society **971,** 16-35.

Helal HA. 1981. Studies on the Zooplankton of Damietta Branch of the River Nile North of El-Mansoura. M Sc Thesis, Faculty of Science, Mansoura University.

Hoffman W. 1977. The influence of abiotic environmental factors on population dynamics in planktonic rotifers. Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie **8,** 77–83.

Kaya M, Segers DFH, Altindağ A. 2010. Temperature and salinity as interacting drivers of species richness of planktonic rotifers in Turkish continental waters. Journal of Limnology **69(2),** 297-304.

Khalifa NS. 2000. Study on the impact of industrial wastes at Helwan on River Nile zooplankton. Ph D Thesis, Faculty of science, Cairo University, Egypt.

Kobbia IM, Metwali RM, El-Adel HM. 1995. Influence of water effluents of soap and oil factory at Benha on Nile phytoplankton communities. Egyptian Journal of Botany **35,** 45-57.

Koste W. 1978. Rotatoria. Die Rädertiere Mitteleuropas. Gebrüder Borntraeger **1(2),** Berlin, 673 pp + 234 pl.

Lair N. 2005. Abiotic vs. biotic factors: lessons drawn from rotifers in the Middle Loire, a meandering river monitored from 1995 to 2002, during low flow periods. Hydrobiologia **546,** 457-472.

Lieberman DM, Grabowski SJ. 2007. Physical, Chemical, and Biological Characteristics of Cle Elum and Bumping Lakes in the Upper Yakima River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Series No. PN-YDFP-005, Bureau of Reclamation, Boise, Idaho, March 2007.

May L, Bass JAB. 1998. A study of rotifers in the River Thames, England, April–October, 1996. Hydrobiologia **387(388),** 251-257.

Monterio MT, Oliveira R, Vale C. 1995. Metal stress on the plankton communities of Sado River (Portugal). Water Research **29,** 695-701.

Nassif MG. 2012. Ecological studies on aquatic invertebrates of Ismailia Canal, Egypt. M Sc Thesis, Faculty of science, Ain Shams University, Egypt.

Pace ML, Findlay SEG, Lints D. 1992. Zooplankton in advective environments: The Hudson River community and a comparative analysis. Canadian Journal of Fisheries and Aquatic Sciences **49,** 1060–1069.

Pejler B, Bērziņš B. 1989. On chice of substrate and habitat in brachionid rotifers. Hydrobiologia **186(187),** 137–144.

Sendacz S, Kubo E, Cestarolli MA. 1985. Limnologia de reservatórios do sudeste do Estado de São Paulo, Brasil. VII. Zooplâncton. Boletim do Instituto de Pesca **12,**187-207.

Shayestehfar A, Soleimani M, Mousavi SN, Shirazi F. 2008. Ecological study of rotifers from Kor river, Fars, Iran. Journal of Environmental Biology **29(5),** 715-720.

Sladecek V. 1983. Rotifers: an index of water quality. Hydrobiologia **100,** 169-201.

Stahl R, Ramadan AB. 2008. Environmental Studies on Water Quality of the Ismailia Canal, Egypt. Scientific Report, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft Wissenschaftliche Berichte FZKA 7427.

Stemberger RS. 1990. An inventory of rotifer species diversity of northern Michigan inland Lakes. Archiv für Hydrobiologie **118,** 283-302.

Sulehria AQK, Malik MA. 2012. Population dynamics of Planktonic Rotifers in Balloki Headworks. Pakistan Journal of Zoology **44(3),** 663-669.

Unni S. 1986. Biological indicators of water pollution. Abst. Inter. Workshop on Surf. Water Mang. Bhopal, M. P.

Van Dijk G M, Van Zanten B. 1995. Seasonal changes in zooplankton abundance in the lower Rhine during 1987-1991. Hydrobiologia **304,** 29-38.

Wrona EJ, Cash KJ. 1996. The ecosystem approach to environmental assessment: moving from theory practice. Agu. Ecosys. **5,** 89-97.