International Journal of Applied Environmental Sciences
ISSN 0973-6077 Volume 11, Number 2 (2016), pp. 683-700

http://www.ripublication.com

Composition and Biodiversity of Zooplankton and Macrobenthic Populations in El-Rayah El-Menoufy, Egypt

Nehad Khalifa[*] and Reda E. Bendary

National Institute of Oceanography and Fisheries,
101 Kasr Al Ainy, P. C. 11694, Cairo, Egypt.
[*]Corresponding author: E-mail: nehadkhalifa@hotmail.com

Abstract

Due to the importance of irrigation canals of River Nile as a source of drinking and irrigation water; an ecological study was carried out to show the abundance and diversity of zooplankton and macrobenthic invertebrates in relation to some environmental variables in El-Rayah El-Menoufy (one of the main irrigating canals of Nile Delta). The study also aimed to assess the seasonal changes in zooplankton and macrobenthos species richness, evenness and diversity. A sharp increase in total zooplankton density in spring season (average, 1868 Ind. l^{-1}) and a marked decrease in summer and winter seasons with average of 203 and 54 Ind. l^{-1} respectively, suggests seasonal changes in the trophic conditions of El-Rayah El-Menoufy water. Rotifers formed a main component of zooplankton which indicates eutrophic state of El-Rayah El-Menoufy. *Keratella cochlearis* was the main rotifer in spring and winter, *Brachionus calyciflorus* and *Epiphanes macrura* dominated in summer and *Collotheca pelagica* flourished in spring and autumn seasons. *Vorticella campanula* was the most abundant protozoan; it appeared in spring, summer and autumn with highest population density of 149 Ind. l^{-1} in autumn. Macrobenthic invertebrates was represented by three groups; Mollusca (9 species), Annelida (4 species) and Arthropoda (3 species). Low taxon richness of macroinvertebrate in sediment of El-Rayah El-Menoufy with 16 species; may be due to pollution discharged from cites and cultivated lands. Among molluscs, *Cleopatra bulimoides* was the most dominant species except in summer season, *Melanoides tuberculata* flourished in summer and autumn, *Corbicula fluminalis* and *Theodoxus niloticus* were common. The predominance of oligochaetes due to the abundance of *Limnodrilus udekedmianus* during the study period and it was the sole form of annelids in autumn season. *Chironomus* sp. was the most common arthropod and it highly

flourished in summer at sites had relatively low dissolved oxygen values. The Principal Component Analysis (PCA) showed that the dominant zooplankton species were struggle ones that can tolerate changes in physico-chemical variables. The PCA indicated that most of macrobenthos species were positively influenced by temperature and pH and negatively with Electrical Conductivity (EC) and Dissolved Oxygen (DO) of El-Rayah El-Menoufy water.

Key words: River Nile, El-Rayah El-Menoufy, irrigation canals, Rotifera, Protozoa, Macrobenthic invertebrates.

INTRODUCTION

Irrigation in Egypt mainly depends on River Nile water through a system of main canals and rayahs, secondary canals, third order and meskas [1]. These irrigation canals are widespread over the Nile Delta area and it run towards the Mediterranean coastal plain and discharge their water into the northern lakes or the sea [2]. The main use of irrigations canals and rayahs is drinking, irrigation, navigation and fishing purposes likewise the River Nile.

El-Rayah El-Menoufy is one of four rayahs are branched from the Nile at the Delta Barrages, it starts from Rosetta branch at El-Kanater El-Khayria city and extends into the middle of Delta breaking Menofeya, Dakahlia and Gharbiah governorates, then heading north even Gamasa city and the south of Lake Burullus.

Sources of pollution in the Nile system (irrigation and drainage canals and rayahs) include the extensive use of chemicals (herbicides, pesticides and fertilizers), industrial effluents, domestic sewage and refuse, oil pollution and agricultural drainage. This subsequently, contributes to water pollution with a lot of negative effects on aquatic fauna and flora.

Macrobenthic invertebrates and zooplankton are major components in the tropic dynamics of freshwater ecosystems. They not only regulate the aquatic productivity by occupying intermediate position in the food chain, but they also indicate the environmental status in given time [3].

Due to the importance of rayahs as a source of drinking and irrigation water, the present study of zooplankton and macrobenthic invertebrates aimed to investigate its species composition, distribution and seasonal changes related to some environmental variables in water body of El-Rayah El-Menoufy. The study also aimed to assess the seasonal changes in zooplankton and macrobenthos species richness, evenness and diversity.

MATERIAL AND METHODS

Study Area

The length of El-Rayah El-Menoufy is about 200 Km beginning from El-Kanater El-Khayria city with average width 40-50 m and average depth 2-3 m. This Rayah is characterized by the existence of many drinking water plants and electrical power

stations on its banks. Seven sampling sites were chosen along El-Rayah El-Menoufy (Fig. 1) during four seasons from spring 2014 to winter 2015 and described as follow: M1 (El-Kanater El-Khayria City), M2 (Middle of agricultural and residential regions), M3 (Shebeen El-Koum City), M4 (El Santa City), M5 (receives water from Damietta branch), M6 (El Mahalla City) and M7 (Middle of agricultural regions and Before bifurcation of El-Rayah to small branches).

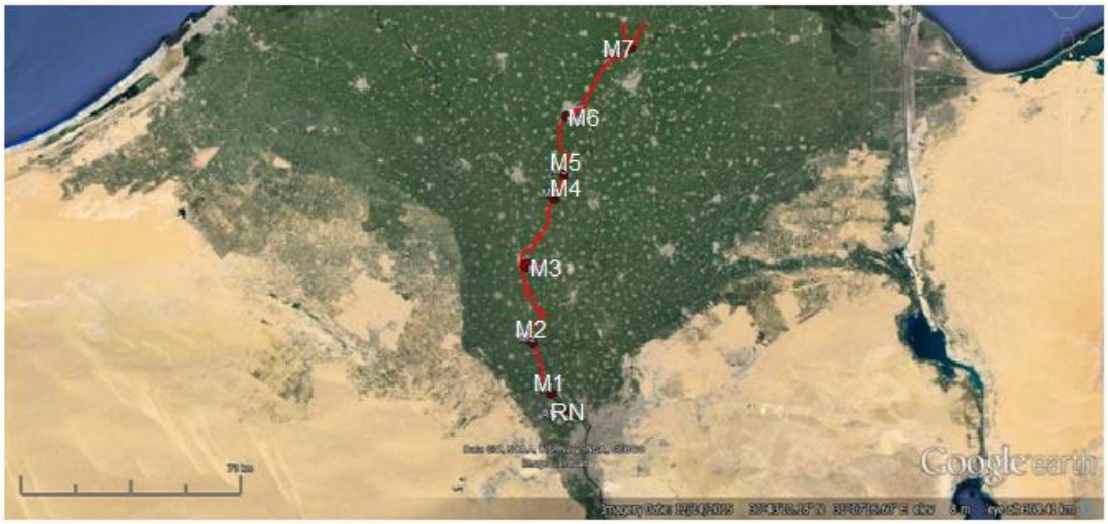

Figure 1: Location of Sampling Sites in El-Rayah El-Menoufy. (RN: River Nile).

Physico-chemical Parameters

At each sampling site, the following environmental variables were measured *in situ*: water temperature, pH and Electrical conductivity (EC) by using the Hydrolab (Multi Set 430i 126 WTW). Dissolved oxygen (DO) was measured by using the modified Winkler method.

BIOTIC PARAMETERS

Qualitative and Quantitative Analysis of Zooplankton

Zooplankton samples were collected by filtering an approximate volume of 30 liters of water from the littoral zone through 55 µm mesh plankton net. Each collected sample was transferred to a labeled clean bottle and fixed with 4% formaldehyde. Samples were brought to the laboratory for identification mainly following the following references[4-7] in addition to the World Wide Web. Zooplankton numbers were expressed as number of organisms per liter.

Qualitative and Quantitative Analysis of Macrobenthic Invertebrates

Macrobenthos samples were collected from all sampling sites during the study period (except at site M1 in spring). Samples were collected using Ekman grab sampler with opening area of 225 cm2. Three grabs samples were taken from each site from the

upper layer of the bottom sediments. The samples were immediately washed to remove any adhering sediments or mud and sieved through 500 μm mesh diameter net and stored in polyethylene jars carrying the relevant date and mixed with 10% neutral formaldehyde solution. In the laboratory, the samples were washed and sieved again through 0. 5 mm mesh diameter net. Benthic animals were sorted to their genera or species using a zoom stereo microscope. Every species was kept in a glass bottle with 7% formalin for identification. The main references used in macroinvertebrate identification were [8-14].

STATISTICAL ANALYSIS

The diversity indices of zooplankton and macrobenthos species were seasonally calculated as Species Richness, Shannon-Weaver Diversity Index and Index of Evenness by using Primer 5 (2001); the indices were calculated at individual species level. Principal component analysis (PCA) between different zooplankton and macroinvertebrate main species and environmental variables at the study area was performed using XLSTAT 2015. 1.

RESULTS AND DISCUSSION

Environmental Characteristics:

The physico-chemical data during the study period are presented in table 1. Temperature effects directly or indirectly not only on the survival and distribution of aquatic organisms, but also on their growth, activity, development, activation of reproduction processes and susceptibility to diseases [15]. During the study water temperature ranged from 14. 5 to 31. 6°C with the minimum value in winter and the maximum in summer; it showed high positive correlation with pH (r = 0. 863). The values of pH at the studied area were in the alkaline side (7. 9-8. 6) with small local and seasonal differences and it increased to an average of 8. 53 in summer. Alkaline pH helps flourishment and growth of zooplankton and macrobenthic invertebrates [16]. Factors such as dissolved oxygen, algal photosynthetic activity, temperature, sewage discharge, decomposition of organic matter and others related to geology of the under-laying sediment may control the pH values of water [17]. During the study the pH values were negatively correlated with DO and EC (r =-0. 637;-0. 526). Electrical conductivity values in El-Rayah El-Menoufy ranged between 352 and 466 μs/cm. The highest values of EC was detected at sites M5, M6 and M7 during autumn and winter and decreased to lowest readings in spring and summer, EC negatively correlated with water temperature (r =-0. 637). The lowest value of EC during spring and summer in Rosetta branch of River Nile may be attributed to the increase of water level during flood period and uptake of dissolved salts by phytoplankton [18]. Electrical conductivity (EC) and total dissolved salt are important factors affecting zooplankton distribution [19]. Dissolved oxygen is an important factor in assessment the degree of water pollution [20]. Dissolved oxygen values varied from minimum average of 6. 05 mg/l in summer season to highest of 8. 15 mg/l in winter. The elevation of water temperature and increase in oxidative processes of organic matter

may be the reason in decrease of DO values in summer [21]. Also, the increase of DO at low water temperature may be due to the high solubility of oxygen and the activities of wind action which allow transfer of more oxygen across the air-water interface [20].

Table 1: Seasonal Variations of Physico-chemical Parameters of El-Rayah El-Menoufy.

Parameter	Spring	Summer	Autumn	Winter
Water Temperature (ºC)	27. 7±1	30. 4±0. 98	22. 5±0. 59	15. 6±0. 58
pH	8. 35±0. 14	8. 53±0. 07	8. 35±0. 08	8. 09±0. 06
Electrical Conductivity (µS/cm)	378. 29±20. 7	367. 14 ±14. 6	430. 71±21. 2	427. 14±25
Dissolved Oxygen (mg/l)	7. 06±0. 8	6. 05±0. 6	6. 52±1. 4	8. 15±1. 5

Zooplankton Community Composition

Zooplankton occupy an important position in pelagic food webs, as they transfer energy produced through photosynthesis from phytoplankton to higher trophic levels (fish) consumed by humans. They are also play role in determining the composition and amount of particles sinking to the benthos, which provides a food source for benthic organisms and participate to burial of organic compounds [22]. Rotifers were the dominant group (78. 6%), followed by Protozoa (16. 8 %). Similar domination of rotifers was observed in different segments of River Nile and its branches [23-28]. The dominance of rotifers over other zooplankton groups in many tropical water bodies may be due to high predation pressure by fish larvae on microcrustaceans [29]. Also, the dominance of rotifers, almost at all sites of the longest lake in Poland, indicates an eutrophic state of the lake [30]. Rotifera and Protozoa were the most dominant among zooplankton in Dahab and El-Warrak islands along River Nile [26]. Rotifers formed a main component of freshwater zooplankton and significantly contribute to their dynamics and production [31]. In this work the remarkable increase in the average density of rotifers from 22 Ind. l^{-1} in winter to 1572 Ind. l^{-1} in spring (Fig. 2), suggests seasonal changes in the trophic conditions of El-Rayah El-Menoufy water. Abundance of rotifers populations has been reported to be a more sensitive indicator of changes in trophic state of water than rotifer species composition [32].

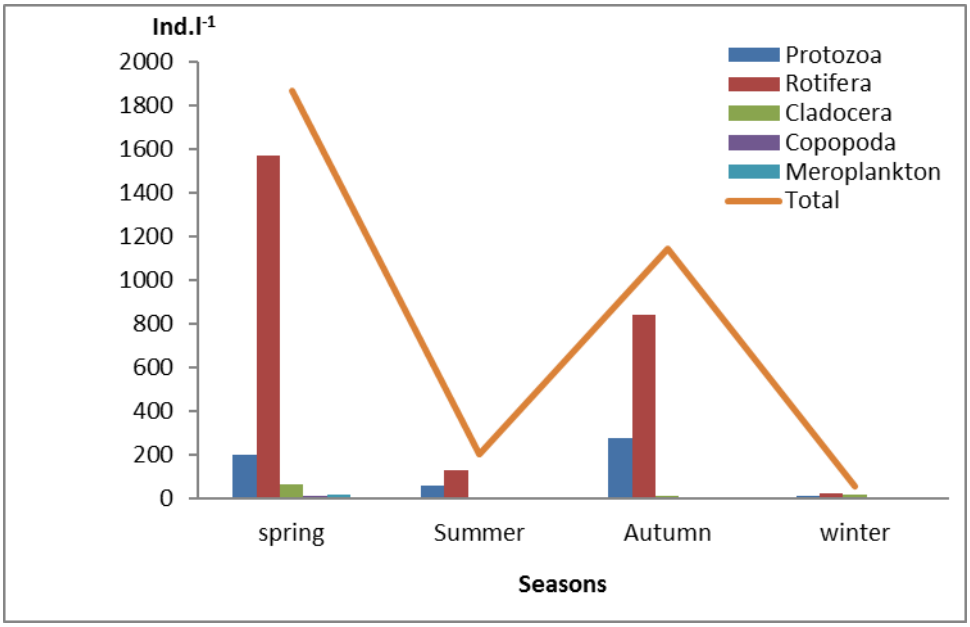

Figure 2: Seasonal Variations of Zooplankton Groups in El-Rayah El-Menoufy.

Genus *Keratella* was the dominant rotiferan genus during spring and winter seasons, It contributed about 44. 5%, 49% of the total rotifers populations respectively (Table, 2), it was represented by *K. cochlearis* and *K. tropica*. *Keratella cochlearis* constituted about 29% of rotifers with high average density of 463 Ind. l^{-1} in spring and 44 % of total Rotifera with least average count of 10 Ind. l^{-1} in winter. *Keratella cochlearis* is one of the most common representatives of the family Brachionidae and is known to inhabit a diverse range of waters [33]. *Keratella cochlearis* is an euplanktonic, eurithermic species, very common in lakes and reservoirs and tolerates a wide range of mineralization [34], it feeds on a variety of algae, organic detritus and bacteria [35], it attained a negative correlation with EC during the present study (r=-416). Also, *Keratella* species has been indicated as an indicator of pollution [36]. *Brachionus* was the most taxon-rich genus being represented by eight species, *B. calyciflorus* and *Epiphanes macrura* dominated in summer each formed about 13 % of the total Rotifera with a density of 17 Ind. l^{-1} (Table, 2). The occurrence of *Brachionus* is related to eutrophic condition of water [37-38], also the high richness of Brachionidae indicates eutrophic conditions [39]. The study of [40] recorded rotifer as indicator of water pollution and described *Keratella* sp. and *Brachionus* sp. pollution indicator species. *Collotheca pelagica* nearly contributed about 30% of the total rotifers during the study period. Although *C. pelagica* attained its highest percentage of about 44% of total rotifer with a population density of 367 Ind. l^{-1} in autumn, its density slightly increased in spring to reach 394 Ind. l^{-1} to form about 25 % of total rotifers (Table, 2), it sharply declined in winter to count only 1 Ind. l^{-1}. *Collotheca pelagica* flourished in spring season in Ismaillia Canal [41, 42], it is a typical form of large water bodies, cosmopolite, euplanktonic and warm water species [34].

Table 2: Seasonal average density (Ind. l^{-1}) and percentage to the total group of most frequently recorded species in zooplankton groups in El-Rayah El-Menoufy.

Group	Spring	density	%	Summer	density	%	Autumn	density	%	Winter	density	%
Rotifera	*Keratella Cochlearis*	463	29.4	*Brachionus Calyciflorus*	17	13.0	*Colltheca pelagica*	367	43.5	*Keratella cochlearis*	9.7	44.0
	Colltheca Pelagic	394	25.1	*Epiphanes Macrura*	17	13.0	*Trichocerca* spp.	147	17.4	*Polyarthra vulgaris*	2.9	13.2
	Keratella tropica	237	15.08	*Colltheca pelagica.*	16	12.4	*Keratella tropica*	124	14.8	*Conochilus* sp.	2.2	10.0
				Trichocerca spp.	16.7	12.7	*Polyarthra vulgaris*	76	9.0	*Philodina roseola*	1.5	6.7
							Brachionus calyciflorus	59	7.0			
Protozoa	*Vorticella Campanula*	120	59.6	*Vorticella Campanula*	50	83.5	*Vorticella campanula*	149	54.5	*Vorticella campanula*	5	33.6
	Difflugia spp.	24	11.8				*Acineta* spp.	44	16	*Sphenoderia* sp.	2	13.9
Cladocera	*Bosmina longirostris*	31	47.0	*Ceriodaphnia* sp.	2	57	*Bosmina Longirostris*	5.5	47.5	*Bosmina longirostris*	9.8	61.7
	Ceriodaphnia sp.	16	24.8				*Ceriodaphnia* sp.	3.7	32.5	*Chydorus sphaericus*	2.6	16.3
	Chydorus sphaericus	5	8.1									

The population density of *Polyarthra vulgaris* increased in autumn and winter seasons to form about 9 and 13 % of the total Rotifera with densities of 76 and 29 Ind. l^{-1} respectively. *Polyarthra vulgaris* is cosmopolitan truly planktonic rotifer and regarded as a good indicator of eutrophication [43], it is euplanktonic, euritherm and perennial species; prefers well oxygenated and superficial waters environments [34].

Other rotifers' genera detected in the study area such as *Lecane*, *Filinia*, *Philodina* and *Trichocerca* present with low densities, these species became more abundant with increase in eutrophication.

Protozoa attained an overall average of 137 Ind. l^{-1}, it cropped the highest population density of 274 Ind. l^{-1} in autumn season (Fig. 2). *Vorticellac campanula* was the most abundant protozoan and it contributed about 59% of the total Protozoa populations, it flourished in spring, summer and autumn with highest population density of 149 Ind. l^{-1} in autumn (Table, 2). The study of [44] considered ciliated protozoan, *Vorticella campanula* as one of species which are indicators of high water pollution status. Also species of *Difflugia* spp. and *Centropyxis oculeata* were common among protozoa in the water samples of El-Rayah El-Menoufy.

Cladocera rarely recorded during the study period except in winter where it formed about 29% of total zooplankton with an average density of 16 Ind. $l^{-1}$and its density increased to 65 Ind. l^{-1} which only formed about 3. 5% of the total zooplankton community in spring. *Bosmina longirostris* dominated and constituted about 49 % of the total cladoceran populations and it nearly disappeared in summer, it was reported as an indicator of eutrophic lakes [45]. Copepoda are sparse among the zooplankton of El-Rayah El-Menoufy during the study, it was mainly composed of its larval form (nauplii). Main zooplankton species detected in the studied area previously recorded in different segments of River Nile and its two branches [24, 25, 27, 28].

Seasonal fluctuations in the total zooplankton crop in El-Rayah El-Menoufy and diversity indices of zooplankton species are shown in Table (3). A marked decrease in total zooplankton density in winter and it sharply increased in spring season. Zooplankton also attained the greatest species number (43 species) in spring season and consequently the highest species richness with maximum of 2. 983 and 2. 816 at M1 and M3 respectively. Species numbers, species richness and diversity index decreased to minimum in winter with least values of 6 species, 0. 524 and 1. 593 respectively at M5. Evenness was increased to the highest values in summer at sites M3 (0. 906) and M4 (0. 958) and in winter at M4 (0. 931); it decreased at all sampling sites in autumn season. The highest species diversity index reached 2. 801 at M5 in summer season.

Table 3: Seasonal variations in zooplankton density (ind.l^{-1}) and diversity indices values in El-Rayah El-Menoufy.

Sampling sites	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Spring							
Population density	1300	3096	3006	1428	1422	1827	999
No. of species (s)	43	41	43	40	36	40	37
Species richness (d)	2. 983	2. 676	2. 816	2. 752	2. 47	2. 705	2. 606
Evenness (J´)	0. 613	0. 631	0. 676	0. 670	0. 761	0. 728	0. 703
Diversity index (H´)	2. 306	2. 344	2. 544	2. 47	2. 727	2. 684	2. 538
Summer							
Population density	360	297	144	57	213	216	135
No. of species (s)	19	24	20	10	25	20	19
Species richness (d)	1. 407	1. 825	1. 600	0. 822	1. 956	1. 547	1. 524
Evenness (J´)	0. 772	0. 821	0. 906	0. 958	0. 870	0. 862	0. 868
Diversity index (H´)	2. 274	2. 611	2. 713	2. 205	2. 801	2. 581	2. 557
Autumn							
Population density	2404	876	1002	615	1293	1089	714
No. of species (s)	30	23	32	20	26	26	25
Species richness (d)	1. 974	1. 608	2. 244	1. 425	1. 777	1. 798	1. 781
Evenness (J´)	0. 665	0. 664	0. 637	0. 677	0. 607	0. 649	0. 646
Diversity index (H´)	2. 262	2. 083	2. 209	2. 027	1. 977	2. 114	2. 079
Winter							
Population density	95	115	48	14	14	52	41
No. of species (s)	19	17	17	10	6	21	16
Species richness (d)	1. 57	1. 373	1. 484	0. 943	0. 524	1. 842	1. 412
Evenness (J´)	0. 889	0. 752	0. 817	0. 931	0. 889	0. 849	0. 730
Diversity index (H´)	2. 619	2. 130	2. 316	2. 144	1. 593	2. 584	2. 024

Macrobenthic Invertebrates Community Composition

Benthic communities commonly used as indicator of ecological disturbance [46] due to easiness of sampling and their sensitivity to environmental changes. In aquatic ecosystems benthic macroinvertebrates used as essential food-web components that link of primary production to fisheries [47]. Sixteen macrobenthic invertebrates' species were identified in the present study belonging to three phyla, Mollusca (9 species) and Annelida (4 species) formed the most population density of the community contributed 46% and 45% of the total macrobenthic fauna respectively. Arthropoda had only 3 species which formed about 9% of the total benthic community. Very low taxon richness of macroinvertebrate were detected in sediment of El-Rayah El-Menoufy may be due to pollution discharges from cites and cultivated lands as a result of urbanisation and heavily population in the studied area or because most of these organisms are belonged to weed beds and sediments on the banks of the canals. Twenty-two molluscs taxa were recorded from clean area in River Nile; the number of species declined to only 5 species in area subjected to thermal stress comes out from electrical power station and to 9 species in area affected by chemical wastes of sugar factory [48]. The total population density of macrobenthic invertebrates in El-Rayah El-Menoufy during the study period was 854 Ind. m^{-2}, the highest average density was in summer (1543 Ind. m^{-2}), due to intensive numbers of Annelida, while the lowest values of 546 and 539 Ind. m^{-2} were in spring and autumn respectively (Fig. 3).

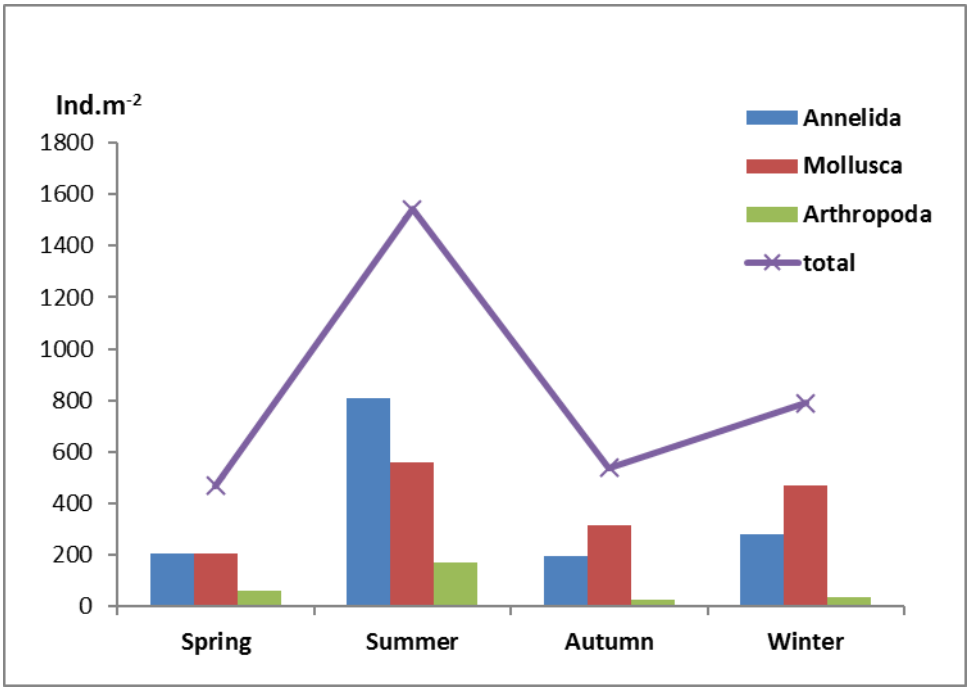

Figure 3: Seasonal Variations of Macrobenthic Groups in El-Rayah El-Menoufy.

In Egypt molluscs play an important role in fresh water ecosystem and some of their members were recently incriminated in transmitting serious human diseases [14]. In the present study Mollusca group dominated at many sites, it showed the highest densities at sites 1 and 4 with average values of 763 and 756 Ind. m^{-2} respectively; its numbers sharply decreased to 69 Ind. m^{-2} at site 6. Freshwater Mollusca are known to exhibit high degree of tolerance and adaptation within a reasonable range of physicochemical fluctuation [49-51]. Mollusca attained the highest species number of 7 species in autumn season. Some studies found that the species richness and diversity of molluscan community reach the maximum level in spring and summer months [52], others reported that the snail abundance was high in spring and low in summer [53]. While, the study of [54] recorded thirteen species of Mollusca in Qena Governorate with high snail population in autumn. In an aquatic ecosystem the seasonal changes play a major role in structuring the benthic community [55]. In El-Rayah El-Menoufy, *Cleopatra bulimoides* was the most dominant species during the study period except in summer season, *Melanoides tuberculata* flourished in summer and autumn, *Corbicula fluminalis* and *Theodoxus niloticus* were common among molluscs (Table, 4). The constant species recorded in the benthic mollusc communities of River Nile and its branches at Assiut governorate, Egypt were *Cleopatra bulimoides, Lanistes varicus, Lanistes carinatus, Melanoides tuberculata* and *Caelatura aegyptiaca*, while *Corbicula fluminalis* and *Theodoxus niloticus* with other fifteen species were among the accessory species [52]. The study of [56] found the maximum reproduction of *Melanoides tuberculata* between June and November and the most important cohort of young snails appeared in June and it grow slowly with long life span.

Table 4: Density (Ind. m^{-2}) and percentage of most frequently recorded macrobenthos species in El-Rayah El-Menoufy water during the study.

Group	Spring	density	%	Summer	density	%	Autumn	density	%	Winter	density	%
Mollusca	*Cleopatra Bulmoides*	61	29. 8%	*Melanoides tuberculata*	246	43. 9%	*Cleopatra bulimoides*	96	30. 7%	*Cleopatra bulimoides*	246	52%
	Bellamya unicolor	54	26. 3%	*Bulinus truncates*	164	29. 3%	*Melanoides tuberculata*	96	30. 7%	*Corbicula fluminalis*	114	24%
	Corbicula fluminalis	21	10. 5%	*Theoduxus nilotcus*	82	14. 6%	*Theoduxus nilotcus*	36	11. 4%	*Theoduxus nilotcus*	36	8%
	Theoduxus nilotcus	21	10. 5%	*Cleopatra bulimoides*	57	10. 2%	*Lanistes carinatus*	36	11. 4%			
	Melanoides tuberculata	21	10. 5%									
Annelida	*Limnodrilus udekedmianus*	196	96. 5%	*Limnodrilus udekedmianus*	696	85. 9%	*Limnodrilus udekedmianus*	196	100%	*Limnodrilus udekedmianus*	229	81%
	Helobdella conifera	4	1. 8%	*Branchiura sowerbyi*	100	12. 3%				*Helobdella conifera*	29	10%
	Branchiura sowerbyi	4	1. 8%	*Helobdella conifera*	14	1. 8%				*Branchiura sowerbyi*	18	6%
Arthropoda	*Pentaneura* sp.	32	52. 9%	*Chironomus* sp.	161	93. 8%	*Pentaneura* sp.	18	62. 5%	*Chironomus* sp.	36	100%
	Chironomus sp.	29	47. 1%	Oxyethira sp.	11	6. 2%	*Chironomus* sp.	11	37. 5%			

Annelida showed the highest density in the site 1 with average value of 781 Ind. m^{-2} and it decreased to its lowest average density in the site 5 (150 Ind. m^{-2}). Annelida

density highly increased in summer season mainly due to the abundance of oligochaete *Limnodrilus udekedmianus* which formed about 86 % of the total group, it also dominated in the other seasons and it was the sole form of annelids in autumn (Table, 4). The dominance of *L. udekedmianus* may be attributed to soft muddy substratum which is suitable for oligochaetes [57], or to their ability to adapt to various habitats and the tolerance to oxygen depletion accompanied with excess decomposable organic matter [58]. The study of [41] mentioned that the variation in temperature not determined as a factor limit distribution of *L. udekedmianus*. The distribution of *L. udekedmianus* was mostly confined to summer and early autumn in Lake Nasser due to the increase of sediment organic carbon [59]. The study of [60] reported that the oligochaetes are truly cosmopolitan and widely distributed among different habitats**.**

In El-Rayah El-Menoufy, Arthropoda was represented by *Chironomus* sp., *Pentaneura* sp. and *Oxyethira* sp. It showed the highest average value of 171 Ind. m^{-2} in summer season due to the dominance of *Chironomus* sp. which formed about 94% of the total group (Table, 4). *Chironomus* sp. highly flourished at site 6 in summer to reach 500 Ind. m^{-2}, this site had relatively low dissolved oxygen value of 5. 8 mg/l. In warmer waters suitability for arthropods affected by oxygen concentrations and most of them can't live under anoxic conditions, but some chironomid midges can thrive at very low oxygen concentrations by using hemoglobin (vs. hemocyanin) and by following anaerobic metabolic pathways [61].

Seasonal fluctuations in the total macrobenthic invertebrates in El-Rayah El-Menoufy and diversity indices of its species were shown in Table (5). The highest species number was detected in spring season; it ranged from 2 to10 species. In Egypt benthic macroinvertebrate species richness amounts to about 7-31 species at individual bank-side sites of River Nile and its delta [62]. High species richness of 1. 177 and in turn the maximum species diversity index value of 1. 894 were detected at M4 in spring. *Limnodrilus udekemianus* was the only species detected at M6 and M7 in autumn. Evenness values differed slightly between particular sampling sites in each season, but it increased at most sites in spring and sharply declined at site M3 (0. 235) which also attained the least species richness of 0. 154 in autumn.

Table 5: Seasonal variations in macrobenthic invertebrates' density (Ind. m^{-2}) and diversity indices values in El-Rayah El-Menoufy.

Sampling sites	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Spring							
Population density	-	275	125	2100	275	225	275
No. of species (s)	-	2	4	10	3	2	5
Species richness (d)	-	0. 178	0. 621	1. 177	0. 356	0. 185	0. 712
Evenness (J´)	-	0. 440	0. 961	0. 823	0. 971	0. 991	0. 879
Diversity index (H´)	-	0. 305	1. 332	1. 894	1. 067	0. 687	1. 414
Summer							
Population density	3950	1425	800	1500	375	825	1925
No. of species (s)	3	5	5	3	3	4	5

Species richness (d)	0. 242	0. 551	0. 598	0. 274	0. 337	0. 447	0. 529
Evenness (J´)	0. 563	0. 773	0. 790	0. 669	0. 784	0. 771	0. 911
Diversity index (H´)	0. 618	1. 244	1. 271	0. 735	0. 861	1. 069	1. 466
Autumn							
Population density	925	1325	650	475	150	75	175
No. of species (s)	5	7	2	3	2	1	1
Species richness (d)	0. 586	0. 835	0. 154	0. 325	0. 200	0	0
Evenness (J´)	0. 881	0. 891	0. 235	0. 601	0. 650	0	0
Diversity index (H´)	1. 418	1. 734	0. 163	0. 661	0. 451	0	0
Winter							
Population density	1750	550	250	625	1025	925	400
No. of species (s)	7	3	3	6	7	3	3
Species richness (d)	0. 804	0. 317	0. 362	0. 777	0. 866	0. 293	0. 334
Evenness (J´)	0. 623	0. 743	0. 730	0. 850	0. 924	0. 774	0. 670
Diversity index (H´)	1. 211	0. 816	0. 802	1. 522	1. 798	0. 850	0. 736

PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (PCA) considering physical and chemical data beside the densities of main zooplankton and macrobenthos species for El-Rayah El-Menoufy is shown in figure (4). The first axes of the PCA explained 24. 95% of the variance and was positively correlated with *C. pelagica*, *K. cochlearis*, *K. tropica Brachionus* spp. and *B. longirostris*. Axes 2 explained 18. 15% of the variance; it was positively correlated with physico-chemical variables conductivity, temperature, dissolved oxygen, pH, and the tubificid *Branchiura sowerbyi*. The PCA indicated that most of macrobenthos species richness (except for *Corbicula fluminalis*, *Cleopatra bulmoides*) were positively influenced by temperature and pH and negatively with EC and DO of El-Rayah El-Menoufy water. Dissolved Oxygen and pH were the most effective variables on the species richness of Mollusca in River Nile at Luxor, Egypt [48]. Considering zooplankton species, the PCA showed that the dominant zooplankton species were struggle ones that can tolerate changes in physico-chemical variables. The study of [63] recorded the abundance of rotifers in waters with different physical and chemical variables at sites polluted with industrial, domestic and municipal wastes.

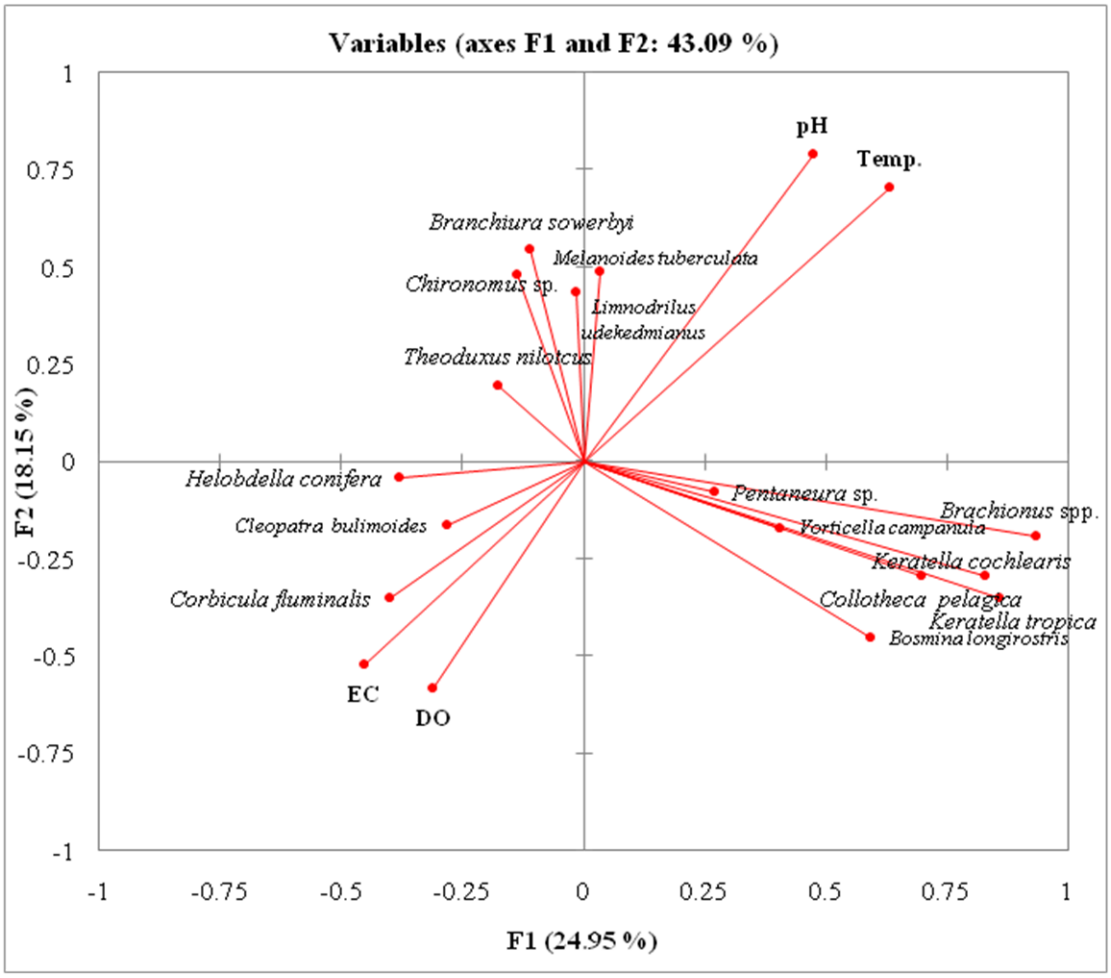

Figure 4: Principal Component Analysis (PCA) of Physico-chemical Variables and the Main Zooplankton and Macroenthos Species. Temp. : Temperature, EC: Electrical Conductivity and DO: Dissolved Oxygen.

CONCLUSIONS

El-Rayah El-Menoufy is considered as a source of water supply for drinking, irrigation and fishing. The present data indicated that the zooplankton density dominated by rotifers which are typical for eutrophic waters. An alarming state of El-Rayah El-Menoufy as the dominance of *Keratella cochlearis, K. tropica, Brachiouns calyciflours, Brachiouns angularis Polyarthra vulgaris, Vorticella campanula, Difflugia* spp., and *Bosmina longirostris* indicate high trophic status of the studies area as these species are indicators of eutrophication. Also, the uncontrolled growth of human population and activities in El-Rayah El-Menoufy lead to the decrease in macroinvertebrate species number and the loss of biodiversity which is considered a sign of polluted ecosystems.

REFERENCES

[1] Radwan, M. and El-Sadek, A., 2008, Water Quality Assessment of Irrigation and Drainage Canals in Upper Egypt, Proc. Twelfth Int. Conf. on Water Technology (IWTC12), Alexandria, Egypt, pp. 1239-1251.

[2] Elewa, H. H., 2010, Potentialities of Water Resources Pollution of the Nile River Delta, Egypt. The Open Hydrology Journal, 4, 1-13.

[3] Varsha, M. R., 2013, Studies on macrobenthos and seasonal variation with special reference to zooplankton diversity of Titwi Dam (Titwi) Dist-Buldana (M. S.). Trends in Life Sciences, 2(3), 37-40.

[4] Bick, H., 1972, Ciliated Protozoa: 198 pp. (An Illustrated Guide to the Species Used as Biological Indicators in Freshwater Biology), World Health Organization, Geneva.

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

[6] Dodson, S. I., Frey, D. G., 1991. Cladocera and Other Branchiopoda. In Ecology and Classification of North American Freshwater Invertebrates. 723-785. Academic Press, New York.

[7] Foissner, W. and Berger, H., 1996, A user-friendly guide to the ciliates (Protozoa, Ciliophora) commonly used by hydrobiologists as bioindicators in rivers, lakes and wastewaters with notes on their ecology. Freshwater Biology, 35, 375-482.

[8] Day, W. C., 1956, Ephemeroptera. In Usinger, R. L. (ed.), Aquatic Insecta of California. University of California Press, Los Angeles, 79-105.

[9] Walker, B., 1959, The Mollusca. In Ward, H. B. & G. C. Wipple (eds), Fresh Water Biology, 2nd ed. (ed. W. T. Edmondson). John Wiley and Sons. Inc., New York, pp. 957-1020.

[10] Brinkhurst, R. O. and Jamison, B. G. M., 1971, Aquatic Oligochaeta of the World. University of Toronto Press, Ontario 860 pp.

[11] Flemming, F., 1983, A Field Guide to Fresh Water Snails in Countries of the WHO Eastern Mediterranean Region. Danish Bilharziasis Laboratory, Charlottenlund.

[12] Brown, D. S., Fison, T., Southgate, V. R. and Wright, C. A., 1984, Aquatic snails of the jonglei region, southern Sudan and transmission of trematode parasites. Hydrobiologia 110, 247-271.

[13] Hussein, M. A., Kinzelbach, R. and El-Shimy, N. A., 1988, A key for freshwater Hirudinea of Egypt. Bulletin, Faculty of Science, Assiut University, Egypt 17(1-E), 29-43.

[14] Ibrahim, A. M, Bishai, H. M. and Khalil, M. T., 1999, Freshwater molluscs of Egypt. Publication of National Biodiversity No. 10.

[15] Moustafa, M. M., Ali, M. H. H., Abdel-Satar, A. M., Mohamed, T. Y. and Madbouly, S. M., 2010, Water quality assessment of Rosetta and Damietta branchs, River Nile, Egypt. African J. Biol. Sci., 6(2), 127-142.

[16] Sharma, K. K., Kour, S. and Antal, N., 2015, Diversity of zooplankton and macrobenthic invertebrates of two perennial ponds in Jammu Region. J. Glob. Biosc., 4(2), 1383-1393.

[17] Abdel-Satar, A. M., 1994, Studies on some environmental factors affecting the distribution of some chemical elements and productivity of River Nile at El-Kanater El-Khyria, M. Sc. Thesis, Faculty of Science, Cairo Univ., Egypt.

[18] Saad, S. M. M., El-Deeb, A. E., Tayel, S. I. and Ahmed N. A. M., 2011, Haematological and histopathological studies on *Claris gariepinus* in relation to water quality along Rossetta branch, River Nile, Egypt.. Egypt. J. Exp. Biol. (Zool.), 7(2), 223-233.

[19] Yildiz, S., Altindaú, A., and Ergönül, M. B., 2007, Seasonal Fluctuations in the Zooplankton Composition of a Eutrophic Lake: Lake Marmara (Manisa, Turkey). Turk. J. Zool. 31(2), 121-126.

[20] Mahmoud, S. A., Tayel, S. I. and Yacoub, A. M., 2008, Histopathological changes in kidneys of the fish *Tilapia zillii* and *Clarias gariepinus* under the effect of several pollutants along the River Nile. J. of the Egyptian German Society of Zoology, 56(C), 219-246.

[21] Abdel-Satar, A. M., 2005, Water quality assessment of River Nile from Idfo to Cairo. Egyptian J. Aqua. Rese. 3 (2), 200-223.

[22] http://www. vims. edu/cbnerr/_docs/research_docs/9SteinbergandCondonZooplanktonofYorkRiver. pdf.

[23] Ramadan, S. E., El-Serehy, H. A., Farghaly, M. E., and El-Bassat, R. A., 1998, Zooplankton community in the Nile River, Egypt. Bull. Nat. Inst. of Oceanogr. and Fish., 24, 139-159.

[24] Khalifa, N., 2000, Study on the impact of industrial wastesatHelwan on River Nile zooplankton. Ph. D. Thesis, Fac. Sci., Cairo Univ., Egypt.

[25] El-Shabrawy, G. M. and Khalifa, N., 2002, Zooplankton abundance and community structure in the northern part and estuary of Rosetta Nile branch in relation to some environmental variables. Egypt. J. Aquat. Biol. Fish., 6 (4), 69-90.

[26] Sleem, S. H. and Hassan, M. M., 2010, Impact of pollution on invertebrates biodiversity in the River Nile associated with Dahab and El-Warrak Islands, Egypt. International Journal of environmental Science and Engineering, vol. 1, 15-25.

[27] Khalifa, N. and Sabae, S. Z., 2012, Investigation on mutual relations between bacteria and zooplankton in Damietta Branch, River Nile, Egypt. Journal of Applied Sciences Research, 8(5), 2679-2688.

[28] Khalifa, N. and Sabae, S. Z., 2013, Seasonal variation and interaction between rotifers and bacteria in Rosetta Branch, River Nile, Egypt. Australian Journal of Basic and Applied Science, 7(2), 752-762.

[29] Nandini, S, Ramírez-García, P. and Sarma, S. S. S., 2015, Water quality indicators in Lake Xochimilco, Mexico: zooplankton and *Vibrio cholera*. Journal of Limnology, Under Publication.

[30] Dembowska, A. P. Napiórkowski, P. Mieszczankin, T. and Józefowicz, S., 2015, Planktonic indices in the evaluation of the ecological status and the trophic state of the longest lake in Poland. Ecological Indicators 56, 15-22.

[31] Sharma, B. K., 1991, Rotifera. In : Animal resources of India-State of art. ZSI Publication. pp. 69-88.

[32] May, L., and O'Hare, M., 2005, Changes in rotifer species composition and abundance along a trophic gradient in Loch Lomond, Scotland, UK. Hydrobiologia 546, 397-404.

[33] Pejler, B., and Bērziņš, B. 1989. On chice of substrate and habitat in brachionid rotifers. Hydrobiologia 186 (187), 137-144.

[34] Jordi De Manuel, B., 2000, The rotifers of Spanish reservoirs: ecological, systematical and zoogeographical remarks. Limntica, 19, 91-166.

[35] Boon, P. I. and Shiel, R. J., 1990, Grazing on bacteria by zooplankton in Australian Billalongs. Austral. J. Mar. Fresh w. Res., 41, 247-257.

[36] Bahura, C. K., Bahura, P., and Saxena, M. M., 1993, Zooplankton community of Shivbari temple tank, Bikaner. Journal of Ecology 5, 5-8.

[37] Sladeček, V., 1983, Rotifers as indicator of water quality. Hydrobiologia. 100, 169-201.

[38] Perbiche-Neves, G., Fileto, C., Laçoportinho, J., Troguer, A., and Serafim-Júnior, M., 2013, Relations among planktonic rotifers, cyclopoid copepods, and water quality in two Brazilian reservoirs. Latin American Journal of Aquatic Research, 41 (1), 138-149.

[39] Claps, M. C., Gabellone, N. A. and Benítez, H. H. 2011. Seasonal Changes in the Vertical Distribution of Rotifers in a Eutrophic Shallow Lake with Contrasting States of Clear and Turbid Water. Zoological Studies 50(4): 454-465.

[40] Kumari, P., Dhadse, S., Chaudhari, P. R., and Wate S. R., 2008, A biomonitoring of plankton to assess quality of water in the lakes of Nagpur city. In: Sengupta M. and Dalwani R. (Eds). Proc. of Taal. The 12th World Lake Conference, 160-164.

[41] Nassif, M. G., (2012), Ecological studies on invertebrates of Ismailia Canal, Egypt. M. Sc. Thesis, Fac. Sci., Ain Shams Univ., Egypt.

[42] Khalifa, N., 2014, Population dynamics of Rotifera in Ismailia Canal, Egypt. J. Biodivers. Environ. Sci., 4 (2), pp. 58-67.

[43] Stemberger, R. S., 1990, An inventory of rotifer species diversity of northern Michigan inland Lakes. Archiv für Hydrobiologie 118, 283-302.

[44] Gideon, A. A., Mirela, P., Maria, C., Constantin, O, Palela, M., and Bahrim, G., 2014, Biological and Physico-Chemical Evaluation of the Eutrophication Potential of a Highly Rated Temperate Water Body in South-Eastern Romania. Journal of Environment and Ecology, 5 (2), 108-129.

[45] Ryding, S. O. and Rast, W. 1989. The Control of Eutrophication of Lakes and Reservoirs, Man and Biosphere Series, Vol I. The Parthenon Publishing Group.

[46] Lewis, P. A., Klemm, D. J., and Thoeny, W. T., 2001, Perspectives on the use of multimetric lake bioassement integrity index using benthic macroinvertebrates. Northeast. Nat., 8, 233-246.

[47] Kouamélan, E. P., Koné, N'Douba, V., and Ollevier, F., 2006, Food habit and trophic resource partitioning among three mormyrid fishes from man-made Lake Ayamé, Ivory Cost. Afr. Zool., 41, 266-274.

[48] Abd El-Aziz, F. A., 2016, Impact of Thermal and Chemical Stress on Molluscas Community in the River Nile at Luxor, Egypt. Global Journal of Science Frontier Research. 16 (1), under publication.

[49] Imafidon, E. U. (1991): Ecological studies of freshwater snails in Ibadan, Nigeria. Nigerian Journal of Parasitology, 12, 59-63.

[50] Agi, P. I., 1995, Survey of freshwater snail vectors of Schistosomiasis and study of physicochemical parameters of the water bodies in Ogoni Communities, River State, Nigeria. Act. Hydrobiologica, 21: 31-36.

[51] Agi, P. I. and Okwuosa, V. N., 2001, Aspects of water quality of freshwater systems harboring snail vectors Schistosome parasites in Jos, Nigeria. Journal of Aquatic Science, 16, 13-17.

[52] Abd El-Wakeil, K. F., Obuid-Allah, A. H., Mohamed, A. H., and Abd El-Aziz F. E. A., 2013, Community structure of molluscans in River Nile and its branches in Assiut governorate, Egypt. Egyptian Journal of Aquatic Research 39, 193-198.

[53] Diab, M. R. M., 1993, Biological studies on Trematode larvae and freshwater snails. M. Sc. Thesis, Vet. Med. Fac., Alexandria Univ, Egypt.

[54] Hussein, M. A., Obuid-Allah, A. H., Mahmoud, A. A. and Fangary, H. M., 2011, Population dynamics of freshwater snails (Mollusca: Gastropoda) at Qena Governorate, Upper Egypt", Egypt. Acad. J. Biolog. Sci., 3(1), 11-22.

[55] Ngqulana, S. G., 2012, Spatial and temporal distribution of the benthos in the Mfolozi-Msunduzi Estuary, KwaZulu-Natal. M. Sc. Thesis, Department of Zoology, University of Zululand.

[56] Pointier, J. P., Théron, A. and Borel, G., 1993, Ecology of the introduced snail *Melanoides tuberculata* (Gastropoda: Thiaridae) in relation to *Biomphalaria glabrata* in the marshy forest zone of Guadeloupe, French West Indies. J. Moll. Stud., 59, 421-428.

[57] Fishar, M. R. A., 1995, Studies on bottom fauna in Lake Nasser, Egypt (Ph. D. thesis). Suez Canal Univ., Egypt.

[58] Rashid, R., and Pandit, A. K., 2014, Macroinvertebrates (oligochaetes) as indicators of pollution: a review. J. Ecol. Nat. Environ. 6 (4), 140-144.

[59] EI-Tantawy, A., Bishai, R. M., Abdel-Latif, A., Samaan, A. A. and Iskaros, I. A., 2003, Species Composition and Seasonal Population Dynamics of the Benthic Fauna in Khor Kalabsha, Lake Nasser, Egypt. Egypt J. Aqua. Bio. Fisiu, 4, 2U-240.

[60] Abdel Salam, K. H., and Tanida, K., 2013, Diversity and spatio-temporal distribution of macro-invertebrates communities in spring flows of Tsuya Stream, Gifu prefecture, central Japan. Egypt. J. Aquat. Res. 39, 39-50.

[61] Thorp, J. H. and Rogers D. C., 2015, Introduction to the Phylum Arthropoda, Thorp and Covich's Freshwater Invertebrates (Fourth Edition), pp. 591-597.

[62] El-Shabrawy, G. M. and Fishar, M. R., 2009, The Nile Benthos, In: The Nile: Origin, Environments, Limnology and Human Use. H. J. Dumont (ed.), Springer Science + Business Media B. V, pp. 563-583.

[63] Vishwakarma, S. Alok Varma, A. and Saxena, G. 2014. Rotifer diversity in most polluted areas (Mandideep and Nayapura) of river Betwa, Madhya Pradesh, India. Int. J. of Pharm. Life Sci. 5(12):4055-4062.