Egyptian Journal of Aquatic Research (2014) **40**, 415–423

HOSTED BY

ELSEVIER

National Institute of Oceanography and Fisheries

Egyptian Journal of Aquatic Research

http://ees.elsevier.com/ejar
www.sciencedirect.com

FULL LENGTH ARTICLE

Spatio-temporal variations of macrobenthic fauna in Lake Nasser khors, Egypt

Hesham R. Abdel Mola *, **Soad S. Abdel Gawad**

National Institute of Oceanography and Fisheries, 101, Kasr El-Einy St., Cairo, Egypt

Received 9 November 2014; revised 17 December 2014; accepted 17 December 2014
Available online 6 January 2015

KEYWORDS

Macrobenthic fauna;
Lake Nasser khors;
Biological indices;
ANOVA

Abstract Spatial and temporal variations of macrobenthic fauna in Lake Nasser khors, were studied at four subsequent seasons during 2013. Khor Tushka West recorded the highest average number (597 Org./m^2). It was decreased at khor Kursku (112 Org./m^2) and Kalabsha (105 Org./m^2) while it reached the lowest at khor Wadi Abyad (65 Org./m^2). The highest average number was recorded during spring (447 Org./m^2). It decreased during winter (174 Org./m^2) and summer (151 Org./m^2), then reached the lowest during autumn (107 Org./m^2). Annelida, Arthropoda and Mollusca were the most dominant groups in the lake during the study being 72.65%, 26.09% and 1.35%, respectively. The highest number of species (16) was observed at khor Kalabsha. This may be due to its nature of sandy bottom. Biological indices showed high richness values of all the studies khors except khor Tushka West.

These low values of indices may be due to the dominance of Annelids species especially, *Limnodrilus* spp. and *Branchiura sowerbyi*. There is a positive correlation between these species and total annelids with all physico-chemical parameters. The analysis of variance between the different khors based on the main macrobenthic groups showed a highly significant value ($p < 0.001$).

Introduction

Benthic macroinvertebrates are animals inhabiting the substratum of lakes, streams, estuaries, and marine waters. In Lake Nasser, benthic organisms are represented by 5 major groups, namely, Annelida (oligochaetes), Arthropoda (Insecta and Crustacea), Mollusca, Cnidaria (Hydrozoa) and Bryozoa (Abdel Gawad et al., 2014). Freshwater benthic macroinvertebrates include representatives of many oligochaetes, insects, crustaceans, gastropods and bivalves (Merritt et al., 2008). They contribute in many important ecological functions, such as decomposition, nutrient recycling, as well as serve an important role in aquatic food webs as both consumers and prey (Covicch et al., 1999; Vanni, 2002; Moore, 2006). Benthic macroinvertebrate assemblages are structured according to physical and chemical parameters that define habitat and other biological parameters that influence their reproductive success (Abdelsalam and Tanida, 2013). In addition, they provide a more accurate understanding of changing in aquatic conditions than chemical and microbiological data, which at least give short-term fluctuations (Ravera, 1998, 2000). Moreover, the Water Framework Directive (WFD, 2006) demands the establishment of biomonitoring programmes for European aquatic ecosystems and includes macroinvertebrates as one of the biological elements to be monitored.

* Corresponding author.

Peer review under responsibility of National Institute of Oceanography and Fisheries.

http://dx.doi.org/10.1016/j.ejar.2014.12.001

The different groups of benthos serve as an important food for various fish species in Lake Nasser (Latif, 1974; Iskaros, 1993). These authors found that chironomid larvae form the major food items for *Mormyrus kannume*, *Mormyrus caschive* and *Chrysichthys auratus* throughout the different seasons. *Synodontis schall* and *Synodontis serratus* feed mainly on gastropods, *Bulinus truncatus* and *Physa acuta*. Furthermore, they report that nymphs of Odonata and Ephemeroptera, larvae of Trichoptera, Corixidae are also infrequently recorded in the guts of the above 5 fish species. *Hydrocynus* spp., particularly *Hydrocynus forskalii*, subsists mainly on insect larvae (Iskaros, 1993; Mola, 2009). The changing of macrobenthic fauna in the main channel was studied by many authors (Entz, 1978; Latif et al., 1979; Latif, 1974; Fishar, 1995) while at Lake Nasser khors was not studied for a long time on a wide scale except Iskaros (1993) and El-Tantawy et al. (2003) who studied the bottom fauna in khor Kalabsha only. Hence, the aim of the present work is to study the abundance, species composition and seasonal population dynamics of macrobenthic fauna in different khors of Lake Nasser and its relation to some environmental parameters.

Material and methods

Area of study

The lake shoreline is very irregular, with numerous embayments which are called khors (inundated valleys) the total number of important khors are 85 of which 48 lie on the eastern side and 37 on the western one (Entz, 1974). The investigation includes selection for the study khors (Kalabsha, Wadi Abyad, Kurusku and Tushka West). On the bases of quantitative and qualitative analysis, the benthic fauna were sampled at many stations of each khor (Table 1 and Fig. 1) during the study period to elucidate the changing in macrobenthos distribution. Field work was conducted seasonally during the period from February, 2013 to November, 2013.

Collection and analysis of samples

Some physico-chemical parameters e.g. temperature, Electrical conductivity (EC), pH were measured immediately by multiprob Hydrolab (Model CRISON-Spain). Transparency was measured by Secchi disk and dissolved Oxygen was measured according to APHA (2005). The bottom fauna was collected by the Ekman Grab bottom sampler, covering an area of about 0.03 m^2. After collection the bottom fauna was washed thoroughly in a small hand net of bolting silk (0.5 mm mesh size) and picked in and preserved immediately in 10% neutral formalin solution in polyethylene jars. In the laboratory, samples were washed again. However, each species was counted separately. The bottom fauna was identified and sorted into groups and species according to Edmondson (1966), Brown (1980, 2001), and Bishai et al. (2000).

Statistical analysis

Biological indices and similarity index were conducted with PRIMER 5 (version 5.2.0) software. The correlation coefficient between different Physico-chemical parameters and the dominant zooplankton groups was carried out by SPSS (version 16) software. ANOVA two-way was conducted between the different khors and the dominant macrobenthic groups by SAS, 2004 program.

Results

Physico-chemical parameters

The average pH values fluctuated between 8.21 during spring and 8.65 during autumn. Temperature ranged between 18.2 °C during winter and 28.7 °C during summer. Transparency ranged between 185 cm during spring and 257 cm during winter while Electrical conductivity ranged between 189 and 228 μS/cm (Fig. 2). Dissolved oxygen was measured at the bottom water layer of each khor. It was fluctuated between 2 mg/l at khor Kursku during summer and 7.8 mg/l at khor Tushka West during autumn (Fig. 3). The data of physic-chemical were cited from Tawfeek and Koriem (2014).

Abundance and distribution of the macrobenthic fauna

The maximum number (1421 Org./m^2) of macrobenthic invertebrates was recorded at khor Tushka West during spring while the lowest number (36 Org./m^2) was recorded at khor Wadi Abyad during autumn (Fig. 4). The highest average abundance was recorded at khor Tushka West (597 Org./m^2), followed by khor Kalabsha (105 Org./m^2) and Kursku (112 Org./m^2) while the lowest abundance was recorded at khor Wadi Abyad (65 Org./m^2). At all seasons, the highest average number was recorded during spring (447 Org./m^2). It decreased during winter (174 Org./m^2) and summer (151 Org./m^2), then reached the lowest during autumn (107 Org./m^2). Annelida, Arthropoda and Mollusca were the most dominant groups in the lake during the study being 72.56%, 26.09% and 1.35% respectively.

Species composition of the macrobenthic fauna in the Lake khors

The highest number of taxa and species was recorded at khor Kalabsha (16 species). It decreased at khor Kursku and

Table 1 Latitudes, longitudes average depths and nature of the bottom (some morphometry) for the studied khors.

Khor name	Kalabsha	Wadi Abyad	Kurusku	Tushka West
Latitude	32°51′25″E–32°32′4″E	32°57′47″E–33°4′56″E	32°19′3″E–32°20′29″E	31°45′53″E–31°33′27″E
Longitude	23°41′13″N–23°26′32″N	23°24′34″N–23°20′47″N	22°32′45″N–22°33′26″N	22°37′42″N–22°35′8″N
Average depth	29 m	17 m	32 m	22 m
Nature of the bottom	Sandy	Sandy gravel	Rocky	Sandy mud

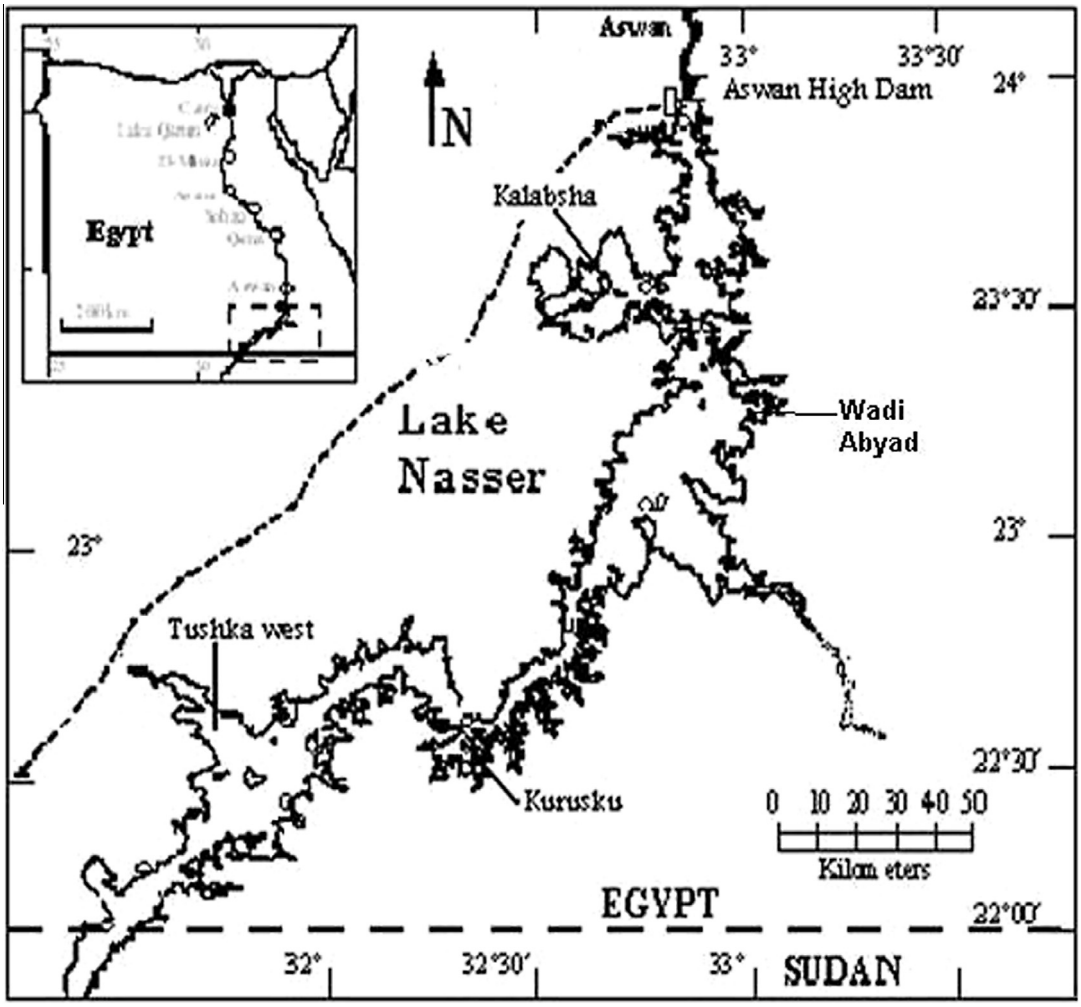

Figure 1 Map of Lake Nasser showing the selected khors during the study.

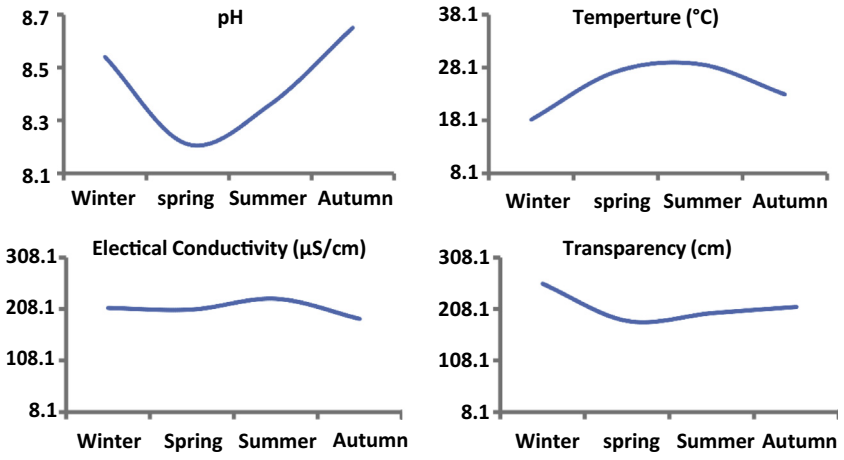

Figure 2 Seasonal variations of some physico-chemical parameters (pH, temperature, electrical conductivity and transparency) during the study.

Tushka West (15 species) and reached the lowest at khor Wadi Abyad (13 species). Twenty species and taxa were recorded at Lake khors during the study belonging to four phyla (Bryozoa, Arthropoda, Annelida and Mollusca). Phylum Arthropoda (9 species) and Annelida (7 species) were recorded as the highest number of taxa and species while phylum Mollusca (3 species) and Bryozoa (1 species) were observed the lowest (Table 2, Fig. 5).

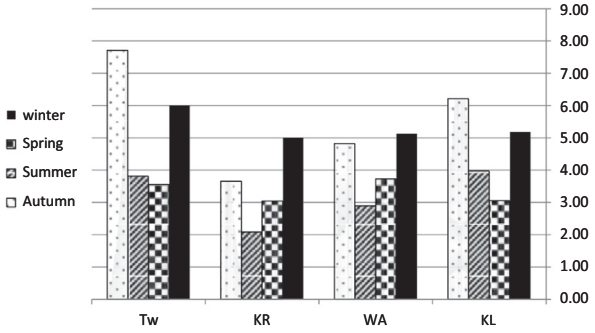

Figure 3 Seasonal variations of dissolved oxygen (mg/l) in bottom water layers of Lake Nasser khors during the year 2013.

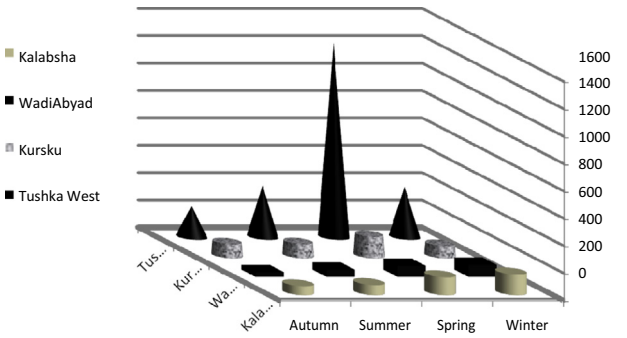

Figure 4 Seasonal abundance of the macrobenthic fauna (Org./m^2) in Lake Nasser khors during the year 2013.

khor Kalabsha

Annelida formed the most dominant group (90.93%) at khor Kalabsha while Arthropoda (8.49%) and Mollusca (0.58%) formed the lowest percentages (Fig. 2). Seasonal variations of Macrobenthic invertebrates (Fig. 3) of khor Kalabsha during the study period showed a gradual decrease from season to season. The highest numbers were recorded during winter (151 Org./m^2) and spring (131 Org./m^2) while the lowest were recorded during summer (74 Org./m^2) and autumn (65 Org./m^2). During summer, Mollusca was recorded with few numbers (5 Org./m^2) while Arthropoda was not recorded.

At khor Wadi Abyad, Annelida recorded the most dominant group (77.57%). Arthropoda showed a relative increase being 18.73% while Mollusca was the lowest dominant group (3.7%). The highest average numbers were recorded during winter (89 Org./m^2) and spring (82 Org./m^2) while the lowest were recorded during summer (54 Org./m^2) and autumn (36 Org./m^2). During spring, Mollusca was recorded (27 Org./m^2) while Arthropoda was not recorded.

Table 2 Checklist of benthic invertebrates recorded in Lake Nasser during the study and by different authors (+ = Present, – = Not recorded): Elewa (1987), Iskaros (1988, 1993), Fishar(1995), Ibrahim and Mageed (2005) and Present study (2013).

Taxa and species	(1987b)	(1988 and 1993)	(1995)	(2005)	Present study
Phylum: Bryozoa					
Class: Phylactolaemata					
Fredericella sultana	–	–	+	–	+
Phylum: Arthropoda					
Class: Insecta					
Chironomus sp.	–	+	+	+	+
Cricotopus sp.	–	+	+	+	–
Cryptochironomus sp.	+	+	+	+	+
Enallagma sp.	–	–	+	–	+
Microtendipes sp.	+	+	+	–	+
Nilodorum sp.	–	+	+	+	+
Polypedilum sp.	–	+	+	–	+
Procladius sp.	+	+	+	+	+
Tanytarsus sp.	+	+	+	–	+
Cardina nilotica P.	–	–	+	–	+
Phylum: Annelida					
Class : Oligochaeta					
Branchiura sowerbyi	+	+	+	+	+
Chaetogaster	–	–	–	–	+
Limnodrilus	+	+	+	+	+
Limnodrilus	+	+	+	+	+
Nais sp.	–	–	–	–	+
Pristina sp.	–	–	+	–	+
Class: Hirudinea					
Helobdella conifera (Moore, 1933)	–	+	+	–	+
Phylum: Mollusca					
Class: Gastropoda					
Bulinus truncatus (Audouin, 1827)	+	+	+	+	+
Valvata nilotica Jickeli, 1874	+	+	+	+	+
Eupera ferruginea (Krauss, 1848)[2]	–	–	+	–	+

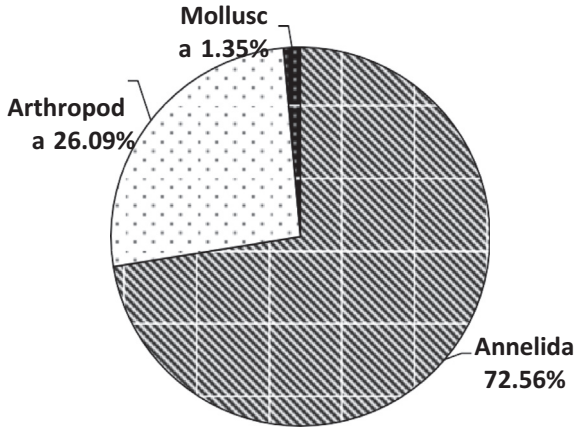

Figure 5 The average percentage composition of macrobenthic groups at all the studied khors during the study period.

Vice versa to all the studied khors, the highest dominant group at khor Kurusku was Arthropoda (54.52%) followed by Annelida (44.33%) while Mollusca was the lowest (1015%). The highest average numbers were recorded during spring (155 Org./m^2). It decreased during summer (102 Org./m^2) and autumn (101 Org./m^2) and reached the lowest during winter (88 Org./m^2). The maximum number of Arthropoda (Insect larvae) was recorded at khor Kurusku during summer being 306/Org./m^2.

Mollusca were not recorded at khor Tushka West, this may be due to the high turbidity of mud at this southern khor which coincided with the live nature of Mollusca. Annelid formed the most dominant group followed by Arthropoda being 77.42% and 22.58% with an average of 795 and 400 Org./m^2, respectively. At all the studied khors, the highest average number of Annelida and Arthropoda was recorded during spring being 1533 and 1309 Org./m^2, respectively (Figs. 6 and 7).

Statistical analysis

Correlation coefficient

The correlation coefficient matrix between the most dominant macrobenthic groups and species and some physico-chemical parameters was conducted depending on the data collected from all the studied khors. Total Annelida and the most dominant annelid species recorded a positive correlation with all the environmental parameters. The highest positive correlation was recorded between dissolved oxygen and (*Limnodrilus hoffmeisteri*, *Branchiura sowerbyi*) being (0.89 and 0.85), respectively.

Arthropoda especially, Larvae of Trichoptera recorded a negative correlation with all parameters except transparency which recorded a positive correlation (0.41). Vice versa, *Chironomus* larvae recorded a positive correlation with all parameters. Mollusca recorded a negative correlation with all parameters except pH. Also a highly significant negative (−0.95) correlation with dissolved oxygen was recorded. pH recorded the highest significant values at the level of $p < 0.05$, it showed the highest positive (0.99) with the arthropod *Cryptochironomus* sp. and the highest negative (−0.99) with the molluscs *Eupera ferruginea*.

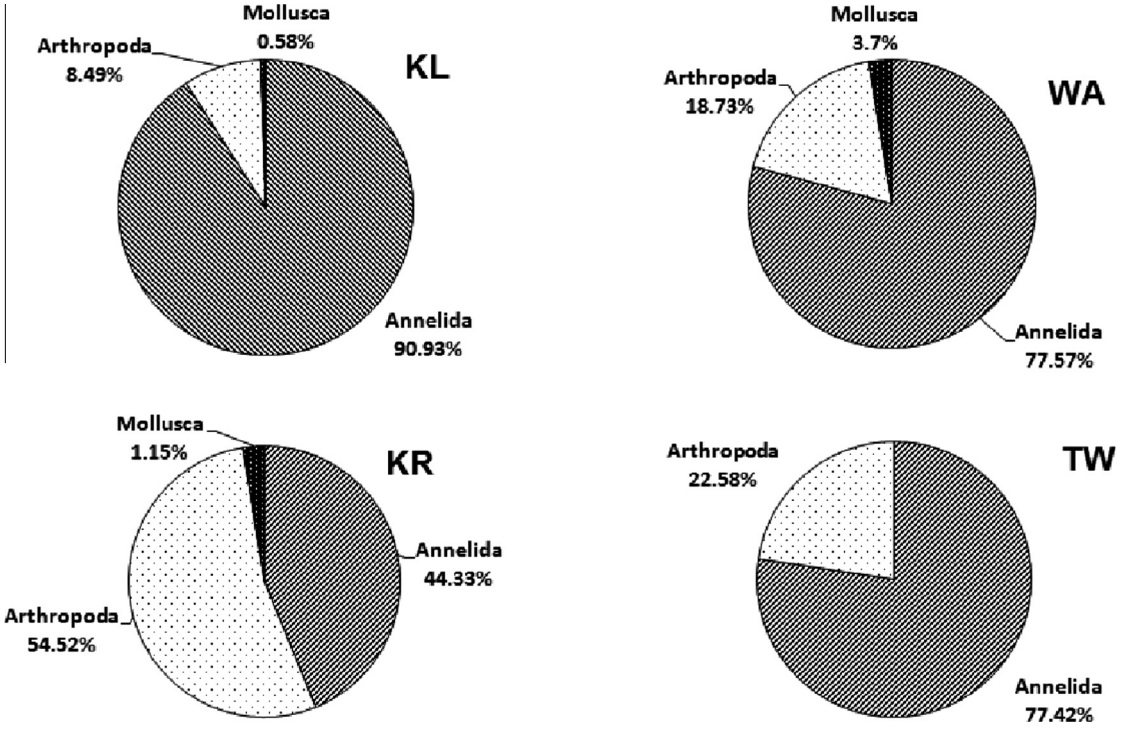

Figure 6 Percentage composition of macrobenthic groups at khor Kalabsha (KL), Wadi Abyad (WA), Kurusku (KR) and Tushka West (TW) during the study.

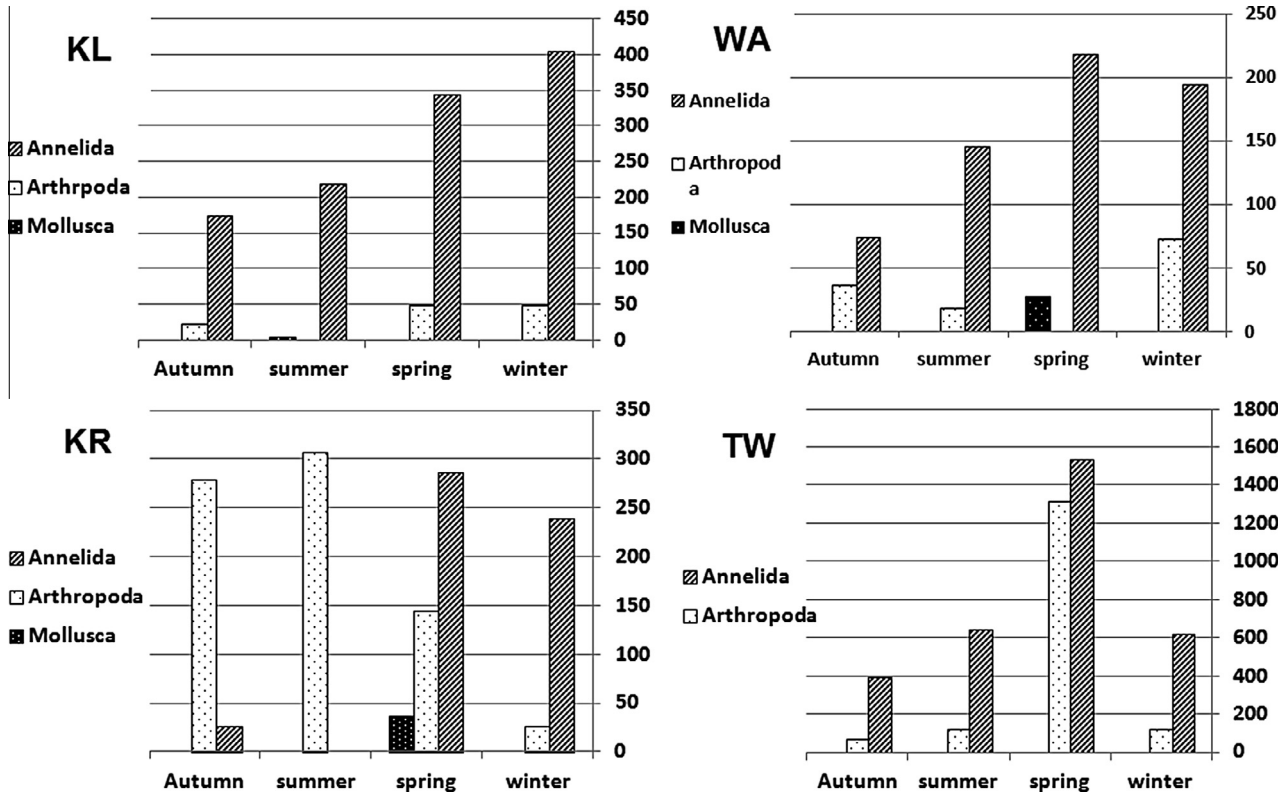

Figure 7 Seasonal variations of macrobenthic groups at khor Kalabsha (KL), Wadi Abyad (WA), Kurusku (KR) and Tushka West (TW) during the study.

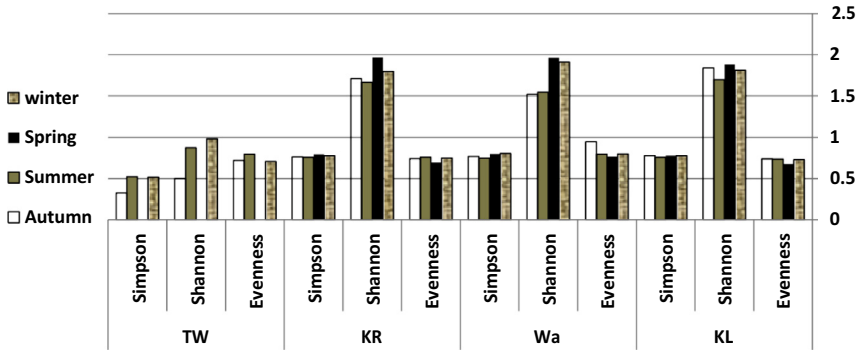

Figure 8 Seasonal variations of biological indices (Evenness, Shannon and Simpson) in the different studied khors of Lake Nasser during the year 2013.

Biological indices

Seasonal variations of total species, total individuals and biological indices reached the highest values during spring at all the studied khors. However, it recorded high number of individuals at khor Tushka West, the biological indices not computed statistically due to the dominance of one oligochaete species (*Limnodrilus* spp.).

The highest number of total species (17 species) Species Richness (2.3083), Shannon (1.9668) and Simpson (0.7914) were observed at khor Kurusku while Shannon–Weiner index recorded the lowest value at the same khor during spring (0.6942). The diversity index values showed a relative decrease at khor Kalabsha and Wadi Abyad while it reached the lowest values at khor Tushka West (Fig. 8).

Analysis of variance

The analysis of variance between the different khors based on the main macrobenthic groups showed a highly significant value ($p < 0.001$) in most of the analysis in all khors (Table 3). The analysis of variance between khor Kalabsha and Wadi

Table 3 Analysis of variance (P value) between the different khors based on abundance of the main macrobenthic groups.

Khor	Arthropoda	Annelida	Mollusca	Grand total
KL*WA	0.0742	0.0003	0.0019	0.0004
KL*KR	0.0001	0.0001	0.0052	0.0001
KL*TW	0.0001	0.0001	0.0052	0.0001
WA*KR	0.0078	0.0004	0.4226	0.0006
WA*TW	0.0001	0.0001	0.4226	0.0001
KR*TW	0.0001	0.0001	0.0000	0.0001
All khors	0.0001	0.0001	0.0001	0.0001

Note: $p < 0.05$ = Significant, $p < 0.01$ = Very significant, $p < 0.001$ = Highly significant, KL = Kalabsha, WA = Wadi Abyad, KR = Kurusku, TW = Tushka West.

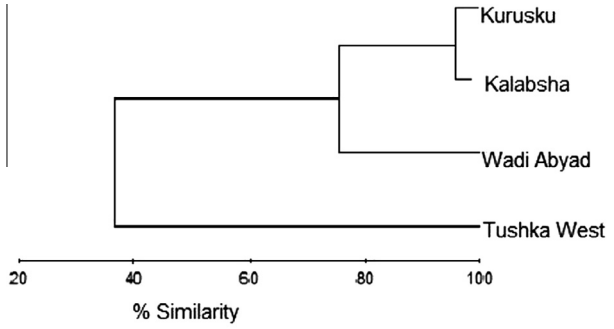

Figure 9 Similarity index between the studied khors of Lake Nasser.

Abyad depending on Mollusca and between Wadi Abyad and Kurusku depending on Arthropoda showed a very significant value ($p < 0.01$). The analysis of variance showed a significant value between Wadi Abyad and Kalabsha ($p = 0.0742$) depending on the abundance of Arthropoda. It recorded the highest significant value (0.4226) Wadi Abyad and Kurusku (WA*KR) and Wadi Abyad and Tushka West (WA*TW) depending on the abundance of Mollusca. The analysis of Variance between all the studied khors showed highly significant values ($p < 0.001$) depending on the grand total of macrobenthic invertebrates.

Similarity index

The highest similarity between the studied khors in the lake was observed between khor Kurusku and khor Kalabsha (96%). Khor Wadi Abyad showed low similarity (76%) with khor Kurusku and khor Kalabsha. The lowest similarity (38%) was observed between khor Tushka West and all the other khors (Fig. 9).

Discussion

The variations of macrobenthic invertebrates were attributed to the type of sediment grains especially at the southern part (clay and silt) while they were observed as sandy bottom at khor Wadi Abyad. This coincided with Iskaros and Dardir (2010) who mentioned the highest densities of benthic biota, particularly at Tushka, accompanied by clay and silt grains and subsequently high content of organic matter. Contrary to that, they reached the lowest densities in the khors where the types of sediments were mainly sandy with low organic matter. The lowest number of macrobenthos at khor Wadi Abyad may be due to the high percent of silt in sediment. This observation agreed with Gindy (2010) who stated that the highest average percent of silt (16.1%) at all khors was observed at khor Wadi Abyad.

Twenty species and taxa were recorded whereas; two Annelids (Oligochaeta) species; *Nais* and *Chaetogaster* were recorded for the first time in the lake. Brinkhurst and Gelnder (2001) and Abdelsalam and Tanida (2013) reported that the oligochaetes especially which affiliate to family Naididae are truly cosmopolitan and widely distributed among different habitats. The highest number of taxa and species was recorded at khor Kalabsha (16 species), it decreased at khor Kursku and Tushka West (15 species) and reached the lowest at khor Wadi Abyad (13 species). Although, the highest number was recorded at khor Tushka West, it showed a low variety of groups and species and it was dominated by *Limnodrilus* spp. This observation agreed with Iskaros (1993), Fishar (1995) and Iskaros and Dardir (2010). Nevertheless, the mud habitat was highly productive because it has high organic matter, burrowing (tube makers and builders), and soft substratum (Merritt et al., 2008; Abdelsalam and Tanida, 2013). Certain submerged macrophyte species which were previously recorded during the early stages of Lake Nasser i.e. *Potamogeton autesniloticus*, by Latif (1984) were not recorded in any recent study. *Myriophyllum spicatum* was considered the most dominant macrophyte, new associated aquatic invertebrates were recorded. This agreed with Ali et al. (2007) and Mola (2009).

Annelida formed the most dominant group (72.64%) at the lake khors while Arthropoda (26.17%) and Mollusca (1.43%) formed the lowest percentages. This coincided with Ibrahim and Mageed (2005) and Iskaros and Dardir (2010) and particularly coincided with the other previous studies. The predominance of oligochaetes in the lake is possibly due to their ability to adapt to various habitats and to their tolerance to low oxygen content in anoxic conditions of the bottom sediment (Iskaros and Dardir, 2010).

The highest average abundance was recorded at khor Tushka West (597 Org./m^2), followed by khor Kalabsha (105 Org./m^2) and Kursku (112 Org./m^2) while the lowest abundance was recorded at khor Wadi Abyad (65 Org./m^2). The lowest abundance in this khor might also refer to the nature of bottom. This agreed with Salem (2014) who recorded the high percentage of gravels (33.13%) at khor Wadi Abyad. At all seasons, the highest average number was recorded during spring (447 Org./m^2). It decreased during winter (174 Org./m^2) and summer (151 Org./m^2), then reached the lowest during autumn (107 Org./m^2). Iskaros and Dardir (2010) stated that a marked difference in the bottom fauna stock was noticed during the four seasons. They also noticed, that the main channel during spring reached its highest density, while the khors sustained the lowest densities. The abundance of bottom fauna in the main channel during spring and/or in the khors in summer was correlated with the amount of organic matter. The present study recorded similar average values and similar distribution with Ibrahim and Mageed (2005) while it recorded low average values with many studies (Iskaros, 1988, 1993; Fishar, 1995; El-Tantawy et al., 2003; Iskaros and Dardir, 2010).

Latif et al. (1979) found that the major component of Lake Nasser was the oligochaetes, whereas that of Lake Nubia was composed mainly of mollusks. This may be referred to the fact that Mollusks need more time for formation and metamorphosis than oligochaetes. Most of Mollusca were recorded as empty shells, this may be due to the high turbidity and the change in water level, especially, at the southern part of the lake. In addition to the deficiency of dissolved oxygen as mentioned by Entz (1978) who stated that all bivalves already existing in the old river bed died during the stagnation period because of lack of oxygen. Flood considered as the most important factor affecting on the abundance and distribution of fauna in the lake. Epiphytic fauna and flora which are attached to submerged plants play an essential role in the fish production in the shallow areas (khors) in Lake Nasser (Abd El-Karim et al., 2009; El-Serafy et al., 2009; Mola, 2009). Some macrobenthic assemblages especially, Oligochaeta, Insecta and shrimps were observed and a good selective index was recorded for the two economic fishes, *Alestes* sp. and *H. forskalii* (Mola, 2009).

It could be concluded that, Annelida, Arthropoda and Mollusca were the most dominant groups in the lake during the study. The predominance of oligochaetes especially *Limnodrilus* spp. in the lake is possibly due to their ability to adapt to various habitats and to their tolerance to low oxygen content in anoxic conditions of the bottom sediment. The lowest abundance of macrobenthos at all the studied khors was observed during autumn (flood season). For this reason, flood is the main factor affecting the distribution of bottom fauna of Lake Nasser.

References

Abd El-Karim, M.S., Fishar, M.R., Abdel Gawad, S.S., 2009. Epiphytic algae and macroinvertebrates communities of *Myriophyllum spicatum* Limm and their cascade in the littoral food web of Lake Nasser, Egypt. Global Vet. 3 (3), 165–177.

Abdel Gawad, S.S., Mola, H.R.A., Fishar, M.R., 2014. In: Macrobenthos in Lake Nasser. In: El-Shabrawy, G.M. (Ed.), . Ecological Basis for Lake Nasser Ecosystem. Lap Lambert Academic Publishing, pp. 213–231.

Abdelsalam, K., 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.

Ali, M.A., Mageed, A.A., Heikal, M., 2007. Importance of aquatic macrophyte for invertebrate diversity in large subtropical reservoir. Limnolgica 37, 155–169.

APHA (American Public Health Association), 2005. Standard Methods for Examination of Water and Wastewater, 21st ed. American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF), Washington, DC, USA.

Bishai, H.M., Abdel Malek, S.A., Khalil, M.T., 2000. Lake Nasser. Egyptian Environmental Affairs Agency (EEAA production). National Biodiversity Unit. No. 11.

Brinkhurst, R.O., Gelnder, S.R., 2001. In: Annelida: Oligochaeta, including branchiobdellidae. In: Thorp, J.H., Covich, A.P. (Eds.), . Ecology and Classification of North American Freshwater Invertebrates. Academic Press, pp. 431–463.

Brown, D.S., 1980. Fresh Water Snails of Africa and Their Medical Importance. Taylor & Francis Ltd, London.

Brown, K.M., 2001. In: Mollusca: gastropoda. In: Thorp, J.H., Covich, A.P. (Eds.), . Ecology and Classification of North American Freshwater Invertebrates. Academic Press, pp. 297–329.

Covicch, A.P., Palmer, M.A., Crowl, T.A., 1999. The role of benthic invertebrate species influence energy flows and nutrient cycling. Bioscience 49, 119–127.

Edmondson, W.T., 1966. Freshwater Biology, second ed. John Wiley and Sons Inc., New York & London.

Elewa, A.A., 1987. Fish stock assessment in Lake Nasser. A Nile project, Inst. Oceanogr. and Fish. Acad. Sci. Technol., Cairo. A.R.E. July, 1987.

El-Serafy, S.S., Mageed, A.A., Mola, H.R., 2009. Impact of flood water on the distribution of zooplankton in the main channel of Lake Nasser, Egypt. J. Egypt. Acad. Soc. Environ. Develop. 10 (1), 121–141.

El-Tantawy, S.A., Bishai, R.M., Abdel Latif, A.F., Samaan, A.A., Iskaros, I.A., 2003. Species composition and seasonal population dynamics of the benthic fauna in khor Kalabsha, Lake Nasser, Egypt. Egypt. J. Aquat. Biol. Fish. 7 (4), 211–240.

Entz, B.A.G., 1974. In: Limnology. In: Entz, B.A.G., Latif, A.F. (Eds.), . Report on Survey to Lake Nubia (1972–1973). Lake Nasser Development Center, Aswan, pp. 4–63 (Working Paper, 6).

Entz, B., 1978. The appearance of a littoral fauna in Lake Nasser-Nubia, a newly formed tropical man-made Lake. Syst. Biol. Hung. 19, 201–209.

Fishar, M.R.A., 1995. Studies on Bottom Fauna in Lake Nasser, Egypt (Ph.D. thesis). Suez Canal University.

Gindy, N.N., 2010. Sedimentological and mineralogical characteristics of khors sediments, Lake Nasser, Egypt. Egypt. J. Aquat. Res. 36 (4), 641–652.

Ibrahim, E.A., Mageed, A.A., 2005. Project for Studying the Distribution of Algae and Aquatic Plants in Lake Nasser. Final Report. National Institute of Oceanography and Fisheries, Cairo.

Iskaros, I.A., 1988. Biological Studies on Bottom Fauna of Lake Nasser and Adjacent Waters (M.Sc., thesis). Fac. Sci., Alex. University.

Iskaros, I.A., 1993. Ecological Studies on the Distribution of Zooplankton and Benthic Fauna in khor Kalabsha in Lake Nasser (Ph.D. thesis). Zool. Dep., Fac. Sci., Mansura University.

Iskaros, I.A., Dardir, M., 2010. Factors affecting the distribution and abundance of bottom fauna in Lake Nasser, Egypt. Nat. Sci. 8 (7), 95–110.

Latif, A.F.A., 1974. Fisheries of Lake Nasser. Aswan Reg. Plan.. Lake Nasser Develop. Center, Aswan.

Latif, A.F.A., 1984. In: Lake Nasser. The New man-made lake in Egypt (with reference to Lake Nubia). In: Taub, F.B. (Ed.), . Lakes and Reservoirs. Elsevier Science Publishers, Amsterdam, Netherlands, pp. 385–410.

Latif, A.F.A, El-Etreby, S.G., Agaiby, I., 1979. Bottom Fauna of High Dam Reservoir. Report, River Nile and Lake Nasser Project. Acad. Sci. Technol., Cairo.

Merritt, R.W., Cummins, K.W., Berg, M.B., 2008. An Introduction to the Aquatic Insects of North America, fourth ed. Kendall Hunt Publishing, Dubuque, Iowa, USA.

Mola, H.R.A., 2009. Ecological Studies on Planktonic and Epiphytic Microinvertebrates in Lake Nasser, Egypt (Ph.D. thesis). Faculty of Science, Banha University, Egypt.

Moore, J.W., 2006. Animal ecosystem engineers in streams. Bioscience 56, 237–246.

Ravera, O., 1998. Utility and limits of biological and chemical monitoring of the aquatic environment. Annal. Dichim. 88, 909–913.

Ravera, O., 2000. Ecological Monitoring Tailormade III. International Workshop on Information for Sustainable Water Management, pp. 157–167.

Salem, G.S., 2014. Sedimentology of Lake Nasser khors. Environmental and Biological Monitoring of Lake Nasser for Casting the Impacts of the Ethiopian Renaissance Dam. Ministry of Scientific Research, National Institute of Oceanography and Fisheries, Inland Water and Aquaculture Branch, First year survey, Final Report, pp. 465.

Tawfeek, M.S., Koriem, M., 2014. Physico-chemical characteristic of Lake Nasser water. Environmental and Biological Monitoring of Lake Nasser for Casting the Impacts of the Ethiopian Renaissance Dam. Ministry of Scientific Research, National Institute of Oceanography and Fisheries, Inland Water and Aquaculture Branch, First year survey, Final Report, pp. 465.

Vanni, M.J., 2002. Nutrient cycling by animals in freshwater ecosystems. Ann. Rev. Ecol. Syst. 33, 341–370.

Water Framewoke Directive (WFD), 2006. Directive 2000/60/EC of the European parliament and of the council of 23 October 2000: establishing a framework for community action in the field of water policy. Official J. Eur Comm.