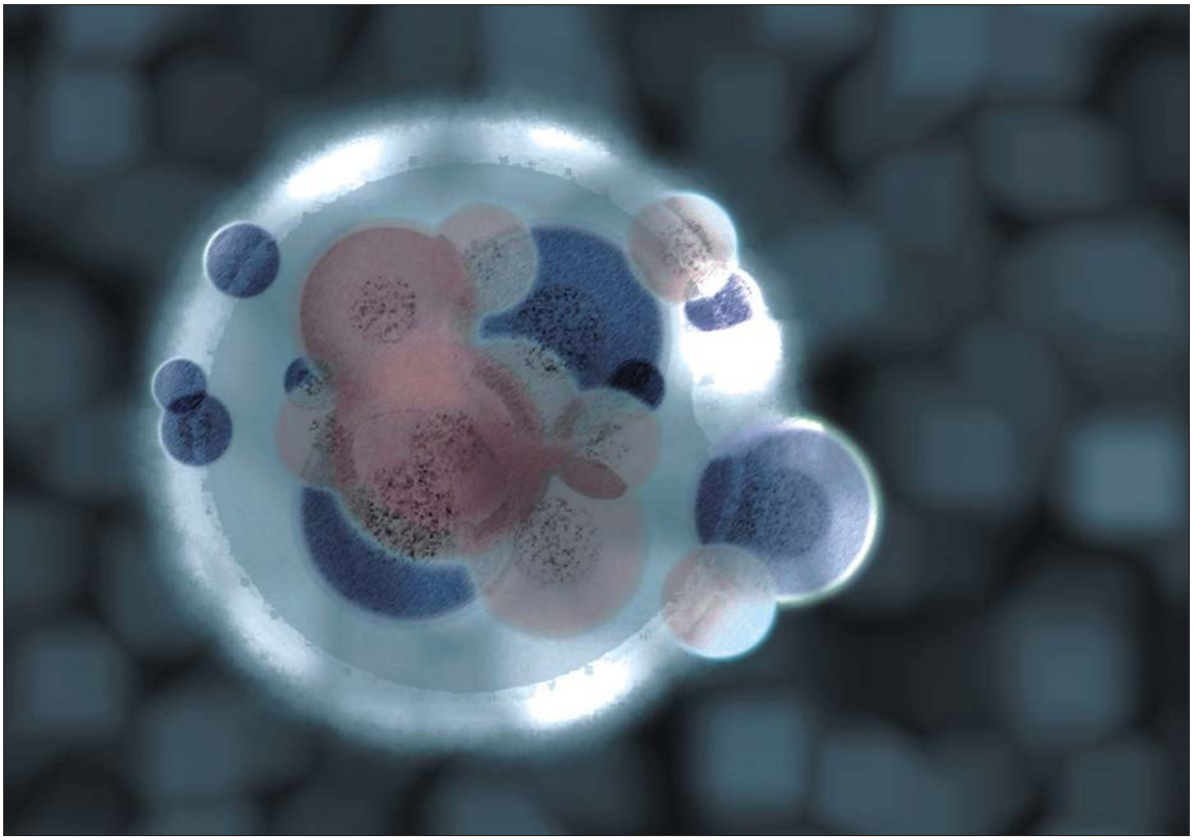

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Research Article
Impact of Flood Cycle on Phytoplankton and Macroinvertebrates Associated with *Myriophyllum spicatum* in Lake Nasser Khors (Egypt)

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Abstract
Background and Objective: Phytoplankton and macroinvertebrates are two of the most interesting groups in freshwater habitat and aquatic food chains. The objective was to study phytoplankton and macroinvertebrates associated with aquatic macrophyte *Myriophyllum spicatum* (*M. spicatum*) at Dahmeit and Tushka West khors of Lake Nasser during flood cycle (before, during and after flood). **Materials and Methods:** About 1.0 L Ruttner Sampler was used to collect composite surface water samples for studying phytoplankton. Macrophyte, *Myriophyllum spicatum* was collected from the same sites at the same times. The associated macroinvertebrates were separated with a net 500 µm for identification and the macrophyte was dried and weighed. Correlation analysis between the measured parameters of water, phytoplankton and macroinvertebrates associated with *Myriophyllum spicatum* were carried out using Statgraphics program. **Results:** The dominant groups of phytoplankton were Cyanophyta, Chlorophyta and Bacillariophyta while, Oligochaeta, Hirudinea, Crustacea, Insecta and Gastropoda were the dominant groups of macroinvertebrates associated with *Myriophyllum spicatum*. The highest densities of phytoplankton were recorded after flood (8.16×10^6 and 1.27×10^7 cells L^{-1} at Dahmeit and Tushka khors, respectively). Meanwhile, the highest densities of associated macroinvertebrates were recorded during flood (576 and 690 organisms/100 g plant dry wt at Dahmeit and Tushka khors, respectively). The most dominant macroinvertebrate taxa were *Pristina* sp., *Bulinus truncatus*, *Gyraulus ehrenbergi* and Chironomid larvae while those of phytoplankton were *Chroococcus* spp., *Pseudoanabaena* sp., *Ankistrodesmus falcatus*, *Dictyosphaerium pulchellum*, *Scenedesmus bijugatus* and *Aulacoseira granulata*. The results of water quality index (WQI) and species diversity indicate the improvement of water quality in the study area by flood. Tushka West khor (upstream) was more productive in phytoplankton and associated macroinvertebrates than Dahmeit khor (downstream). Species evenness of macroinvertebrates shows negative significant correlation with species diversity (-0.6) and evenness (-0.5) of phytoplankton. Also, negative significant correlation (-0.76) was detected between species richness of phytoplankton and associated macroinvertebrates. Canonical correspondence analysis (CCA) shows that total count of phytoplankton was not affected by total count of associated macroinvertebrates and its groups. **Conclusion:** The flood cycle influenced microalgae and macroinvertebrate communities by stimulating spatial and seasonal variations of phytoplankton and invertebrates succession and density.

Key words: Flood, phytoplankton, macroinvertebrates, *Myriophyllum spicatum*, Lake Nasser Khors

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Flood events are a major modifying influence on phytoplankton and invertebrate fauna of the rivers. These affect individuals abundance and community composition by causing increase water velocity and bed load movement by increasing the suspended sediment load of the river, physical damage to some individuals and a reduction in the food supply available from the substrate[1]. Phytoplankton and macroinvertebrates are two of the most interesting groups in freshwater habitat especially in Lake Nasser. Phytoplankton contributes at least one quarter of the biomass of the world's vegetation and the changes in phytoplankton community composition affect the abundance and diversity of marine organisms, eutrophication and food web structure in the aquatic ecosystems[2,3]. Macroinvertebrates occupies intermediate position in the food chain of most aquatic ecosystems. It occupies different habitats, living in association with the upper layer of sediment and living in association with submerged aquatic plants (macrophytes). Aquatic macrophytes have been shown to support high macroinvertebrate densities[4,5] and support more diverse taxa than adjacent benthic habitats, providing food, shelter and oxygen for macroinvertebrates[6-9]. Aquatic macrophytes affect also the macroinvertebrate community structure by influencing both physical and biotic characteristics[10]. These phytoplankton and macro-invertebrate faunal communities form the food for fish, prawns and birds.

Lake Nasser is the second largest manmade lake in Africa, after Lake Volta (Ghana). It is the major source for drinking, irrigation and domestic purposes in Egypt. There is an annual cycle of water level changes which is related to the seasonal flood pattern of the rivers Nile system, together with long-term pattern of net rise and fall of the mean lake level. Flood occurs from August (late summer) and originating from the Ethiopian highlands[11]. The yearly flood of the Nile is the most important factor affecting the ecosystem of Lake Nasser and hence it may affect the temporal abundance and community composition of organisms in the lake (e.g., planktonic algae, zooplankton and others)[12,13]. This study aims to study the impact of flood on the abundance and composition of phytoplankton and also on macroinvertebrates associated with submerged macrophyte *Myriophyllum spicatum* Lemm and their correlation to water quality at Dahmeit and Tushka West khors of Lake Nasser.

MATERIALS AND METHODS

Area of study: Lake Nasser shore line is very irregular, with numerous inundated valleys called khors. Two main khors of Lake Nasser, Dahmeit khor (lies at the Northern area of the Lake) and Tushka West khor (lies at the Southern area of the Lake) were selected for this study. Five stations covering the area of each khor were selected for sampling (Fig. 1). Sampling stations with their longitude and latitude are listed in Table 1.

Water characteristics: Some water physicochemical variables including depth (D), temperature (Temp.), transparency, dissolved oxygen (DO), pH, electrical conductivity (EC), total dissolved salts (TDS), total inorganic nitrogen (TIN) (nitrite, nitrate and ammonia) and total phosphorus (TP) were measured according to APHA[14] during flood cycle (before, during and after flood). The water quality index (WQI) proposed by the American National Sanitation Foundation (NSF) was calculated according to Kahler-Royer [15].

Sampling methods and analysis

Phytoplankton: Composite surface water samples were collected using 1.0 L Ruttner Sampler in polyethylene bottles from Dahmeit and Tushka West khors of Lake Nasser before flood (May, 2016), during flood (August, 2016) and after flood (December, 2016). The collected water samples were immediately preserved using 4% formalin and Lugol's iodine solution to fix and preserve algal taxa. In the laboratory, the preserved samples were transported into a glass cylinder and left for 5 days for settle down. Approximately, 90% of the supernatant was siphoned off by plastic tubes protected with plankton mesh (5 μ). Sub-samples were used for identification of the algal taxa followed[16-21]. The phytoplankton crops (cells L^{-1}) was carried out using Sedgwick-Rafter cell of 1 mL capacity.

Macroinvertebrates associated with *Myriophyllum spicatum*: The macrophyte *Myriophyllum spicatum* Lemm is an invasive species[22], in1993, *M. spicatum* was recorded in Lake Nasser. Changes in the lake environment with increased human activity associated with flood events of the Lake lead to high invasion of *M. spicatum*[23]. It was collected before flood (May, 2016), during the flood (August, 2016) and after flood (December, 2016) with minimal disturbance and placed in polyethylene bags along with some lake water. The specimens were fixed with five drops of neutralized formalin (30-35%). In the laboratory, this submerged macrophyte were placed separately in large plastic bottle containing water. The bottle was closed and shacked strongly many times to detach all animals from the macrophyte. The associated macroinvertebrates were separated with a net 500 μm and placed into labelled bottle and fixed with 10% neutral formalin solution for latter laboratory identification using binocular microscope. The plants were dried at 60°C in the oven until

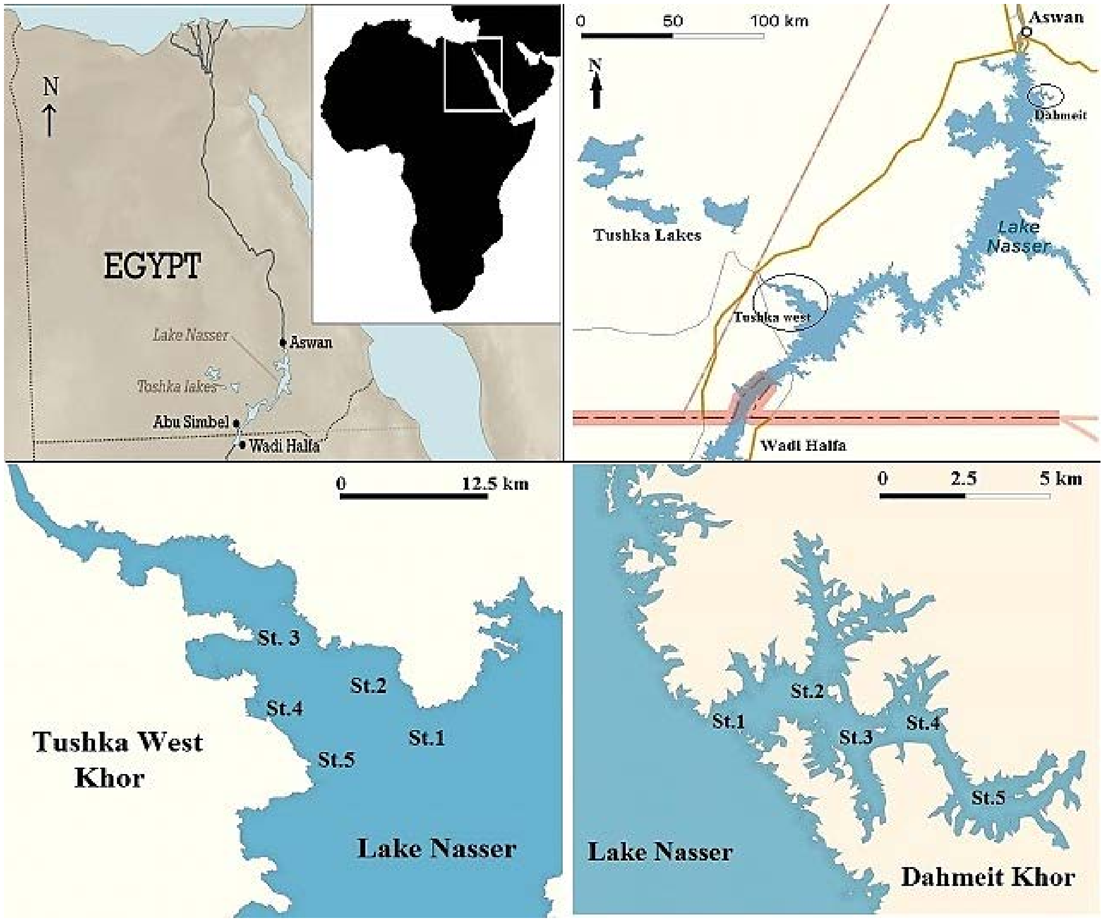

Fig. 1: Maps of Lake Nasser, Dahmeit and Tushka West khors with marked positions of the sampling stations

Table 1: Latitude and Longitude of each sampling station at Dahmeit and Tushka West khors

Khors	Sampling stations	Latitude	Longitude
Dahmeit	St.1	23°44'55.98"N	32°57'31.73"E
	St.2	23°45'29.31"N	32°59'2.32"E
	St.3	23°44'51.30"N	32°59'52.12"E
	St.4	23°45'4.39"N	33° 1'6.49"E
	St.5	23°43'51.66"N	33° 2'0.44"E
Tushka West	St.1	22°32'1.51"	31°47'3.32"
	St.2	22°34'25.82"	31°44'44.18"
	St.3	22°37'50.12"	31°41'35.19"
	St.4	2°36'0.97"	31°40'42.09"
	St.5	22°33'14.10"	31°43'17.78"

constant weight and weighed. Invertebrate abundances were presented by a number of individuals per/100 g of plant dry weight[24,25]. Identification of phytophilous macroinvertebrates followed keys of[26-30]. The submerged macrophyte *Myriophyllum spicatum* L. was identified according to Zaharan and Smith[31].

Statistical analysis of data: Correlation analysis between the measured parameters of water, phytoplankton and macroinvertebrates associated with *Myriophyllum spicatum* were carried out using STATGRAPHICS program (ver. 16.2.4). Correlation coefficients were considered significant at 95% confidence level ($p \leq 0.05$). Also, the multivariate technique, canonical correspondence analysis (CCA)[32] using the CANOCO program version 4.0[33] was used to analyze the fauna and phytoplankton groups. Biological indices such as Shannon-Weaver's index of diversity[34], evenness index[35] and species richness[36] were used for further analysis.

RESULTS AND DISCUSSION

Physicochemical characteristics of water: Gradual increase in average values of some water parameters including depth, EC, TDS, PO_4 and WQI were recorded from before to after flood seasons at Dahmeit and Tushka West khors (Table 2). However, the changes in water temperature follow that of the weather, reached its maximum (29.8°C) during flood (summer season) and minimum (19.6°C) after flood (autumn season). Temperature plays an important role in the physical and

Table 2: Mean values (±SD) of physico-chemical characteristics of water at Dahmeit and Tushka West khors of Lake Nasser

	Dahmeit khor			Tushka West khor		
Parameters	BF	DF	AF	BF	DF	AF
Water temperature (°C)	26.98±0.78	29.80±0.4	20.40±0.24	29.26±1.15	29.70±0.79	19.60±1.17
Depth (m)	14.40±9.57	18.90±10	21.30±9.36	10.20±2.22	11.00±5.4	10.70±3.06
pH	8.77±0.11	8.45±0.04	8.51±0.18	8.65±0.18	8.71±0.19	8.78±0.05
EC (μmhos cm^{-1})	243.00±8.2	253.00±8.9	270.00±5.88	253.00±8.02	237.00±4.75	250.00±1.6
Transparency (cm)	178.00±95.2	357.00±166	256.00±28.8	236.00±71.6	218.00±43.2	160.00±20
D.O. (mg L^{-1})	9.13±0.59	7.68±0.19	8.18±1.24	8.25±0.33	7.13±0.69	9.59±0.25
TDS (mg L^{-1})	157.90±5.3	164.90±5.8	177.60±1.7	164.30±5.2	154.20±3.1	162.70±0.9
TIN (μg L^{-1})	233.00±46.1	169.00±9.24	180.00±9.9	292.00±43.5	143.00±13.9	157.00±29.7
PO_4 (μg L^{-1})	6.41±2.9	10.50±2.3	9.45±3.6	2.11±0.88	4.13±1.1	7.80±1.6
WQI	67.8±0.5[a]	68.5±0.6[a]	71.8±0.84[b]	68.40±0.5[a]	69.80±0.89[a]	74.00±1.2[b]

BF: Before flood, DF: During flood, AF: After flood, EC: Electrical conductivity, DO: Dissolved oxygen, TDS: Total dissolved salts, TIN: Total inorganic nitrogen, PO4: Phosphate, WQI: Water quality index, a: Medium water quality, b: Good water quality

chemical characteristics of lake environment, it affects the rate of CO_2 fixation by phytoplankton (primary productivity) and solubility of gases as O_2, CO_2, NH_4 which on turn affect all aquatic organisms. Transparency was higher at Dahmeit khor (Northern area) than that of Tushka khor (Southern area). This agrees with Mola and Abdel Gawad[37]. The average pH values of Dahmeit khor and Tushka West khor were 8.58 and 8.71, respectively during the whole period of study, they lie within the permissible range[38]. The lowest values of oxygen levels (7.13 and 7.68 mg L^{-1}) were recorded during summer at two khors which may be due to the removal of free oxygen through respiration by bacteria and animals. The row data of physicochemical parameters were cited from the report of the National Institute of Oceanography and Fisheries (NIOF), 2017.

Phytoplankton composition and abundance: The habitat and distribution of different phytoplankton species reveals the features of water where they survive[39,40]. The production of freshwater community which regulates the fish growth is controlled by its physico-chemical and biotic background[41]. Spatial and seasonal abundance patterns and composition of phytoplankton were studied in Dahmeit and Tushka West khors, in order to establish the relationship between phytoplankton and water quality during the flood cycle. A total of 137 algal taxa belonging to 6 different groups were recorded at Dahmeit and Tushka West khors at 2016 during the whole flood cycle (Table 3). Chlorophyta was the most diversified group (60 taxa), followed by Bacillariophyta and Cyanophyta representing 32 taxa for each group, Dinophyta (5), Cryptophyta (4) and Euglenophyta (4). The variations of phytoplankton composition in the two khors during this study are shown in Table 3. Gradual increase in number of identified taxa was detected in Tushka khor, in which, the lowest number of taxa (63 taxa) was recorded before flood season and the highest one (81 taxa) was recorded after flood season (Table 3). This agrees with Harper[42], who found that the species number decreased due to high nutrient concentrations, as in before flood season (Table 2). Meanwhile, at Dahmeit khor, the number of taxa varied from 70 taxa before and after flood seasons to 76 taxa during flood season (Table 3). It is evident that the number of phytoplankton species increased with Lake Nasser age, in which the recorded identified species by Samaan[43] (27 species), Zaghloul[44] (43), El-Otify[45] (59), Mohammed *et al.*[46] (50), Abdel-El-Moniem[47] (84), Ibrahim and Mageed[48] (94), Hussian *et al.*[49] (104 species) and the present study (137 species).

Marked spatial and seasonal variations in number of identified taxa were detected (Table 4). Chlorophyta, Bacillariophyta and Cyanophyta were the dominant microalgae groups in the two khors comprising more than 99% of the total phytoplankton abundance at the different sampling stations (Table 4). Meanwhile, the Dinophyta, Euglenophyta and Cryptophyta were contributed to about 1% of the total phytoplankton community. Representatives of the same algal groups are correspond to those found in Lake Nasser and other freshwater bodies in Egypt[12,11,47,49-54]. The variations in distribution of different microalgae groups during the flood cycle at Dahmeit and Tushka west khors were as follow.

Cyanophyta: Cyanophyta was the dominant group in all the sampling seasons with an average percentage abundance of 76.18 and 88.41% at Dahmeit and Tushka khors, respectively, before flood season. Meanwhile, the percentage abundance of Cyanophyta during the flood and after flood seasons at the two khors was higher than 92% (Table 4). This could be due to high temperature, water column stability due to the start of the flood and nutrients availability[55,56], adaptions to diverse ecosystem[57]. Out of the 32 identified cyanophycean taxa, the *Chroococcus* spp., were the most frequent species representing from 11-62% (Dahmeit khor) and 3.5-35%

Table 3: Species composition of phytoplankton recorded in Dahmeit and Tushka Khors (+ = Present)

	Dahmeit			Tushka West				Dahmeit			Tushka West		
Species	BF	DF	AF	BF	DF	AF	Species	BF	DF	AF	BF	DF	AF
Cyanophyta													
Anabaena affinis				+			*Chlamydomonas snwoii*			+			
Anabaena subclindrica		+			+		*Chlorella vulgaris*		+	+		+	+
Anabaena sp.	+	+					Closteriopsis longissima	+	+	+	+	+	+
Aphanocapsa elachista var. *conferta*					+	+	*Clostridium* sp.		+			+	
Aphanothece nidulaus			+		+	+	*Coelastrum cambricum*	+	+	+	+	+	+
Chroococcus dispersis	+	+	+	+	+	+	*Coelastrum microporum*						+
Chroococcus dispersis var. *minor*	+	+	+	+	+	+	*Cosmarium* sp. 1		+	+		+	+
Chroococcus minimus	+	+					*Cosmarium* sp. 2		+	+		+	+
Chroococcus minutus				+		+	*Crucigenia tetrapedia*	+			+	+	
Chroococcus minor	+	+	+				*Crucigenia rectangularis*		+				+
Chroococcus turgidus	+	+	+	+	+	+	*Dictyosphaream ehrenbergianum*			+			
Chroococcus sp.		+	+		+	+	*Dictyosphaerium pulchellum*	+	+	+	+	+	+
Coelosphaerium dubium	+	+	+	+	+	+	*Elakatothrix gelatinosa*		+	+		+	+
Coelosphaerium kuetzingianum					+	+	*Elakatothrix genevensis*	+		+	+		
Cylindrospermopsis raciborskii	+	+	+	+	+	+	*Golenkinia radiata*	+	+		+		+
Gleocapsa sp.		+					*Kirchneriella lunaris*		+				
Gomospheria aponina var. *gelatinosa*						+	*Kirchneriella obesa*			+		+	+
Leptolyngbya granulifera		+	+		+	+	*Lagerheimia citriformis*	+	+		+	+	+
Leptolyngbya foveolarum						+	*Lagerheimia quadriseta*	+	+	+	+	+	+
Merismopedia gluca			+				*Lagerheimia longiseta*					+	
Merismopedia punctata	+	+	+	+	+	+	*Micractinium pusillum*			+			+
Merismopedia tenussima						+	*Mougetia* sp.	+					
Microcystis aurgenosa			+		+	+	*Monoraphidium contortum*	+			+		
Microcystis incerta	+		+				*M. graffithii*	+		+	+		+
Oscillatoria hamellii	+	+	+	+	+	+	*M. minutum*	+			+		
Oscillatoria tenuis	+	+	+				*M. pusillum*		+			+	+
Oscillatoria tenuis var. *tergestina*	+			+			*Nephrocytium lunatum*			+			+
Oscillatoria sp.					+		*Oedogonium* sp.			+			
Phormidium sp.		+					*Oocystis crassa*		+	+		+	+
Pseudoanabaena sp.	+	+	+	+	+	+	*O. elliptica*		+	+		+	+
Spirulina laxa					+	+	*O. parva*	+	+	+	+	+	+
Synechococcus sp.		+	+				*O. solitoria*	+	+	+	+	+	
Number of species	14	18	17	11	17	19	*Pandorina morum*		+			+	+
Chlorophyta							*Pediastrum duplex*					+	
Actinastrum hantzchii		+				+	*Pediastrum simplex*	+	+	+	+	+	+
Ankistrodesmus falctuts	+	+	+	+	+	+	*Pediastrum tetras*		+				+
Ankistrodesmun falctuts var. *marabilis*	+						*Protococcus viridis*	+	+	+	+	+	+
Ankistrodesmus fusiforms	+			+			*Scenedsmus arcuatus*				+		
Botryococcus borybencnous				+			*Scenedsmus bijugatus*	+	+	+	+	+	+
Chlamydomonas globosa	+	+	+	+	+	+	*Scendesmus bijugatus* var. *alterans*			+		+	+

Table 3: Continue

	Dahmeit			Tushka West				Dahmeit			Tushka West		
Species	BF	DF	AF	BF	DF	AF	Species	BF	DF	AF	BF	DF	AF
Scendesmus dimporphous					+	+							
Scendesmus quadricauda	+	+	+			+							
Scendesmus quadricauda var. *biqudatus*		+			+	+	*Navicula cryptocephalea*	+	+	+	+	+	+
Schroederia setigera			+				*Navicula cuspidata* var. *Ambigua*	+	+	+	+	+	+
Stigocolonium sp.	+	+	+	+	+	+	*Navicula exigua*					+	+
Staurastrum gracile	+	+	+	+	+	+	*Navicula muralis*	+	+		+	+	+
Staurastrum sp.					+	+	*Navicula* sp.	+	+		+	+	+
Staurodesmus convergens	+	+	+	+	+	+	*Nitzschia dissipata*	+	+	+	+	+	+
Staurodesmus extensus	+				+		*Nitzschia hungerica*			+			
Tetraëdron caudatum		+	+		+		*Nitzschia paradoxa*				+		
Tetraëdron minimum	+	+	+	+	+	+	*Rhopalodia gibba*	+			+		
Tetraëdron trigonium						+	*Staurosirella leptostauron*	+			+		
Tetrallantos lagerheimii						+	*Surirella capronii*	+			+		
Westella botryoides					+	+	*Synedra acus*		+	+		+	+
Zygnema sp.			+		+		*Synedra ulna*	+	+	+	+	+	+
Number of species	27	33	34	25	37	40	Number of species	20	17	12	20	17	16
Bacillariophyta							**Euglenophyta**						
Achnanthidium minutissimum	+	+	+		+		*Euglena gracilis*				+		
Aulacoseira granulata	+	+	+	+	+	+	*Euglena elongata*	+					
Aulacoseira granulata var. *angistutum*						+	*Euglena* sp.	+					
Amphora ovalis				+	+		*Phacus* sp.	+					
Cocconies placentula	+			+			Number of species	3			1		
Coscinodiscus sp.	+						**Dinophyta**						
Cyclotella kutiaingiam			+			+	*Ceratium cornutum*		+	+	+	+	+
Cyclotella menginiana						+	*Ceratium hirundinella*	+		+	+		
Cyclotella glomerata			+		+	+	*Peridinium gatunense*	+	+	+	+	+	+
Cyclotella ocellata	+	+	+	+	+	+	*Peridinium* sp.		+			+	
Cymatopleura solea		+		+			*Gymnodenium* sp.	+	+		+	+	
Cymbella affinis	+	+	+		+	+	Number of species	3	4	3	4	4	2
Denticula elegans		+					**Cryptophyta**						
Diploneis smithii	+			+			*Chroomonas nordstedii*	+	+	+	+	+	+
Epithemia sp.	+	+		+	+		*Cryptomonas erosa*	+	+	+		+	+
Fragillaria construens		+			+		*Cryptomonas ovata*		+	+		+	+
Gomphonema olivaceum	+			+			*Rhodomonas* sp.	+	+	+	+	+	+
Gomphonema parvulum	+	+		+		+	Number of species	3	4	4	2	4	4
Merlosira granulta	+	+		+	+		**Total number of species**	**70**	**76**	**70**	**63**	**79**	**81**

Table 4: % abundance of different microalgae classes in Dahmeit and Tushka West Khors

Sampling stations	Microalgae groups: Cyanophyta BF	Cyanophyta DF	Cyanophyta AF	Chlorophyta BF	Chlorophyta DF	Chlorophyta AF	Bacillariophyta BF	Bacillariophyta DF	Bacillariophyta AF	Dinophyta BF	Dinophyta DF	Dinophyta AF	Euglenophyta BF	Euglenophyta DF	Euglenophyta AF	Cryptophyta BF	Cryptophyta DF	Cryptophyta AF	Total number of identified taxa BF	DF	AF
Dahmeit khor																					
St.1	76.99 (8)*	96.64 (8)	91.82 (9)	8.55 (13)	2.12 (12)	5.17 (12)	13.55 (7)	0.66 (6)	2.45 (7)	0.63 (3)	0.053 (1)	0.11 (1)	0.09 (1)			0.18 (2)	0.53 (3)	0.44 (2)	34	30	31
St. 2	65.06 (6)	82.1 (6)	95.26 (9)	13.51 (13)	8.29 (9)	3.36 (18)	18.53 (7)	3.49 (7)	1.23 (5)	1.158 (3)	0.87 (2)	0.17 (2)	0.386 (1)			1.35 (2)	6.55 (4)	0.22 (2)	32	28	36
St. 3	74.45 (9)	97.69 (9)	92.58 (10)	12.18 (20)	1.41 (19)	5.26 (21)	11.618 (7)	0.404 (7)	1.58 (6)	0.733 (3)	0.081 (2)	0.197 (2)	0.113 (1)			0.902 (2)	0.404 (4)	0.39 (3)	42	41	42
St. 4	87.76 (5)	96.54 (11)	91.15 (9)	5.89 (18)	2.51 (18)	6.23 (23)	5.80 (9)	0.76 (8)	1.26 (6)	0.298 (3)	0.152 (3)	0.146 (2)				0.22 (2)	0.038 (1)	1.117 (4)	37	41	44
St. 5	76.67 (6)	95.79 (11)	92.94 (7)	9.04 (20)	3.65 (23)	4.75 (15)	12.83 (8)	0.44 (8)	0.89 (5)	0.312 (1)	0.025 (1)	0.156 (2)				0.78 (2)	0.098 (3)	0.784 (3)	37	46	32
Average % abundance	76.18	93.75	92.75	9.83	3.15	4.96	12.46	1.15	1.48	0.63	0.24	0.16	0.12			0.68	1.52	0.59			
Tushka West khor																					
St.1	90.86 (7)	98.55 (10)	91.32 (15)	5.92 (18)	0.97 (12)	6.86 (20)	2.53 (5)	0.39 (6)	1.73 (11)	0.287 (4)	0.055 (2)	0.031 (1)	0.115 (1)			0.286 (2)	0.028 (1)	0.062 (2)	37	31	49
St. 2	84.5 (9)	98.31 (11)	94.76 (11)	12.5 (16)	0.99 (9)	3.27 (15)	2.16 (4)	0.56 (7)	1.85 (10)	0.31 (2)	0.043 (1)	0.034 (1)	0.087 (1)			0.35 (3)	0.087 (3)	0.1 (1)	35	31	38
St. 3	92.5 (9)	97.84 (12)	93.87 (14)	5.6 (16)	1.79 (25)	3.72 (26)	1.40 (3)	0.32 (5)	2.23 (12)	0.41 (4)	0.053 (2)	0.76 (2)	0.065 (1)					0.076 (1)	33	44	55
St. 4	87.9 (9)	98.53 (11)	95.35 (11)	10.03 (16)	1.14 (25)	2.58 (17)	1.51 (5)	0.19 (8)	1.81 (9)	0.44 (2)	0.05 (3)	0.032 (1)				0.087 (1)	0.094 (2)	0.223 (3)	33	49	41
St. 5	86.3 (8)	98.05 (11)	95.81 (10)	10.9 (18)	1.1 (16)	2.08 (13)	2.5 (10)	0.673 (11)	1.83 (8)	0.27 (3)	0.016 (1)						0.064 (2)	0.256 (3)	39	41	34
Average % abundance	88.41	98.26	94.22	8.99	1.198	3.678	2.02	0.427	1.89	0.343	0.043	0.171	0.053			0.145	0.055	0.143			

BF: Before flood, DF: During flood, AF: After flood, *Number of identified taxa

(Tushka khor) of the total Cyanophyta community before flood season, followed by *Pseudoanabaena* sp., which representing 12-42 and 45-56% and *Microcystis incerta* representing 22-30 and 11-35%. During the flood season, the most frequent cyanophycean species were *Pseudoanabaena* sp., representing 47-60 and 54-68%, of the total identified Cyanophyta recorded at Dahmeit khor and Tushka khor, respectively, followed by *Oscillatoria hamellii* (13-50%) and (8-22%), *Chroococcus* spp. (13-36%) and (3-20%) and *Leptolyngbya granulifera* (10-14%) and (4-11%). Meanwhile, after flood season the *Chroococcus* spp. and *Pseudanabaena* sp. represent 72-91 and 6.5-14.6% of the total identified Cyanophyta species at Dahmeit khor. Meanwhile, at Tushka khor, Cyanophyta community was dominated by *Chroococcus* spp. (22-44%), *Pseudoanabaena* sp. (6-34%), *Leptolyngbya agranuliferm* (5-31%) and *Oscillatoria hamellii* (6-18.5%).

Chlorophyta: Chlorophyta comprises 3.15-11.83% of the total community at khor Dahmeit and from 1.198-8.99% at khor Tushka, with the lowest values during the flood season (summer season) and the highest one during the post flood season (Table 4). This may be explained by the tendency of Chlorophyta to reach its highest density in water with lower temperatures[58]. The most frequent green algae of recorded species in khors Dahmeit and Tushka were *Ankistrodesmus falcatus*, *Dictyosphaerium pulchellum*, *Coelastrum cambricum*, *Lagerheimia citriformis*, *Protococcus viridis*, *Scenedesmus bijugatus* and *Stigeoclonium* sp. These species found to contribute to 47-72.6, 18-55 and 24-75% of the total green microalgae at khor Dahmeit during post flood season, flood season and after flood season, respectively. Meanwhile, these species comprise 49-67, 13-52 and 34-62% of the total green microalgae at the different stations at khor Tushka during the flood cycle. The filamentous green microalgae, *Mougeotia* sp. was recorded, only, at St. 5 of Dahmeit khor before flood with 4.87% of total green microalgae.

Bacillariophyta: Diatoms are generally the pioneers in seasonal sequences or successions, which are often ended by the influx of relatively turbid though nutrient-rich floodwater. Bacillariophyta found to comprise 1.15-12.46% of the total community at Dahmeit khor and from 0.427-2.02% at Tushka khor, with the lowest values during the flood season and the highest one before flood season (Table 4). *Cyclotella ocellata* was the dominant diatom species at Dahmeit and Tushka khors before flood season comprising 79-95 and 50-90% of the total recorded diatoms, respectively. During the flood season, *Cyclotella ocellata* and *Navicula muralis* were the dominant diatoms species at khor Dahmeit with precentage contribution to the total diatoms of 20-48%. Meanwhile, *Aulacoseira granulata* and *Cyclotella ocellata* were the dominant diatoms species at khor Tushka with 20-51% contribution to the total diatoms. After flood season, *Cyclotella ocellata* was the dominant diatom at Dahmeit khor with a contribution of 45-93%, while at Tushka khor, *Aulacoseira granulata, Cyclotella glomerata*, *Cyclotella ocellata* and *Synedra* spp., contribute to the total diatoms by 4-14.5, 4-16, 43-60 and 3-25%, respectively.

Other phytoplankton groups: Dinophyta, Euglenophyta and Cryptophyta were recorded at the different seasons of the flood in the two khors with a percentage contribution to the total phytoplankton community varied from station to another and from season to another (Table 4). In average, Dinophyta varied from 0.16% (after flood season) to 0.63% (post flood season) at Dahmeit khor and from 0.043% (during flood season) to 0.343% (before flood season) at khor Tushka (Table 4). The euglenoid algae were completely absent during the flood and the after flood season at the two khors (Table 4). The percentage contribution of Euglenophyta to the total community at Dahmeit khor varied from 0.09-0.386% with an average of 0.12%, while they contribute 0.065-0.115% of the total community at Tushka khor (Table 4). Cryptophyta contributed about 0.6-1.5% of total phytoplankton community at Dahmeit khor and 0.06-0.14% at Tushka khor (Table 4).

Macroinvertebrates associated with macrophyte *Myriophyllum spicatum*

Macrophytes and macroinvertebrates: Aquatic macrophytes are an important habitat for invertebrates. Invertebrates utilize them as a direct food source[59,60], shelter from predators[61], spawning and attachment sites[62] as well as feeding on the periphyton growing on their surfaces[63]. Number of samples collected submerged macrophyte during flood were fewer than the number of samples collected before and after flood seasons, this may be due to water velocity during flood season. This agrees with Franklin *et al.*[64] and Padial *et al.*[65], who stated that water velocity is the main factor controlling the presence, distribution and diversity of submerged macrophytes. The composition and abundance of invertebrate groups associated with macrophytes varies with the plant species that are present[66,67]. Feeding groups of macroinvertebrates associated with aquatic macrophyte *Myriophyllum spicatum* typically include shredders and grazers, detritivores and predators[68]. This agrees with the results of present study when all the previous groups are recorded in the area of investigation (Table 5)[69,66].

Community composition and abundance of macroinvertebrates associated with macrophyte *Myriophyllum spicatum*: Macroinvertebrate species identified in the present study were represented in five classes namely Oligochaeta, Hirudinea belonging to phylum Annelida, Crustacea, Insecta belonging to phylum Arthropoda and class Gastropoda belonging to phylum Mollusca. Olson *et al.*[70] found that four classes (Hirudinea, Isopoda, Mollusca and Insecta) were most abundant in Macrophyte *Typha* sp., in Sawn Lake Nicollet County, MN. Fishar and Abdel Gawad[71] found Oligochaeta Crustacea, Insecta and Mollusca were attached to macrophyte *Potamogeton pectinatus* in Lake Manzala. The highest averages of associated macroinvertebrates (576 and 690 individuals/100 g plant dry wt at khor Dahmeit and khor Tushka West, respectively) were recorded during Flood season (Table 6). Some macroinvertebrates swam or flew to protected habitats to avoid floods. The highest number of species (22) was recorded before flood season while the lowest number (15 species) was recorded during flood season.

Before flood: At Dahmeit khor, Gastropoda was the first group constituted about 75.7% of total macroinvertebrates. Insecta, Crustacea constituted approximately the same percentages about 12% of the total fauna. Oligochaeta disappeared totally from khor Dahmeit before flood. The highest count of total macroinvertebrates before flood was found at stations 1 and 2 at khor Dahmeit, (514 and 330 organisms/100 g plant dry wt respectively). The lowest density (137 organisms/100 g plant dry wt.) was recorded at station 3. At khor Tushka West, Oligochaeta

Table 5: Macroinvertebrates associated with aquatic macrophyte *Myriophyllum spicatum* recorded during this study and by another authors Cummins[69], Dvorak and Bestz[66] (+ = Present)

Feeding group	Feeding habit	Cummins[69], Dvorak and Bestz[66]	Present study
Shredders/Grazers	Macroinvertebrates that consume living plant tissue	Some Lepidoptera (moth larvae) and Trichoptera (caddisflies)	+
Detritivores	Organic material and/or scrape periphyton from plants	Hemiptera Gastropoda	+
Predator	Prey on smaller invertebrates	Odonata (dragonflies)	+
Filter feeder	Filter water to gain detritus from around plants and small crustaceans	some insect larvae and small crustaceans	+

Table 6: Temporal variations of total and the different macroinvertebrate groups (individuals/100 g plant dry wt.) associated with *M. spicatum* at Dahmeit and Tushka West Khors during this study

Sampling stations	Oligochaeta			Hirudinea			Gastropoda			Insecta			Crustacea			Total		
	B.F.	D.F.	A.F.	B.F.	D.F.	A.F.	B.F.	D.F.	A.F.	B.F.	D.F.	A.F.	B.F.	D.F.	A.F.	B.F.	D.F.	A.F.
Dahmeit Khor																		
St. 1	0.0	-	511	8	-	9	370	-	52	40	-	69	96	-	0.0	514	-	641
St. 2	0.0	235	42	0.0	0.0	0.0	249	153	4	59	100	9	22	200	0.0	330	688	55
St. 3	0.0	150	57	0.0	0.0	0.0	115	22	7	22	52	9	0.0	22	0.0	137	246	73
St. 4	0.0	-	210	0.0	-	0.0	272	-	13	24	-	17	0.0	-	0.0	296	-	240
St. 5	0.0	159	167	0.0	9	0.0	100	346	10	30	155	15	50	127	0.0	180	796	192
Average number of individuals at Dahmeit Khor	0.0	181	197.4	1.6	2.3	1.8	221	173.7	17.2	35	102.3	23.8	34	116	0.0	292	576	240
Tushka West Khor																		
St. 1	-	-	100	-	-	0.0	-	-	0.0	-	-	30	-	-	7	-	-	137
St. 2	92	516	76	0.0	0.0	0.0	309	216	1	160	119	78	319	97	1	880	948	156
St. 3	0.0	287	128	4	0.0	4	192	0.0	6	32	49	3	320	0.0	9	548	336	150
St. 4	0.0	35	-	0.0	35	-	20	754	-	83	93	-	7	116	-	110	1033	-
St. 5	12	72	207	0.0	0.0	0.0	50	300	2	217	0.0	166	0.0	72	0.0	279	444	375
Average number of individuals at Tushka Khor	20	227.5	128	1	9	1	143	318	2	161.5	65	69	161.5	71	4	448	690	205
Total Number of individuals at the two khors	104	1454	1498	12	44	13	1677	1791	95	667	568	396	814	634	17	3274	4491	2019

B.F. = Before Flood, D.F. = During Flood, A.F. = After Flood, - : No plant found

represented least percentage (4.5% of total density). Insecta, Crustacea equally shared the first position constituted about 36% of total fauna associated with *M. spicatum*. Stations 2 and 3 at khor Tushka show the highest count (880 and 548 organisms/100 g plant dry wt., respectively) while, the lowest (110 organisms/100 g plant dry wt.) was recorded at station 4 (Table 6).

During flood: Oligochaetes was represented the major part of the fauna at khor Dahmeit where, it constituted about 31.4% of total density of total macroinvertebrates. It followed by Gastropods and crustaceans (30.2 and 20%, respectively). Stations 2 and 5 of khor Dahmeit were the richest sites with total macroinvertebrates where 688 and 796 organisms/100 g plant dry wt. were found (Table 6). Station 3 has the lowest density of macroinvertebrates. At khor Tushka West, Gastropoda ranked the first position (46%) during flood, followed by Oligochaeta constituted about 33% of the total fauna. Station 5 has the highest peak of total macroinvertebrates (1033 organisms/100 g plant dry wt.), this attributed to the increase of gastropods.

After flood: Oligochaeta was the most dominant group constituted about 81 and 62% of the total associated fauna at Dahmeit khor and Tushka West khor, respectively. Average densities of total associated fauna at Dahmeit and Tushka were 240 and 205 organisms/100 g plant dry wt., respectively. This Season was the poorest season with macroinvertebrates at the two khors. Station 1 at Dahmeit and Station 5 at Tushka have the highest densities (641 and 375 organisms/100 g plant dry wt., respectively). While, the lowest ones (55 and137organisms/100g plant dry wt.) were recorded at stations 2 at Dahmeit khor and station 1 at Tushka West khor, respectively.

Common recorded species

Oligochaeta: *Pristina* sp., was the most common oligochaete species in the area investigated. It formed about 24.1 and 27% of total macroinvertebrates associated with *M. spicatum* at khor Dahmeit and khor Tushka West, respectively. Station 1 at Dahmeit khor and station 2 at Tushka were the most favorable ground for *Pristina* sp. (Table 7). *Limnodrilus* spp., were found in a weak representation constituted about 1.38 and 5% of total macroinvertebrates and total oligochaetes at khor Dahmeit. It formed about 0.82 and 3% of total macroinvertebrates and total oligochaetes at khor Tushka West. In eutrophic waters very successful taxonomic groups, present in high abundance are oligochaetes according to

Table 7: Temporal variations of dominant species of macroinvertebrates associated with *M. spacitum* (individuals/100 g plant dry wt.) at Dahmeit and Tushka West khors of Lake Nasser

	Pristina sp.			*Valvata nilotica*			*Gyraulus ehrenbergi*			*Bulinus truncatus*			*Chlamydotheca unispinosa*			*Chironomus* sp.		
Sampling stations	BF	DF	AF	BF	DF	AF	BF	DF	AF	BF	DF	AF	BF	DF	AF	BF	DF	AF
Dahmeit khor																		
St. 1	0.0	-	450	240	-	0.0	120	-	8	24	-	32	80	-	0.0	12	-	0.0
St. 2	0.0	14	42	64	14	2	223	14	2	58	0.0	0.0	11	14	0.0	11	28	3
St. 3	0.0	-	52	7.5	-	1	74	-	4	37	-	0.0	0.0	-	0.0	0.0	-	3
St. 4	0.0	-	198	104	-	4	32	-	9	136	-	0.0	0.0	-	0.0	0.0	-	6
St. 5	0.0	159	160	0.0	0.0	0.0	10	0.0	5	90	273	3	40	127	0.0	0.0	59	0.0
Tushka West khor																		
St. 1	-	-	100	-	-	0.0	-	-	0.0	-	-	0.0	-	-	7	-	-	30
St. 2	68	484	75	209	0.0	0.0	55	141	0.0	46	62	1	319	97	1	46	66	30
St. 3	0.0	287	125	0.0	0.0	2	80	0.0	2	112	0.0	3	320	0.0	9	4	16	3
St. 4	0.0	23	-	0.0	35	-	3	348	-	17	348	-	7	116	-	17	23	-
St. 5	24	72	202	0.0	0.0	0.0	43	172	2	55	129	0.0	0.0	72	0.0	122	0.0	90
Total	92	1039	1404	625	49	9	640	675	32	575	812	39	777	426	17	212	192	165

BF: Before flood, DF: During flood, AF: After flood, -: No plant found

Mackie[72] and Cerba *et al.*[25]. Oligochaetes is a typical detritivorous[73]. The submersed parts and roots of macrophytes accumulates detritus and organic matter, favoring the establishment of population detritivorous[74].

Gastropoda: Some gastropods were among the most common species in the area of study probably because gastropods would be more vulnerable in moving substrates than mobile and free living insects[1]. *Bulinus truncates* was the most common gastropod in the area investigated constituted about 34.3, 45.3 and 41.1% of total gastropoda recorded in whole area before, during and after flood, respectively . It also formed about 14.6% of total macrofauna attached to *M. spicatum* in the whole area during the whole period of study. Station 5 at khor Dahmeit and Station 4 at khor Tushka West were the most favourable stations specially during flood (Table 7). *Gyraulus ehrenbergi* occupies the second position and constituted about 38.1, 37.7 and 33.7% of total gastropods recorded before, during and after flood in the whole area of study. Station 2 at khor Dahmeit before flood and station 4 at khor Tushka during flood were the richest sits with *G. ehrenbergi*. These two previous gastropods were collected from Lake Manzala associated with macrophyte *Potamogeton pectinatus* by Fishar and Abdel Gawad[71]. *Valvata nilotica* ranked the third position among gastropods. It was more abundant in the two khors before flood season than during and after flood seasons. It formed about 19.2% of total gastropods associated with *M. spicatum* in the whole area. *Ferrissia clessiniana* represented only during flood at stations 2 and 5 at Dahmeit and stations 2 and 4 at Tushka khor. *Theodoxus niloticus* and *Physa acuta* appeared rarely in the area during this study.

Crustacea: *Chlamydotheca unispinosa* was the most abundant crustacean associated with *M. spicatum* in Lake Nasser khors during this study. Stations 2 and 3 at khor Tushka were the most favourable ground where the highest numbers (319 and 320 organisms/100 g plant dry wt) were found. It constituted about 8.8 and 17.6% of total macrofauna at khor Dahmeit and khor Tushka West, respectively during the whole cycle of flood. Ali *et al.*[75] found two unidentified species of Ostracoda attached to macrophytes of Lake Nasser. *Caridina nilotica* was recorded in a weak representation at khor Dahmeit before flood specially at stations 2 and 5 with 11 and 10 organisms/100 g plant dry wt, respectively. *Cyclops* sp., was recorded only one time during this study at station 1 of Dahmeit khor.

Table 8: Macroinvertebrate species associated with *M. spicatum* recorded at the area of investigation during this study (+ = present, - = absent)

Species recorded	BF	DF	AF
Phylum Arthropoda			
Class Insecta			
Order Diptera			
Chironomus sp.	+	+	+
Crypto chironomus sp.	+	-	-
Tanytarsus sp.	+	+	+
Polypedilum sp.	+	-	+
Chironomid pupae	+	+	+
Culex sp.	+	+	+
Order Ephemeroptera			
Caenis sp.	+	+	+
Order Coleoptera			
Unidentified sp.	+	-	-
Order Odonata			
Ischnura sp.	+	+	+
Gomphus sp.	+	-	-
Order Hemiptera			
Micronecta plicta	+	-	-
Urinator sp.	+	-	-
Order Lepidoptera			
Parapoynx sp.	+	+	+
Order Trichoptera			
Macronemum sp.	-	-	+
Potamyia sp.	-	-	+
Class Crustacea			
Caridina nilotica	+	-	-
Chlamydotheca unispinosa	+	+	+
Cyclops sp.	+	-	-
Phylum Annelida			
Class Oligochaeta			
Pristina sp.	+	+	+
Limnodrilus spp.	+	+	+
Class Hirudinea			
Helobdella conifera	+	+	+
Barbronia assiut	-	-	+
Phylum Mollusca			
Class Gastropoda			
Bulinus truncatus	+	+	+
Valvata nilotica	+	+	+
Gyraulus ehrenbergi	+	+	+
Ferrissia clessiniana	-	+	-
Theodoxus niloticus	-	-	+
Physa acuta	-	-	+
Total number of species	22	15	20

BF: Before flood, DF: During flood, AF: After flood

Insecta: The Insect Chironomid larvae was distributed and abundant at most stations of two studied khors during whole flood cycle and represented by 4species (Table 8) with average value of 40.6 and 149 organisms/100 g plant dry wt. at khor Dahmeit and khor Tushka West, respectively. This results agrees with the result of Abd El-Karim *et al.*[76], who found this larvae associated with *M. spicatum* at six khors of Lake Nasser. Hann[77] found that, Chironomidae predominated on the macrophytes *Ceratophyllum* sp. and *Potamogeton* sp., in a prairie wetland. In eutrophic waters very successful taxonomic groups, present in high abundance are chironomidae larvae[78,25].

Odonata nymphs (*Ischnura* sp. and *Gomphus* sp.) were found associated with *M. spicatum* at two khors during this study. Odonata are predatory insects[79] and may use macrophytes as a substrate and also as an ambush point to capture their prey. *Coleoptera* sp. and Hemiptera *Micronecta plicta*, *Urinator* sp., were recorded in the area specially before flood. Patra *et al.*[80] recorded Coleoptera and Hemiptera attached to macrophytes in the Santragachi Jheel Lake (India). Trichoptera larvae (*Macronemum* sp. and *Potamyia* sp.) recorded in a weak representation specially after flood.

Hirudinea: It represented by two species (Table 8) appeared in the two khors in few numbers at some sites during the whole period of study.

Phytoplankton and phytophilous macroinvertebrates association: Significant ($p<0.05$) spatial and seasonal variation in phytoplankton and macroinvertebrates densities were detected in the two khors (Fig. 2). The highest total biomass density of phytoplankton and associated macroinvertebrates were recorded at Tushka West khor. This agrees with Gaber[81], El-Shabrawy and Dumont[82] and El-Serafy *et al.*[13], who concluded that the Southern part of Nasser Lake (upstream) is richer in phytoplankton, zooplankton than the Northern one (downstream). Mola and Abdel Gawad[37] also found Southern khors of Lake Nasser are rich in macrobenthic invertebrates than the Northern khors. During the flood season the biomass of phytoplankton and the density of associated macroinvertebrates were higher than those at the before and after flood seasons. Tundisi and Tundisi[83] reveled that, when the water level increases, the water from the flooded areas of the Lake transports nutrients, thus affecting biogeochemical cycles and consequently the phytoplankton biomass. At Dahmeit khor, the average phytoplankton density were 1.8×10^9, 5.3×10^9 and 3.0×10^9 cells L^{-1} before flood, during flood and after flood (Fig. 2). The same trend was observed for macroinvertebrates when the average of 292, 576, 240 individuals/100 g plant dry weight were calculated before flood, during flood and after flood, respectively. At Tushka West khor, the average of total phytoplankton density were, respectively, 9.16×10^8, 8.7×10^9 and 7.35×10^9 cells L^{-1} while for macroinvertebrates, they were 448, 690, 205 individuals/100 g plant dry wt. (Fig. 2). Some interesting correlation were detected between phytoplankton and macroinvertebrates, where species evenness of macroinvertebrates shows negative significant ($p<0.05$) correlation with species diversity ($r = -0.6$) and evenness ($r = -0.5$) of phytoplankton. Also, negative strong significant correlation ($r = -0.76$)

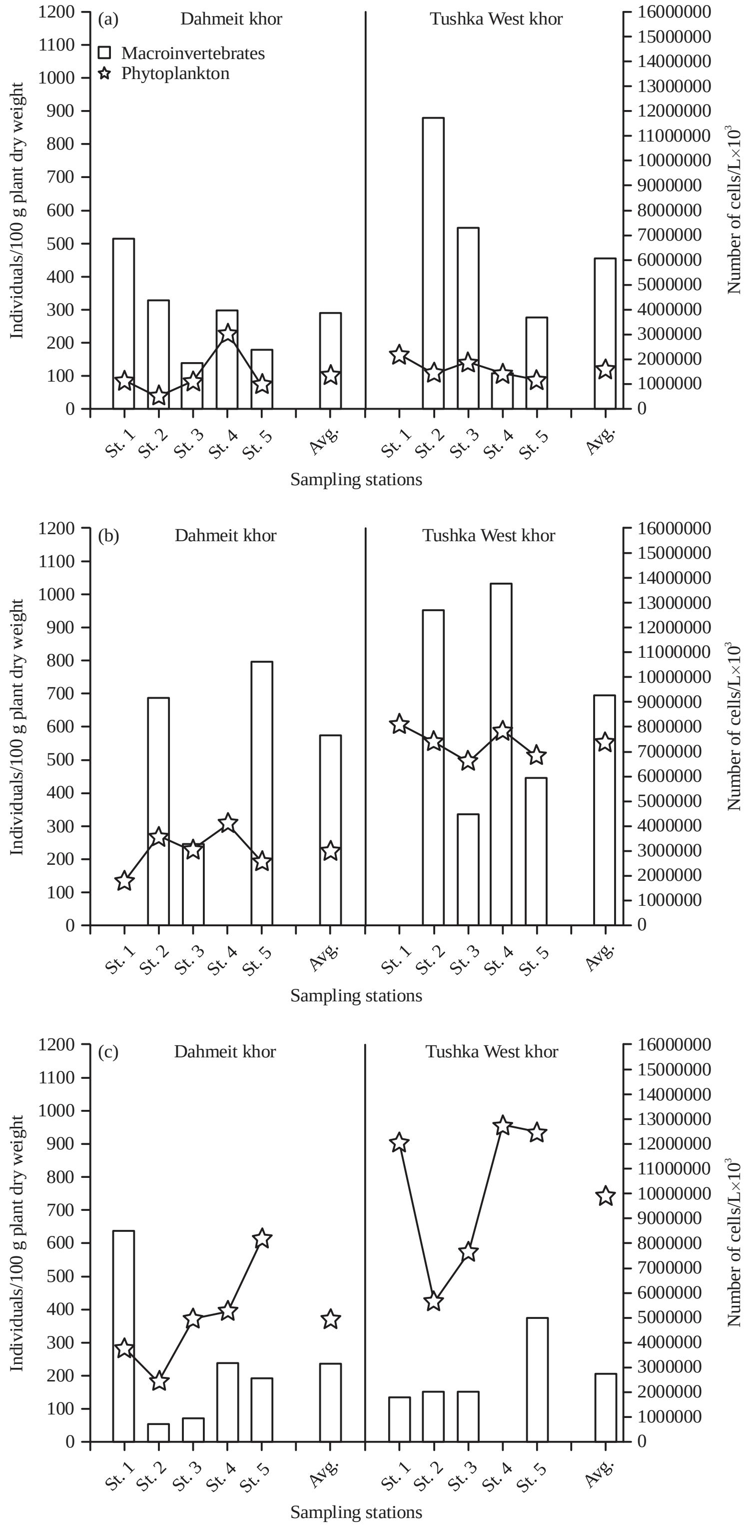

Fig. 2: Spatial and seasonal variation in total count of phytoplankton and macroinvertebtates associated to *M. spicatum* at Dahmeit and Tushka West Khors, (a) Before Flood, (b) During Flood and (c) After Flood

was detected between species richness of phytoplankton and macroinvertebrates. Meanwhile, a positive correlation (r = 0.5) was detected between species richness of phytoplankton and species evenness of macroinvertebrates.

Statistical and biological analysis: The WQI shows significant correlation ($p<0.05$) with water temperature ($r = -0.91$), dissolved oxygen ($r = 0.52$), species diversity ($r = 0.66$) of phytoplankton and also with species evenness ($r = -0.9$) and richness ($r = 0.58$) of macroinvertebrates. Water temperature, DO, transparency and EC were found to be the most effective parameters on the production of different groups of phytoplankton and macroinvertebrates, in addition to total inorganic nitrogen (TIN) which significantly ($p<0.05$) ($r = -0.59$) affect the phytoplankton production, while it shows none or extremely low correlation ($r = 0.11$) with macroinvertebrates. Although, Straskraba and Tundisi[84] revealed positive correlation between pH and phytoplankton diversity, no such correlation between pH and phytoplankton diversity obtained in the present study. The CCA analysis Fig. 3 shows that total count of phytoplankton was not affected by total count of associated macroinvertebrates and its groups and this results agrees with Abd Abd El-Karim *et al.*[76]. Dinophyta shows positive association with Oligochaeta while negative association with other macroinvertebrate groups. Groups of phytoplankton Cyanophyta, Chlorophyta, Cryptophyta Bacillariophyta and Dinophyta was negatively associated with total invertebrates and its groups.

Table 9: Average values of species diversity, evenness and species richness of phytoplankton and macroinvertebrates associated with *M. spicatum* at the studied khors during the flood cycle, 2016

	Phytoplankton			Macroinvertebrates		
Indices	BF	DF	AF	BF	DF	AF
Diversity	0.85	1.65	1.89	2.19	2.15	1.31
Evenness	0.52	0.84	0.91	0.71	0.79	0.44
Species richness	35.8	38.14	40.94	2.59	1.66	2.50

BF: Before flood, DF: During flood, AF: After flood

Shannon-Wiener diversity index, evenness and species richness were used for the analysis of data. The average values of these biological indices for phytoplankton were all trend with the same manner, where, gradual increase was detected from drought to rainy season (Table 9) indicating the gradual improvement of water with the flood. This agrees with the results of WQI shown in Table 2. Meanwhile, H<1 at the before flood season indicates eutrophic conditions[85], in which the highest concentrations of TIN and TP were recorded (Table 2). The average values of Shannon index for macroinvertebrates were 2.19 (before flood), 2.15 (during flood) and 1.44 (after flood) in the whole area of study indicating moderate pollution status. The mean results of evenness indices for macroinvertebrates were 0.71 before flood, 0.79 during flood and 0.44 after flood while it was 0.52, 0.84 and 0.91 for phytoplankton, respectively. However, higher evenness index values of 0.656-0.865 supporting high equitability[86]. It is understood from the above values of the evenness indices that the equitability of phytoplankton increases gradually by the flood, while, for macroinvertebrates community the equitability was high before and during flood seasons. The highest number of total species (22 species) and species richness were recorded before flood for macroinvertebrates while, the highest number of total species (81 species) and species richness for phytoplankton were recorded after flood.

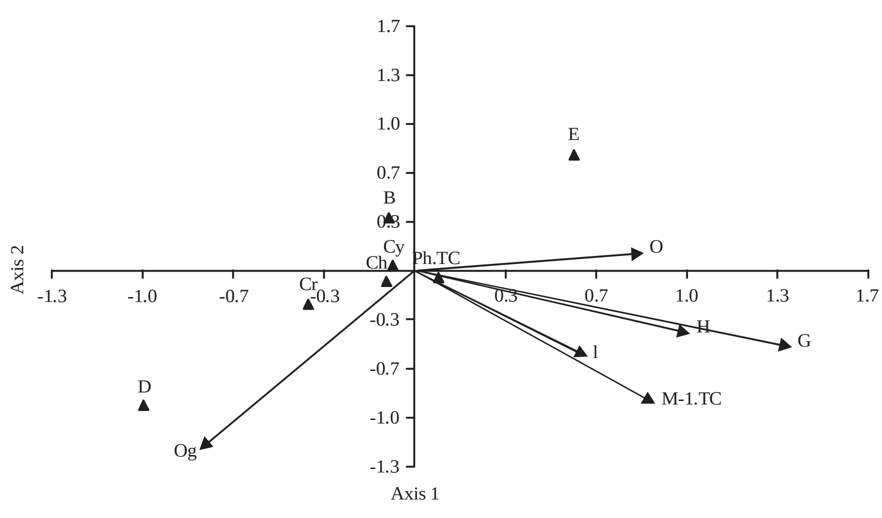

Fig. 3: CCA ordination diagram based on total count and different phytoplankton groups (dependent variables) in relation to total count and different groups of associated macroinvertebrates (independent variables)
Codes (Cy: Cyanophyceae, Ch: Chlorophyceae, B: Bacillariophyceae, E: Euglenophyceae D: Dinophyceae, Cr: Cryptophyceae, Ph.TC: Phytoplankton total count, Og: Oligochaeta, H: Hirudinea, G: Gastropoda, I: Insecta, O: Ostracoda, M-I.TC: Associated macroinvertebrates total count

CONCLUSION AND FUTURE RECOMMENDATIONS

In a complex natural environment, such as Lake Nasser where several factors operate simultaneously, it is difficult to generalize certain factor as being more important than the other. The biological processes at the lake bottom being the end result of the interactions of present organisms with the surrounding environment. This paper gives information providing a base for the future research regarding flood and plant-invertebrate relationship as well as bio-assessment of the ecosystem, considering that there are some human activities present. The flood cycle has obviously influenced microalgae community by stimulating spatial and seasonal variations in phytoplankton succession and density. Also, it is expected that the further research, combined with earlier published data on water quality status and phytoplankton and phytophilous invertebrate composition in the water bodies of the Lake Nasser, will help us in understanding and preservation of the floodplain, bearing in mind the importance and uniqueness of the Lake nature. More studies are needed to understand the exact factors affecting the pattern distribution of fauna and flora in Lake Nasser.

SIGNIFICANCE STATEMENTS

This study reveals that Lake Nasser khors has good water quality. However, the flood affect the distribution, density and diversity of both phytoplankton and phytophilous macroinvertebrates and also confirms that the aquatic macrophytes are an important habitat for invertebrates. During this study, some species of phytoplankton and macroinvertebrates were detected in the lake for the first time. This study will help the researcher to understand the nature of Lake Nasser and its yearly flood.

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