Factors affecting the distribution and abundance of bottom fauna in Lake Nasser, Egypt

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Abstract: This study aim to determine which factors regulate the benthic invertebrates in the offshore area of Lake Nasser. The area investigated represents about 80% of the total lake and that is not well utilized. Seven stations along the main channel of the lake and three main khors out of 85 were selected. Transparency, temperature, conductivity, dissolved oxygen, hydrogen ion concentration, some characteristics of bottom sediments, the population density and biomass of bottom fauna were measured. Only 10 species belonging to oligochaetes (3 species), chironomid larve (4 species) and molluscs (3 species) were recorded. The former were the most common group. The highest standing stock of bottom fauna was noticed in the main channel, particularly during spring (avg. 5846 org./m^2 and 29.6 g. f.w./m^2) associated with clay and silt grains representing (40.5 – 54.5%) and (37.0 – 46.0%), respectively; and subsequently high content of organic matter (8.0 – 12.5%). The three khors sustained low densities of bottom fauna and sediments constituted mainly of sand with low organic matter. [Nature and Science 2010;8(7):95-108]. (ISSN: 1545-0740)

Keywords: Lake Nasser, water quality, bottom sediments, bottom fauna, community structure.

1. Introduction:

The purpose of constructing Aswan High Dam during the period 1959 – 1969 was primarily to benefit the downstream side by controlling annual floods. Aswan High Dam Reservoir covers an area of about 6500 km2 at the final storage level of 183 m above mean sea level (m.s.l), of which northern two – third (known as Lake Nasser) is in Egypt and one – third (called Lake Nubia) in Sudan. Surface area of Lake Nasser is about 5248 km^2, water volume is roughly 131 km^3, mean depth 25.2 m at 180 m above m.s.l. The deepest part of the lake (the item of the present work) is the ancient river bed with its bottom elevation between 85 and 150 m above m.s.l. The lake has many embayments locally called khors. The total numbers of important khors reached about 85 khors. Some khors as Kalabsha, El-Allaqi and Tushka are wide, with a sandy bottom and slope gently; others as El-Sabakha, Singari and Korosko are steep, relatively narrow with a rocky bottom. The water level in Lake Nasser depends on the flood season originating from the Ethiopian highlands that occurs from late August to November. It is known by its high turbidity carrying a heavy load of a mixture of sand, silt and clay. The yearly flood of the Nile is the most important factor affecting the conditions of Lake Nasser (Mageed & Heikal, 2006).

The study of bottom fauna in Lake Nasser has received minor interest. Entz (1978) and Latif *et al*., (1979) regarded gradual change in the components of benthos with the development of the lake, particularly molluscs and oligochaetes. Iskaros (1988 & 1993), Fishar (1995 & 2000) and (SECSF, 1996) identified 48 species in the littoral zones related to four major groups: Cnidaria (Coelentrata) (1 class & 1 sp.), Bryozoa (1 class & 1 sp.), Arthropoda (2 classes & 31 spp.), Annelida (2 classes & 5 spp.) and Mollusca (2 classes & 10 species). The aim of the present study is to carry out quantitative and qualitative estimations on bottom fauna in the offshore area of Lake Nasser which was carried out for the first time in relation to the prevailing environmental conditions, particularly the characteristics of bottom sediments.

2. Material and Methods

The bottom fauna was seasonally collected, during spring (May), Summer (July), autumn (November) 2006 and winter (February) 2007. Seven stations were selected in the main stream of Lake Nasser to represent the different habitats. These were El-Ramla, Kalabsha, El-Allaqi, El-Madiq, Korosko, Tushka and Abu-Simbel. Besides, three main khors were also chosen on both western and eastern sides, namely; Khor Kalabsha, Khor Korosko and Khor Tushka (Fig. 1).

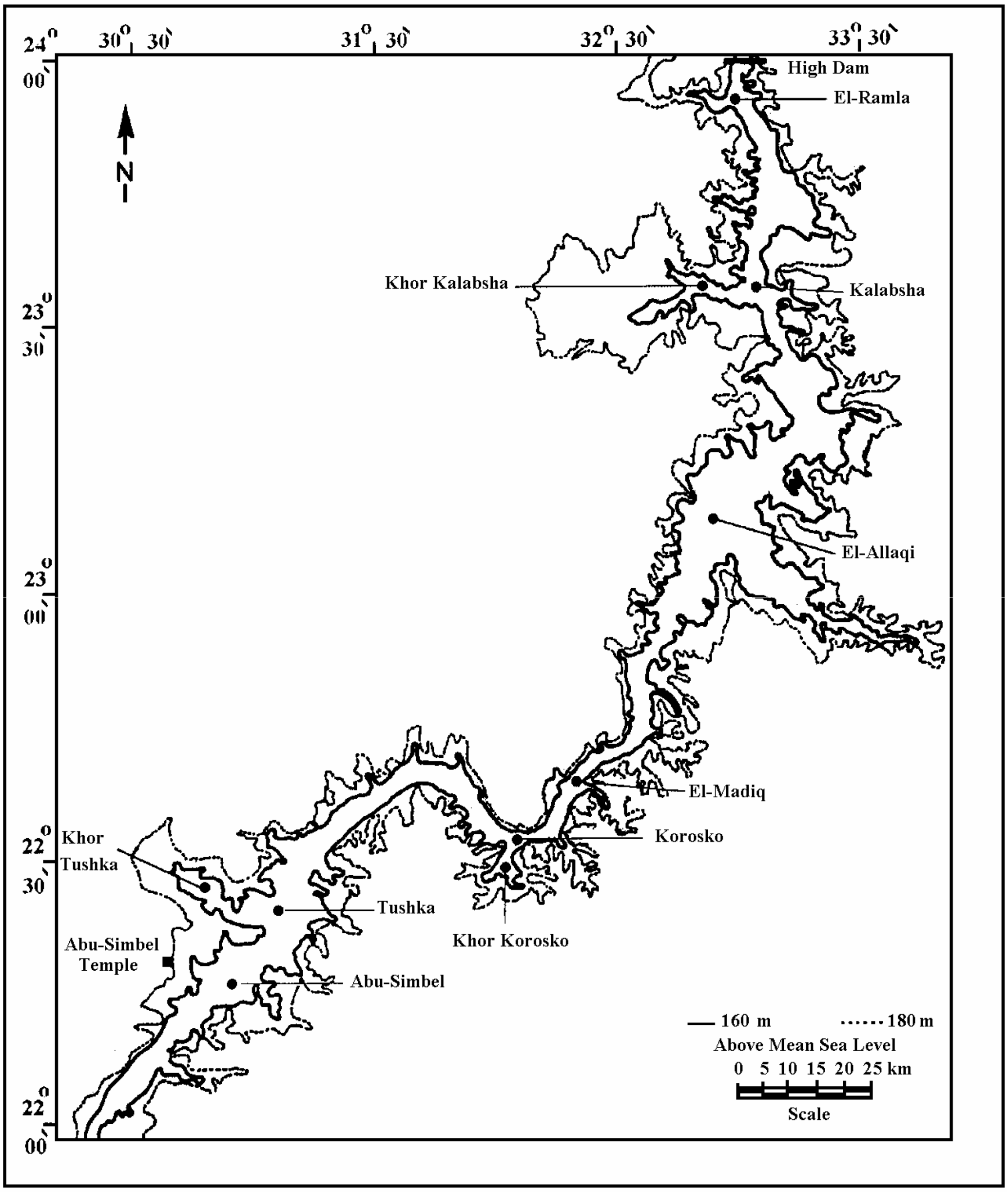

Fig. (1): Map of Lake Nasser showing the stations of study.

Bottom fauna samples were collected using Ponnar bottom grab with an opening of 234 cm^2 (1/43 m^2). Samples were thoroughly washed from muds in a metallic sieve with mesh size of 0.4 mm sorted directly in the field and preserved in 5% formaline solution. In lab, the number of the different species and genera were determined (no. ind./m^2) and their weights (g.f.w/m^2) were also determined. The shells of molluscs were removed for weighing their flesh.

Oligochaetes, were identified according to Brinkhurst & Jamieson (1971) and Pennak (1978) and were further checked by Dr. E.G. Easton from the British Museum. The identification key used by Wirth & Stone (1968) and Hilsenhoff (1975) was adopted for chironomid larvae, while those of Brown (1980) and Brown et al., (1984) for molluscs.

Simultaneous with sample collection, transparency was obtained by a black-white enameled

Secchi disc of 30 cm diameter at the shaded side of the boat. Water samples were collected using Van-dorn bottle at three levels (surface, middle and bottom). Temperature, electrical conductivity, dissolved oxygen and hydrogen ion concentration were analyzed using standard methods (APHA, 1995) in the different sampling stations. Sieving and settling velocity techniques were made for grain size analysis. Organic matter estimation was carried out as described by Hanna (1965). The calcium carbonate was determined using Jackson methodology (1958).

3. Results

3.1. Physicochemical Parameters

3.1.1. Transparency

Transparency fluctuated between 150 cm at Khor Korosko during spring to 450 cm at El-Ramla in winter (Fig. 2). During spring and summer, the flourishing of phytoplankton in Lake Nasser reduces water transparency. The highest values were observed in the north (El-Ramla – El-Allaqi) (170 – 450 cm) and in the middle (El-Madiq – Khor Korosko) (150 – 320 cm) when compared with 160 – 220 cm for the southern ones (Tushka – Abu Simbel) which are affected by the flood.

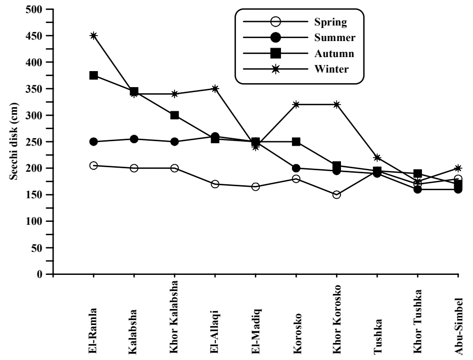

Fig. (2): Secchi disc readings in Lake Nasser during the study.

Table (1): Some water quality parameters measured in Lake Nasser during the study.

Station	Depth	Temperature (T)				Electrical conductivity (μmhos)				Dissolved oxygen (mg/l)				pH values			
		spr.	sum.	aut.	win.	spr.	sum.	aut.	win.	spr.	sum.	aut.	win.	spr.	sum.	aut.	win.
El-Ramla	surface	22.90	29.00	23.50	16.50	236	278	271	230	7.06	7.84	7.98	8.51	8.72	8.76	8.54	8.27
	middle	19.02	19.88	21.97	16.51	231	275	264	225	4.12	0.00	5.46	8.37	8.18	7.69	8.29	8.02
	bottom	18.05	18.72	19.82	16.33	229	264	257	223	2.86	0.00	0.00	8.37	8.17	7.79	7.83	8.00
Kalabsha	surface	23.90	28.80	23.35	17.00	249	253	250	243	7.68	6.84	7.35	8.96	8.67	8.77	8.53	8.12
	middle	18.80	19.93	21.87	16.71	241	245	244	235	2.79	0.00	6.34	8.55	8.07	7.85	8.46	7.67
	bottom	18.23	18.73	19.79	16.39	236	239	240	230	3.06	0.00	0.00	8.54	8.09	7.80	7.83	7.79
Khor Kalabsha	surface	24.34	29.60	23.60	16.90	233	253	245	220	8.03	6.83	8.41	9.13	8.92	8.92	8.56	8.27
	middle	19.90	22.35	22.89	16.69	213	234	225	210	3.02	0.00	6.59	8.90	8.46	7.84	8.50	8.00
	bottom	-	20.05	-	-	195	202	200	188	-	0.00	-	-	-	7.84	-	-
El-Allaqi	surface	24.60	29.55	23.90	17.50	230	248	239	227	8.42	6.77	8.98	8.36	8.77	8.86	8.89	8.48
	middle	18.97	19.91	22.09	17.28	225	243	235	223	3.00	0.00	4.53	8.43	8.23	7.69	8.36	8.36
	bottom	18.45	18.87	-	17.14	221	240	233	218	2.57	0.00	0.00	7.12	8.13	7.68	0.00	8.18
El-Madiq	surface	26.10	29.70	24.80	18.00	239	261	247	235	7.10	6.94	9.20	8.19	8.80	8.97	8.98	8.11
	middle	19.40	20.19	23.07	17.59	229	246	234	225	3.03	0.00	5.21	7.19	8.13	7.64	8.36	8.02
	bottom	-	19.01	-	17.51	221	233	225	220	-	0.00	0.00	7.20	-	7.62	-	8.02
Korosko	surface	25.70	29.99	24.60	18.50	228	239	234	231	7.75	6.88	9.49	8.07	8.99	8.88	8.76	8.37
	middle	20.00	19.77	22.69	17.39	227	237	232	224	2.87	0.27	4.50	7.70	8.39	8.00	8.41	8.24
	bottom	18.38	18.74	-	17.08	210	230	225	205	2.28	0.00	0.00	7.29	8.27	-	-	8.22
Khor Korosko	surface	25.70	31.90	24.90	18.20	243	260	250	230	7.82	6.9	9.24	8.12	8.92	8.91	8.64	8.24
	middle	20.91	24.78	23.60	18.10	240	255	246	226	4.27	1.91	5.50	7.91	8.57	7.22	8.28	8.22
	bottom	-	23.96	-	18.08	235	252	242	223	4.02	1.26	5.39	7.23	8.52	-	8.24	8.26
Tushka	surface	25.70	31.00	23.40	17.50	229	240	235	220	7.97	7.17	6.96	8.99	8.92	8.87	8.33	8.44
	middle	19.71	19.75	22.74	16.95	220	228	225	212	3.56	0.00	6.77	8.54	8.30	7.71	8.26	8.34
	bottom	18.64	18.66	-	16.55	212	220	217	200	3.17	0.00	-	8.38	8.27	7.70	8.20	8.30
Khor Tushka	surface	24.10	30.70	23.40	17.30	228	249	238	225	7.33	7.23	6.91	8.63	8.89	8.84	8.32	8.35
	middle	23.93	25.29	23.22	17.13	227	245	236	223	7.22	0.93	6.98	8.44	8.87	7.88	8.39	8.38
	bottom	-	-	-	-	230	243	233	220	-	0.00	-	8.21	-	-	-	8.38

Table (1): Continue

Station	Depth	Temperature (T)				Electrical conductivity (μmhos)				Dissolved oxygen (mg/l)				pH values			
		spr.	sum.	aut.	win.	spr.	sum.	aut.	win.	spr.	sum.	aut.	win.	spr.	sum.	aut.	win.
Abu-Simbel	surface	24.50	31.90	23.80	17.10	220	267	219	215	7.97	6.56	8.16	9.94	8.93	8.86	8.56	8.30
	middle	19.67	19.83	21.86	16.65	216	265	218	210	3.24	0.23	7.61	-	8.25	7.77	8.33	8.52
	bottom	18.78	19.22	-	-	211	260	215	200	2.50	0.22	-	-	8.17	7.79	-	-

Where spr. = spring, sum. = summer, aut. = autumn & win. = winter

3.1.2. Temperature

The water temperature (Table 1) measured for several depths during the different seasons varied between 18.05 – 26.1, 18.66 – 31.9, 19.79 – 24.9, 16.5 – 18.5 °C in spring, summer, autumn and winter, respectively. The lowest average value of surface water temperature of the lake was 17.4 °C in winter while the highest average value of 30.2 °C recorded in summer. The lake water was vertically homothermal during winter. The increase in air temperature during spring was followed by increase in the surface temperature (avg. 24.75 °C) and the difference in water temperature with depth becomes clear (4.85 – 7.32 °C), indicating progressive development of thermocline which becomes established in summer (7.24 – 12.34 °C). Considerable winds together with the incoming cooling flood water during autumn may be required to mix the whole eplimnion down to the primary thermocline.

3.1.3. Electrical Conductivity

The measured electrical conductivity (E.C.) values (Table 1) for the different depths during the different seasons varied between 195 – 249, 202 – 278, 200 – 271 and 200 – 243 in spring, summer, autumn and winter, respectively. The E.C. was affected by variations of water temperature (Gindy & Dardir, 2008). Thus, the relative increase of E.C. during summer and autumn particularly at the surface (219 – 278) was coincided with the high water temperature which leads the hydrolysis and redissolution of insoluble salts and subsequently their adsorption onto the lake water. Otherwise, the E.C. decreased during spring and winter (188 – 249) with the falling water temperature, may be ascribed to the uptake of dissolved salts by phytoplankton (Awadallah & Moalla, 1996).

3.1.4. Dissolved Oxygen

The values of dissolved oxygen given in Table (1) for the different depths varied between 2.28 – 8.42, 0.0 – 7.84, 0.0 – 9.49 and 7.12 – 9.94 mg/l during spring, summer, autumn and winter, respectively. During winter, dissolved oxygen were more less homogenous at different depths of the lake, reaching its highest concentration for the whole year. During spring, dissolved oxygen showed a gradual decrease towards the bottom which still sustained sufficient amount of dissolved oxygen (2.28 – 4.02 mg/l). During summer, the oxygen depleted layer prevailed at the middle and bottom depths of most stations parallel with the thermal stratification. Oxygenation of the water column was restored again during autumn with the incoming flood water together with the decrease in water temperature where the epilimnion extended to the middle depths at most stations (4.53 – 7.61 mg/l). Iskaros *et al.*(2008) observed that the epilimnion occupied the upper 10 m for most Lake Nasser during summer and there was a sharp drop in dissolved oxygen between 10 & 20 m depth which represents the thermocline.

3.1.5. Hydrogen Ion Concentration

The pH values (Table 1) were always on the alkaline side and varied between 7.22 at the middle depth of Khor Korosko during summer and 8.99 at the surface of Korosko during spring. The highest values of pH were recorded in the surface, particularly during spring and summer (8.67 – 8.99) due to the increased photosynthetic activities of phytoplankton. On the other hand, the middle and bottom water had lower pH values during summer (7.22 – 8.0 & 7.62 – 7.84, respectively), parallel to the development of thermocline while these two layers sustained higher values during the other seasons.

3.1.6. Characteristics of The Bottom Sediments:

a- Grain size analysis

Grain size composition is an important factor that should be taken into consideration to interpret some bottom fauna distribution in the clastic sediments. The mechanical analysis of Lake Nasser sediments are given in Table (2). In the main channel, the silt and clay fractions form the main size of the sediments (37 – 46% and 40.5 – 54.5%), respectively. The distribution of grain size is controlled by depth of sediments where the clay size increased with depth while the silt and sand fractions decreased in the same trend. El-Dardir (1994) concluded that, in the main channel of Lake Nasser, the grain size of sediments decreased from south to north.

This is a reflection of decreasing in the following current competency, but some samples deviate from this pattern. This may be due to the presence of the Nubian sand stone and/or sand sheets on the shores and to geomorphic features of the reservoir. In khors, sand contents are found in high fraction (49.5 – 55.5%) while clay formed low ones. This is attributed to that khors mainly received main detrital sediments from the surrounding sand sheets and rocks drifted by the wind.

Table (2): Distribution of sand, silt and clay of the analysed sediments in Lake Nasser during the study.

station	Km/ H.D	Depth (m)*	Sand (%)	Silt (%)	Clay (%)	Type of sediments
El-Ramla	10	100	8.0	37.5	54.5	Sandy silty clay
Kalabsha	55	90	7.5	39.0	53.5	" " "
Khor Kalabsha	55	35	49.5	38.5	12.0	Clayey silty sand
El-Allaqi	110	85	10.5	37.0	52.5	Sandy silty clay
El-Madiq	140	85	12.5	39.5	48.0	" " "
Korosko	180	80	11.0	40.5	48.5	" " "
Khor Korosko	180	40	56.5	33.5	10.0	Clayey silty sand
Tushka	245	72	12.0	46.0	42.0	Sandy silty clay
Khor Tushka	245	25	55.5	30.5	14.0	Clayey silty sand
Abu-Simbel	280	62	15.5	44.0	40.5	Sandy clayey silt

Km/H.D.: Distance from the High Dam (km); Depth (m): Depth below lake water level.

b- Organic matter

The organic matter content in the bottom sediment of Lake Nasser is represented in Fig. (3). In the main channel, it fluctuated between 8 – 12.5%, 7.5 – 11.5%, 3.5 – 9.5% and 4.0 – 9.5% during spring, summer, autumn and winter, respectively. The organic matter was very high at Kalabsha (12.5 & 11.5%) during spring and summer, respectively while it was low at Abu-Simbel and Tushka representing 3.5% for each during autumn and increased as going from south to north. This is related to organic matter content and grain size distribution. On the other hand, khors sustained low values of organic matter (1.0%) at khors Korosko (spring) and Tushka (winter) and 5.5% at khor Kalabsha during autumn. Hence, the highest values of organic matter in the main channel were explained by high production of bottom fauna (Fig. 4). Besides, the organic matter is used as an indication of the amount and type of food settling to the sediment from the water column.

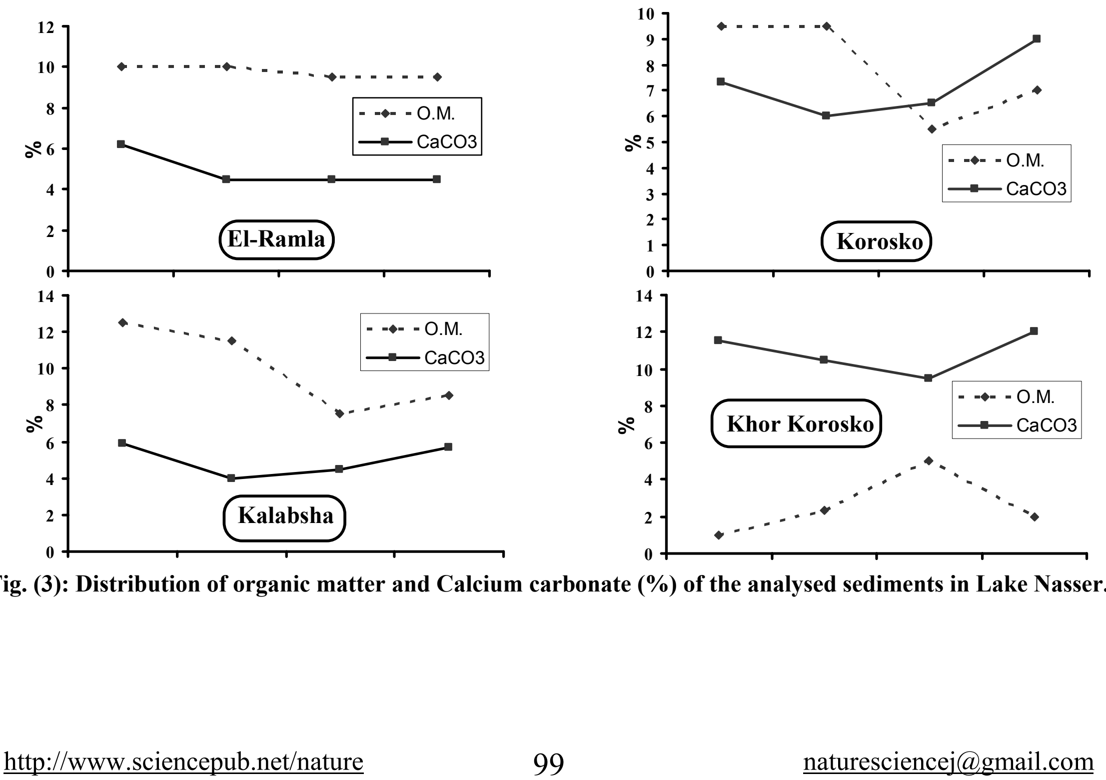

Fig. (3): Distribution of organic matter and Calcium carbonate (%) of the analysed sediments in Lake Nasser.

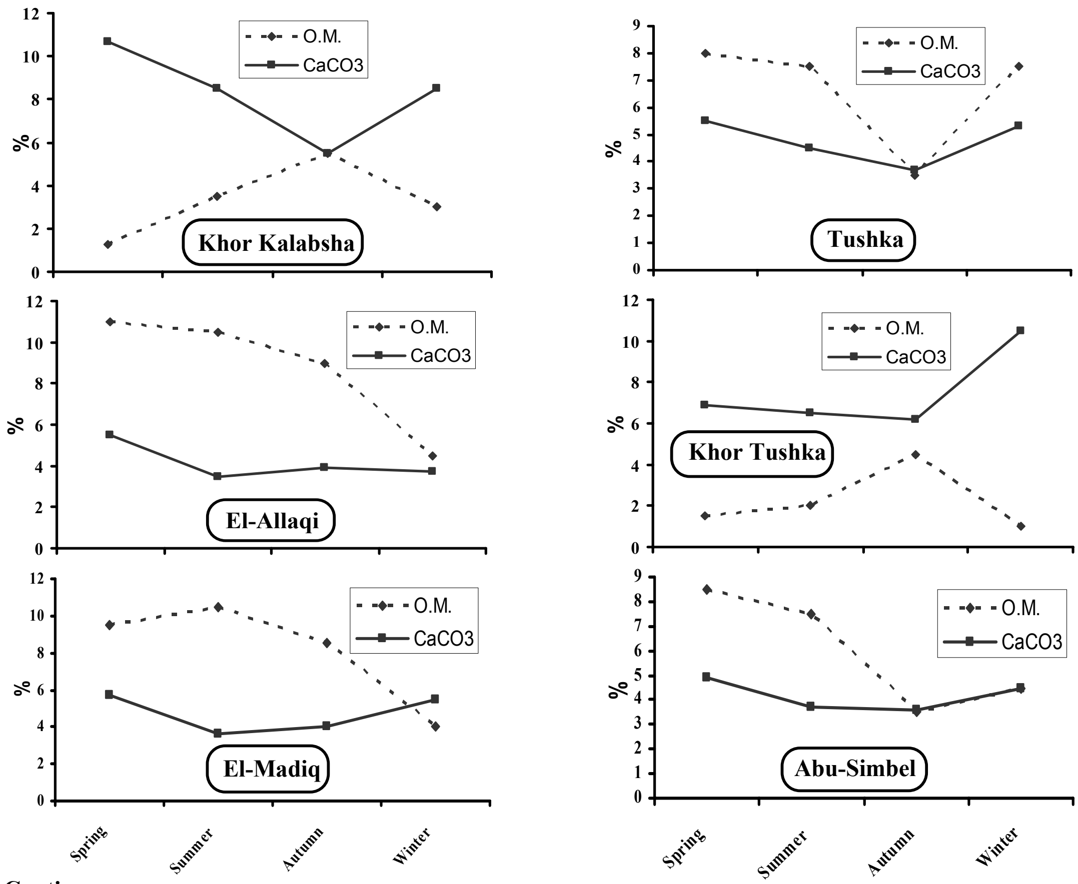

Fig. (3): Continue.

c- Calcium carbonate

The calcium carbonate content in the bottom sediments of Lake Nasser is represented in Fig. (3). In the main channel, $CaCO_3$ content was found to range from 4.9 – 7.3%, 3.5 – 7.0%, 3.6 – 6.5% and 3.7 – 9.0% during spring, summer, autumn and winter, respectively. These values increased in the khors to reach a range from 6.9 – 11.5%, 6.5 – 10.5%, 5.5 – 9.5% and 8.5 – 12.0% during the four above mentioned seasons. In the present study, $CaCO_3$ sediments in Lake Nasser was found to be not related to pH values variation in the water (Table 1 & Fig. 3). This indicates that the $CaCO_3$ abundance is not controlled by chemical precipitation. Consequently it is reliable to say that the $CaCO_3$ content is related to the encrusting organisms i.e. of biogenic origin. El-Dardir (1984) concluded that $CaCO_3$ concentration in the bottom sediments can indirectly help and participate in prognosing the primary productivity in Aswan High Dam Reservoir.

3.2. Bottom Fauna

3.2.1. Community composition, distribution and seasonal variations:

The macrobenthic fauna at the offshore zones of Lake Nasser embrases 10 species belonging to: oligochaetes (3 species), chironomid larvae (4 species) and molluscs (3 species). Oligochaetes were the most dominant group of benthic fauna (Fig. 4), constituting 83.9% (2017 org./m^2) and 91.7% (10.0 g.f.w./m^2) of their total numbers and biomass, followed by chironomid larvae (9.6% with 230 larvae/m^2 & 5.5% with 0.6 g.f.w./m^2) and Mollusca (6.5% with 157 org./m^2 & 2.8% with 0.3 g.f.w./m^2). 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 or anoxic conditions. The highest densities of benthic biota in the offshore zones were recorded in the main channel, particularly at Korosko and Tushka (4387 & 3978 org./m^2, respectively), accompanied by clay & silt grains (40.5 – 54.5%) and (37.0 – 46.0%), respectively (Table 2) and subsequently high content of organic matter (6.0 – 10.0%) (Fig. 3).

Contrary to that, they reached the lowest densities in the khors (634 – 1807 org./m^2) where the type of sediments were mainly sand (49.5 – 56.5%) with low organic matter (2.25 – 3.3%). The total biomass was nearly proportion to the numerical density (2.6 – 20.7 g.f.w./m2). The annual average density and biomass of bottom fauna for the whole offshore zones of the lake amounted 2404 org./m^2 and 10.9 g.f.w./m^2.

A marked difference in the bottom fauna stock was noticed during the four seasons (Fig. 4). They were more abundant in the main channel during spring with peaks at Kalabsha (11051 org./m^2 & 48.6 g.f.w/m^2) and at Korosko (10965 org./m^2 & 43.2 g.f.w./m^2) while the khors sustained the lowest densities (559 – 1462 org./m^2 and 1.3 – 2.5 g.f.w./m^2). On the other hand, the opposite occurred in summer during thermal stratification except at Tushka (6278 org./m^2 & 18.9 g.f.w./m^2) followed by another small ones in the khors (1204 – 2795 org./m^2 and 5.0 – 12.5 g.f.w./m^2). The community decreased more at most stations during autumn (86 – 2838 org./m^2 & 0.3 – 5.6 g.f.w./m^2) and winter (516 – 4171 org./m^2 & 0.7 – 25.0 g.f.w./m^2) with the continuity of the oxygen depleted layer and the falling of water temperature (Table 1), respectively. 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 (8.0 – 12.5% & 4.5 – 5.5%, respectively) (Fig. 3).

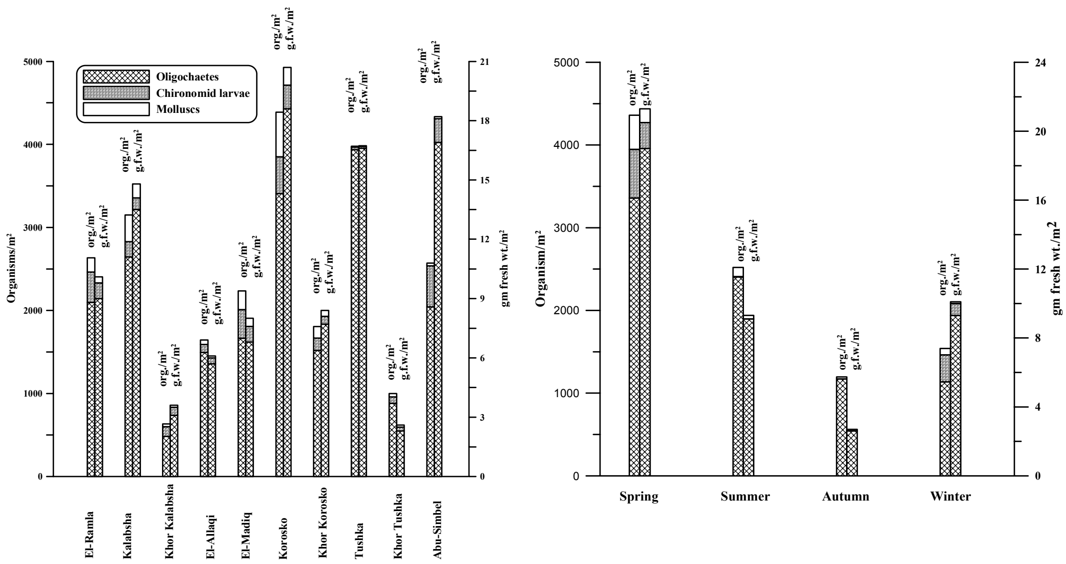

Fig. (4): Distribution and seasonal variations of bottom fauna (avg. org./m^2 & g.f.w./m^2) in Lake Nasser during the study.

3.2.2. Oligochaetae

As shown in Fig. 4, oligochaetes were most abundant in the main channel (1494 – 3935 org./m^2 & 5.7 – 18.6 g.f.w./m^2) than in the khors (484 – 1516 org./m^2 & 2.3 – 5.7 g.f.w./m^2). They were represented by 3 species, namely; *Limnodrilus udekemianus* Claparede, *L. hoffmeisteri* Claparede and *Branchiura sowerbyi* Beddard. Peaks of oligochaetes abundance were mainly recorded during spring (Fig. 4) at most main channel stations, particularly at Kalabsha (9761 org./m^2 & 47.0 g.f.w./m^2) and Korosko (7353 org./m^2 & 35.4 g.f.w./m^2) and/or in summer mainly at Tushka (6278 org./m^2 & 18.9 g.f.w./m^2). Such peaks produced large numbers of *Limnodrilus udekemianus* (Fig. 5) which contributed 72.3 & 86.2% (avg. 1738 org./m^2) of the total bottom fauna and oligochaetes, respectively. *Limnodrilus hoffmeisteri* contributed 6.2% of the oligochaetes (125 org./m^2). Its major occurance was recorded between El-Allaqi and Korosko (range 161– 333 org./m^2) (Fig. 5) with a peak during spring (Fig. 5), particularly at the two above mentioned stations (1161 & 903 org./m^2, respectively). *Branchiura sowebyi* contributed 7.6% of the oligochaetes (154 org./m^2) where its major distribution was recorded at comparable densities at El_Ramla, Kalabsha and Abu-Simbel (398, 484 & 441 org./m^2, respectively) (Fig. 5) which also harboured the highest numbers during winter and spring being 817 and 1505 and 1376 org./m^2, respectively (Fig. 5).

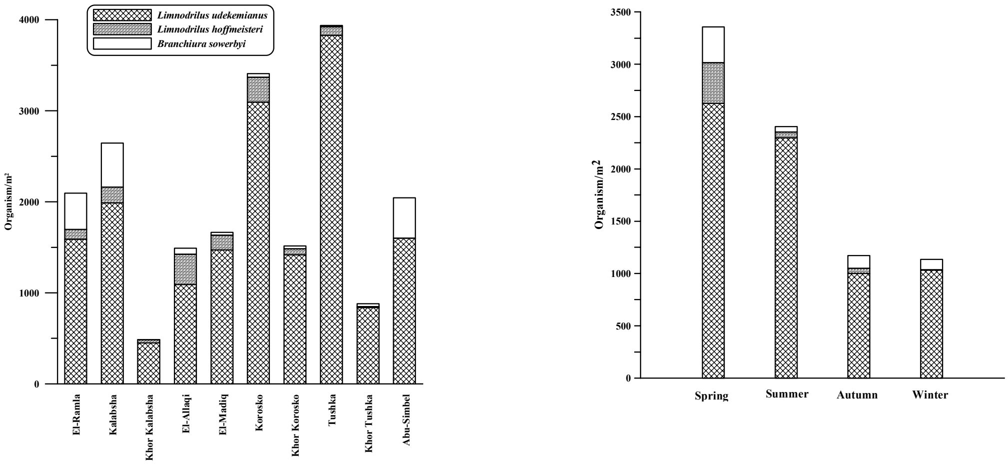

Fig. (5): Distribution and seasonal variations of Oligachaetae (avg. org./m^2) in Lake Nasser during the study.

3.2.3. Chironomid larvae

Chironomid larvae reached their highest density at comparable values at Abu-Simbel and Korosko (495 & 441 larvae/m^2, respectively & 1.2 g.f.w./m^2 for each) (Fig. 4) whereas, the low densities were detected between Khor Kalabsha and El-Allaqi and at Tushka and its khor (32 – 118 larvae/m^2 and 0.1 – 0.4 g.f.w./m^2). Larvae of Chironomidae were represented by *Procladius* sp., *Microtiendipes* sp., *Cryptochironomus* sp. and *Clinotanpus* sp. They were confined to spring (Fig. 4) with peaks at Abu-Simbel (1892 larvae/m^2 & 4.6 g.f.w./m^2) and at Korosko (1462 larvae/m^2 & 3.5 g.f.w./m^2) and during winter, particularly at El-Ramla (1462 larvae/m^2 & 3.2 g.f.w./m^2), mainly consisting of *Procladius* sp. (Fig. 6) which contributed 8.3 & 89.9% (avg. 199 larvae/m^2) of the bottom fauna yield and the chironomid larvae, respectively. *Microtiendipes* sp. was only encountered during spring at El-Allaqi, Korosko and its khor and Abu-Simbel (avg. 90 larvae/m^2) and at Kalabsha in summer (43 larvae/m^2). *Clinotanpus* sp. and *Cryptochironomus* sp. were recorded in few numbers during spring at Khor Kalabsha and El-Allaqi (172 & 86 larvae/m^2, respectively). Pupae probably of *Procladius* sp. were scarcely recorded during spring at Kalabsha (43 pupae/m^2).

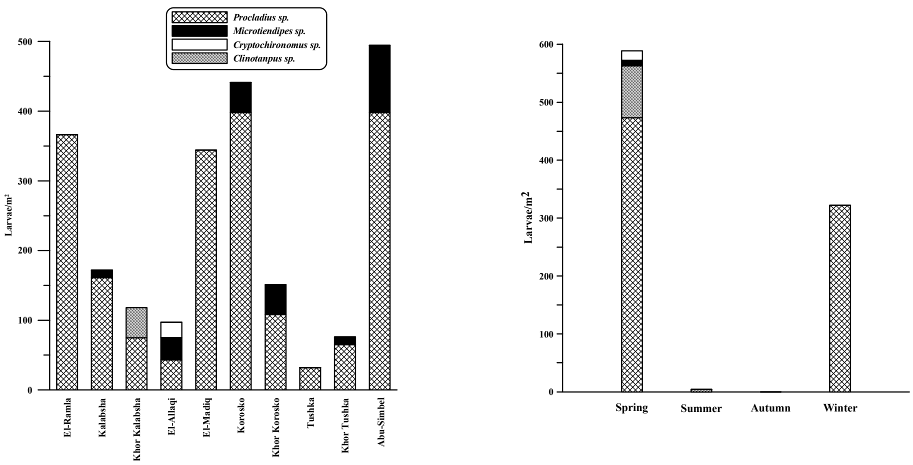

Fig. (6): Distribution and seasonal variations of the Larvae of Chironomidae (avg. larvae/m^2) in Lake Nasser during the study.

3.2.4. Mollusca

Mollusca attained its maximum abundance at Korosko (538 org. & 0.9 g.f.w.) followed by Kalabsha (322 org. & 0.7 g.f.w./m^2) (Fig. 4). The lowest record was at the south sector (range 11 – 43 org./m^2 & 0.03 – 0.1 g.f.w./m^2). Mollusc were represented by a single gastropod *Valvata nilotica* Jickeli and two bivalvia *Pisidium pirothi* Jackeli and *Corbicula fluminalis* Müller. They were common during spring (Fig. 4), being more abundant at the two above mentioned stations (2150 org./m^2 with 4.3 g.f.w./m^2 and 1290 org./m^2 with 2.6 g.f.w./m^2, respectively), associated with an increase of phytoplankton standing crop, increasing amount of calcium carbonate (range 4.9 – 11.5%) (Fig. 3) when the water column was well saturated with dissolved oxygen (Table 1). They sharply declined during summer and autumn with free oxygen hypolimnion and in winter with the falling water temperature. *Valvata nilotica* (Fig. 7)was the major species of Mollusca, contributing 6.4 & 98.7% (avg. 155 org./m^2/year) of total the bottom fauna and mollusc, respectively. Few individuals of *Pisidium pirothi* and *Corbicula fluminalis* were recorded during spring and winter at Kalabsha and Abu-Simbel being 43 org./m^2 for each & 0.1 & 0.2 g.f.w. /m^2, respectively.

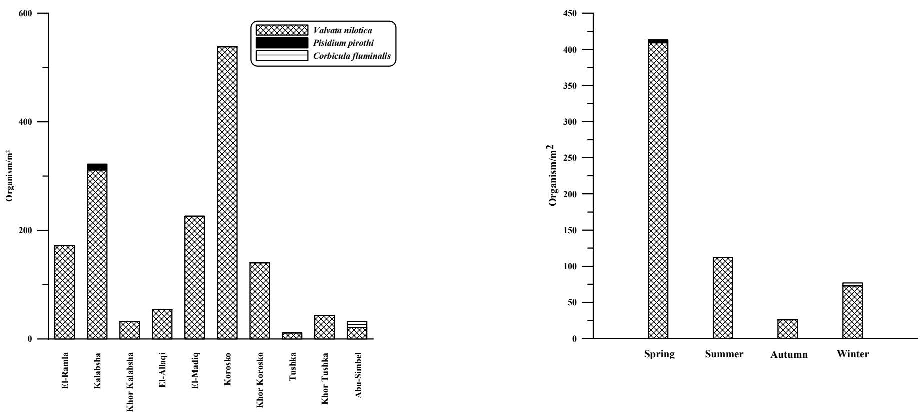

Fig. (7): Distribution and seasonal variations of Mollusca (avg. org./m^2 & g.f.w./m^2) in Lake Nasser during the study.

4. Discussion

In a complex natural environment, such as Lake Nasser where several factors operate simultaneously, it is not easy to generalize and designate certain factor as being more important than the other. The biological processes taking place at the lake bottom being the end result of the interactions of organisms present with the surrounding environment (Bishai et al., 2000). The benthic invertebrates in Lake Nasser exhibited marked variations from one station to another and this is attributed to the variations in the prevailing physico-chemical conditions as well as to their biological productivity. The substrate status of the bottom sediments are also of great importance.

The decrease in water's transparency in Lake Nasser is mainly caused by two factors: allochtonic inorganic silt and mud of riverine origin and autochtonic suspended organic matter (plankton & detritus). The northern and middle parts of the lake with their adjacent khors were showed the highest transparency (Fig. 2), particularly during autumn and winter (maximum Secchi depth 450 cm) and lower values during spring and summer (minimum Secchi depth 150 cm) due to phytoplankton blooming. On the other hand, the southern end of the lake exhibited the lowest transparency, thus coinciding with the introduction of flood turbid water in late summer and autumn.

A direct relation appeared to exist between the density of the molluscs and the rate of silting. Thus, the higher density of molluscs at the north (avg. 145 org./m^2 with 0.3 gm/m^2) and middle stations (avg. 301 org./m^2 with 0.5 gm/m^2) (Fig. 4) is attributed to the negligible amount of the silt that may reach these areas whereas the poorest values were observed at the southern ones (avg. 29 org./m^2 with 0.1 gm/m^2) in relation to the instability of the substrate, resulting from deposition of silt load carried by the flood. Present work results are in good accordance with those given by El-Dardir (1984) who mentioned that the maximum sedimentation in Lake Nasser takes place at the south sector. Brown & Lemma (1970) and Kloose & Lemma (1974) concluded that the influx of inorganic material in Awash River (Ethiopia) is inhospital for most molluscs because of their heavy silt load.

The grain size analysis (Table 2) in Lake Nasser revealed that the studied sediments in the main channel are mainly composed of sandy silty clay (60%) and sandy clayey silt (10%) whereas khors samples are clayey silty sand (30%). Consequently, the values of the total organic content (Fig. 3) in the sediments of the lake are higher in the main channel stations (4.0 –

12.5%) than those of the khors (1.0 – 5.5%). This may be attributed to the main channel sediments fine texture which can sustain high content of those elements. According to Tjoe-Awie (1975), the fine detrital fraction is usually richer in organic material than the coars ones which acts as a dilutant. Therefore, the total organic content of the lake sediments is well correlated with the silt and clay fractions size (r = 0.360 & 0.811, respectively), contrary to sand (r = -0.786)(Table 3).

The nature of the bottom sediments has a selective influence on quality and quantity of benthos and it is considered the most significant factor determining their distribution (Welch, 1952 and Brinkhurst & Jamieson, 1971). A direct relation was recorded between the magnitude of the standing stock of benthos and the type of sediments (Table 2 & Fig. 4). Thus, a positive correlation was found between most bottom fauna species abundance and the silt and clay fractions (r = 0.112 – 0.355 & 0.167 – 0.275, respectively) (Table 3). Our results were emphasized by Wirth & Stone (1968) and Brinkhurst & Jamieson (1971) who stated that the Tubificidae and Tanypodinae are more often found in mud or soft black mud of rivers and lakes.

Most of the benthic fauna probably derive the bulk of their nutritional requirements from micro-organisms, ingested along with allochthonous and autochthonous organic matter in sediments (Payne, 1986). The increased of total organic content in the sediments during spring (avg. 7.3%) and summer (avg. 7.5%) was generally in concomitance with a parallel density of bottom fauna (Fig. 3 & 4). Thus a positive correlation stands for the abundance of the bottom fauna and the total organic content (r = 0.208 – 0.457) (Table 3). This indicates that the organic content may be an important relative to the population growth of the bottom fauna in Lake Nasser. Brinkhurst & Jamieson (1971) and Brown (1980) findings confirm present work results as they stated that the growth and reproduction of the oligochaetes and molluscs are apparently related to available food supply. Della Croce (1955) and Brinkhurst (1965 & 1967) concluded that there exist few clear correlations between the variations in particle size or total organic matter present and the distribution and abundance of bottom fauna, particularly concerning oligochaetes which have been demonstrated.

The present work results indicate that temperature, electrical conductivity, dissolved oxygen and pH proved to be of variable effect in controlling the flourishing and existence of different species in Lake Nasser. However, Brinkhurst & Jamieson (1971) agree in demonstrating an overall lack of correlation between the data obtained from chemical analysis of the overlying water and the sort and proportion of the species encountered. This may be attributed to other environmental conditions prevailing there and not prevailing in Lake Nasser.

Table (3): Correlation coefficient between the ecological parameters and the main bottom fauna species in Lake Nasser during the study.

	T	E.C.	D.O.	pH	O.M.	Sand	Silt	Clay	Limn. ud.	Limn. ho.	Bran. so.	Proc.
EC	0.530											
DO	0.162	-0.161										
pH	0.647	0.030	0.428									
O.M	-0.287	0.273	-0.312	-0.175								
Sand	0.536	-0.098	0.145	0.161	-0.786							
Silt	-0.204	-0.352	-0.123	0.071	0.360	-0.660						
Clay	-0.526	0.200	-0.137	-0.199	0.811	-0.982	0.508					
Limn. ud.	0.122	0.065	-0.186	0.112	0.395	-0.289	0.355	0.243				
Limn. ho.	-0.047	-0.037	-0.100	0.052	0.457	-0.247	0.035	0.275	0.420			
Bran. so.	-0.167	0.071	0.060	0.041	0.387	-0.269	0.126	0.277	0.337	0.193		
Proc.	-0.245	-0.225	0.347	0.136	0.208	-0.176	0.112	0.174	0.122	0.230	0.410	
Valv. ni.	0.019	0.001	-0.040	0.091	0.291	-0.149	0.012	0.167	0.592	0.651	0.243	0.339

T.: Temperature; E.C.: Electrical conductivity
D.O.: Dissolved oxygen; O.M.: Organic matter
Limn. ud.: *Limnodrilus udekemianus*
Limn. ho.: *Limnodrilus hoffmeisteri*
Bran. so.: *Branchiura sowerbyi*
Proc.: *Procladius* sp.
Valv. ni.: *Valvata nilotica*

The bottom fauna in the deep areas of Lake Nasser was poor in number of species, being mainly oligochaetes (3 species), chironomid larvae (4 species) which are the only temporary residents of the lake bed together with the gastropods (1 species) and the bivalves (2 species). This lack of species diversity is found to be due to the unstable and deoxygenated nature of the mud. Similar status have been encountered in Lake George (Uganda) (Burgiess et al., 1973) and in central areas of the Varzea Lakes on the Amazon (Reiss, 1977). However, in the littoral areas af Lake Nasser and among the marginal vegetations, the diversity increases as a wide variety of insects appear, particularly the larvae of Chironomidae (17 species), Pupae of Chironomidae, Nymph of Odonata (8 species), Nymph of Ephmeroptera (1 species), larvae and adult of Coleoptera (1 species for each), adult Hemiptera and Larvae of Trichoptera together with Oligochaetae (4 species), Hirudinea (1 species), Crustacea (3 species), Mollusca (10 species), Hydrozoa (1 species) and Phylactolamata (1 species) as shown in Table (4).

Table (4): Cheklist of benthic inverlebrates recorded in Lake Nasser by different authors. (+ = present, - = not recorded).

Taxa & species	Iskaros (1988 & 1993)	Fishar (1995 & 2000)	The present work (2008)
Phylum: Cnidaria			
Class: Hydrozoa			
Hydra vulgaris Pallas	-	+	-
Phylum: Bryozoa			
Class: Phylactolaemata			
Fredericulla sultana Blumenbach	-	+	-
Phylum: Arthropoda			
Class: Insecta			
Procladius sp.	+	+	+
Clinotanpus sp.	+	-	+
Coelotanpus sp.	+	+	-
Pelopia sp.	+	-	-
Conchapelopia sp.	+	-	-
Tanpus sp.	+	-	-
Ablabesmyia sp.	+	+	-
Einfeldia sp.	+	-	-
Nilodorum sp.	+	+	-
Tanytarsus sp.	+	+	-
Dicrotiendipes modestus	+	-	-
Polypedilum sp.	+	+	-
Cryptochironomus sp.	+	+	+
Microtiendipes sp.	+	+	+
Microchironomus sp.	+	-	-
Chironomus sp.	+	+	-
Circotopus sp.	+	+	-
Pupae of Chironomidae	+	+	+
Ischnura sp.	+	+	-
Pseudagrion niloticum Dumont	+	-	-
Perithemis sp.	+	+	-
Libellula sp.	+	-	-
Neurocordulia sp.	+	+	-
Gomphus sp.	+	-	-
Enallagma sp.	-	+	-
Plathemis sp.	-	+	-
Caenis sp.	-	+	-
Dytiscus sp.	-	+	-
Hydrovatus sp.	-	+	-
Larvae of Tricoptera	+	+	-
Adult Hemiptera	+	-	-
Class: Crustacea			
Cardinea nilotica Roux	-	+	-
Chlamydotheca unispinosa Baird	-	+	-
Stenocypris malcolmosoni Braird	-	+	-

Table (4): Continue

Taxa & species	Iskaros (1988 & 1993)	Fishar (1995 & 2000)	The present work (2008)
Phylum: Annelida			
Class: Oligochaetae			
Branchiura sowerbyi Beddard	+	+	+
Limnodrilus udekemianus Claparede	+	+	+
Limnodrilus hoffmeisteri Claparede	+	+	+
Pristina sp.	-	+	-
Class: Hirudinea			
Helobdella conifera Moore	+	+	-
Phylum: Mollusca			
Class: Gastropoda			
Bulinus truncates Audouim	+	+	-
Physa acuta Darparnaud	+	+	-
Melanoides tuberculata Müller	+	+	-
Valvata nilotica Jickeli	+	+	+
Cleopatra bulimoides Olivier	-	+	-
Gyraulus ehrenbergi Beck	-	+	-
Class: Bivalvia			
Corbicula consobrina Cailliaud	-	+	-
Corbicula fluminalis Muller	+	-	+
Pisidum pirothi Jickeli	+	+	+
Eupera ferruginea Krauss	-	+	-
Total 48	33	38	10

Worthmentioning that Lake Nasser is considered among the highly eutrophic lake and its productivity ranged from 4.32 – 128.15 mg c/m3/h during 1990 (Abdel-Monem, 1995). The community of planktonic algae during the period 1981 – 1993 was fairly diversified, belonging to 5 classes: Chlorophyceae (54 species), Cyanophceae (34 species), Bacillariophyceae (33 species), Dinophyceae (13 species) and Euglenophyceae (1 species) (Bishai, et al., 2000). The standing crop of the phytoplankton in the upper water layer tended to increase southwards from 3.405 x 10^6 algal units/l at El-Ramla to 15.272 x 10^6 algal units/l at Adindan. Also, zooplankton was rich and diversified (Ali et al., 2007 & Iskaros et al., 2008) where its standing crop in the upper water layer amounts to 73521 org./m^3 with 57 species belonging to Copepoda (4 species), Rotifera (39 species), Cladocera (12 species) and Protozoa (2 species) of which the former group constitutes 62.2% of the zooplankton populations. The benthic fauna represents the third component among the food chain in the fresh water habitats. It converts sediments detritus, micropes and other small preys onto their body's flesh that is available to capture. Iskaros (1988) pointed out that the average annual number and biomass of the bottom fauna recorded for Lake Nasser as a whole during 1986 – 1987 amounted to 2659 org./m^2 with 13.1 gm/m^2 at the littoral stations and only 288 org./m^2 with 1.9 gm/m^2 at the offshore ones. In the present study, however, the standing crop of bottom fauna at the offshore stations increased much to 2404 org./m^2 with 10.9 gm/m^2. This may be attributed to the gradual accumulation of organic matter during the last 24 years where the organic matter fluctuated between 1.96 and 3.39% in the period 1981 – 1983 (Latif, et al., 1989). Because in Lake Nasser, there is a prominent phytoplankton population and slow circulation, there can be a continual rain of plankton on to the lake bed providing organically rich sediments, like the same found by Payne (1986) when he investigated some tropical lakes. Latif et al., 1979 and Iskaros (1988 & 1993) found that in Lake Nasser the different groups of benthos serve as an important food for various fish species, therefore it participate in enriching an economic fish yield. Members of the Tanypodinae are regarded as eutrophic species (Rosenberg et al., 1984) while Brinkhurst (1964) postulated to the possibility of using the natural tubificid population in lakes to classify them in regards to their annual fish yield.

The fish crop in any water mass represents the final link culminating the food cycle. More than 55 fish species belonging to 15 families were recorded from Lake Nasser (Latif 1974 & 1977). The annual yield fluctuated between 30000 ton in 1983 and 17563 ton in 2008. *Tillapia* spp. (*Sarotherodon galilaeus* and *Oreochromis niloticus*) formed 90% of the total production. These species mainly caught from the coastal areas and khors of the lake. The offshore area (about 80% of the total lake area) is not well utilized, except for a minor catch of *Hydrocynus* spp., *Alestes* spp. and others. El-Shabrawy & Dumont (2003) suggested the possibility of introducing a pelagic freshwater fish species (the Tanganika sardine, *Limnothressia miodon*) in to Lake Nasser – to consume the large quantities of plankton in the open water area. This species has been introduced to and successfully exploited in Lake Kariba (25000 ton/annum) and spread down the middle Zambezi to Lake Cahora Bassa (Skelton, 1993). Also, it was introduced to Lake Kivu, but it has decimated the zooplankton (Dumont, 1986). A phase of careful testing should therefore precede its possible introduction to Lake Nasser.

5. Conclusions

Three main benthic fauna groups were identified in the offshore area of Lake Nasser (Oligochaetae, Larvae of Chironomidae and Mollusca) with 10 identified species of which the former group contributed 83.9 & 91.7% of their number and biomass, respectively. The highest standing crop of benthos was recognized during spring while it decreased in its density in summer during thermal stratification and more in autumn and winter with the continous of oxygen depleted layer and the failing of water temperature, respectively. Spatially, the highest standing crop of benthos appeared at the main channel stations accompanied by the silt and clay fractions and subsequently high content of organic matter. Contrary to that, it reached the lowest density in the khors where the type of sediments were mainly sand with low organic matter. Also, transparency, temperature, dissolved oxygen, calcium carbonate and hydrogen ion concentrations proved to be of variable effect in controlling the assemblage of bottom fauna species. The physico-chemical features as well as the characteristics of the bottom sediments in Lake Nasser are in favour for producing high standing crop of benthos which in turn, provide the main food items for the various fish inhabitants of the lake.

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