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Factors affecting seasonal patterns in epilimnion zooplankton community in one of the largest man-made lakes in Africa (Lake Nasser, Egypt)

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Abstract

The objective of the study was to determine which factors regulate zooplankton organisms along Lake Nasser. Temperature, pH, DO, conductivity, turbidity, nutrients, and zooplankton abundance were measured. Twenty-three species of zooplankton were recorded in Lake Nasser included in Copepoda, Cladocera and Rotifera. Copepoda represented the main bulk of the community. The lowest standing stock of zooplankton was noticed during spring due to the highest fish predation during this season associated with the lowest turbidity. Big difference in temperature in Lake Nasser along the year round is considered as a controlling factor related to range of tolerance of species. The oscillation of the lake water level and the different factors affect the standing stock of zooplankton in the lake. Thus, continuous monitoring of Lake Nasser biota should be undertaken to follow the changes in the ecosystem.

Keywords: Physico-chemical factors; Zooplankton; African lakes; Lake Nasser; Turbidity

Introduction

Lake Nasser is the second largest man made lake in Africa, after Lake Volta (Ghana). It is a monomictic subtropical lake (Heikal & Abdel Bary, 1999) with prevalent lacustrine properties. The only source of lake water is the River Nile. The outflow is the continuation of the Nile towards the north. Lake Nasser is unique in its performance because it is situated in pure desert. The Nile flood comes once a year in late August originating from the Ethiopian highlands. It is known by its high turbidity carrying a heavy load of mud consisting of a mixture of sand, silt and clay. The yearly flood of the Nile is the most important factor affecting the conditions of the reservoir. Lake Nasser is rich in dissolved nutrients (Entz, 1972). Elewa, Sayyah, Latif, and Touffek (1988) found the average nitrate values between 0.159 and 0.378 mg L^{-1}, while phosphorus was between 0.010 and 0.105 mg L^{-1}.

Abdel Rehim, Abdel Bari, Khalil, Heika, and Salem (2002) found that water quality in Lake Nasser is improved during turnover and mixing period in winter. Abouel Kheir, Ibrahim, Khalil, Heikal, and Yousry (2003) showed that phosphorus is a limiting factor around the year in the lake. Rzoska (1976) and Dumont (1986) reviewed the zooplankton of the Nile and Lake Nasser-Nubia. These revealed that the species

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composition has been remarkably stable over time, and does not deviate from that in the 19th century.

However, few studies have dealt with the ecology of the zooplankton, particularly in the main channel of Lake Nasser. Zaghloul (1985) studied plankton along the lake during 1981 before the African drought (1983–1990), while Mageed (1995) studied zooplankton in the lake after the drought (1992). They found Lake Nasser is rich in zooplankton with high differences in the density and species composition between the two studies. The other studies were related to the costal areas and the side branches of the lake.

The changes in the physico-chemical factors due to the coming flood will affect the biota in the lake, thus it is very important to understand the effect of these factors on the seasonal variations of zooplankton organisms. The study deals with water quality and zooplankton in the main channel of Lake Nasser to elucidate these factors that affect the dynamics of zooplankton along the lake during the different seasons.

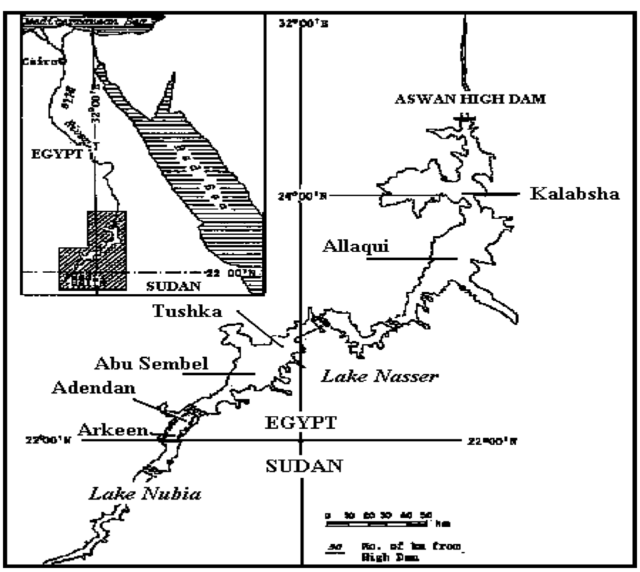

Fig. 1. Map showing sampling stations in Lake Nasser.

Materials and methods

Description of site studied

Aswan High Dam (AHD) reservoir lies between 22°00′N and 23°58′N in Egypt, and extends southward into Sudan to 20°27′N as Lake Nubia. Lake Nasser (Fig. 1) formed behind AHD, completed in 1968. The reservoir has a maximum water level of 183 m ASL and a volume of $162 \times 10^9\,m^3$. At this level the reservoir has a length of close 500 km, an average width of 12 km and surface area of 6540 km^2. The lake shoreline is very irregular, with numerous inundated valleys (Khors). The water level varies from year to other according to the coming flood and the discharge from the lake through AHD.

Sampling regime

The samples were collected from six stations (Table 1) along the pelagic water of the main channel in Lake Nasser (Egypt). Sampling was performed four times; spring (May 2002), summer (July 2002), autumn (October 2002) and winter (January 2003). Each cruise starts at the upstream (with the water direction) persisting for 20 days. Samples of water quality analysis at upstream station Arkeen during autumn were not collected.

Water analysis

Water samples from 0.5 m below the surface were collected. Temperature, pH, dissolved oxygen (DO) and conductivity were measured in the field immediately. The other parameters were analyzed after filtration of samples through Whatman GF/C filters. The chemical measurements were performed in the Research Vessel laboratory within a few hours of collection. Water temperature and DO were measured with WTW Model Oxi197 temperature-DO meter, pH was measured by pH meter model WTW 179, water conductivity was

Table 1. Position, depth and distance of the sampling stations from the High Dam

Station	Abbreviation	Position		Depth (m)	km from HD
		Latitude	Longitude		
Arkeen	ARK	22°01.34′	31°20.71′	34	333
Adendan	AD	22°14.73′	31°31.83′	45	307
Abu Sembel	ABS	22°19.69′	31°37.19′	52	281
Tushka	TUS	22°36.28′	31°55.23′	55	247
Allaqui	ALL	23°00.20′	32°30.11′	66	171
Kalabsha	KAL	23°33.4′	32°52.03′	90	41

measured with WTW Model LF197 conductivity meter, and total depth was measured by current meter (Valeport BFM 108 MK11). The following variables were determined as described in APHA (1992): turbidity (Nephelometric method), nitrite-nitrogen (Colorimetric method), nitrate-nitrogen (nitrate selective method), orthophosphate-phosphorus (OP) (Stannous chloride method), total phosphate-phosphorus (TP) (stannous chloride method), and silica (silico-molybdate method). Chlorophyll-*a* (chl.-*a*) was extracted in 90% acetone and measured by a Turner III flurimeter.

Zooplankton

Zooplankton samples were carried out seasonally during the daytime by vertical rows from 5 m to the surface (in the photic layer) using a plankton net (30 cm in mouth opening diameter, 1-m long, 55 μm in mesh size). Previous works in Lake Nasser (El Shabrawy, 2000; El Shabrawy & Dumont, 2003; Mageed, 1995) had shown that most zooplankton community resides in the euphotic layer. Therefore, little could be gained by the additional effort of sampling the entire water column. All samples were immediately fixed with 4% formalin and examined in the laboratory.

Data analysis

Pearson correlation between species of zooplankton and the different environmental variables.

Correspondence Analysis (CCA), release 4.0 of CANOCO for Windows (Ter Braak, 1987) was carried out using the metrics drawn from the zooplankton counts per litres (species) × the water (environmental) variables.

Results

Physico-chemical characteristics, and chlorophyll-*a*

The water temperature fluctuated in the range of 18.3 °C in winter and 31 °C in summer (average of 25.6 °C). DO was measured with an average of 7.95 mg L^{-1}. The surface water in Lake Nasser was well oxygenated but under saturated with DO at most stations in the period of study. The percentage saturation ranged between 75% at Arkeen in summer and 114% at Adendan in winter. pH values are on the alkaline side and varied between 7.74 and 8.73 with maximum value during spring (8.57). Conductivity ranged between 221 and 256 μS cm^{-1} with annual average of 239 μS cm^{-1}. Their values increased toward the downstream at Kalabsha with maximum peak during autumn (252 μS cm^{-1}) compared to spring (229 μS cm^{-1}). Turbidity was measured with the greatest value in summer with the highest values in the upstream, especially Arkeen (avg. 54.77 NTU), and gradually decreased toward the downstream. The lowest turbidity was measured in spring (3.68 NTU).

For nutrients, nitrite was the least abundant form of inorganic nitrogen in the lake. High nitrite concentrations were measured during summer at Adendan (0.021 mg L^{-1}). Most nitrite concentrations were $<$0.008 mg L^{-1}, the range was 0.001–0.021 mg L^{-1}. A relatively high nitrate values has been found in Abu Sembel during autumn (1.6 mg L^{-1}). The southern part of the lake has higher nitrate values than the north. The concentration of nitrate ranged from 0.2 to 1.6 mg L^{-1}. OP ranged between 0.03 and 0.15 mg L^{-1} with the highest concentration in Adendan and the lowest in Allaqui and Kalabsha. Its peak was noticed in summer (avg. 0.087 mg L^{-1}). TP varied from 0.05 mg L^{-1} at Abu Sembel to 0.45 mg L^{-1} at Arkeen with annual average of 0.131 mg L^{-1}. Summer was characterized by high TP. The concentration range for silica was between 7.00 and 14.50 mg L^{-1}, with the greatest concentrations occurring in autumn followed by winter (12.58 and 12.17 mg L^{-1}, respectively) and minimum levels observed in spring (7.37 mg L^{-1}).

Chl.-*a* increased during summer and autumn (21.9 and 17 mg m^{-3}, respectively), while it decreased in spring (9.3 mg m^{-3}). The maximum value was measured at Arkeen (25.3 mg m^{-3}) and decreased gradually to down stream at Kalabsha (3 mg m^{-3}). Nano and pico plankton represented more than 63% of total chl.-*a* (Abouel Kheir et al., 2003).

Zooplankton community dynamic

Twenty-three zooplankton species were recorded in Lake Nasser included in Copepoda (three species), Cladocera (nine species) and Rotifera (11 species). Copepoda was the dominant group in the lake representing about 59% of total zooplankton number followed by Cladocera (about 30%) as shown in Table 2. The greatest zooplankton number was noticed at Adendan followed by Abu Sembel (85 and 78 org. L^{-1}, respectively), while the lowest number was recorded at Kalabsha (31 org. L^{-1}) (Fig. 2). A great difference in the stock of zooplankton was noticed during the four seasons. The maximum zooplankton number was recorded during autumn (75 org. L^{-1}) due to the increase of the copepod number (ca. 73%), while the lowest number was recorded during spring (38 org. L^{-1}). The density during summer and winter was more or less similar (66 and 67 org. L^{-1}, respectively).

Population of Copepoda

Copepoda constituted the main bulk of zooplankton in Lake Nasser. They were represented by the three life

Table 2. The average number of the dominant zooplankton genera (org. m^{-3}) and their frequency to the total zooplankton number in Lake Nasser

Group	Dominant genera	No. of org. m^{-3}	% to total zoopl.
Rotifera	*Keratella*	6920	08.7
	Brachionus	724	01.0
	Others	1228	01.7
	Subtotal	7871	11.4
Cladocera	*Ceriodaphnia*	10,522	15.5
	Diaphanosoma	4876	07.2
	Daphnia	2707	04.1
	Others	1891	02.8
	Subtotal	19,996	29.6
Copepoda	Nauplius larvae	22,168	32.4
	Copepodite stages	12,775	18.7
	Thermocyclops	3512	05.2
	Mesocyclops	202	00.3
	Thermodiaptomus	1602	02.4
	Subtotal	40,260	59.0
	Grand total	68,127	

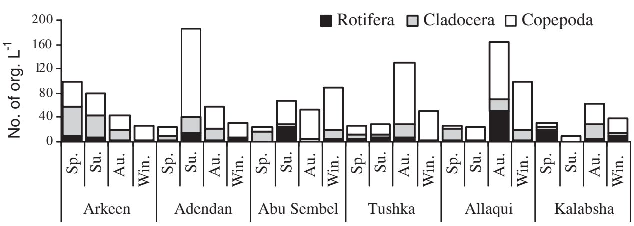

Fig. 2. Distribution of total zooplankton number (org. L^{-1}) in Lake Nasser during 2002/2003.

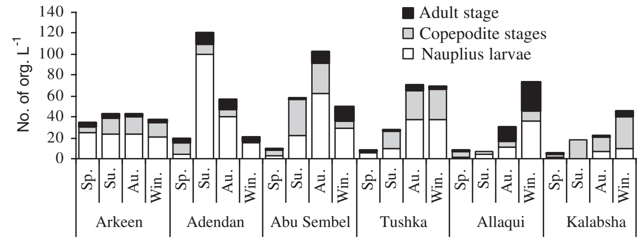

Fig. 3. Distribution of the copepod developmental stages (org. L^{-1}) in Lake Nasser during 2002/2003.

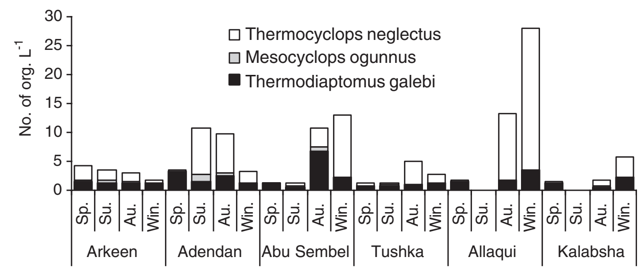

Fig. 4. Distribution of the adult copepod species (org. L^{-1}) in Lake Nasser during 2002/2003.

cycle stages of Cyclopoida and Calanoida; nauplius larvae (55.1% of copepods, 32.4% of zooplankton), copepodite stages (31.7% of copepods, 18.7% of zooplankton) and adult stage (13.2% of copepods, 7.9% of zooplankton). Copepoda increased from 16,216 org. m^{-3} at the downstream toward the upstream, up to Adendan (66 org. L^{-1}), and decreased at Arkeen to 34 org. L^{-1}. Their maximum peak was noticed during autumn (54 org. L^{-1}) while the minimum number was recorded during spring (14 org. L^{-1}) (Fig. 3).

Cyclopoida were represented by *Thermocyclops neglectus* (Sars) and *Mesocyclops ogunnus* Onabamiro, while Calanoida were represented by *Thermodiaptomus galebi* (Barrois). *Thermocyclops neglectus* formed 66.1% of adult copepods. Its peak was noticed during winter (7 org. L^{-1}) with maximum count at Allaqui (9 org. L^{-1}). *M. ogunnus* was recorded with little density (3.8% of adult copepods). It was concentrated at the upstream mostly during summer followed by autumn. *T. galebi* constituted 30.1% of adult copepods with a maximum number in Abu Sembel during autumn (7 org. L^{-1}) (Fig. 4).

Population of Cladocera

Cladocera were dominated by *Ceriodaphnia*, *Diaphanosoma* and *Daphnia* (52.6%, 24.4% and 13.5% of total Cladocera, respectively). *Ceriodaphnia* was represented by *C. reticulata* (Jurine) and *C. cornuta* Sars (88.7% and 11.3% of *Ceriodaphnia*, respectively). The maximum peak of the genus was recorded at Arkeen (20 org. L^{-1}) and decreased toward the downstream with high density during spring (8 org. L^{-1}). *Diaphanosoma excisum* Sars was the second dominant cladocerans. Its highest density was recorded at Allaqui (9 org. L^{-1}) followed by Abu Sembel (7 org. L^{-1}). Spring was the season with the highest density. *Daphnia* was represented by *D. longispina* Muller and *D. barbata* Dodson (72.7% and 27.3% of *Daphnia*, respectively). They were noticed with maximum standing stock at Arkeen (5 org. L^{-1}) and decreased toward the upstream with slight decrease at Adendan and Tushka. Their peak of dominance was noticed during spring (9 org. L^{-1}) followed by winter (7 org. L^{-1}) at Arkeen and during autumn toward the upstream as in Fig. 5.

Population of Rotifera

Contribution of rotifers to the total zooplankton number was weak (11%, with 8 org. L^{-1}). Their number increased from 4 org. L^{-1} at Arkeen to 9 org. L^{-1} at Kalabsha passing through high number at Allaqui (14 org L^{-1}). Winter and spring were rich with these organisms.

Rotifera was dominated by *Keratella* and *Brachionus* (75% and 9% of total rotifers, respectively). *Keratella*

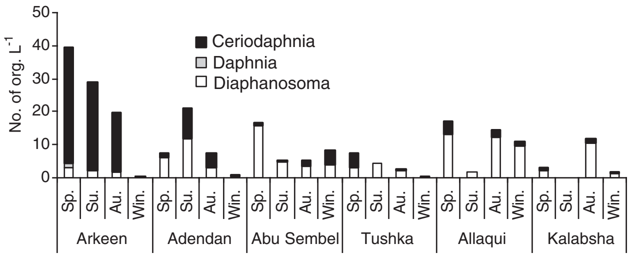

Fig. 5. Distribution of the dominant cladoceran genera (org. L^{-1}) in Lake Nasser during 2002/2003.

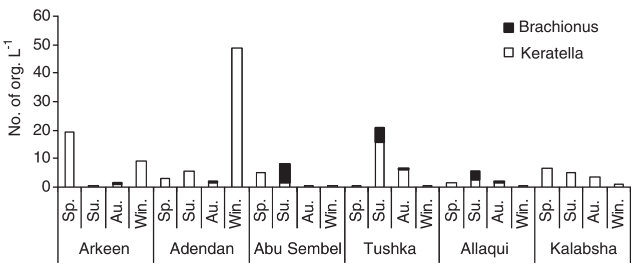

Fig. 6. Distribution of the dominant rotiferan genera (org. L^{-1}) in Lake Nasser during 2002/2003.

spp. was represented by *K. cochlearis* (Gosse), *K. tropica* (Apstein) and *K. quadrata* (Muller). *K. cochlearis* represented the main bulk of rotifers (66% of total rotifers). This genus occurred in greatest number at Allaqui during winter (due to the high dominance of *K. cochlearis*), during summer at Adendan–Abu Sembel and during spring at the other stations (Fig. 6). *Brachionus* spp. formed 9% of rotifers and 1% of zooplankton. It was represented by *B. calyciflorus* Pallas and *B. falcatus* Zacharias (96% and 4% of the genus, respectively). Its maximum density was noticed at Abu Sembel and Tushka mostly during summer (5 and 6 org. L^{-1}, respectively), while it totally disappeared from Arkeen and Kalabsha.

Statistical analysis

For CCA ordination, the species environmental biplot (Fig. 7) shows the relations of the species and environmental variables with the ordination axes. The length of the arrow indicates the relative importance of the environmental variable in determining the axes. The position of the species centers (points) along the ordination axes represent their respective optima along the environmental gradient. The species–environmental correlation with axis 1 was 0.9. It correlated well with pH, OP, silicate, and conductivity. The copepod nauplius larvae, *Keratella* and *Brachionus* had the highest values on this axis, while *Bosmina*, *Thermocyclops neglectus*, and *Thermodiaptomus galebi* showed

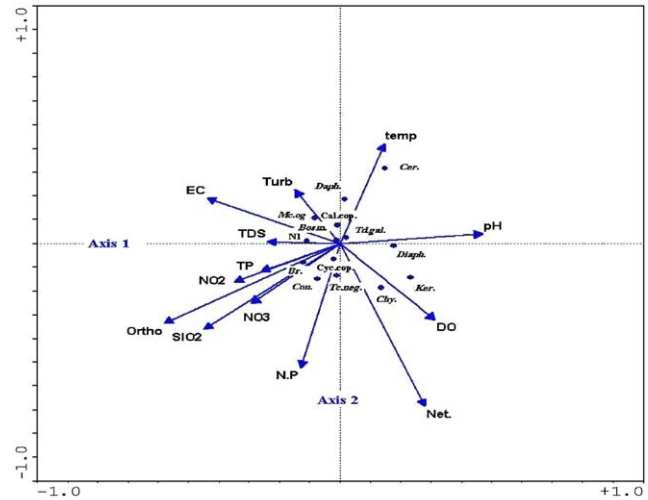

Fig. 7. Canonical correspondence analysis (CCA) ordination diagram with 17 zooplankters (genus, developmental stage, and group) (●) and 13 quantitative environmental variables (arrows). The zooplankton are Ker. = *Keratella* spp., Br. = *Brachionus* spp., Con. = *Conochilus* sp., T.Rot. = Total Rotifera, Chy. = *Chydorus* sp., Bosm. = *Bosmina* sp., Daph. = *Daphnia* spp., Cer. = *Ceriodaphnia* sp., T. Clad = Total Cladocera, N.l. = Nauplius larvae, Cal.cop. = Calanoid copepodites, Cyc. cop. = Cyclopoid copepodites, Td.gal. = *Thermodiaptomus galebi*, Mc.og. = *Mesocyclops ogunnus*, Tc.neg. = *Thermocyclops neglectus*, T.Cop. = Total Copepoda. The environmental factors are: temp = temperature, pH, EC, electrical conductivity, DO = dissolved oxygen, TDS = total dissolved solids, Turb = turbidity, Ortho = orthophosphate-phosphorus, TP = total phosphorus, NO_3 = nitrate-nitrogen, NO_2 = Nitrite, SIO_2 = Silicate, Net. = chl.-*a* of netplankton, N + P = chl.-*a* of nano and picoplankton.

lowest values on the axis. The species–environmental correlation for axis 2 was 0.829. It well correlated with fractions of chl.-*a* and temperature. Species with high correlation with this axis were *Ceriodaphnia*, *Chydorus*, and *conochillus*.

Discussion

The African Lakes were classified by Talling and Talling (1965) according to their conductivity into three classes. Lake Nasser belongs to the first class with low conductivity, less than 600 μS cm^{-1}. Its conductivity ranged between 221 and 261 μS cm^{-1} during the study. Morales-Baquero, Cruz-Pizarro, and Carrillo (1989) found low conductivity lakes yielded greater densities of typical planktonic species. This agrees with our results as in Table 3.

Lake Nasser lies in the arid zone of the subtropical area of Africa. The temperature range of Lake Nasser was from 18.3 to 31 °C with the minimum during winter and the maximum during summer. The big difference in temperature of Lake Nasser water along the year round considered as a controlling factor related to range of tolerance of species. From CCA, some species reacted positively to water temperature as *Ceriodaphnia*, contrary to *Conochilus unicornis* and *Thermocyclops neglectus*. We believe that the reproduction of these species is correlated with temperature preference.

Turbidity values were highest during summer at the upstream. Habib (2000) and Mohamed and Ioriya (2000) found the blooming of the Cyanophyta *Microcystis aeruginosa* Kutz was through the period before the flood at the southern area of the reservoir between Wadi Halfa (Sudan) and Abu Sembel. Turbidity in Lake Nasser is caused by two main factors, namely allochtonic silt of riverine origin, in the upstream area, and autochtonic suspended organic material (plankton and detritus), in the downstream area (Latif, 1984). A large amount of silt sedimentation is deposited in the southern part of the lake, mainly extending from the mouth of Lake Nubia (Sudan) to nearly Adendan at the Egyptian border. Cladocera had different reaction to turbidity from species to the other, *Diaphanosoma excisum* correlated negatively with turbidity ($r = -0.11$, $p = 0.64$) while *Ceriodaphnia* spp., the main dominant cladoceran, were correlated positively with turbidity ($r = 0.59$, $p = 0.003$). The latter ones were recorded mainly at the upstream with maximum densities at Arkeen (333 km from HD), which is characterized by semi-riverine properties according to Entz and Latif (1974). Rotifera decreased toward the upstream of the lake during autumn due to the low productivity associated with the permanent turbidity due to flood in the upstream especially during autumn. El Shabrawy and Dumont (2003) reported these results in Lake Nasser. Abdel Monaem (1995) and Abouel Kheir et al. (2003) noticed the minimum primary productivity in Lake Nasser was at the upstream part of the lake in autumn.

Table 3. Frequency of abundance of the recorded zooplankton species in Lake Nasser during the study

Species	Frequency
Rotifera	
Keratella cochlearis (Gosse)	B
K. tropica (Apestin)	E
K. quadrata (Müller)	F
Brachionus calyciflorus (Pallas)	E
B. falcatus (Zacharias)	F
Platyas patulus (Müller)	F
Trichocerca similes Wierzejski	F
T. longiseta (Schrank)	E
Filina opoliensis (Zacharias)	F
Polyarthra vulgaris (Carlin)	F
Conochillus unicornis Rousslet	E
Cladocera	
Chydorus sphaericus Müller	F
Alona rectangular Sars	F
Bosmina longirostris Müller	E
Daphnia longispina Müller	C
D. barbata Dodson	E
Diaphanosoma excisum Sars	B
Ceriodaphnia cornuta Sars	D
C. reticulata (Jurine)	A
Simocephalus vetulus Müller	E
Copepoda	
Thermodiaptomus galebi (Barrois)	D
Mesocyclops ogunnus Onabamiro	F
Thermocyclops neglectus (Sars)	C

Note: A, >6 org. L^{-1}; B, 6–4 org. L^{-1}; C, 4–2 org. L^{-1}; D, 2–1 org. L^{-1}; E, 1–0.5 org. L^{-1}; and F, <0.5 org. L^{-1}.

The copepod *Thermocyclops neglectus* is considered as carnivore copepod, feed mainly on rotifers (El Shabrawy & Dumont, 2003). It correlated negatively with rotifers. While *Thermodiaptomus galebi* was recorded with maximum counts at Abu Sembel during autumn where the peak of orthophosphate and nitrate which are responsible for phytoplankton growth. Taha and Mageed (2002) revealed negative correlation between *T. galebi* and chl.-*a*. It is by far the most typical herbivore calanoid of the Nile system (Verhey & Dumont, 1984).

The lowest zooplankton standing stock was noticed during spring coincided with the lowest chl.-*a* values. According to Duncan and Schiemer (1988), the ratio of cladocerans to copepods may be a good indicator of the extent to which the zooplankton is being utilized by fish. The results of this relation indicated that, the highest fish predation in the study was during spring (value was only 0.8 during spring and varied between 7.2 and 3.5 during the other seasons) with the lowest water turbidity. The large cladoceran *Daphnia* suffer more from fish predation than smaller species. Its maximum peak was recorded at Arkeen with the highest turbidity. The density of zooplankton started to increase toward the upstream. This was coincided with rich nitrate and orthophosphate. At the downstream, the fish predation increases due to high transparency, leading to decrease in the zooplankton density. While juvenile crustacean zooplankters and rotifers may actually increase under fish predation (El Shabrawy & Dumont, 2003; Nielsen, Hillman, Smith, & Shiel, 2000).

The density of zooplankton in Lake Nasser change with the oscillation of the lake water level. During the last 20 years, water level decreased from 176 m above sea level (asl) during 1981 to 170 m asl during 1992/1993, the level increased again up to 179 m asl during 1996. During the study, the lake level was 178 m asl. The lake water level is varying according to the coming flood to the lake each year. The standing stock of zooplankton was higher at low water level in comparison with the highest level (Mageed, 1995; El Shabrawy, 2000; Zaghloul, 1985). Agaypi (2000) found high positive relationship between water level and the total annual fish catch. Khalifa, Agaypi, and Adam (2000) explained that, when the water level rises, the shallow water areas increase. This provides more spawning areas for fishes, mostly tilapia species (>90% of the total catch in the lake). This high fish production lead to high predation on zooplankton and thus decrease zooplankton density during the high water level in the lake.

Continuous monitoring of water characteristics and biota in Lake Nasser should be undertaken to follow the changes in the ecosystem.

References

Abdel Monaem, A. M. (1995). *Spatial distribution of phytoplankton and primary productivity in Lake Nasser*. Ph.D. thesis, Botany Department, Collage of Girls, Ain Shams University (161pp.).

Abdel Rehim, S. S., Abdel Bari, M. R., Khalil, M. M., Heika, M. T., & Salem, T. A. (2002). Impact of heat on the physical and chemical properties of Lake Nasser water. *Journal of Environmental Science*, *5*(2), 325–349.

Abouel Kheir, W., Ibrahim, E. A., Khalil, M. M., Heikal, M. T., & Yousry, K. M. (2003). Assessment of physico-chemical characteristics of water and phytoplankton growth in Lake Nasser. *Journal of Environmental Science*, *7*(1), 59–84.

Agaypi, M. Z. (2000). A note on the relationship between catch and water level. In J. F. Craig (Ed.), *Sustainable fish production in Lake Nasser: Ecological basis and management policy. ICLARM conference proceedings* 61 (pp. 85–86).

APHA – American Public Health Association. (1992). *Standard methods for the examination of water and waste-water*. New York: American Public Health Association (1268pp.).

Dumont, H. J. (1986). Zooplankton of the Nile systems. In B. R. Davies, & K. F. Walker (Eds.), *The ecology of river systems*. The Hauge: Monographiae Biologicae W. Junk Publishers.

Duncan, A., & Schiemer, F. (1988). Fish pressure on ecosystems: Dynamic, holistic indices. In S. S. De Silva (Ed.), *Proceedings of the symposium on reservoir fishery management and development in Asia* (pp. 176–182). Ottawa: International Development and Research Council.

Elewa, A. A., Sayyah, S. M., Latif, A. F. A., & Touffek, M. F. (1988). Nutrient status in Lake Nasser and River Nile at Aswan, Egypt. *Bulletin of Institute of Oceanography and Fisheries, ARE*, *14*(3), 177–188.

El Shabrawy, G. M. (2000). Seasonal and spatial variation in zooplankton structure in Lake Nasser. I-Pelagic area of the main channel. *Egyptian Journal of Aquatic Biology and Fisheries*, *4*(3), 75–101.

El Shabrawy, G. M., & Dumont, H. J. (2003). Spatial and seasonal variation of the zooplankton in the coastal zone and main khors of Lake Nasser (Egypt). *Hydrobiologia*, *491*, 119–132.

Entz, B. A. (1972). Comparison of the physical and chemical environments of Volta and Lake Nasser. In *Proceedings of freshwater. UNESCO symposium on productivity problems of freshwaters*, Kasimierz Dolny, 1970 (pp. 883–891).

Entz, B. A., & Latif, A. F. A. (1974). *Report on survey to Lake Nasser and Lake Nubia, 1972–1973*. Lake Nasser Development Center Project (RPA, UNDP, FAO), working group, No. 6 (33pp).

Habib, O. A. (2000). Seasonal variation of phytoplankton abundance. In J. F. Craig (Ed.), *Sustainable fish production in Lake Nasser: Ecological basis and management policy. ICLARM conference proceedings* 61 (pp. 43–49).

Heikal, M. T., & Abdel Bary, M. R. (1999). Stratification variability and trophic state along Lake Nasser. In *Lake 99. Eighth international conference on the conservation and management of lakes*, Copenhagen.

Khalifa, U. S. A., Agaypi, M. Z., & Adam, H. A. (2000). Population dynamics of *Oreochromis niloticus* L. and *Sarotherodon galilaeus* Art. In J. F. Craig (Ed.), *Sustainable fish production in Lake Nasser: Ecological basis and management policy* (pp. 87–90). *ICLARM Conf. Proc*. 61.

Latif, A.F.A. (1984). Lake Nasser – the new man-made lake in Egypt (with references to Lake Nubia). In *Ecosystem of the world, lakes and reservoirs* (Vol. 23). Amsterdam: Elsevier; p. 410.

Mageed, A. A. (1995). *Studies on zooplankton from Lake Nasser, Egypt*. Ph.D. thesis, Faculty of Science Al-Azhar University (215pp.).

Mohamed, I., & Ioriya, T. (2000). *Microcystis aeruginosa* Kutz water blooms. In J. F. Craig (Ed.), *Sustainable fish production in Lake Nasser: Ecological basis and management policy. ICLARM conference proceedings* 61 (pp. 59–60).

Morales-Baquero, R., Cruz-Pizarro, L., & Carrillo, P. (1989). Patterns in the composition of the rotifer communities from high mountain lakes and ponds in Sierra Nevada (Spain). *Hydrobiologia*, *186/187*, 215–221.

Nielsen, D. L., Hillman, T. J., Smith, F. J., & Shiel, R. J. (2000). The influence of a planktivorous fish on zooplankton assemblages in experimental billabongs. *Hydrobiologia*, *434*, 1–9.

Rzoska, J. (1976). Zooplankton of the Nile System. In J. Rzoska (Ed.), *The Nile, biology of an ancient river* (pp. 333–343). The Hague: W. Junk.

Taha, O. E., & Mageed, A. A. (2002). Spatial distribution and relationship between phytoplankton and zooplankton in Lake Nasser (Egypt) after the flood season. *Egyptian Journal of Aquatic Biology and Fisheries*, *6*(4), 265–281.

Talling, J. F., & Talling, T. B. (1965). The chemical composition of African lake waters. *Internationale Revue der Gesamten Hydrobiologie*, *50*(3), 421–463.

Ter Braak, C. J. F. (1987). CANOCO – a FORTRAN program for canonical community ordination by partial detrended canonical correspondence analysis, principal components analysis and redundancy analysis (Version 3.1). Agriculture Mathematics Group, Wageningen.

Verhey, H. M., & Dumont, H. J. (1984). The calanoid copepods of the Nile systems. *Hydrobiologia*, *110*, 191–212.

Zaghloul, F. A. (1985). *Seasonal variations of plankton in Lake Nasser*. Ph.D. thesis, Faculty of Science, Suez Canal University, Egypt (364pp.).