Effects of zooplankton Grazing on Phytoplankton succession in the River Nile, Egypt: an enclosures study

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ABSTRACT

In situ three grazing experiments were carried out for determining the grazing rate of zooplankton on phytoplankton species during autumn 2002, spring and summer 2003. Water samples from euphotic zone of the River Nile were inoculated with zooplankton organisms as its density in the Nile water and twice of that initial found in their natural field.

Phytoplankton communities in the different enclosures were dominated by Chlorophyceae, Bacillariophyceae and Cyanophyceae, whereas zooplankton organisms were represented by Rotifera, Cladocera, and Copepoda with the dominance of rotifers (>95%).

Grazing rate reached the maximal in 2nd day of double field zooplankton enclosures during autumn and indicated that green algae and diatoms, especially *Planktonema lauterbornii* Schmidle, *Dictosphaerium pulchellum* Wood, *Cyclotella operculata* Kutz and *Syndra ulna* (Nitzsch) Ehr. were the most preferable algal cells grazed by zooplankton organisms (0.0599, 0.0174, 0.0530, 0.0371/h, respectively). Moreover, zooplankton organisms grazed to large extent on *Microcystis aeruginosa* Kutz (0.0504 h^{-1}) and *Merismopedia glauca* (Ehr.) Nageli (0.0105/h). Contrary, the grazing rate during spring and summer seasons was obviously high on blue greens, such as *Chroococcus disperses* Lemm., followed by diatoms and green algae, due to the abundance of rotifers during this period. Rotifers are able to graze even on blue green algae. The results revealed that, there was no evidence of strong negative effects on phytoplankton number, whereas the grazing rate decreases with increasing zooplankton number due to the nutrient regeneration by zooplankton, which induces phytoplankton growth.

Zooplankton abundance and community structure were important factors determining grazing rates in large rivers. Zooplankton density and phytoplankton can be increase two folds that found in Nile water especially in fish farms utilize River Nile water in aquaculture. Autumn season is the best time for zooplankton grazing on the different algal species inhabiting the River Nile.

Key Words: water quality, phytoplankton, zooplankton, grazing, River Nile.

INTRODUCTION

Understanding of aquatic organisms is extremely important in the development of a water body management. In agitated water a larger reduction in grazing rate is observed at any water velocity, than in stagnant water (Miquelis *et al*., 1998). The grazing pressure of zooplankton was mainly on the nano- and picophytoplanktonic fraction in Lake Qarun-Egypt (El–Shabrawy & Taha, 1999). The ratio between the number of algal cells grazed by zooplankton and the algal production was 132% in August and 489 % in September, due to the strong influence exerted by zooplankton on phytoplankton (Ravera and Scotto, 1999). Grazing rates in freshwater lakes (USA) dominated by some blue–greens were 10-fold lower than in water without these blue–greens, due to defense against grazing (Hambright *et al*., 2001). Phytoplankton densities in the freshwater fish farm (Egypt) were correlated with the densities of zooplankton where they can stimulate phytoplankton growth (Mageed and Konsowa, 2002). The combined impact of Cladocera and Copepoda led to a substantial decline in total phytoplankton biomass in Germany mesotrophic lakes (Sommer *et al*., 2003). In the River Nile (Egypt), centric diatoms are digested by zooplankton groups, and double cone diatoms are inedible by zooplankton, the daily growth rates of green algae are highly affected by grazing especially in enclosures containing great numbers of cladocerans (Khalifa 2004). The grazing impact of zooplankton community, especially copepods in the Pearl River estuary changed seasonally and spatially, being varied between 0.3 % and 75 % of the chlorophyll, or up to 104 % of the daily phytoplankton production in summer and 21 % in winter (Tan *et al*., 2004).

The major goal of this study was to evaluate the relationship between phytoplankton and zooplankton and their potential impact on water quality of the River Nile at El-Kanater El-Khayria.

MATERIALS AND METHODS

Three grazing experiments were conducted *in situ* during autumn 2002, spring and summer 2003. Up to 20 liters from the River Nile water at delta barrages (10Km north Cairo) were taken from the euphotic zone of the Nile. Immediately on collection, the water was sieved through 44µm mesh net to remove zooplankton as possible. Three sets of 3 clear polyethylene bottles (20-liters capacity) were filled with the Nile water. The first set represents the un-grazed aspirators (control), the second set was inoculated with freshly collected zooplankton from the same site as its density in the River Nile water (Z enclosure), while the third set was inoculated with zooplankton organisms twice of that initial found in their natural field (2Z enclosure). The containers were incubated under the surface water of the River Nile for 48 hours. Sampling for water quality analysis, phytoplankton and zooplankton identification and counting were withdrawn from the enclosures at 0 hour, 24 hours, and 48 hours of incubation.

Water temperature, pH and Electrical conductivity were measured directly in the enclosures. The nutrient salts; ammonium, nitrite, nitrate, total organic nitrogen, orthophosphate, total organic phosphorus (TOP), and silicate were measured according to APHA (1995).

For phytoplankton, 500ml of water were preserved immediately in 4% formalin. The preserved samples were transferred in a clean graduated cylinder of 500ml capacity and few drops of Lugol's Iodine solution were added. The phytoplankton cells were allowed to settle, for 5 days. The supernatant was carefully siphoned off with a small plastic tube ending with a fine net of 20µm mesh diameter, until the samples were concentrated to 50ml. The drop method was applied for counting and identification of different algal species as in APHA (1995).

Zooplankton samples were collected through a filtration of 2L by a plankton net, with 55µm mesh size. The samples were preserved using 4% neutral formalin solution. In the laboratory, zooplankters were identified, and the number of zooplankton individuals (indv.) per litre was calculated.

Grazing rate (per hour) in each manipulation is the slope of the following equation "1": $r = b(ZC) + A$. Where "r" is the realized algal growth rate (per hour), "ZC" is zooplankton concentration and A is the realized algal growth in the absence of zooplankton (per hour) (Draper & Smith, 1981). Realized algal growth rate (r) was measured from changes in the number of cells of phytoplankton per hour during the manipulation according to Vanderploeg *et al.* (1988). Realized algal growth rate (r, per hour) was calculated as in the following equation "2": $r = \ln(C_1 / C_0) / T$. Where C_0 and C_1 are number of cells per liter, and T is the time period (hours) over which grazing is measured. The realized growth rates measured in each enclosure were used in equation "1" to calculate zooplankton grazing rate.

Data analysis

Analysis of variance (ANOVA), Pearson correlation between species of plankton and the different environmental variables, and regression between grazing rate and zooplankton concentration were carried out using Minitab ver. 12 under Windows. The data of phytoplankton, zooplankton and water quality variables were drawn up in the form of three matrices and were analyzed by Canonical Correspondence Analysis (CCA) using Brodgar Program, version 2.4.8 (Highland Statistics, 2005).

RESULTS

Physicochemical characteristics are shown in Table (1). The highest water temperature was recorded during summer, while the minimum was observed in autumn. Its values ranged from 20.5°C to 33.6°C. pH values ranged between 7.91 and 8.80 in the three experiments. pH values were low at zero time compared to that recorded in the first and the second day at all sets of the

experiments. Water conductivity was often high at zero time in comparison with the other times of the three experiments, with range of 288 to 411µmohs/Cm.

Table (1): Physicochemical characteristics during grazing experiments in field zooplankton (Z) and double field zooplankton number (2Z) enclosures.

Parameters	Season	Control			Z			2Z		
		0 h.	24 h	48 h	0 h.	24 h	48 h	0 h.	24 h	48 h
Water Temperature	Autumn	22.4	23.9	21.7	22.1	24.3	21.7	22.2	24.3	21.6
	Spring	22.0	31.0	29.1	22.4	30.5	29.2	20.5	30.9	29.2
	Summer	29.9	33.6	33.2	30.1	33.2	33.0	29.8	33.2	33.0
pH values	Autumn	8.2	8.3	8.4	8.3	8.3	8.4	8.3	8.3	8.4
	Spring	7.9	8.4	8.2	8.1	8.4	8.2	8.2	8.4	8.3
	Summer	8.1	8.5	8.4	8.1	8.6	8.7	8.2	8.8	8.8
Conductivity (µmohs Cm^{-1})	Autumn	390	332	365	361	338	353	411	351	354
	Spring	350	350	349	353	352	347	351	352	348
	Summer	324	320	321	335	328	304	339	288	297
Ammonium-N (μgL^{-1})	Autumn	39	42	25	48	30	30	49	45	38
	Spring	47	53	50	63	91	30	81	75	48
	Summer	105	97	105	116	112	106	124	108	100
Nitrite-N (μgL^{-1})	Autumn	4.0	5.7	3.3	4.8	7.6	2.0	4.2	7.2	4.9
	Spring	14.5	12.7	9.2	13.8	8.5	11.9	9.0	11.9	14.5
	Summer	2.3	2.2	2.5	1.6	2.7	3.2	2.1	2.7	3.5
Nitrate-N (μgL^{-1})	Autumn	179	94	25	100	65	37	135	63	68
	Spring	24	17	12	17	14	24	14	14	24
	Summer	616	592	583	617	570	623	651	576	608
Total organic nitrogen (mgL^{-1})	Autumn	4.0	3.9	1.1	3.5	1.2	1.4	3.8	14.5	2.2
	Spring	3.3	4.8	7.5	10.6	6.9	9.6	2.6	2.9	5.0
	Summer	1.4	4.5	23.3	7.2	9.9	3.8	6.3	6.1	5.5
Orthophosphate (μgL^{-1})	Autumn	14	4	2	7	15	3	8	6	16
	Spring	39	17	18	22	46	49	17	35	37
	Summer	71	53	54	55	54	42	89	35	107
Silicate (mgL^{-1})	Autumn	0.80	0.60	0.20	0.90	0.50	0.10	0.80	0.50	0.10
	Spring	1.10	1.55	1.12	0.76	1.20	0.73	0.68	0.64	0.03
	Summer	1.90	2.30	2.30	2.30	1.50	1.10	1.80	1.50	0.90

Nitrate values had substantially increased the nitrite and ammonium concentrations. Ammonium and nitrate values were obviously high during summer rather than recorded in the other seasons. NH_4-N concentrations were often decreased with time at the grazed enclosures. Its values ranged from 24.7 to 124.3µg/L. Nitrite concentrations varied from 1.6 to 14.5µg/L, while nitrate concentrations showed wide variations between 12.1 and 650.6µg/L. Total organic nitrogen (TON) exhibited a different pattern in each enclosure, but its

values were usually low after 48 hours from the beginning of the experiment. It attained the maximum value of 14.5mg/L in 2Z enclosures after 24 hours, while its minimum value of 1.2mg/L occurred in control enclosure after 48 hours. Orthophosphate values decreased after 48 hours in all groups of enclosures, except a sharp increase at the last day of the third set. Its values showed a strong variation between 1.4 and 16.3µg/L. Total organic phosphorus (TOP) showed an irregular distribution at most sets of this experiment. TOP attained the maximum value of 88.1µg/L at 2Z set after 24 hours, while its minimum value of 11.5µg/L occurred at the same set after 48 hours. Silicate had gradually decreased with increasing time. Its values fluctuated between 0.1 and 0.8 mg/L.

Total phytoplankton crops (Table 2) increased with time as well as in autumn and summer compared to spring season. Chlorophyceae, Bacillariophyceae and Cyanophyceae were the prevailing classes during grazing experiments. Green algal crop attained its highest value of 8044×10^4 cells/L after 48 hours at 2Z enclosures in summer, while lowest density of 336×10^4 cells/L was found at zero time of control in spring.

Table (2): Total phytoplankton density during grazing experiments (No. of 10^4/L)

Phytoplankton classes		Control			Z			2Z		
		0 h.	24 h	48 h	0 h.	24 h	48 h	0 h.	24 h	48 h
Autumn	Chlorophyceae	991	1178	590	1102	903	2650	528	1248	5722
	Bacillariophyceae	1010	884	264	1095	910	2090	597	1864	1987
	Cyanophyceae	154	433	254	149	292	297	286	175	488
	Total phytoplankton	2155	2495	1108	2346	2105	5037	1411	3287	8197
Spring	Chlorophyceae	336	582	856	476	757	712	346	550	2522
	Bacillariophyceae	137	233	456	122	600	548	205	378	964
	Cyanophyceae	220	347	410	159	167	368	266	140	377
	Total phytoplankton	693	1162	1722	757	1524	1628	817	1068	3863
Summer	Chlorophyceae	553	1680	1868	1902	5260	5000	3106	5160	8044
	Bacillariophyceae	251	93	276	532	999	1064	1395	1682	1076
	Cyanophyceae	95	196	104	87	218	215	46	206	503
	Total phytoplankton	899	1969	2248	2521	6477	6279	4547	7048	9623

Diatom crops at the grazed enclosures were often higher than control and its values commonly increased with time. Bacillariophyceae attained minimum density (93×10^4 cells/L) after 24 hours at control enclosures, however its maximum crop (2090×10^4 cells/L) was counted after 48 hours at Z enclosures. The most dominant species among Bacillariophyceae were *Melosira granulata* (Ehr.) Ralfs, *M. granulata* var. *angustissima* Muller, *Syndra ulna* (Nitzsch) Ehr., *Cyclotella ocellata* Pant, and *C. operculata* Kutz. Numerical density of pennales diatom had obviously increased centrals forms in summer at the enclosures inoculated with zooplankton.

Blue green algal crops were low compared to green algae and diatoms. Its lowest crop of 46×10^4 units/L was observed at zero time of 2Z enclosures while its highest of 503×10^4 units/L occurred after 48 hours of the same set. The dominant species of the blue green algae were *Microcystis aeruginosa* Kutz., *M. elachista* (W. & G. S. West) Starmach and *Merismopedia glauca* (Ehr.) Nageli.

Chrysophyceae (*Mallomonas* sp.), Cryptophyceae (*Cryptomonas ovata* Ehr., *Chromonas acuta* Utermohl, *C. nordstedtill* Hansgirg), Dinophyceae (*Peridinium cinctum* Muller) and Euglenophyceae (*Phacus curvicauda* Swirenko) were rarely occurred during the grazing experiments.

Zooplankton organisms (Table 3) were represented by three groups namely Rotifera, Cladocera, and Copepoda. Rotifera was dominated by *Keratella cochlearis* (Gosse), *Conochillus unicrnis* Rousslet, while Cladocera was the second group dominated by *Ceriodaphnia cornuta* Richard and *Alona intermedia* Sars. Copepoda occupied the third group and was represented only by *Thermocyclops* sp. and its larval stages.

Table (3): Total number of zooplankton organisms (indiv./L) in each enclosure (Z and 2Z) and their dominant species in the three grazing experiments.

Groups		***Taxa of zooplankton***	***Autumn, 2002***		***Spring, 2003***		***Summer, 2003***	
			Z	**2Z**	**Z**	**2Z**	**Z**	**2Z**
Rotifera	Dominant sp.	*Keratella cochlearis* (Gosse)	467	777	1417	2194	906	1678
		Conochilus unicrnis Rousslet	583	783	666	1111	1792	3834
		Brachionus calyciflorus (Pallas)	0	0	34	169	1026	3345
		Keratella tropica (Apstein)	0	0	317	503	953	2345
	Other rotifers		723	677	217	222	814	2044
	Total Rotifera		1773	2237	2650	4199	5490	13246
Cladocera	Dominant sp.	*Diaphanosoma excisum* Sars	0	0	52	67	0	0
		Ceriodaphnia cornuta Richard	17	26	59	180	0	0
		Alona intermedia Sars	4	17	9	19	0	0
		Bosmina longirostris Muller	0	0	0	0	28	43
	Other Cladocera		16	20	63	83	0	58
	Total Cladocera		37	63	183	350	28	101
Cope-poda	Dominant sp.	*Thermocyclops* sp.	7	15	42	61	28	1968
	Other copepods		0	0	0	0	27	33
	Total Copepoda		7	15	42	61	55	2001
Total other zooplankton			50	73	133	161	111	67
Total zooplankton			1867	2373	3008	4771	5684	15415

Zooplankton number was the highest during summer. The number during autumn was 1867 indiv./L in all Z sets and 2373 indiv./L in all 2Z enclosures, with the dominance of *Conochilus unicornis*. The number during spring experiment was 3008 indiv./L in Z set and 4771 indiv./L in 2Z

enclosures, with the dominance of *Keratella cochlearis*. The zooplankton number during summer experiment was 5684 indiv./L in all Z sets and 15415 indiv./L in all 2Z groups, with the dominance of *C. unicrnis*, *Brachionus calyciflorus*, *Keratella* spp. and *Thermocyclops* sp.

Maximum grazing rate was observed during autumn (Table 4) chiefly in 2Z enclosures of second day. Also, its values were fairly high during 1st day (Z enclosures) in summer. In general; its value was very low in 2nd day in Z enclosures during the whole period of study. Grazing rate on Chlorophyceae revealed the preference of zooplankton grazing on *Planktonema lauterbornii* Schmidle and *Dictosphaerium pulchellum* Wood where its values reached 0.0599/h and 0.0174/h at 2Z & Z enclosures, respectively of 2nd day. Also, grazing rate on diatoms indicated the tendency of zooplankton grazing on *Cyclotella operculata* Kutz and *Syndra ulna* (Nitzsch) Ehr. Its values were 0.0530/h and 0.0371/h in Z and 2Z enclosures, respectively. The dependence of zooplankon on Cyanobacteria was low compared to the previous two groups. Zooplankton organisms grazed to large extent on *Microcystis aeruginosa* Kutz and *Merismopedia glauca* (Ehr.) Nageli. The grazing rates on these blue green algae were 0.0504 and 0.0105/h in 2Z and Z enclosures during 2nd and 1st day respectively. Also, the grazing rate on the other groups of phytoplankton was very low except on *Chromonas acuta* Utermohl (0.0251/h) and *Peridinium cinctum* Muller (0.0230/h) during 1st day of this experiment.

Analysis of variance (ANOVA) for the grazing rate of zooplankton concentration on total phytoplankton density was not significant for the three seasons. The difference in the grazing rate during the seasons was found between the grazing rate of the different phytoplankton species (not as total density) during autumn ($p= 0.016$), while it was non significant during spring and summer ($p= 0.15$ and 0.18, respectively). For grazing rate of the two zooplankton concentrations (Z and 2Z), ANOVA evaluated high significant difference during autumn and low difference during spring, while no significant difference during summer ($p= 0.01$, 0.8, and 0.07, respectively).

Table (4): Grazing rate / hour in autumn, spring and summer seasons

Species	*First day*		*Second day*	
	Z	**2Z**	**Z**	**2Z**
Autumn				
Planktonema lauterbornii	-0.002	-0.009	0.022	0.060
Cyclotella operculata Kutz	0.053	0.004	-0.040	0.007
Microcystis aeruginosa	0.000	-0.047	0.021	0.050
Spring				
Planktonema lauterbornii	-0.039	-0.015	0.017	0.009
Oocystis parva W. & G. S. West	-	0.017	-	-0.006
Cyclotella ocellata Pant	0.020	0.002	-0.004	0.006
Cyclotella operculata Kutz	0.019	0.002	-0.009	0.000
Chroococcus disperses Lemm	0.032	-	-0.001	-
Summer				
Planktonema lauterbornii	0.008	0.004	-0.011	-0.005
Cyclotella ocellata Pant	0.005	0.004	-0.003	-0.002
Cyclotella operculata Kutz	0.008	0.001	-0.006	0.001
Chroococcus disperses Lemm.	0.011	0.009	-0.004	-0.001

Canonical correspondence analysis (CCA) for 8 environmental variables, 4 phytoplankton classes, and 6 dominant zooplankton species relationships of the data of the three experiments are displayed in Figure (1). CCA axis 1 (29.8%) and axis 2 (20.8%) explained a substantial proportion of the variation in the zooplankton-phytoplankton and environment relationships.

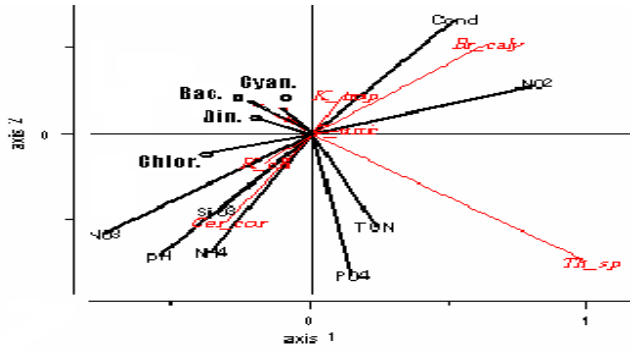

Fig.1. Canonical correspondence analysis (CCA) diagram with 6 zooplankters, 4 phytoplankton classes and 8 quantitative environmental variables. The phytoplankton classes are, Bac.= Bacillariophyceae, Cyan.= Cyanophyceae, Din.= Dinophyceae, Chlor.= Chlorophyceae. Zooplankters are *K. coch.= Keratella cochlearis, K. trop.= Keratella tropica, Br. caly.= Brachionus calyciflorus, Con.= Conochilus* sp., *Cer. cor.= Ceriodaphnia cornuta, Th.* sp.= *Thermocyclops* sp. The environmental factors are pH, EC= electrical conductivity, PO_4= orthophosphate-phosphorus, NH_4= ammonium, NO_2= Nitrite, NO_3= nitrate-nitrogen, SiO_3= Silicate, TON= total organic nitrogen.

It is noted that axis 1 is more effective than axis 2 however they recorded eignvalues of 0.006 and 0.003 respectively. The most important factors explaining the zooplankters-phytoplankton variation on the first axis of CCA diagram were conductivity, nitrite, nitrate, pH, and ammonia. Chlorophyceae, *Brachionus calyciflorus*, and *Thermocyclops* sp. were strongly related to axis 1. The most important factors explaining the zooplankters variation on the second axis of CCA diagram were phosphorus and pH. Bacillariophyceae, and *Ceriodaphnia cornuta* were strongly related to axis 2.

DISCUSSION

In all grazing experiments, water temperature increases with increasing in phytoplankton crops where temperature increase more rapidly in turbid water regardless, of whether turbidity is mineral or organic matter (Ellis, 1989). pH values were low at zero time compared to the first and second day, due to the minimum phytoplankton crops at the first enclosures (zero time) of grazed and ungrazed groups ($r= 0.71$, $p= 0.001$), as reported by Elewa & Mahdi (1988) at River Nile water. They pointed out that, increasing pH value at the River Nile was related to increase in primary production and photosynthetic activity of phytoplankton that uptake carbon dioxide from carbonate bicarbonate buffer system. Water conductivity decreased with increasing phytoplankton density. This result could be realized to phytoplankton consumption some of ionizable salts in solution with time ($r= - 0.52$, $p= 0.006$) as reported by Konsowa and Taha (2002).

Ammonium concentrations were obviously high during summer compared to autumn and spring seasons. This is mainly realized to the flourishing of zooplankton organisms in hot season that responsible for excretion processes. This view agrees with Harris and Malej (1986) and McCarthy and Eppley (1972) who pointed to the importance of zooplankton excretion in the nitrogen cycle. On the other side, nitrate concentrations follow to a large extent the abundance of total phytoplankton crop ($r = 0.50$, $p = 0.01$). However, orthophosphate concentrations were usually increase after 24 and 48 hours at the grazed enclosures compared with the ungrazed sets, while silicate contents were obviously decreased with time. This observation can be attributed to nutrients recycling by zooplankton that returned proportionally more phosphorus than silicon to the environment. This process was disadvantage for diatoms and benefit green algae. This view is confirmed by positive significant correlation between green algae and PO_4-P ($r= 0.52$, $p= 0.01$) as reported by (Sommer, 1988). CCA analysis showed correlation between nitrate, Chlorophyceae and zooplankton species (*Brachionus calyciflorus* and *Thermocyclops* sp.). Lehman (1980) and Scavia & Fahnenstiel (1984) observed that, nutrient regeneration by zooplankton might affect phytoplankton communities, depending on the regeneration rates of specific nutrients and the requirements of the different phytoplankton species. So zooplankton grazing and availability of nutrients

regulate phytoplankton communities, but the relative strengths of these two factors vary seasonally.

Grazing rate indicated that, green algae and diatoms, especially *Planktonema lauterbornii*, *Dictosphaerium pulchellum*, *Cyclotella operculata* and *Syndra ulna* were the most preferable algal cells for zooplankton diets (0.0599, 0.0174, 0.0530, and 0.0371/h, respectively). Also, these organisms grazed to large extent on *Microcystis aeruginosa* (0.0504/h) and *Merismopedia glauca* (0.0105/h). This agrees with the findings of Fulton and Paerl (1987a & b). They reported that, grazing rates of most herbivores were much higher for the diatom *Melosira* sp. than for similarly sized blue green algal filaments. Cyr and Pace (1992) found that the zooplankton grazing rate was 0.48-5.52/h on algae <35µm in 16 lakes (USA). Contrary, the grazing rate during the spring and summer seasons, was obviously high on blue green algae such as *Chroococcus disperses* followed by diatoms & green algae, due to the abundance of rotifers during this period. This view is confirmed by De Bernardi and Giussani (1990) who reported that rotifers are able to graze even on these toxin-producing species more successfully than cladocerans and copepods. This condition results in a peak of rotifer density, because they do not have to compete for this food source with the other zooplankton. Furthermore, studies on Cyanobacteria-zooplankton interactions have failed to demonstrate toxic effects in the field (Haney, 1987). Also, complex assemblages of algae can support zooplankton growth rates and reproduction, even in environments dominated by Cyanophyceae (Fulton and Jones, 1991). Some selective filter feeders, like copepods, can differentiate between toxic and non toxic algae and are therefore less susceptible to blue greens (De-Mott and Moxter, 1991).

The highest significant difference (using ANOVA) in zooplankton grazing rate was found during autumn, corresponding to the lowest zooplankton number, compared with the grazing rate during spring and summer. This result indicates the impact of zooplankton nutrient regeneration which increases with zooplankton number increase, leading to grow of phytoplankton. Hunt and Matveev (2005) indicated that nutrients regenerated by zooplankton could be rapidly assimilated into phytoplankton growth. Zooplankton may regulate phytoplankton not only by grazing, but also by the re-supply of nutrients through excretion. Whether the recycling effects would be strong or not, would depend on the degree of phytoplankton nutrient limitation and on which nutrient is limiting. Regression analysis (Figure 2) for grazing rate against zooplankton concentration showed there was no evidence of strong negative effects on phytoplankton number, whereas the grazing rate decrease with increasing zooplankton number.

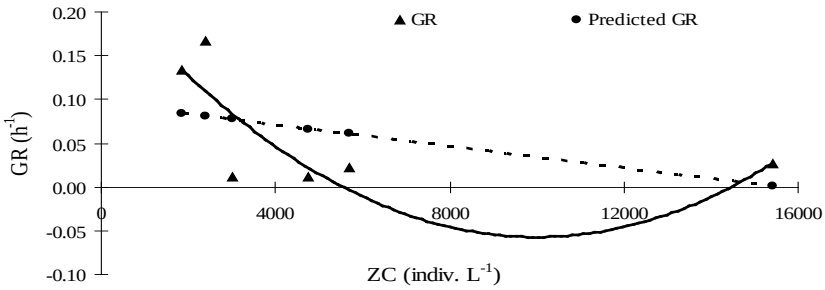

Figure 2: Grazing rate of zooplankton (GR, h^{-1}) in response to zooplankton number (ZC, indiv. L^{-1}) showing the observed and predicted grazing rate in a regression analysis.

In this study, grazing rates were sometimes negative values, due to exceed of algal growth rate in control enclosures compared to their values in the grazed set as also found by Gosselain *et al*. (1998).

This study illustrated the most preferable algal species for zooplankton and their grazing rate during the different season. Zooplankton density can be increase two folds that found in Nile water, in fish farms utilize River Nile water in aquaculture. Autumn season is the best time for zooplankton grazing on the different algal species inhabiting River Nile.

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