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The interaction between phytoplankton and zooplankton in a Lake-Sea connection, Alexandria, Egypt.

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Abstract

The interaction between phytoplankton and zooplankton was studied weekly in Boughaz El-Maadia, a mixing area connecting Lake Edku to Abu-Qir Bay on the Egyptian Mediterranean coast. Zooplankton grazing has been postulated to play at times an effective role in regulating the phytoplankton cycle and causes losses in its standing crop. In spite of large weekly variations in the abundance and community structure, phytoplankton and zooplankton usually showed an obvious inverse relationship during different periods. However, dense accumulation of phytoplankton seems to be due to the existence of unfavorable phytoplankton species to be grazed by the existing zooplankters. The grazing pressure appeared to be affected by the environmental conditions, like temperature, as well as the species composition of both phytoplankton and zooplankton communities. The multiple regression analysis indicated that some zooplankton species had no food selectivity, such as the rotifers *Brachionus plicatilis, Br. urceolaris*, the cladoceran *Moina micrura*, and cirripede larvae, while others showed clear selectivity to certain phytoplankton species, such as the rotifers *Br. calyciflorus, Synchaeta pectinata*, the copepod nauplii and adult copepod species *Oithona nana, Paracalanus parvus, Euterpina acutifrons, Acanthocyclops americanus and Halicyclops magniceps*. Rotifers were more effective grazers than copepods. However, both groups had strong correlation with the dominant phytoplankton groups (diatoms, blue green and green algae). The abundance of phytoplankton as a whole, and that of different groups were affected by dissolved oxygen, nitrite, ammonium, phosphate and temperature, while zooplankton appeared to be influenced by phytoplankton biomass, salinity and temperature.

Key words: Phytoplankton, zooplankton, grazing, food selectivity, zooplankton diet, zooplankton feeding.

Introduction
In the open sea, the relationship between phytoplankton and zooplankton is usually ascribed as inverse one, which is explained by two main theories; the animal exclusion and grazing [1], [2]. In

the estuarine areas, pronounced variation would be expected in such relationship. The linkage between phytoplankton and zooplankton is a dynamic process controlled by several factors, including the environmental and biological factors which affect the growth of each community and the interaction between them. Grazing is one of the most important factor controlling the relationship between the two communities .

Although phytoplankton bloom is tightly related to nutrient enrichment and it may decrease drastically under the effect of intensive grazing [3], [4], [5], [6], the effect of which depends on zooplankton composition , since the nature of food selection varies among herbivores taxa [7]. The current direction, the wave action, the environmental conditions, the composition and abundance of planktonic flora and fauna in both sea and lake and their seasonal variations must also be considered when studying the nature of the concerned relationship in the estuarine area. The complex nature of the relationship between phytoplankton and zooplankton communities is broad and sustained interest of the aquatic biologists, but little is known about such relationship in the Egyptian waters.

The present study highlights the concurrent dynamics of both phytoplankton and zooplankton communities and assesses the trophic linkage between them in Boughaz El-Maadia. It aims also at examining seasonal patterns of phytoplankton and zooplankton abundances to evaluate the importance of different zooplankton groups in terms of their grazing impact on phytoplankton abundance.

Study area

The connection between Abu Qir Bay on the Egyptian Mediterranean coast and Lake Edku (Boughaz El-Maadia) is a highly dynamic area characterized by strong mixing, variable species composition and abundance of both phytoplankton and zooplankton communities, as well as the physico- chemical properties [8], [9], [10], [11]. The description of the study area was given by Abdel Aziz [11].

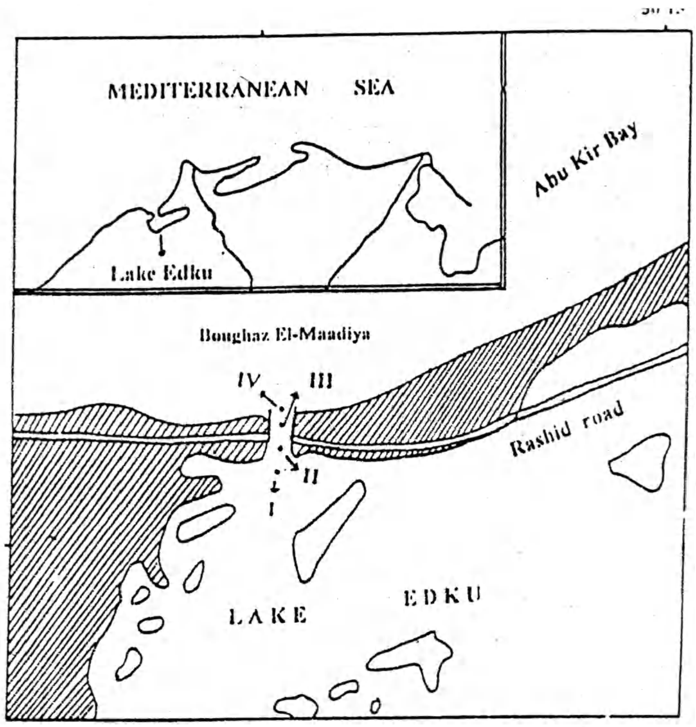

Figure 1: The Study area and positions of sampling stations.

Material and methods

The present study was based upon weekly phytoplankton and zooplankton samples collected concurrently with the measurements of physical and chemical parameters from the end of April to the end of October 1997 at four stations along Boughaz El Maadia (Fig. 1).

For phytoplankton study, two liters of water were collected at each station, preserved in 4% neutralized formaldehyde, left 3-4 days for settling. The supernatant water was then decanted and the concentrated were examined for species identification and counting. Zooplankton samples were collected through vertical hauls by using plankton net of 55µm mesh size and 50 cm mouth diameter and the concentrated samples were preserved in 5% formaldehyde and then examined and counted.

The identification of both phytoplankton and zooplankton taxa was carried out according to the most known references ([12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24]). The phytoplankton count followed the procedure of Uttermohl [25], while zooplankton standing crop was calculated from the mean count of three aliquots of 5 ml for each concentrated sample and expressed as organisms/m^3.

A simple correlation coefficient between the different groups of both phytoplankton and zooplankton was calculated . Multiple regression analysis was applied to define the main environmental factors affecting the growth patterns of both communities and the most significant correlation between the dominant species as indication of their feeding linkage. The correspondence analysis was also applied by using SPSS program on the PC computer.

Results

The physico-chemical characteristics of Boughaz El-Maadia were studied parallel to the present plankton study at the same time and at the sampled stations [26]. The data which are summarized in Table 1 indicate high eutrophication of the study area, due to the great supply of nutrients from Lake Edku, which with the other environmental parameters were exposed to great weekly variations relative to strong mixing between the lake and seawaters. These variations were reflected on the abundance of both phytoplankton and zooplankton in the study area.

The phytoplankton community in Boughaz El-Maadia was highly diversified, represented by 182 species, 79% of which were freshwater forms and 21% were marine forms. The most dominant species are given in Table 1.

Zooplankton community was also characterized by high diversity, comprising 167 species of both freshwater and marine affinities. Rotifers formed 47.8%, copepods 26.9% and cladocerans 13.9% of the total zooplankton. The most dominant species are shown in Table 2.

Phytoplankton abundance was usually high during the study period ($0.11x10^6$ – $13.2x10^6$ units /l). Four different sized peaks were reported at stations 1-3, while two peaks only appeared at station 4 (Fig. 2). The first peak occurred on 14th of May at all stations with the dominance of *C. meneghiniana* and the second one appeared on 28th of May and 4th of June with the dominance of *Skeletonema costatum*, which constituted 98% of total phytoplankton at station 4. The small two peaks occurred at the beginning and the end of July and were dominated by *C. meneghiniana* and *Nitzschia* spp.

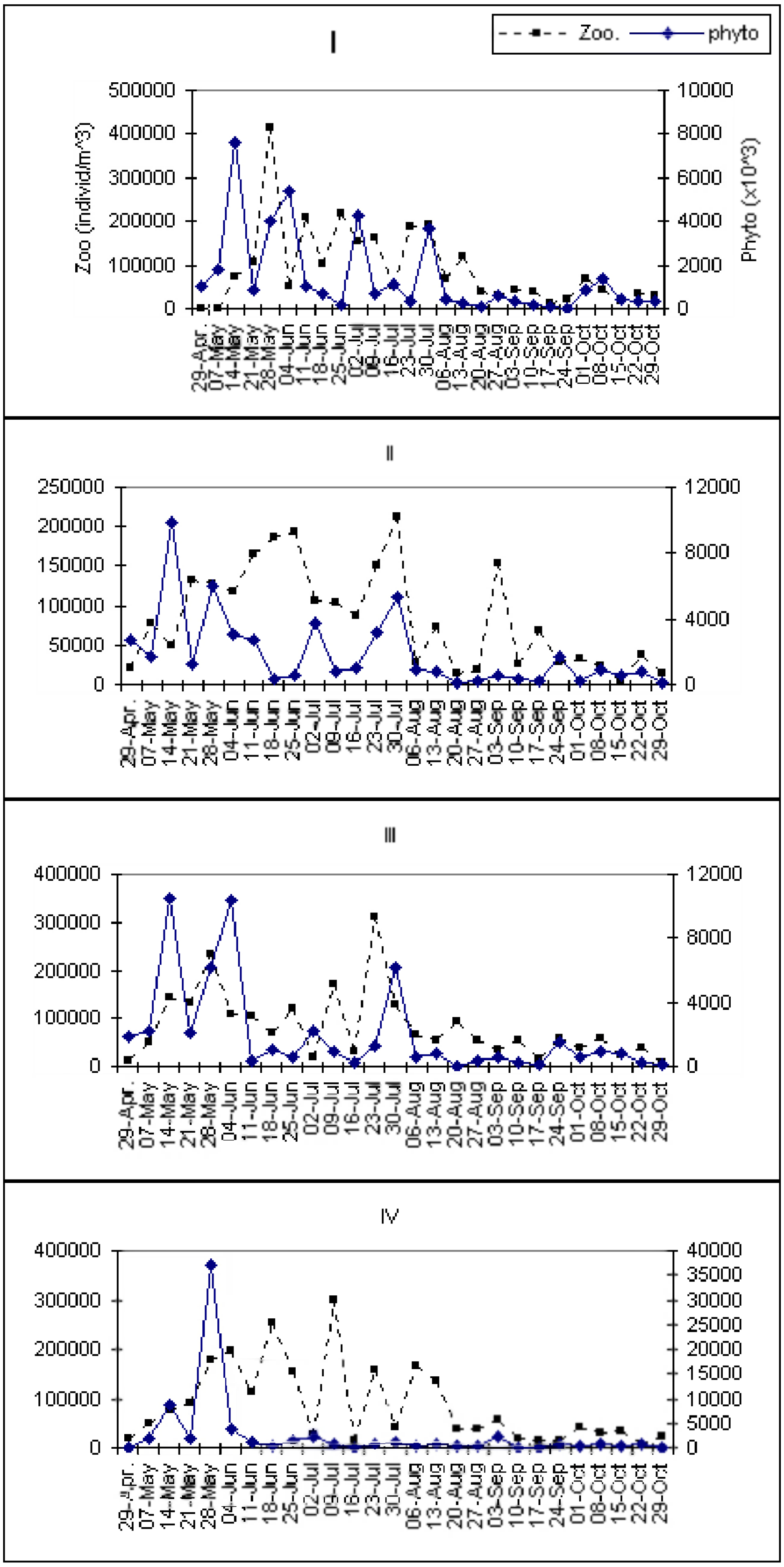

Figure 2: Weekly abundance of phytoplankton and zooplankton at different stations in Boughaz El-Maadia.

Zooplankton showed pronouncedly different patterns of temporal variations, having several unequal peaks at the different stations (Fig 2). Two phases could be distinguished for zooplankton count, the phase of intensive growth that extended from 14 May to 13 August with weekly count between $86.5x10^3$ and $238x10^3$ individuals/m^3. During this phase, the timing of the abundance peaks was more or less different at different stations (Fig. 2). The second phase occurred during September-October and was characterized by comparatively low production. The rotifer *Br. calyciflorus* and the cladoceran *M. micrura* were commonly the dominant species in the high productive phase, except in June, when other species were co-dominant, like *A. americanus, H. magniceps, Br. angularis*, cirripede larvae and copepod nauplii.

The multiple regression analysis revealed that the phytoplankton abundance in Boughaz El-Maadia was supposed to be more affected by dissolved oxygen (DO), ammonium, phosphate and temperature, as shown from the following estimated model:

phytoplankton crop = -6439.3 + 798.4*DO – 27.85*NH_4 – 189.7*PO_4+ 234.8*temp.

These factors, in addition to nitrite, were more effective on Cyanophyceae, Chlorophyceae and Euglenophyceae rather than on diatoms, which are usually silicate dependent group (Fig. 3). On the other hand, phytoplankton biomass, salinity and temperature were the most effective factors on the zooplankton abundance, which is estimated from the following multiple regression model:

zooplankton abundance = - 251402.3 + 1092.6*Chl. *a* + 1464.46*S%o + 11221.78* temp.

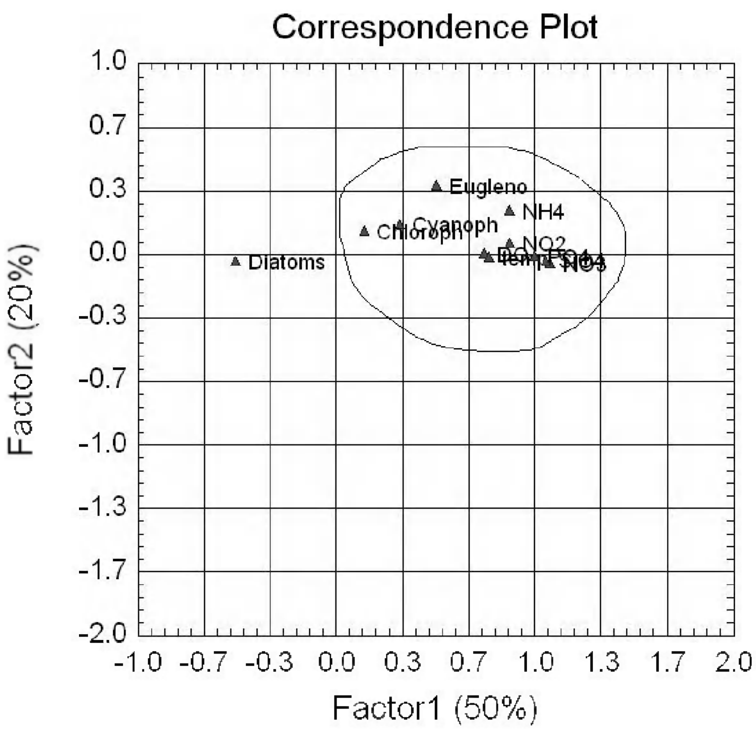

Figure 3: Factor analysis of relationship between dominant phytoplankton groups and ecological parameters in Boughaz El-Maadia.

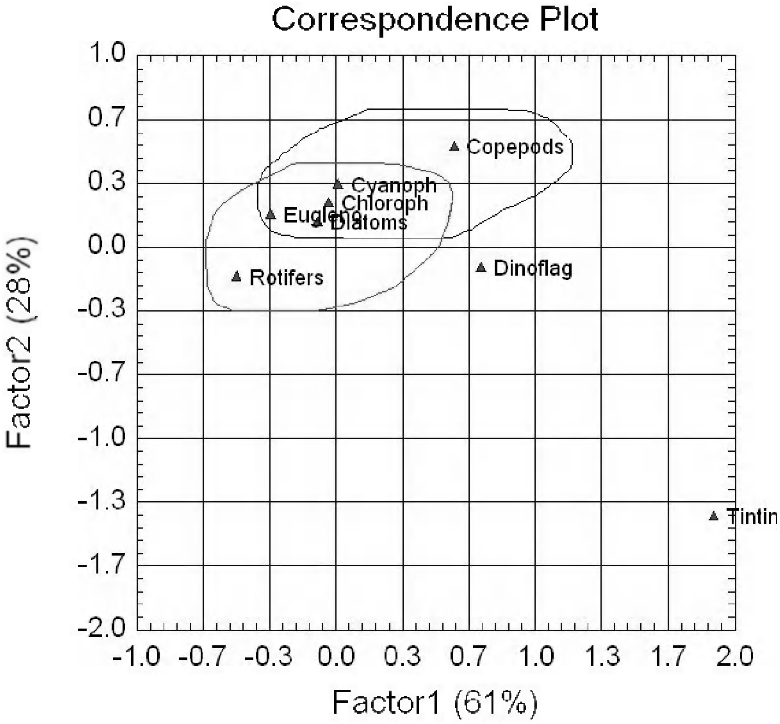

Figure 4: Factor analysis of relationship between dominant phytoplankton and zooplankton groups in Boughaz El-Maadia.

According to the correspondence analysis (Fig. 4), the community structure plays a significant role in the interrelationship between phytoplankton and zooplankton components, whereas the dominant groups (copepods and rotifers) had strong relationship with all the existing phytoplankton groups (diatoms, blue green algae, green algae, euglenoids), except the dinoflagellates.

The multiple regression analysis reported significant correlation between several zooplankton and phytoplankton species (Table 3) that may be considered as indication of trophic relationships between them.

Discussion

Although phytoplankton bloom is tightly related to nutrient enrichment and it may decrease drastically under the effect of intensive grazing [5], [6], the grazing pressure depends on the zooplankton composition, since the nature of food selection varies among herbivores taxa [7]. This statement may explain the significant correlation between the dominant zooplankton groups (copepods and rotifers) and most phytoplankton groups (diatoms, blue green algae, green algae and euglenoids) in Boughaz El-Maadia. However, dinoflagellates seem to be not preferable by different zooplankters during the present study, a case which is in agreement with Ismael and Abdel-Aziz [27] who reported that the dinoflagellates *Prorocentrum micans, P. minimum* and *P. triestinum* are unsuitable food for micro- and meso-zooplankton. Also *Prorocentrum* was reported to have harmful effect on grazers [28], but Heinbokel *et al* [29] noted that rotifers often constituting the dominant grazer on the dinoflagellates.

Table 1: Average and variation ranges of ecological parameters at different stations in Boughaz El-Maadia

		St I	St. II	St. III	St. IV
temp	Range	19.5-27	19.5-28	19-27	19-27
	Average	7.87	24.91	24.50	24.42
S%o	Range	.84-27.64	.84-30.19	.84-33.81	1.11-35.69
	Average	12.84	4.8	5.20	9.73
SD	Range	35-80	30-90	30-90	30-100
	Average	14.45	46.1	44.07	50.74
DO	Range	2-4.9	1.95-5.89	1.9-5.5	1.9-4.9
	Average	11.62	3.44	3.00	2.75
pH	Range	7.73-8.77	7.72-8.85	7.61-8.81	7.51-8.67
	Average	8.25	8.23	8.32	8.24
NH4	Range	0-69.9	0-10.3	0-10.25	0-12
	Average	9.08	4.89	4.56	5.18
NO2	Range	.99-14.08	.21-16.81	.69-16.84	.32-9.15
	Average	6.95	4.72	5.14	4.23
NO3	Range	.42-41.52	2.57-41.95	0-37.81	.08-36.49
	Average	26.78	21.50	20.04	17.67
PO4	Range	1.14-6.9	1.08-5.7	1.2-6.3	1.26-5.28
	Average	4.22	3.06	3.71	3.32
SiO4	Range	3.2-163.5	24.1-164.1	28.8-153.5	23.3-165.5
	Average	93.58	99.33	99.31	95.43

Table 2: Relative abundance (% to total count) of dominant phytoplankton taxa at different stations in Boughaz El-Maadia.

	St. I	St. II	St. III	St. IV
Cyclotella	21.2	20.2	18.8	21.7
Nitzschia	15.7	16.3	21	17.7
Navicula	1.4	1.4	1.2	1.4
Rhizosolenia	0	0	1	0.04
Chaetoceros	0.02	0.02	2.3	0.5
Sk. Cost	2.6	2.4	0.5	6.3
Scenedesmus	21.6	24.4	22.7	19.6
Crucigenia	9.8	9.8	8.3	8.2
Selenastrum sp.	2.3	2.2	2.4	2.3
Tetradron	0.8	1	0.6	0.7
Kirchneriella	0.7	0.9	0.6	1.1
Pediastrum	3.3	1.6	1.7	1.3
Closterium	0.3	0.6	0	1.05
Actinastrum	5.1	6	3	4.1
Oscillatoria	1.5	1.1	1.2	1
Chrococcus	1.1	1.2	0.5	0.6
Spirulina	1.1	0.9	0.5	1
Euglena	2.2	1.8	2	0.8
Peridinium	0	0.4	0.3	1.4

Table 3: Relative abundance (% to total count) of dominant zooplankton species at different stations in Boughaz El-Maadia.

Average	St. I	St II	St III	St IV
Acanthocyclops americanus	3.7	3.11	3.45	2.8
Acartia clausi	0.01	0.04	0.43	1.15
Cyclops vernalis	1	0.88	1.3	1
Euterpina acutifrons	1.4	2.26	1.79	2.9
Halicocyclops magniceps	2.4	3.15	2.72	2.5
Oithona nana	0.7	0.73	2.37	4.5
Paracalanus parvus	0.5	0.53	1.64	2
Copepod nauplii	12.96	13.67	18.05	21.7
Cirripedes larvae	2.02	5.3	3.41	4.3
Polychaete larvae	1.45	0.88	2.29	3.2
Moina micrura	18.7	18.7	11.93	7.9
Brachionus urceolaris	1.1	2	0.26	0
Brachionus plicatilis	8.4	8.14	10.74	9.6
Brachionus angularis	2.42	2.5	2.66	2.2
Asplenchna priodonta	0.6	0.88	0.8	1.6
Brachionus calyciflorus	27.8	19.55	19.6	12.05
Synchaeta pectinata	0.73	0.44	1.07	2.9
Tintinnopsis nordguistii	2.8	2.75	3.86	4.2
Favella markuzowskii	0.7	1.44	0.5	0.6
Polyarthra vulgaris	1.7	1.5	2.01	1.2

Herbivores have been shown to alter phytoplankton productivity, distribution and overall community structure [30]. This may not agree with the findings of the present study, which revealed that some zooplankton species had no food selectivity toward phytoplankton species, such as the rotifers *Br. plicatilis and Br. urceolaris,* the cladoceran *M. micrura* and cirripede larvae, which grazed on phytoplankton species belonging to different algal groups, as indicated from the significant correlations (Table 4). Sommer *et al* [31] and Sommer *et al* [32] found that copepods generally prefer large phytoplankton than do cladocerans, however, the feeding behavior of these zooplankters may change with the seasons, whereas the grazing stress appeared to be different during different seasons. This contradicts with Kyewalyanga et al., [33], who mentioned that there was no correlation between rotifer density and abiotic variables, such as nutrients, dissolved oxygen and water temperature. The increase in the rotifer counts was accompanied by decrease *in Selenastrum* and the increase in all other preys in May, decrease in *Navicula*, *Scenedesmus, Kirchneriella* and *Actinastrum* in June and a decrease in *Actinastrum* in July (Tables 5 and 6). Such pattern may reflect the effect of temperature on the grazing efficiency in different months at variable temperatures. Wlodarczyk *et al* [34] documented the effect of increased temperature on the grazing pressure of *Acartia* species on *Thalassiosira* spp. and Martin [35] reported that low temperature has reduced grazing.

Food selectivity was reported in the study area for two other dominant rotifers, *Br. calyciflorus* and *Synchaeta pectinata*. The first species fed upon *Navicula*, which decreased in number with the increase in the predators in June, while the second species grazed on *Nitzschia* and *Actinastrum.* Sometimes, the number of preys increased with increasing numbers of predators (Tables 5 and 6), a trend which could be explained by the faster growth rate of phytoplankton species that enables them to replenish their loss by grazing. The life histories of copepods reveal that while juvenile stages are herbivores, the adult stages are not, so they are frequently carnivores [36]. In the present study, copepod nauplii exhibited some selectivity, whereas they and some adult dominant species, such as *O. nana, Euterpina acutifrons,* and *Paracalanus parvus* which were significantly correlated with the green alga *Kirchneriella spp.,* indicating their selectivity to this alga. Similarly, the copepods *A. americanus* and *H. magniceps* demonstrated selectivity towards the green alga *Crucigenia.*

Table 4: Multiple regression Correlations between dominant phytoplankton and zooplankton species in Boughaz El-Maadia.

	Coefficient	Stand. Error	t Stat	P-value	R		Coefficient	Stand. Error	t Stat	P-value	R
Brachionus plicatilis						Cirripede larvae					
Nitzschia	177.9657025	37.232889	4.7797984	0.0020127	0.9651	Nitzschia	111	47.884	2.318	0.0536	0.9651
Scenedesmus	57.74238526	14.381423	4.0150675	0.0050914	0.9577	Scenedesmus	49.62	18.495	2.683	0.0314	0.9577
Kirchneriella	1.918114023	0.5347226	3.5871196	0.0088912	0.9439	Kirchneriella	1.611	0.6877	2.343	0.0516	0.9439
Selenastrum	4.678281887	1.6167983	2.893547	0.0231985	0.9314	Selenastrum	5.847	2.0793	2.812	0.0261	0.9314
Actinastrum	14.74417638	3.5375294	4.1679304	0.0042	0.9416	Actinastrum	2.3724	0.6968	3.4048	0.0114	0.9416
Brachionus urceolaris						Synchaeta pectinata					
Nitzschia	494.7571421	123.30061	4.0126091	0.0051073	0.9651	Actinastrum	11.8826902	4.279986	2.77634	0.0274425	0.9416
Navicula	9.031720325	3.1808327	2.8394201	0.0250654	0.9653	Nitzschia	179.757974	45.047326	3.99042	0.0052536	0.9651
Scenedesmus	187.842594	47.625589	3.9441526	0.0055736	0.9577	Brchionus calyciflorus					
Pediastrum	8.342431121	2.4749509	3.3707462	0.0119082	0.9906	Navicula	0.57309596	0.17787	3.22199	0.014613	9653
Kirchneriella	5.347061713	1.77079	3.0195911	0.0193975	0.9439	Euterpina acutifrons					
Selenastrum	14.92840387	5.3541968	2.7881687	0.0269793	0.9314	Kirchneriella	4.1457605	1.4018124	2.95743	0.0211822	0.9439
Actinastrum	30.75232461	11.714899	2.625061	0.0341569	0.9416	O.nana					
						Kirchneriella	-8.0190365	3.2461982	-2.47029	0.0428151	0.9439
Moina micrura						Paracalanus parvus					
Nitzschia	-123.7017541	24.696023	-5.0089747	0.0015495	0.9651	Kirchneriella	3.4582256	1.2281208	2.81587	0.0259266	0.9439
Scenedesmus	-42.03205652	9.538985	-4.4063448	0.0031327	0.9577	Acanthocyclops americanus					
Kirchneriella	-1.688280146	0.3546736	-4.7600954	0.0020592	0.9439	Crucigenia	32.8238666	14.299537	2.29545	0.0553611	0.8541
Selenastrum	-3.875526825	1.0723983	-3.6138874	0.0085797	0.9314						
Actinastrum	-6.620865338	2.3463908	-2.8217231	0.0257096	0.9416	Halicyclops magniceps					
Chrococcus	-1.184153174	0.404075	-2.9305285	0.0220077	0.9102	Crucigenia	-63.080165	27.082609	-2.32918	0.0526778	0.8541

The inversed relationship between phytoplankton and zooplankton in several weeks during May-July (Fig. 2) indicates high grazing pressure which, caused clear drop in phytoplankton abundance and consequently changes in its community structure. The zooplankton grazing pressure could help the change in dominance of phytoplankton [30] and [37]. On 28 May, the peak of phytoplankton was mainly due to *Sk. Costatum,* which coincided with high count of the rotifer species *Sy. pectinata*, copepod nauplii, *Asplenchna priodonta* and *O. nana*. The great drop of *Sy. Pectinata, As. priodonta* and *O. nana* in the next week supposes that *Sk. costatum* is unfavorable diet for them, while the increase in *E. acutifrons* and copepod nauplii provides a probability of their grazing upon *Sk. costatum.* Also, on 28 May the majority of phytoplankton species were not fed by different *Brachionus spp.* dominated in the area, as indicated from the marked drop of their count after a week, but the copepods *A. americanus, E. acutifrons,* copepod nauplii, and the tintinnid species *Tintinnopsis nordguistii* fed upon different phytoplankton species, particularly *Crucigenia, Pediastrum,* and *Scenedesmus,* which decreased in the next week. This contradicts with Abdel Mowla [38], who reported that Chlorophyceae and Cyanophyceae were unfavored food for many zooplankters, particularly copepods and rotifers and the major zooplankton groups in freshwater (copepods, rotifers and cladocerans) depend mainly on Bacillariophyceae more than Chlorophyceae and Cyanophyceae as alga food supply.

The green algae *Kirchneriella lunaris, Pediastrum simplex, Selenastrum gracile* and the blue green *Anabaenopsis circularis* were highly selected by zooplankton in autumn, particularly at the dominance of *Keratella* spp. [38]. These observations confirm the results recorded in Boughaz El-Maadia, where all these phytoplankton species existed and most of them serve as prey for the rotifer species, *Br. plicatilis* and *Br. urceolaris*, the dominant zooplankters in autumn. However,

Table 5: Weekly differences in the count of Dominant zooplankton (individuals/m^3)species in Maadia
(The negative symbol indicates the increased count in the next week and the positive indictes the decreased count)

	Tin. nordguistii	Asp. priodonta	B.angularis	B.calyciflorus	B. plicatilis	B. urceolaris	Poly. vulgaris	Syn.pectinata	Acan.americanus
29Ap-7M	0	-19	-417	32	387	-766	-630	0	-3614
7-14 M	0	-852	-1591	-29591	-9271	-3354	387	0	1922
14-21 M	0	807	1548	30107	9183	4383	195	0	-994
21-28 M	0	-7132	-22896	-43941	-3486	-18581	-2264	-23440	1932
28 M- 4 Jn	-17984	3754	23355	42525	2808	17945	2198	-34	-6422
4-11 Jn	17972	1626	-8596	-4116	-3626	-2431	-5266	23474	-12251
11-18 Jn	-47591	-297	8606	5810	3614	2552	5133	-376	19522
18-25 Jn	47603	-4576	-6870	-38841	-37420	-463	-18349	376	-2271
25 Jn-2Jl	0	6624	4235	-8728	29282	1017	17854	0	2336
2-9 Jl	0	-2724	-3617	-34521	-17935	0	-3660	0	-649
9-16 Jl	0	2648	5908	61930	23308	-14	3585	0	382
16-23 Jl	0	-2518	-1700	-95182	-25874	-37	-9353	0	-529
23-30 Jl	-7	2171	1314	32011	15008	-191	8334	-917	721
30 Jl-6 Ag	7	-3687	270	50702	547	242	-1114	917	13
6-13 Ag	0	4133	-733	4786	-5716	0	2095	0	70
13-20 Ag	0	-493	-415	20111	10281	0	426	0	158
20-27 Ag	-123	506	1524	5836	4819	0	164	-12	-2983
27 Ag-3 Sp	-393	-825	-120	-10833	-4665	0	-1564	12	2290
3-10 Sp	516	760	-786	9851	3729	0	1367	0	152
10-24 Sp	0	40	774	104	2570	0	93	0	-424
24 Sp-1 Oc	-109	54	339	-1110	786	0	-557	-829	-8950
1-8 Oc	109	-532	-299	-7185	-3445	-92	-1971	829	8794
8-15 Oc	-1706	532	732	12090	5549	92	2915	0	895
15-22 Oc	1576	-127	-832	-1523	-634	0	-6309	0	-654

Table 5 Continue..

	Eut. acutifrons	Hal.magniceps	O. nana	Par. parvus	Cop. nauplii	M. micrura	Polych. larvae	Cirrip. larvae
29Ap-7M	7	-978	-340	18.7	-17447	-0.3	-783	422
7-14 M	-900	516	-1204	-56	15199	-1935	866	-7517
14-21 M	-32109	-55	-11655	-1139	-15529	1918	-7849	7165
21-28 M	31333	827	9792	913	4509	-65961	6014	-2909
28 M- 4 Jn	-4876	449	-38	-862	217	62422	-1328	3027
4-11 Jn	6162	-12620	2923	1132	-2681	-30241	3178	-13512
11-18 Jn	-2733	12763	-8345	-21389	5805	33456	-3555	12932
18-25 Jn	2831	-2264	8743	21300	4420	-30006	3197	-2267
25 Jn-2Jl	124	2263	-89	-47	8993	25973	-1095	2820
2-9 Jl	56	-3494	-284	148	-10808	-21564	1376	-1582
9-16 Jl	-112	2512	314	-294	10632	22552	-2301	1608
16-23 Jl	6	-2537	207	280	-4120	-17998	2488	-2200
23-30 Jl	-338	3105	-710	-1785	-6700	11243	-1509	1472
30 Jl-6 Ag	535	-803	527	1404	6386	496	1368	-156
6-13 Ag	-316	-1210	112	240	2894	-22591	-28	990
13-20 Ag	330	288	85	155	-2425	21704	169	-103
20-27 Ag	-216	1517	-2764	-511	3105	4010	-1265	-287
27 Ag-3 Sp.	-545	-215	1607	221	-6714	-8064	1038	-10064
3-10 Sp	611	463	1145	278	6003	1820	215	10316
10-24 Sp	95	-448	12	12	873	3374	12	-4893
24 Sp-1 Oc	-1137	-963	-2799	-1206	-7228	8249	-1581	4585
1-8 Oc	736	1577	2327	1194	9097	-8133	1581	469
8-15 Oc	463	-131	-853	-47	-2535	9276	-792	-1231
15-22 Oc	-21	-234	1278	-59	-858	-7493	792	-1378

Kirchneriella spp. and *Selenastrum spp.* were considered among the preys of the cladoceran *M. micrura,* the copepods *O. nana, E. acutifrons and P. parvus,* copepod nauplii and/or cirripede larvae during the present study. A pronounced decrease in numerical densities of the two phytoplankters frequently associated the increase in those zooplankton components. However, the role of adult copepods mentioned above appeared to be limited in phytoplankton grazing since during the high algal spring bloom, the pressure exerted by meso–zooplanktonic copepods *(*as *Paracalanus parvus* , *Oithona nana*, and *Acartia clausi)* on the algal stock was very low in the field [39].

The Chlorophycean *Crucigenia rectangularis* was avoided by zooplankton community in all seasons in Nozha Hydrodrome [38] and exhibited a strong development with low densities of planktonic herbivores [40]. Such relationship is attributed to the thick cellulose cell wall of Crucigenia which is difficult to the zooplankton diet [41]. In the present study, the significant correlation between *Crucigenia* and the cyclopoid copepods, *A. americanus* and *H. magniceps* suggests that this alga could be used as food by these zooplankters. In the meantime, pronounced increase was reported for both zooplankton species at the decrease in *Crucigenia* spp. and vise versa during several weeks. Furthermore, Ismael and Abdel-Aziz [27] reported *Spirulina* as prey for cirripede larvae, the blue-green *Oscillatoria* spp. for the copepod *P. parvus* and *C. meneghiniana* for copepod nauplii, while Guergues [42] found the diatom *Nitzschia* sp. in the gut of *A. americanus*. Similarly, trophic relations could be expected in Boughaz El-Maadia between the zooplankton and phytoplankton species mentioned in the above two references, since all of these species were found during the present study.

Conclusion

The interaction between phytoplankton and zooplankton is governed by environmental factors, as well as the species composition and abundance of both communities. The grazing by zooplankton undertakes by either selective or nonselective mechanisms, but sometimes a zooplankton species may alternate the two mechanisms according to the available composition of phytoplankton community. Although the grazing causes serious changes in the phytoplankton structure, the bulk of these changes occurs in the dominant species, which are usually grazed more than those exist in low density or as rarely. Food selectivity is a significant mechanism for control the structure of phytoplankton communities. Zooplankton has an effective role in regulating the rate of further accumulation of phytoplankton or even prevent it. On the other hand, some zooplankton species are important stabilizers of planktonic population.

Table 6: Weekly differences in the count (units/l) of Dominant phytoplankton (units/l)species in Madia
(The negative symbol mean increasing count in the next week and the positive means decreasing)

	Cyclotella	Nitzschia	Navicula	Scenedesmus	Tetradron	Pediastrum	Kirchneriella
29Ap-7M	40516	295896	7016	1788	3325	14921	16046
7-14 M	-1498577	-4145822	-54624	-1547077	-24353	-37071	-47454
14-21 M	1629065	3866932	54127	1622062	24726	37706	41256
21-28 M	-273427	-1391746	-111460	-704433	-21737	-188193	-5725
28 M- 4 Jn	-291318	-1456257	69862	107483	9873	149214	-5980
4-11 Jn	471227	2676481	29715	383308	-10835	-4257	707
11-18 Jn	58825	390910	13495	296378	23509	45044	18470
18-25 Jn	37784	-8759	-2691	-21815	-13409	-9462	-4349
25 Jn-2Jl	-1123745	-411893	-14975	-473061	-15755	12679	-19616
2-9 Jl	1029520	652731	19612	304278	24936	-12120	28224
9-16 Jl	-19117	-11829	-3090	63750	1704	22426	-1243
16-23 Jl	-581100	-20678	-44781	-81984	815	-17640	-6881
23-30 Jl	-1431423	-386260	-23633	-132410	-42789	-12050	1283
30 Jl-6 Ag	2165297	375281	67198	234133	38537	23199	4596
6-13 Ag	14318	27663	-8677	56136	4857	-4271	1621
13-20 Ag	56359	24766	13238	112647	711	5357	745
20-27 Ag	-75992	-21145	-10050	-49595	-1842	3111	-584
27 Ag-3 Sp.	-108967	-34767	-23433	-138833	-3941	-9192	-5005
3-10 Sp	172050	44280	30373	160228	4156	12400	3630
10-24 Sp	-179065	-113471	-20926	-69397	-8456	-39994	2593
24 Sp-1 Oc	152632	58056	11887	33640	4882	37529	-6924
1-8 Oc	-359378	-45478	-20942	-28661	-5516	-8206	20
8-15 Oc	318147	26676	19340	28765	-3720	11658	5012
15-22 Oc	76892	45040	12147	-14386	8301	-643	-2141

Table 6 continue..

	Crucigenia	Selenastrum sp.	Actinastrum hantzschia	Spirulina laxissima	Chrococcus	Oscillatoria
29Ap-7M	68065	57015	*-27947*	22028	4174	13837
7-14 M	-207803	-136161	-310958	-5366	-34193	-20114
14-21 M	191151	113873	311925	-70	36004	13715
21-28 M	-230313	35428	-53940	4500	-25269	471
28 M- 4 Jn	78862	-20964	-164540	-14021	905	-1783
4-11 Jn	69913	-10591	226883	-29398	-31	-1434
11-18 Jn	87089	41474	4375	43707	20146	10325
18-25 Jn	-55023	-10099	7772	-895	2345	-12301
25 Jn-2Jl	-58579	-20459	-97142	-1695	-33760	266
2-9 Jl	108013	17150	63309	2387	32037	1336
9-16 Jl	-3632	7710	837	-200	254	4374
16-23 Jl	-1989	-1813	16858	-920	1543	-7387
23-30 Jl	-373825	-29731	-18745	-1922	-763	3032
30 Jl-6 Ag	370476	25581	3663	2662	1017	-832
6-13 Ag	-34098	5264	-53570	-3773	-2721	-5486
13-20 Ag	59799	6628	83020	4930	3532	14040
20-27 Ag	-55152	-5634	-16340	-11575	344	-1153
27 Ag-3 Sp.	-37873	-42212	-87996	-19392	-4024	3482
3-10 Sp	54883	40609	99794	28448	3589	-971
10-24 Sp	-29930	-1605	-6923	-25724	-1933	-2110
24 Sp-1 Oc	-86556	-3867	12222	26217	-2939	-2069
1-8 Oc	66917	1268	-12416	-9510	2507	3215
8-15 Oc	51684	-5302	12677	6647	-343	1382
15-22 Oc	-36249	-1604	-4830	-12995	-3547	-5889

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