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DISTRIBUTION AND LONG-TERM HISTORICAL CHANGES OF ZOOPLANKTON ASSEMBLAGES IN LAKE MANZALA (SOUTH MEDITERRANEAN SEA, EGYPT)

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ABSTRACT

The northern lakes of Egypt have always acted as a buffer zone between the drainage system in the Nile Delta and the Mediterranean Sea. Most of these lakes are exposed to high inputs of industrial and domestic wastewater as well as agricultural drainage water, like Lake Manzala, which influence the living organisms on the long run. Samples of zooplankton were collected monthly from ten stations among Lake Manzala showing the different microhabitat of the lake. A one year monitoring has been carried out. Lake Manzala has been changed from marine ecosystem to eutrophic, nearly, freshwater system with the dominance of rotifers (cal ~ 97%). Twenty newly recorded zooplankton taxa were found for the first time in the lake during the study, while thirteen taxa disappeared from the lake in the last fifty years due to these changes. The apparent species turnover rate in the lake increased from 3.26%/year during 60's-80's to 10.29%/year in 00's-03's. Zooplankton abundance was high in northern stations compared with other stations with high densities during March and April. The outlets between the lake and the sea should be more effective to increase the alteration of the lake water with the sea leading to renewal the lake water and decreases the pollution effect on the lake ecosystem.

1. INTRODUCTION

Lake Manzala is the largest and the most productive of the northern Egyptian lakes (Khalil and Salib, 1986). It is an eutrophic lake (Donia and Hussein, 2004), located in the north eastern part of the Nile Delta between Suez Canal and Damietta branch, and partly separated from the Mediterranean Sea by a narrow peninsula.

The Egyptian National Environmental Action Plan of 1992 identified Lake Manzala as among the most heavily polluted water bodies in the country. The effect of pollution is most noticed along the whole lake. At the northern end, Ashtoum El-Gamil outlet and another outlet to the Mediterranean Sea allow seawater to flow in and out of the lake. But traveling south toward the outfall of Bahr El Baqar Drain, the water changes from an inviting sea blue to a repulsive brown and the smell changes from the freshness of sea to the stench of sewage (Abdel-Gawad and El-Sayed, 1998).

Water quality and fisheries of Lake Manzala are reasonably well documented by many authors (among these; Bishai and Youssef, 1977; Shaheen and Youssef, 1978; Sabae, 2000; Abdel-Moula, 2004; and Donia and Hussein, 2004). Zooplankton of Lake Manzala was studied by El-Maghraby *et al.* (1963), Guerguess (1979), MacLaren (1982), El-Sherif *et al.* (1994) and Khalifa & Mageed (2002). However, little information is available on the changes of zooplankton and the state of these organisms due to the pollution of the lake.

The aim of the present study is to estimate the distribution and the long-term changes of the different zooplankton assemblages in the lake to evaluate the conditions of the lake.

2. MATERIALS AND METHODS

2.1. Study area

Lake Manzala lies at Lat. 31°15΄ N and Long 32° 00΄ E. The surface area of the lake has been decreasing steadily over the past few decades from 1709 km^2 in 1907 to 1470 km^2 in 1949 (Fouad, 1926) and to 1260 km^2 during 1960's (Bishai and Youssef, 1977) reaching to 895 km^2 in 1979 (Abdel-Gawad and El-Sayed, 1998). Now, the area of Lake Manzala has been reduced to only 120 km^2 (Khalifa and Mageed, 2002). Widespread land reclamation and establishment of fish farms have resulted in major reduction in the area of the lake and its marshlands (Meininger and Atta, 1990). Lake Manzala is rather acting as a number of confined compartments (Fig. 1). The locations of these compartments are remained unchanged and their interconnections are well maintained to be used as navigation canal by local residents. Bahr El Baqar Drain, which starts at East Cairo and goes north through the Nile Delta, carrying municipal, industrial wastes and agricultural drainage water into the lake through Genka compartment. At the northern end of the lake, two outlets to the Mediterranean Sea allow seawater to flow in and out of the Lake.

The pollution loads flowing from the major water systems into Lake Manzala are mainly by Bahr El Baqar Drain (Table 1). The highest water volume and inflow to the lake was through it (13.9x10^{3}m^3 and 58.6m^3/second respectively) followed by Hadus Drain (9.4x10^{3}m^3 and 39.4m^3/second, respectively) (after NWRC, Ministry of Irrigation, Egypt). The total discharged water to Lake Manzala during 2002 ca. 4 x 10^9 m^3/year (ECRI, 2003)

2.2. Sampling and analysis

Samples were collected every month from Jan. to Dec. 2003. The samples were taken from ten stations selected to represent different parts of the lake (Fig. 1). Zooplankton samples were collected by filtering thirty liters of lake surface water through 55µm mesh size plankton net. Samples were fixed with 5% formalin, adjusted to 100 ml, three successive sub-samples of 3ml were examined under a binocular research microscope. The average count was taken and the results were expressed as the number of animals per m^3.

Apparent turnover of zooplankton (between any two years) was estimated for the lake as: $T = 100(N + D)/[(R_1 + R_2)t]$

Where: N is the number of taxa appearing in the second year, D is the number of taxa lost between the censuses, R_1 is the number of taxa in year 1, R_2 is the number of taxa in year 2, and t is the number of years between the censuses. This equation was applied by Magnuson *et al*. (1994) for species turnover rate in fishes.

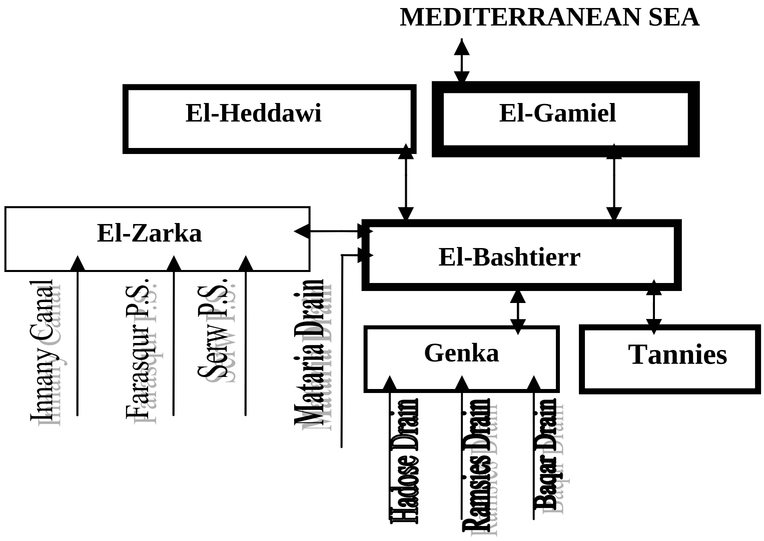
2.3. Statistical analysis

One way analysis of variance (ANOVA) and cluster analysis were carried out on data of zooplankton number at stations by MINITAB 12 under Windows.

Table (1): Average pollution loads flowing into Lake Manzala(ton/day) after Abdel-Gawad and El-Sayed (1998).

	Serw PS	*Mataria PS*	*Farasqur PS*	*Hadus Drain*	*Baqar Drain*	***Total load***
BOD	67	60	28	61	149	365
COD	143	230	114	220	821	1528
NH_4	1.6	3.9	1.3	2.8	49.9	59.6
HM*	0.35	0.50	0.43	0.76	2.64	4.69

HM*: Sum of heavy metals (Fe, Cu, Pb and Zn). PS: Point sources.



Schematic diagram of Lake Manzala

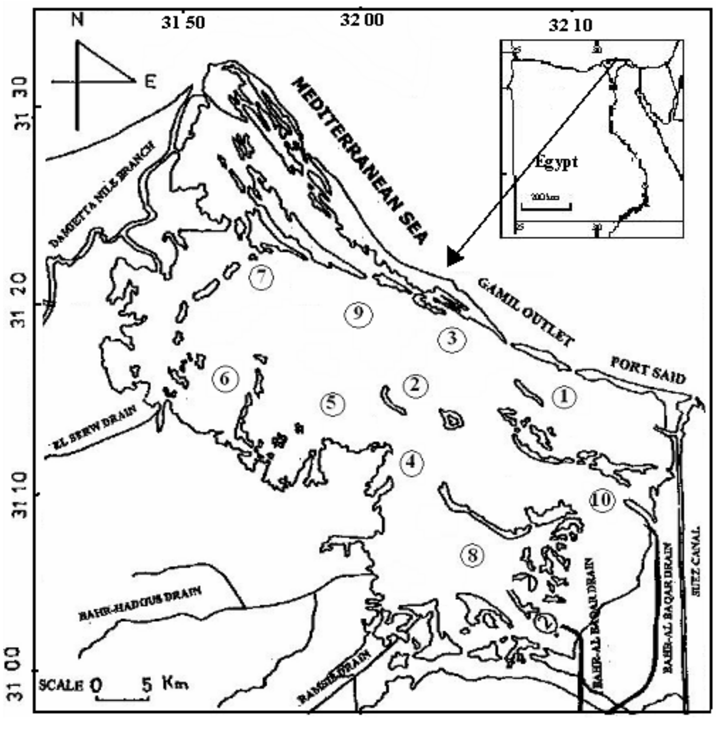


Fig. (1): Map of Lake Manzala Showing Sampling Stations of the study.

3. RESULTS AND DISCUSSION

3.1. Annual abundance of major zooplankton groups

Zooplankton community was represented by three main holozooplankton groups (Rotifera, Cladocera, and Copepoda) comprised in 52 species representing 32 genera, in addition to the larvae of benthic invertebrates (meroplankton) and the tychoplanktonic forms.

Rotifera were the highest overall abundant group, representing 97% of the total zooplankton number (963x10^3 animals/m^3), while tychoplanktonic forms and the Copepoda counted 12x10^3 and 11x10^3 animals/m^3, respectively. Cladocera were only represented by 0.5% of total zooplankton number. For species number, Rotifera contained the largest number of species (38 species- representing >70% of all taxa). Cladocera were represented by 8 species while copepods were represented by 6 species.

3.2. Distribution and monthly variations of the major groups

The average number of zooplankton was about 1212 x10^3 animals/m^3. The northern stations 1 and 3 were influenced by the sea, whereas the most southern stations 4, 5, 6, and 8 were influenced by the drainage water. Usually, mean zooplankton number was high in northern stations (1 and 3) while decreased to a minimum at stations 2 & 7-10 (Fig. 2). Numbers of the zooplankton at stations 4, 5, and 6 were nearly similar (1842x10^3, 1462x10^3, and 1614x10^3 animals/m^3, respectively). This geographical pattern was determined by the rotifers. Copepoda and Cladocera quantities were generally similar in distribution at stations 7 to 10. Their number appeared reverse relation in the other stations. Mero-and tychoplanktonic forms (Polychaeta, Ostracoda, Insecta, Cirripedia, Nematoda, Mollusca, Decapoda, and Fish eggs) were more abundant at station 7 due to the flourishing of the nauplius larvae of cirripeds.

By applying ANOVA for the zooplankton amounts at the stations, F value was 2.12 ($P = 0.033$) and the mean number at stations varied. By applying the cluster analysis (Fig. 3), the highest similarity was between stations 3 and 6 (>80%), while the lowest was between station 2 and the others (63%).

The peak of occurrence of zooplankton was flourishing in April (2840 x10^3 animals/m^3) followed by March (2277x10^3 animals/m^3), while the lowest occurrence was recorded during October and November (338x10^3 and 154x10^3 animals/m^3, respectively) as in figure 4. The peak of rotifers coincided with that of total zooplankton number. Copepods showed two peaks; the 1st was during February-March period, and the 2nd was during July-August period. For cladocerans, their number increased during spring and autumn. The other forms of zooplankton varied in number. They appeared with maximally during April, and decreased gradually until the disappearance in October and start to increase again.

3.3. Dominant and common species

The rotifers *Brachionus angularis* and *B. plicatilis* were numerically the dominant rotifers (307x10^3 and 462x10^3 animals/m^3, forming 35% and 36% of rotifer number, respectively) especially during spring for the first and continued to summer for the second one. *B. calyciflorus* increased during March-April. While *Keratella quadrata* flourished during winter especially in January, but disappeared in June-September period. *Trichocerca stylata* represented 93% of the genus, with maximum during June. *Hexartha*, *Polyarthra*, and *Filina* were greatest during the hot period of May-August.

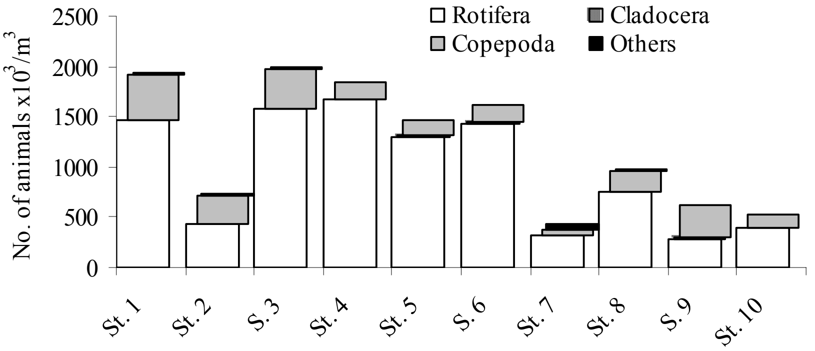


Fig. (2): Distribution of the major zooplankton groups (animals x $10^3/m^3$) along Lake Manzala during 2003.

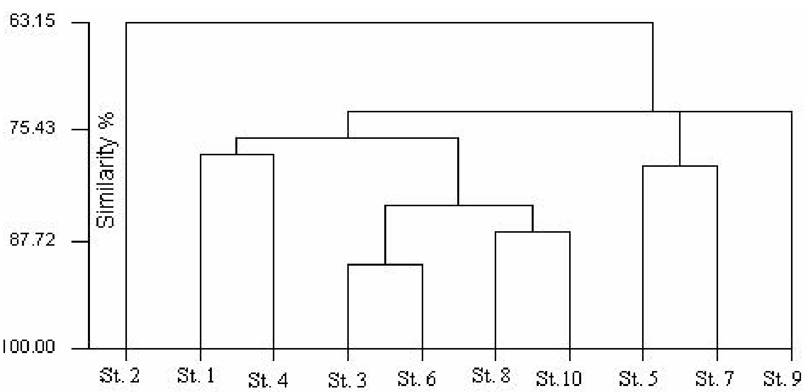


Fig. (3): Dendrogram showing similarity percent for total zooplankton number between the different stations among Lake Manzala during 2003.

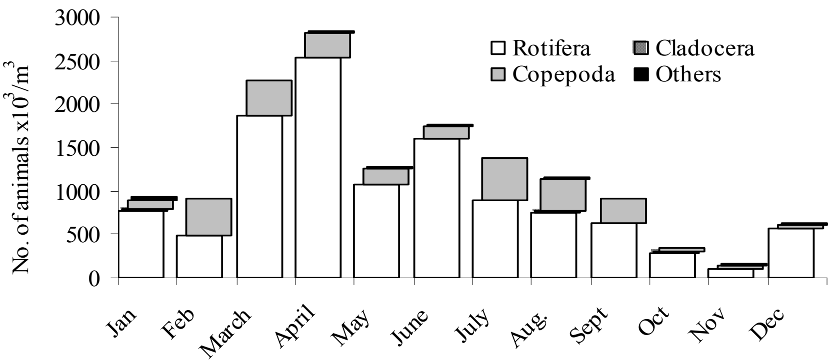


Fig. (4): Monthly variations of the major zooplankton groups (animals x $10^3/m^3$) along Lake Manzala during 2003.

Moina rectirostris and *Diaphanosoma lacustris* were the main dominant cladocerans constituting 48% and 21% of Cladocera, respectively). *M. rectirostris* appeared into two peaks, one during May and September, while the second late in autumn. *Daphnia* was represented by three species; *D. longispina*, *D. magna*, and *D. lumholtzi*. They were recorded as scattered.

Juvenile stages constituted 95% of copepods, with a richness of nauplius larvae (84% of juvenile number). Adult stage was dominated by *Acanthocyclops vernalis* which increased during spring and summer.

The meroplankton was dominated by the larvae of Cirripedia (peak in April) and Bivalvia which appeared in two peaks in March and May followed by two small amounts in September and December. While, tychoplanktonic forms were dominated by the free living nematodes which reached to the maximum number in January.

Over the year round, 4 common species accounted for 88% of the total abundance of zooplankton in number; *Brachionus angularis, B. plicatilis, Keratella quadrata,* and *B. calyciflorus* (36%, 35%, 9.5%, and 7.6% to the total adult zooplankton number, respectively).

3.4. Indicator species

From the data, many species are indicator to the salinity; *B. plicatilis* represented 36% of rotifers in the lake. It is a widespread plastic euryhaline species which inhabits brackish and inland salt-water (Serra and Miracle, 1983). It tolerates high salinity but is probably sensitive to the fluctuating salinity of estuaries (Green, 1993), while large populations of such species are restricted to saline waters (Jose de Paggi, 1990).

On the other hand, all the cladoceran species were characterized by being freshwater or the slightly brackish. Their peaked occurred at stations 5 and 6 probably influenced by freshwater because they decreased at the stations influenced by the sea water (stations 1, 7 and 10).

B. angularis represented 35% of total rotifer crop. This species is cosmopolitan with a broad distribution in the most strongly eutrophical water (Slàdeček, 1983). *B. calyciflorus* constituted 8% of rotifers counts and was considered as indicators of eutrophic condition by Pejler (1983) and Guisande & Joja (1988). According to Angeli (1976), the simultaneous presence of several species of the genus *Brachionus* is a good indication for the eutrophic nature of an aquatic ecosystem. There was represented by 7 species in the lake.

Keratella quadrata formed 10% of rotifers. Radwan and Popiolek (1989) found that in eutrophic lakes *K. quadrata* is one of the main dominants, and were considered as indicators of high trophic status. *Polyarthra vulgaris* occurred throughout the year. Slàdeček (1983) considered it as a permanent inhabitant of all types of fresh water and while Sharma and Pant (1985) regarded it as a good indicator of eutrophication. Thus the author as well as MacLaren (1982), Khalifa & Mageed (2002), El-Sherif *et al*. (1994) and Donia & Hussein (2004) considered that, Lake Manzala is an eutrophic lake.

3.5. Long-term historical changes

The species composition of zooplankton in Lake Manzala appeared to have changed significantly over the last fifty years (Tables 2 and 3). They changed from few mainly marine crustacean zooplankton species during 1959/60 (El-Maghraby *et al*., 1963) to a total of 16 species/genera/development stage during 1979/80 (MacLaren, 1982). During 2000/01, Khalifa and Mageed (2002) recorded a total of 46 zooplankton taxa aggregated by genera, adult species or developmental stages. In the present study, more zooplankton species were found; 62 taxa were recorded; 53 species representing 32 genera of holoplankton, in addition to 7 meroplankton (the larvae of benthic invertebrates) and 2 tychoplanktonic forms.

Table 2: Number of taxa recorded, new record to the lake and disappeared from the lake during the last fifty years.

Group	a	b			c			d		
		R	N	D	R	N	D	R	N	D
Rotifera	1	2	1	0	32	32	2	39	12	7
Cladocera	1	4	4	1	5	4	4	8	2	1
Copepoda	2	3	2	1	4	1	5	6	4	4
Others	3	7	5	1	5	3	0	9	2	1
Taxa no.	7	16	12	3	46	40	11	62	20	13
Animals x10^3/m^3	NA	18			936			1212		

Sources of data: a, El-Maghraby *et al.*(1963); b, McLaren (1982); c, Khalifa & Mageed (2002); and d, the present study.
Presence of taxa: R, total recorded; N, new record, and D, disappeared taxa
NA: Not available data

Table (3): Long-term occurrence in zooplankton community in Lake Manzala during 1959-2003.

	a	b	c	d
Rotifers				
Keratella tropica			#	#
K. cochlearis			#	#
K. quadrata			#	#
K. sp.	#	#		
Anuraeopsis fissa			#	#
Brachionus calyciflorus			#	#
B. quadridentatus			#	#
B. plicatilis			#	#
B. angularis			#	#
B. urceolaris			#	#
B. caudatus			#	#
B. falcatus				#
B. sp.		#		
Monostyla bulla			#	#
M. closterocerca			#	#
M. lunaris			#	#
Asplanchna priodonta			#	#
Pompholyx complanata				#
L. luna			#	#
L. nana				#
L. depressa			#	#
Hexarthra oxyuris			#	#
Lepadella patella			#	#
Synchaeta pectinata			#	#
Cephalodela catellina				#
Macrochaetus serica			#	#
Polyarthra vulgaris			#	#
Filina longiseta			#	#
F. opoliensis			#	#
Colurella adriatica			#	#
Trichocerca stylata				#
T. cylindrica				#
T. pusillus			#	#
T. longiseta				#
T. rousselleti			#	#
Lepadella ovalis			#	#
Pedipartia sp.				#
Rotatoria sp.				#
Rotaria neptunia				#
Scaridium longcaudum				#

	a	b	C	d
Horella brehmi				#
Ascomorpha ecudis			#	
Euclanis dilatata			#	
Monommata aequalis			#	
Philodina roseola			#	
Testudinella patina			#	
Cladocera				
Moina rectirostris		#	#	#
Moina micrura	#			
oxyurella tenuicaudis				#
A. quadrangula			#	#
Alona intermedia		#		#
Daphnia lumholtzi				#
D. longispina		#		#
D. magna		#		#
Diaphanosoma lacustris			#	#
Bosmina longirostris			#	
Ceriodaphnia cornuta			#	
Copepoda				
Acartia latisetosa	#	#		
Paracalanus parvus				#
Aanthocyclops vernalis	#		#	#
Thermocyclops sp.			#	#
Cyclops strenus		#		
Mesocyclops sp.			#	
Oithona nana				#
Nitocra lacustris				#
Mesocra holdeti				#
Harpacticus sp.		#	#	
Others				
Polychaete larvae	#		#	#
Ostracoda				#
Insect larvae		#	#	#
Cirriped nauplius	#	#	#	#
Nematoda		#	#	#
Veliger of Bivalvia	#	#	#	#
Zoea larvae of shrimp		#		
Mysis larvae of shrimp		#		#
Nauplius of crap		#		#
Fish egg				#

Sources of data: a, El-Maghraby *et al.* (1963); b, McLaren (1982); c, Khalifa & Mageed (2002); and d, the present study.

The variation in the species counts within each community was highly changed with time. Twenty zooplankton taxa were recorded for the first time in the lake during the present study (12 rotifers, 2 cladocerans, 4 marine copepods, and 2 of others). However thirteen taxa disappeared from the lake (7 rotifers, 1 cladoceran, 4 copepods, and 1 meroplankton) as in table 3.

By applying apparent species turnover rates on the species number of zooplankton in table 2, the rate of turnover of species among year differences in Lake Manzala was high. It was 3.26%/year between 60's and 80's, 4.11%/year between 80's to 00's, and increased to 10.29%/year during the present study. Zooplankton communities in Lake Manzala became more dissimilar as intercensus interval increased.

The difference between the taxa composition from one study to the other is a good indicator of the dynamic balances of the community (Mc Lachlan, 1974). In some cases it may be deceptive, due to differences in methodology, number of samples, and inclusion or exclusion of littoral species.

The animal counts of total zooplankton assemblages varied through the last thirty years. The average population density of zooplankton in the lake during 1977 was 63×10^3 animals/m^3 (Guerguess, 1979). This number increased by more than 14 folds (936×10^3 animals/m^3) during 2000/01 (Khalifa and Mageed, 2002). During this study, the last number is doubled, reaching to $1,212\times10^3$ animals/m^3. Thus the secondary productivity of Lake Manzala has increased with the long run due to the impact of the drainage water discharge in the lake.

Rotifers accounted for 40% in 1959/60 (El-Maghraby *et al*., 1963), only 1% in 1979/80 (MacLaren, 1982), and 82% in 2000/01 (Khalifa and Mageed, 2002), and during the present study, it increased to 97%. Cladocerans represented less than 1% of zooplankton during 1959/60, 75% in 1979/80, and <1% during 2000/01-2003. Copepoda represented 33% during 1959/60, 23% during 1979/80, and 16.9% during 2000/01. It decreased vigorously to less than 1% of the total zooplankton count during this study. While cirriped larvae declined from 21% during 1959/60 to only 1% in 1979/80 and to less than 1% during 2000/01 and in the present study as well.

4. CONCLUSIONS

We can conclude that, Lake Manzala has been gradually transformed from being a basically marine environment to eutrophic freshwater system. This occurred in response to the increased freshwater inputs and nutrient loading associated with agricultural land reclamation and urban waste disposal. This can be indicated by the increase in the abundance of the eutrophic freshwater species, like rotifers and the decrease of copepods as well as cladocerans.

In order to restore the marine conditions of the lake, which would effective in decreasing the pollution effect, the lake outlets should be activated to renewal the lake water.

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