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Zooplankton community dynamics and environmental factors in Lake Ozeros (Greece)

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Abstract

A one-year investigation of the zooplankton community composition and dynamics in Lake Ozeros (western Greece) revealed 25 invertebrate species (16 rotifers, three copepods, five cladocerans and one mollusc larva). The mean zooplankton abundance fluctuated between 59.4 to 818 ind l^{-1}, with maximum values in spring. The species composition and seasonal variation do not differentiate Lake Ozeros from the nearby lakes. The presence of the dominant calanoid copepod *Eudiaptomus drieschi* and some of the rotifer species recorded are characteristic of either oligo- or eutrophic lakes. According to the trophic state index (TSI), Lake Ozeros is a meso-eutrophic ecosystem, in which the eutrophic character is possibly the result of the high phosphorus load (being 28.9% higher in comparison to previous decades), which is due to the surrounding agricultural cultivations and mainly the pig-raising activities. In contrast, the concentrations of NO_3, NO_2 and NH_4 have considerably decreased possibly due to the termination of tobacco cultivations around the lake during the last years. The novel information on the abiotic and especially the biotic elements of Lake Ozeros provided by this study can contribute to the effective management of this aquatic ecosystem in the future.

Keywords: Lake Ozeros, zooplankton, seasonal variation, physicochemicals.

Introduction

Zooplankton is an important biotic constituent for the structure and function of freshwater lake ecosystems, as it occupies a critical link between phytoplankton and higher consumers such as fishes, while significantly contributing to the recycling of nutrients. The strategic position of zooplankton, both in terms of feeding and energy flow in the ecosystem as well as sensitivity to man-made and natural changes, makes zooplankton quite suitable for biological monitoring of water quality (Caroni & Irvine, 2010). Indeed, although zooplankton is still not included as a biological quality indicator for aquatic ecosystems according to the implementation of the EU Water Framework Directive, several studies have shown its usefulness as an indicator of alterations in the trophic dynamics and the ecological state of lakes related to changes in nutrient loading and climate (Jeppesen *et al.*, 2011).

Lake Ozeros is a karstic natural lake situated in Western Greece (38° 39΄ N, 21° 13΄ E) with a surface area of 10.1 km^2 and a drainage area of 59 km^2 (Zacharias *et al.*, 2002). The lake is supplied with water from small torrents, and also through a canal from the Acheloos River, when it floods. Lake Ozeros is a typical shallow urban Mediterranean lake (maximum depth = 5.6 m) the water of which is used for irrigation purposes. The lake receives large amounts of fertilizers from the surrounding agricultural areas, as well as wastes from nearby farms and small livestock industries, which could lead to eutrophication. Lake Ozeros has considerable ecological importance and, thus, it has been included in the Natura 2000 European network as a habitat for migratory birds and a number of endemic fish species.

In spite of the importance of Lake Ozeros, a limited number studies on the abiotic and biotic elements of this ecosystem have been carried out. Previous information on the physicochemical characteristics of the lake consists of Ministry of Agriculture measurements (www.minagric.gr). As regards the biotic elements, two studies on the phytoplankton of the lake (Kristiansen, 1980; 1983) have been conducted, while there is little information on its zooplankton community, with the exception of a qualitative study conducted by Koussouris (1978) on the occasion of a single sampling.

During the last few years efforts were made to investigate the zooplankton in the lakes of Western Greece along with the abiotic elements of these ecosystems (Kehayias *et al.*, 2004; 2008; Doulka & Kehayias, 2008, 2011; Doulka, 2010; Chalkia *et al.*, 2012a, b). As part of this effort, through a one-year investigation, this study aims to investigate the zooplankton community as a biological element relevant in the assessment of the ecological status of this aquatic ecosystem, and also to explore relationships between community dynamics and environmental factors.

Materials and Methods

Field and laboratory operations

Zooplankton samples were collected monthly from June 2009 to May 2010 at two stations (1 and 2) having a depth variation between 4 and 5.6 m and 3.5 and 5 m, respectively (Fig. 1). The samples were collected with vertical hauls from near the bottom to the surface using a HYDROBIOS plankton net (20 cm in diameter, 100 cm in length, 50 µm mesh size). The net was towed at a speed of approximately 0.5 m sec^{-1}. All samples were taken in the morning and were fixed in 4 % buffered formalin. The zooplankton specimens were examined microscopically and were identified to the lowest taxonomic level possible using the keys of Rylov (1963), Ruttner–Kolisko (1974), Alonso (1996) and Benzie (2005). The copepod nauplii were not identified to species. For the abundance analysis, three counts of 1.5 ml subsamples were made on a Sedwick-Rafter cell from each sample having a total volume of 100 ml (Doulka & Kehayias, 2008).

Vertical profiles of water temperature, pH, conductivity and concentration of dissolved oxygen (DO) were taken at all stations using a TROLL 9500 water quality instrument. Water transparency was measured with a Secchi disc. For the estimation of total phosphorus (TP), phosphates (PO_4), nitrates (NO_3), nitrites (NO_2), ammonia (NH_4) and silicates (SiO_2), water samples were collected at the deepest station (station 1) from 0 and 4 m, with a HYDROBIOS water sampler. Analyses of all chemical parameters were performed according to A.P.H.A., A.W.W.A. & W.P.C.F. (1998). For the determination of chlorophyll-a concentration (chl-a), a volume of 1500 ml of the water samples was taken from the above depths and was filtered through a Whatman GF/A glass fibre filter shortly after collection. Pigment extraction was made in 90% acetone and concentrations were determined spectrophotometrically (A.P.H.A., A.W.W.A. & W.P.C.F., 1998). The trophic classification of the lake was estimated by the Trophic State Index (TSI) using Carlson's (1997) equations for total phosphorus (TP), chlorophyll-a (chl-a) and transparency, which was measured by the Secchi disk (SD), as follows:

TSI (SD) = 60-14.41*ln(SD)
TSI (chl-a) = 30.6+9.81*ln(chl-a)
TSI (TP) = 4.15+14.42*ln(TP)

In order to ascertain the structural features of the zooplankton community, the Shannon-Wiever diversity index H' (Maguran, 1988) was calculated for each sampling station and date:

$$H^1 = -\sum_{i=1}^{s} (p_i \ln p_i)$$

where H' is the diversity index and p_i the relative abundance of each species (i) in a sample.

The Mann-Whitney (U test) test was used for investigating differences in the environmental parameters and in the abundance of zooplankton species and groups between the two stations. Multiple regression analysis was used to clarify the influence of the environmental factors on each of the zooplankton species using data from station 1 for the entire sampling period. The analysis was performed using forward stepwise selection to identify the significant factors. These factors were then correlated with each other (Pearson's *r*) to eliminate those having a strong correlation. Finally, the explanatory factors were standardized so as to compare their relative importance. All data analyses were performed using the SPSS 17.0 (SPSS, Inc. 2008) statistical package.

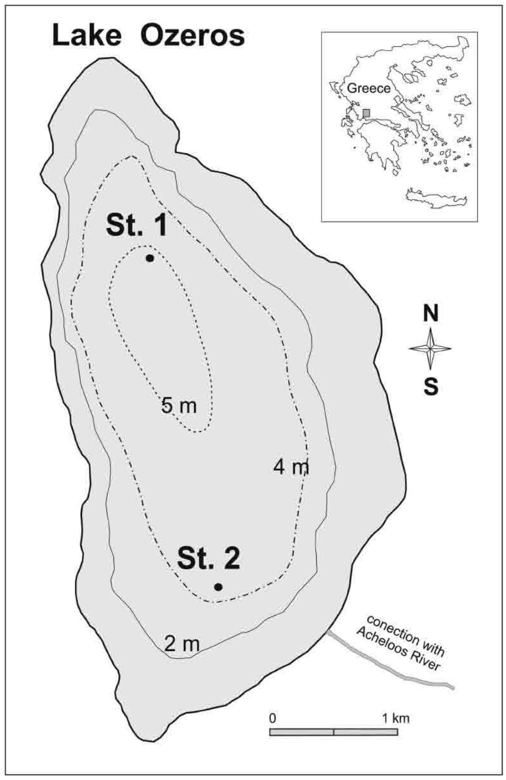

Fig. 1: Lake Ozeros with the sampling stations (1 and 2).

Results

Physicochemical parameters

The temperature fluctuated between 9.9 and 28.9 °C and due to the shallow depth of Lake Ozeros there was no thermal stratification (Fig. 2). The lake was well oxygenated through the entire water column, and presented high oxygen concentrations at the surface during the cold months. The lowest DO value was recorded close to the bottom of the deeper station 1, falling to 7.7 mg l^{-1} in September. The pH was alkaline throughout the sampling period (7.76-8.87) having high values in summer and spring, while the lowest value was recorded in November close to the bottom. Conductivity values fluctuated between 202.6 and 398.6 µS cm^{-1}, being higher in the summer period and lower during winter (Fig. 2). The seasonal variation of water transparency ranged from 0.5 m in November and June to 2 m in Au-

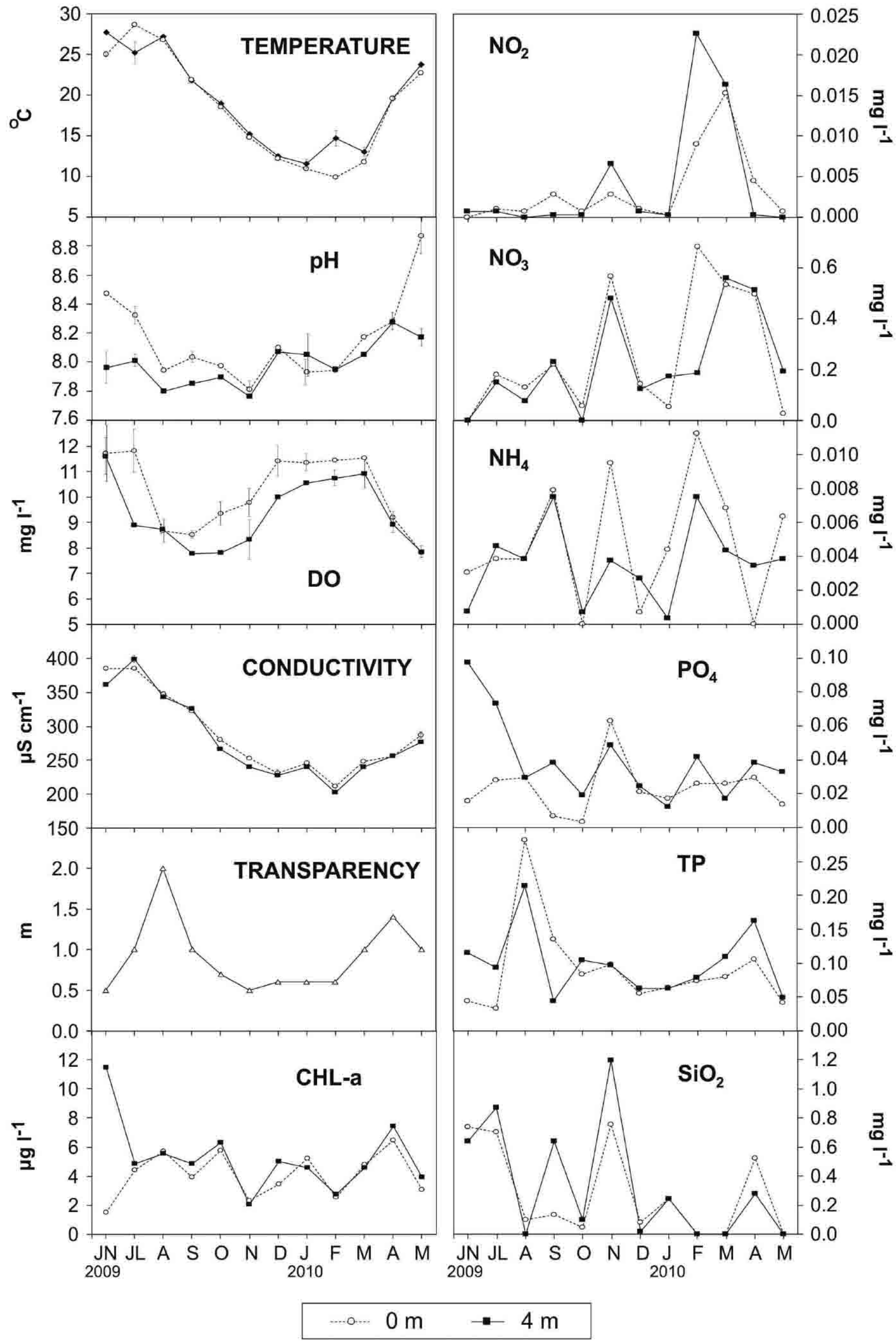

Fig. 2: Monthly variation of the physicochemical parameters (temperature, dissolved oxygen, pH, conductivity, transparency, chl-a, NO_2, NO_3, NH_4, PO_4, TP, SiO_2) at 0 m and 4 m depth in the water column of station 1 during June 2009 to May 2010 in Lake Ozeros. (The vertical lines in the diagrams of temperature, pH, DO, conductivity and transparency correspond to the standard deviation of the mean from both sampling stations).

gust (Fig. 2). There were no differences between the two sampling stations considering all the above parameters (U test, $p>0.05$).

The chlorophyll-a concentration presented a seasonal fluctuation, which was similar between the two depths in all months except June when the highest value was recorded (11.47 mg m^{-3}) at the depth of 4 m and the minimum (1.48 mg m^{-3}) at the surface (Fig.2). The concentration of phosphates (PO_4) and total phosphorus (TP) showed highest values during the summer, reaching 0.098 mg l^{-1} in June near the bottom and 0.281 mg l^{-1} in August at the surface, respectively (Fig. 2). Nitrites (NO_2), nitrates (NO_3) and ammonia (NH_4) presented strong seasonal variations, which fluctuated from undetected values to 0.023, 0.685 and 0.011 mg l^{-1} in February, respectively. Finally, the concentration of silicates (SiO_2) presented a maximum value in November reaching 1.19 mg l^{-1} near the bottom. In the vertical axis, statistically significant differences were found for the concentration of phosphates (U-test, $p<0.05$), having the highest values at 4 m depth.

The application of Carlson's index (TSI) for total phosphorus (TP) and transparency (SD) revealed values between 59.15 to 83.63 and 50.01 to 69.99, respectively, which classify Lake Ozeros to the eutrophic level, while the values for chlorophyll-a (chl-a), which fluctuated between 38.18 to 49.6, classify the lake to the mesotrophic level (Fig. 3).

Zooplankton species composition and variability

The zooplankton investigation in Lake Ozeros revealed 25 invertebrate species which comprised four groups; 16 rotifers, five cladocerans, three copepods and one mollusc larva (Table 1). There were no statistically significant differences in the abundance for total zoo-

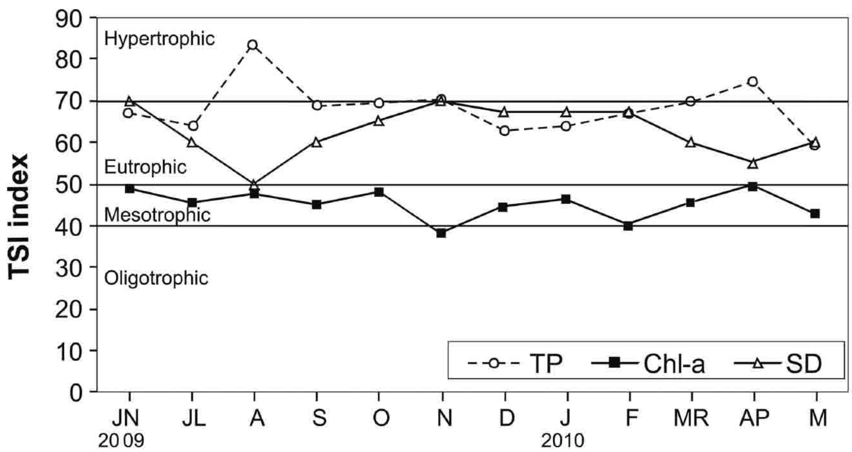

Fig. 3: Monthly variation of the values of TSI index for total phosphorus (TP), chlorophyll-a (chl-a) and transparency (SD) in Lake Ozeros.

Table 1. List of the zooplankton species found in Lake Ozeros during the present study and the study of Koussouris (1978).

ROTIFERS	Present study	Koussouris (1978)
Asplanchna priodonta (Gosse, 1850)	+	
Brachionus angularis (Gosse, 1851) *Conochilus unicornis* (Rousselet, 1892)	+	+
Filinia longiseta (Ehrenberg, 1834)	+	+
Filinia opoliensis (Zacharias, 1898)	+	
Hexarthra mira (Hudson, 1871)	+	
Hexarthra intermedia (Wiszniewski, 1929)	+	
Kellicottia longispina (Kellicott, 1879)	+	
Keratella cochlearis (Gosse, 1851)	+	+
Keratella tecta (Gosse, 1851)	+	
Keratella tropica (Apstsein, 1907)	+	
Keratella quadrata (Müller, 1786)	+	+
Ploesoma hudsoni (Imhof, 1891)	+	
Polyatrthra trigla (Ehrenberg, 1834)		
Polyarthra sp.	+	+
Synchaeta sp.	+	
Trichocerca sp.	+	
Trichocerca similis (Wierzejski, 1893)	+	
COPEPODS		
Eudiaptomus drieschi (Poppe & Mrázek, 1895)	+	
Harpacticoida	+	
Macrocyclops albidus (Jurine, 1820)	+	
CLADOCERANS		
Bosmina longirostris (O. F. Müller, 1785)	+	
Ceriodaphnia pulchella (Sars, 1862)	+	
Daphnia cucullata (G.O. Sars, 1862)	+	
Diaphanosoma orghidani (Negrea, 1982)	+	
Leptodora kindtii (Fock, 1844)	+	
MOLLUSK LARVAE		
Dreissena blanci (Westerlund,1890)	+	

plankton and for any of the species between the two stations (U-test, $p>0.05$). Considering the above and also the different depths of the two sampling stations, we chose to present the results from the deeper station A. The mean integrated abundance of total zooplankton ranged between 59.4 and 818 ind l^{-1} in February and April, respectively (Fig. 4a). Seasonally, total zooplankton presented a decrease after the summer period, remained low during fall and winter and increased at the beginning of spring (Fig. 4a). The peak of abundance in April was the result of the increased number of rotifers. The Shannon diversity index (H') ranged from 0.8 to 1.7 showing generally lower values during winter and higher during the warm months, while presenting no statistical differences between the two stations (U-test, $p = 0.602$).

The group of copepods dominated the zooplankton community, accounting for 40.9 % in average abundance, followed by rotifers (32 %), larvae of the mollusc *Dreissena blanci* (Westerlund, 1890) (19.1 %) and cladocerans (7.9 %) (Fig. 4a). The abundance of copepods ranged between 36.8 and 167.8 ind l^{-1} (in August and September, respectively). The calanoid *Eudiaptomus drieschi* (Poppe & Mrázek, 1895) was the dominant species throughout the sampling period, accounting on average for 46.8% in the copepod's community, while the cyclopoid *Macrocyclops albidus* (Jurine, 1820) had a considerably lower contribution (0.35 %). Nauplii were present in considerable numbers all year round and accounted, on average, for 52.9% (Fig. 4b). A few specimens of unidentified harpacticoid copepods were found sporadically in the samples.

The abundance of rotifers ranged between 2.9 and 877.1 ind l^{-1} (in February and April, respectively). *Filinia longiseta* (Ehrenberg, 1834), *Synchaeta* sp. and *Conochilus unicornis* (Rousselet, 1892) accounted for 20.8, 17.4 and 16.8%, respectively within the rotifer community, followed by *Polyathra* sp., *Keratella quadrata* (Müller, 1786) and *Hexarthra* sp. (14.2, 10.8 and 10.1%, respectively). Most of these species showed a distinct

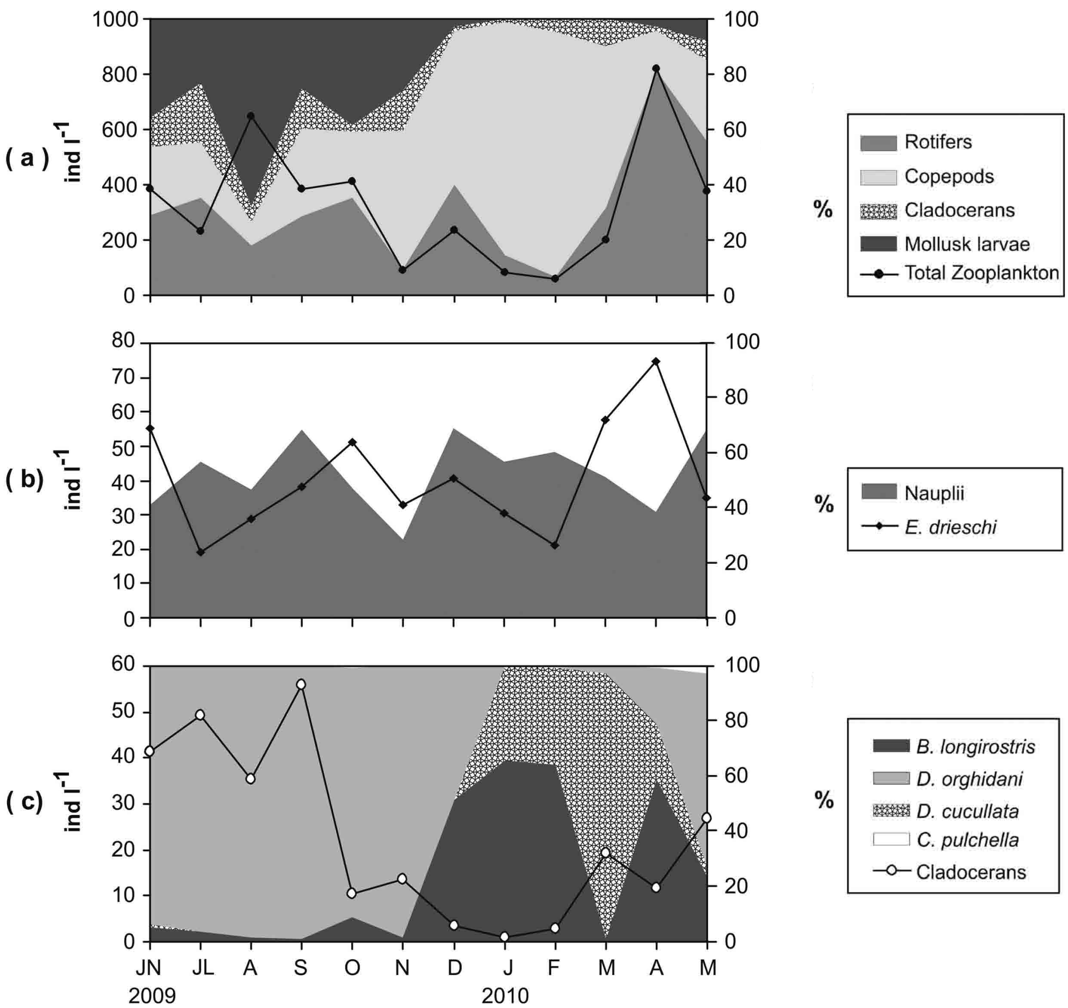

Fig. 4: (a) Seasonal variation of total zooplankton abundance (ind l^{-1}) and percentage (%) contribution of the main zooplanktonic groups from June 2009 to May 2010 in Lake Ozeros. (b) Seasonal abundance (ind l^{-1}) variation of the copepod *Eudiaptomus drieschi* and percentage (%) contribution of nauplii to the copepod's community. (c) Seasonal abundance (ind l^{-1}) variation of total cladocerans and percentage (%) contribution of the species *Bosmina longirostris*, *Diaphanosoma orghidani*, *Daphnia cucullata* and *Ceriodaphnia pulchella* to the cladoceran's community.

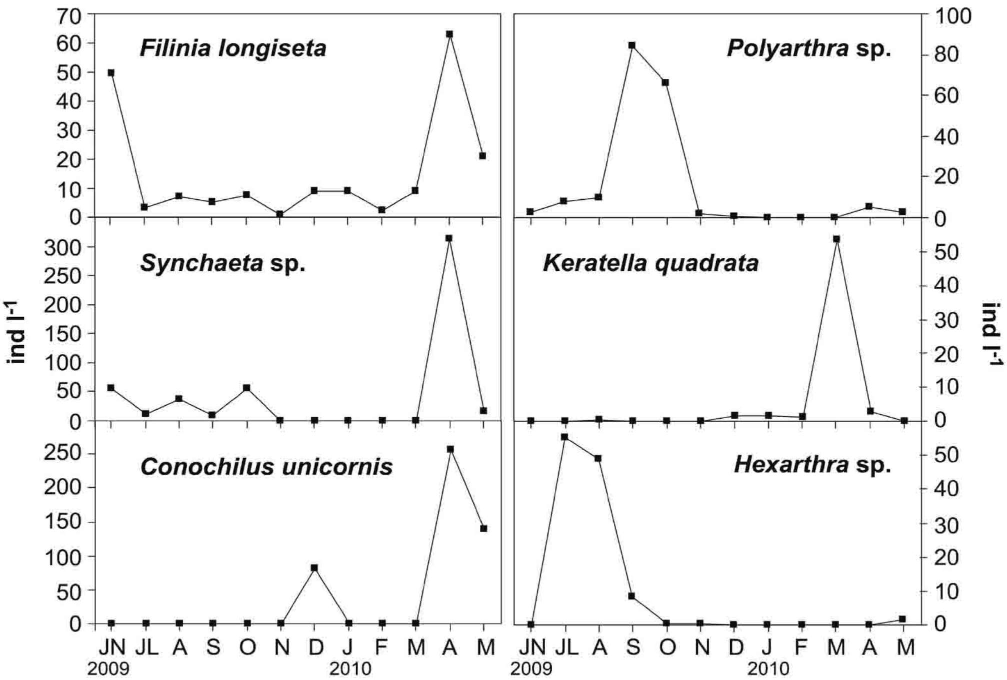

Fig. 5: Seasonal variation of the average abundance (ind l^{-1}) of the six most important rotifer species from June 2009 to May 2010 in Lake Ozeros.

pattern of seasonal variation, with the highest abundance in the warm period, while in winter they were present in low numbers or were absent from the zooplankton community (Fig. 5). Among the less abundant rotifer species, *Asplanchna priodonta* (Gosse, 1850), *Keratella tropica* (Apstsein, 1907) and *Keratella cochlearis* (Gosse, 1851) accounted together for 8.27% within the rotifer community, while *Trichocerca similis* (Wierzejski, 1893), *Trichocerca* sp., *Kellicottia longispina* (Kellicott, 1879), *Filinia opoliensis* (Zacharias, 1898), *Ploesoma hudsoni* (Imhof, 1891) and *Keratella tecta* (Gosse, 1851) were found sporadically in the samples.

The abundance of cladocerans ranged from 0.24 ind l^{-1} in January to 65.1 ind l^{-1} in September. The pattern of seasonal fluctuation of abundance presented higher values mainly in the summer period and lower in late autumn and winter (Fig. 4c). *Diaphanosoma orghidani* (Negrea, 1982), which presented the highest values in summer and early autumn was the dominant species, accounting for 59.8% in the cladoceran community, followed by *Bosmina longirostris* (Müller, 1785), which accounted for 23.9%, presenting peak abundance in spring. *Daphnia cucullata* (Sars, 1862) accounted for 15.8% with maximum abundance in March, while *Ceriodaphnia pulchella* (Sars, 1862) was found only in May having a negligible contribution (0.2%) in the cladoceran community (Fig. 4c). A few specimens of *Leptodora kindtii* (Focke, 1844) were also recorded sporadically mainly during the warm period.

Finally, larvae of the bivalve mollusc *D. blanci* were found throughout the year, except in winter, with maximum abundance in August reaching 440.6 ind l^{-1} (Figure 4a).

Influence of physicochemical parameters

The results of multiple regression analysis showed that temperature was among the main factors correlated with the abundance variation of the zooplankton community in Lake Ozeros (Table 2). Specifically, temperature affected the group of rotifers and especially *Synchaeta* sp., while it also had a great impact on the group of cladocerans affecting the dominant species *D. orghidani*. Moreover, temperature was strongly correlated with the presence of the *D. blanci* larvae. The pH values appear to be crucial for the variation of *B. longirostris* and to a lesser extent for the presence of the rotifer *C. unicornis*, while conductivity seemed to have a strong influence on the distribution of the rotifer species *Hexarthra* sp. and *Tr. similis.* The concentration of phosphates associated with the group of copepods affected the presence of their nauplii (Table 2).

Discussion

Physicochemical parameters

Lake Ozeros is classified as meso-eutrophic according to the TSI index, which accumulates the concentration values of total phosphorus, chlorophyll-a, and transparency (Carlson 1977). The eutrophic character of the lake is the result of the increased concentrations of TP and low transparency. The seasonal TP variation was similar with that of other lakes in the area, such as Trichonis (Doulka, 2010) and Amvrakia (Chalkia *et al.*, 2012a), although the concentration values were higher. Given the presence of human activities around the lake

Table 2. Multiple regression analysis between the environmental factors (transparency, temperature, DO, pH, conductivity, NO3, NO2, PO4, SiO2 and chl-a) and the zooplankton species/groups in Lake Ozeros.

	Environmental factors											
Species / Groups	**Trans**	**T**	**DO**	**pH**	**Cond**	**NO_3**	**NO_2**	**PO_4**	**SiO_2**	**Chl-a**	**(r^2)**	**(d.f.)**
Asplanchna priodonta			-0.641*								0.411	10
Conochilus unicornis				0.595*							0.353	10
Filinia longiseta						-0.718**					0.515	10
Hexarthra sp.	0.580**				0.688**					-0.394*	0.831	8
Keratella quadrata							0.683*				0.467	10
Polyarthra sp.			-0.699*								0.488	10
Synchaeta sp.		1.659**			-1.242**				0.186*	0.518**	0.972	7
Trichocerca similis					0.731**						0.535	10
ROTIFERS		0.663**									0.439	10
Nauplii				0.599**				-0.928**		-0.352*	0.930	8
COPEPODS				0.465*				-0.774**			0.760	9
Bosmina longirostris				0.895**							0.802	10
Daphnia cucullata				0.441*			0.815**				0.715	9
Diaphanosoma orghidani		0.895**									0.801	10
CLADOCERANS		0.885**									0.783	10
Dreissena blanci		1.009**		-0.404**							0.907	9
TOT. ZOOPLANKTON		0.928**						-0.489*			0.767	9

(Explanations: * $p<0.05$, ** $p<0.01$)

and especially small livestock facilities like pig-farms, it is assumed that the high load of TP was possibly the result of the washout of wastes from these industries, although it could also be attributed to fertilizers from agricultural cultivations, or mineral run-off. The maximum TP concentration found during this study was 28.9% higher compared to previous investigations during the period 1981-1997 (www.minagric.gr), revealing that there was an increase in the phosphorus load of the lake. The high phosphate concentrations, which were increased near the bottom of the lake during the summer, could possibly be attributed to decomposition processes (Wetzel, 2001), while it is expected that large amounts of phosphorus could return to a soluble state after sediment disturbance (Søndergaard *et al.*, 2003) (Table 3).

In contrast to phosphorus, the highest values of nitrates, nitrites and ammonia were 86.2, 92.6 and 98.2% lower respectively, compared to the previous investigations (www.minagric.gr). This reduction of nitrogenous substances could be related to the limitation of fertilizers entering the lake from runoff or water discharge, due to the termination of tobacco cultivations in the last years. It must be pointed that, until recently, the main cultivation around the lake was tobacco. However, from 1/1/2006 with the CAP reform in relation to tobacco cultivation, tobacco production was significantly reduced by about 80% in Greece and 100% in the prefecture of Aitoloakarnania. As a result, tobacco producers either turned to other cultivations,

Table 3. Comparison of the range (max – min value) of the environmental parameters recorded in the present study with the previous measurements conducted by the Greek Ministry of Agriculture between 1981 and 1997.

	Present study	**Greek Ministry of Agriculture**
Parameters / Period	**(2009-2010)**	**(1981-1997)**
Temperature (°C)	9.9 - 28.9	6.0 - 30.0
DO ($mg.l^{-1}$)	7.4 - 12.9	7.6 - 14.2
pH	7.7 - 8.8	6.9 - 8.4
Conductivity ($\mu S.cm^{-1}$)	201.3 - 398.6	225 - 630
Transparency (m)	0.5 - 2	-
Chl-a ($mg.m^{-3}$)	1.48 - 11.47	-
TP ($mg.l^{-1}$)	0.033 - 0.281	0.004 - 0.218
PO_4 ($mg.l^{-1}$)	0.003 - 0.098	-
NH_4 ($mg.l^{-1}$)	0.000 - 0.011	0.000 - 0.626
NO_2 ($mg.l^{-1}$)	0.000 - 0.023	0.001 - 0.31
NO_3 ($mg.l^{-1}$)	0.000 - 0.685	0.02 - 4.96
SiO_2 ($mg.l^{-1}$)	0.000 - 1.2	-

or in many cases left their fields uncultivated; this change in agricultural activities has not been recorded in detail for the area.

The water temperature of Lake Ozeros fluctuated according to seasonal patterns that are similar to those observed in Lakes Trichonis and Amvrakia, while the alkaline pH values are considered a characteristic indicator of high photosynthetic activity that occurs mostly during the warm period. Lower water transparency observed mainly in the winter was probably due to increased precipitation and sediment runoff from torrents on the western banks of the lake. The chl-a concentration and seasonal variation was similar to the nearby mesotrophic Lake Amvrakia (Chalkia *et al.*, 2012a). On the vertical axis, the distribution of DO was uniform in the water column and the high concentration values recorded during the cold months is the result of increased oxygen solubility at lower temperatures. Finally, there were no horizontal differences in transparency, temperature, DO, pH and conductivity and this can be attributed to the small size of Lake Ozeros.

Zooplankton community composition and dynamics

There are no previous reports on the zooplankton community of Lake Ozeros and the only existing report came from a survey conducted by Koussouris (1978) who recorded the presence of only five rotifer species: *Brachionus angularis* (Gosse, 1851), *Filinia longiseta*, *Keratella cochlearis*, *K. quadrata* and *Polyarthra trigla* (Ehrenberg, 1834). This study resulted in 21 new records of zooplankton species, which have been recorded as residents in other natural and artificial lakes of western Greece, such as Trichonis (Doulka & Kehayias, 2008), Stratos Reservoir (Kehayias *et al.*, 2008) and Amvrakia (Chalkia *et al.*, 2012a). The absence of *Brachionus* sp. specimens from the samples can be considered as the most remarkable difference of the present findings in comparison to Koussouris (1978) and to the community composition of the other lakes in the area. The general similarities in species composition between all the above aquatic ecosystems can be attributed either to their communication through flooding or irrigation canals, or to their common origin, given that at the end of the Pliocene they belonged to a much larger lake created by the outflow of the River Acheloos (Verginis & Leontaris, 1978).

The values of the diversity index, as well as its seasonal variation reveal another similarity among Lake Ozeros and the nearby lakes Trichonis (Doulka, 2010) and Amvrakia (Chalkia *et al.*, 2012a). Taking into account that increased zooplankton diversity could indicate the internal stability of an aquatic ecosystem (Michaloudi *et al.*, 1997), communities structured in this manner are generally characteristic of stable environments (Ferrara *et al.*, 2002. The mean abundance value of total zooplankton recorded in Lake Ozeros was similar to that of other eutrophic lakes (Michaloudi *et al.*, 1997). However, the dominance of calanoid copepods in the zooplankton community is considered characteristic of oligotrophic ecosystems (Sager & Richman, 1991). The calanoid *Eudiaptomus drieschi* was also the dominant species in the oligotrophic Lake Trichonis (Doulka, 2010) and the mesotrophic Lake Amvrakia (Chalkia *et al.*, 2012a), while it's seasonal variation was similar in the three lakes. The rotifers *Synchaeta* sp. and *Conochilus unicornis* being very abundant in spring are considered indicators of oligotrophic ecosystems, while *Filinia longiseta Keratella quadrata* και *Hexarthra* sp. are common in eutrophic lakes (Mäemets, 1983; Bērziņš & Pejler, 1989). Moreover, the genus *Polyarthra* sp. is comprised of species that are common in oligotrophic to eutrophic lakes (Ruttner-Kolisko, 1974). Consequently, the biotic elements of Lake Ozeros probably indicate a transition of the ecosystem from an oligotrophic to an eutrophic condition; thus, from this point of view, the lake can be considered mesotrophic, which is in accordance with the TSI indications. It therefore appears that biotic elements such as zooplankton could be useful for the determination and/or verification of the state of freshwater ecosystems estimated by the use of trophic indexes. In this sense, chemical parameters, considered independently, may not be sufficient to provide a complete picture of the environment and, thus, ensure more effective management. Examination of biological components, in this case zooplankton, which is an important indicator of the structure and function of freshwater lake ecosystems and their ecological status (Jeppesen *et al.*, 2011), may supply further elements determining the quality of lake water, while a detailed analysis of community composition and seasonal variation could indicate disturbance in the ecosystem or predict future changes.

The community of cladocerans was characterized by a succession of dominance of *Diaphanosoma orghidani* and *Bosmina longirostris*, which could be due to their different food preferences. *D. orghidani*, being a highly efficient bacteriofeeder, was present in summer, while *B. longirostris*, being a low efficient bacteriofeeder, was present mainly in spring (Geller & Müller, 1981). Moreover, the seasonal variation of *Daphnia cucullata* and *D. orghidani* was similar to that described in other Greek lakes (Michaloudi *et al.*, 1997; Doulka & Kehayias, 2008; Chalkia *et al.*, 2012a), and is probably attributed to competitive interactions between them (Matveev, 1987). The absence of large cladocerans after spring could be due to predation by planktivorous fish species (e.g. Cyprinidae adults and larvae), which can drastically affect the crustacean community (Tátrai *et al.*, 2003). However, the predation pressure as regards zooplankton abundance is difficult to estimate, since no such information is available for the specific area.

Finally, the variation in seasonal abundance of the larvae of the bivalve *Dreissena blanci* was similar to that of lakes Trichonis and Amvrakia, where high values were recorded in the summer months, while in winter the larvae were found in low numbers or were absent. However, there was a significant difference between Lake Ozeros and the other lakes in the area as regards the higher density of the *D. blanci* larvae in the former lake. These differences could be explained by the higher trophic state of Lake Ozeros in comparison to the other lakes.

Influence of physicochemical parameters

Multiple regression analysis showed that the most important abiotic parameter influencing zooplankton variation was water temperature and, to a lesser extent, certain water quality variables. Water temperature is considered a crucial factor influencing many aspects of the biology and ecology of zooplanktonic organisms (Wetzel, 2001). In this study, water temperature was significant for the community of rotifers and cladocerans and especially for the larvae of *D. blanci*. The influence of temperature on several rotifer species has been well demonstrated (Hoffmann, 1977; Devetter, 1998; 2011; Akbulut *et al.*, 2008), while *Synchaeta* sp. has been also correlated with temperature in Trichonis Lake (Doulka & Kehayias, 2008). *D. orghidani* is expected to have been affected by temperature as a thermophilous species (Korovchinsky, 1992), while its high density among cladocerans seems to have been responsible for the affection of temperature to the whole cladoceran community. Additionally, temperature seemed to be the most important abiotic factor controlling the seasonal variation of *D. blanci* larvae, as it was also reported from other lakes in the area (Chalkia *et al.*, 2012b). In addition, the positive correlation between temperature and the sister dreissenid species *D. polymorpha* has been found in other Greek lakes (Michaloudi *et al.*, 1997), as well as in lakes of northern Europe (Stańczykowska & Lewandowski, 1993).

The positive correlation of copepod nauplii and the cladoceran *B. longirostris* with pH, could possibly be associated with optimal lake conditions, since higher pH values are an indication of greater photosynthetic production and, consequently, oxygen concentration. On the other hand, the negative correlation of copepod nauplii to phosphates could be explained by taking into account some indirect effects. This means that they present increased abundance in cases of phosphate depletion, as the latter were utilized by the phytoplankton, which at the same time show elevated density. Consequently, this could indirectly indicate the importance of phytoplankton for species variation.

In conclusion, the present results of the physicochemical parameters and zooplankton species composition and abundance show that Lake Ozeros is probably in a transitional state, i.e. meso- to eutrophic. The eutrophic character is considered to be the result of an increased phosphate load entering the lake via the surrounding agricultural cultivations and mainly the pig-raising activities, and not inorganic nitrogen, which is lower compared to the past decades. From a biogeographical point of view, Lake Ozeros does not differ from the other nearby lakes, which is attributed mainly to the geological history of the area and also to the lack of particular human activities that could have caused a dramatic alteration of the structure and function of the ecosystem. This study can be considered as a first step in a monitoring process that could be applied in the next years and serve as a tool for the protection and effective management of this lake.

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