Original Research Article

Influence of some environmental variables on the zooplankton community of Aguieira reservoir (Iberian Peninsula, Portugal): Spatial and Temporal trends

ABSTRACT

The present research was aimed at assessing the spatial and temporal trends in zooplankton community of Aguieira reservoir at the Mondego catchment (Iberian Peninsula, Portugal) in response to some environmental variables. A total of twenty- four zooplankton and water samples were collected in March (spring), May (early summer), September (late summer) and December (winter) 2010 and 2011 from three sampling sites. The samples were analysed following standard procedures. Descriptive (range, percentage) and multivariate statistics (Non-metric Dimensional Scaling (n-MDS), Bray-Curtis distance, Canonical Correspondence Analysis (CCA)) were utilised in data analysis. Twenty-three (23) zooplankton species consisting of Rotifera (12), Cladocera (8) and Copepoda (3) were recorded. In terms of abundance, Rotifera (*Keratella* spp. and *Polyarthra* sp.) dominated the zooplankton community in May and September while Copepoda (*Copidodiaptomus numidicus* and *Tropocyclops prasinus*) was most dominant in December and March. Cladocera was the least abundant taxon. The most abundant cladoceran were *Daphnia longispina and Bosmina coregon*i (December-March), *Chydorus sphaericus, Ceriodaphnia pulchella* and *Diaphanosoma brachyurum* (May-September). Results of n-MDS showed that environmental variables and zooplankton community exhibited similar spatial and inter-annual patterns. However, there were differences between the samples collected in the months of March/December and May/September in both years. Results of CCA revealed water temperature and algal biomass as the main environmental gradients that influenced the zooplankton community. Since some of the observed changes in the zooplankton composition might have been induced by other complex abiotic/biotic interactions, this study therefore concluded that further research is required to understand the complexity of the interactions between biological, environmental and climatic parameters of the reservoir. Understanding the dynamics and nature of zooplankton communities is crucial for the implementation of good management practices for reservoirs.

Keywords: zooplankton, Cladocera, Copepoda, Rotifera, reservoir, Iberian Peninsula (Portugal)

1. INTRODUCTION

Zooplankton community is the result of colonisation followed by species selection processes. Both, colonisation and selection, depend on physical and chemical water conditions in reservoirs. Water quality is directly influenced by watershed geology, climate and by the degree of human disturbance [1]. Therefore, understanding the dynamics and nature of zooplankton communities may constitute an important source of information to implement correct management practices in order to maintain water quality of reservoirs in a perspective of multiple-use approach of these ecosystems. Indeed, zooplankton, despite of not being recognised as a biological quality element by European Union Water Framework Directive, shows quick responses to environmental changes and so, it can be regarded as a valuable indicator for evaluate ecosystem integrity. This value steams from zooplankton position in food web: it constitutes a crucial link in the energy transfer to higher trophic levels being a keystone on ecosystem functioning. Moreover, its size, structure, reproduction and survival, among other characteristics, are affected not only by environmental variables (e.g., water temperature), but also by both top-down (fish or invertebrates) and bottom-up (nutrient level and phytoplankton) controls. Thus, the zooplankton

community structure reflects the variability of environmental factors, disturbance events and ecosystem resilience [2, 3, 4, 5, 6, 7, 8].

The present paper focused on the zooplankton community patterns in Aguieira reservoir, an impoundment built in River Mondego catchment. The aim of this research was: (1) to characterise zooplankton community and (2) to assess how zooplankton community responds to the variations of several environmental parameters.

2. MATERIAL AND METHODS

2.1 Study site

Aguieira Reservoir (40º19'53, 83"N; 8º 11'47, 76"W; altitude: 441 m) is located in the Iberian Peninsula, in Portugal, on the Mondego River catchment (Figure 1). In the region, where this reservoir is located, the climate is influenced by the Mediterranean with warm, dry summers and mild winters.The area of the reservoir is 2000 ha and its total capacity is 423030 x 10^3 m^3. Maximum depth is about 50 m. This reservoir was filled for the first time in 1981, and it is used mainly to generate hydro electrical power and to provide urban water supply. The catchment is occupied with intensive forestry, agriculture, livestock production and by several medium sized towns. The main industrial activities are olive oil and textile industries. Further information concerning this reservoir can be found in Anonymous (2005).

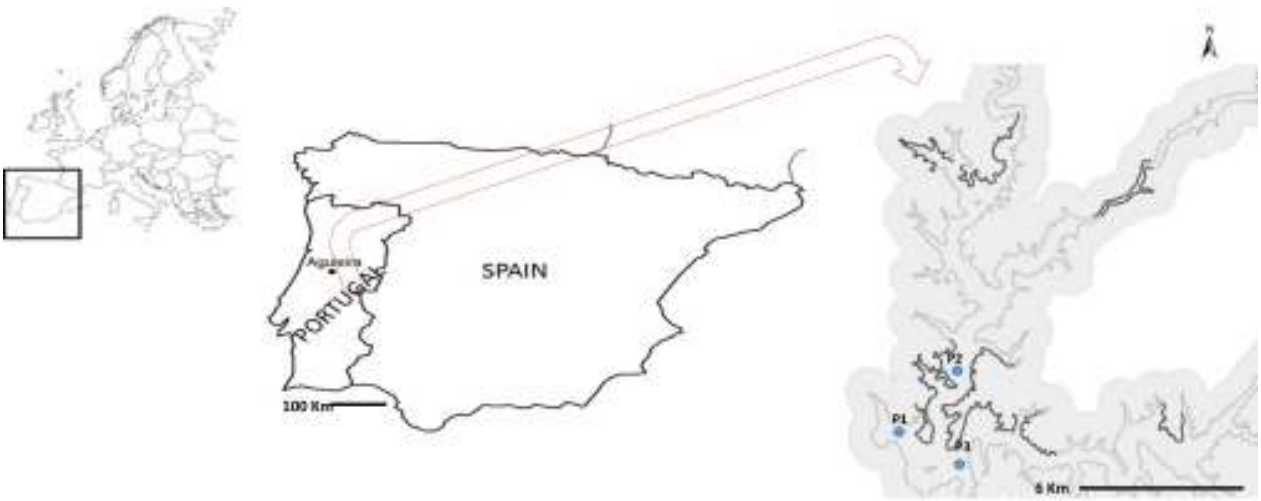

Fig. 1. Aguieira Reservoir location and sampling sites.
Reservoir's map was adapted from [9]

2.1 Field sampling and laboratory analysis

A total of twenty-four zooplankton and water samples were collected in March (spring), May (early summer), September (late summer) and December (winter) in 2010 and 2011 at three sampling sites: P1, P2, P3 (Figure 1).

Chlorophyll *a* concentrations (CHL *a*) were calculated from water samples taken with a van Dorn bottle at 2 m intervals in the euphotic zone (the extension of euphotic zone was considered to be about twice the Secchi depth). CHL *a* concentrations were determined spectrophotometrically after overnight extraction in 90% acetone [10]. Water temperature, pH and conductivity were determined "in situ" using a multiparameter probe (YSI 6820). Water transparency was estimated as Secchi disk depth (20 cm diameter black and white disk). Zooplankton was collected on each sampling date and site by taking two vertical hauls using a 64 µm mesh size Wisconsin type net equipped with a flowmeter. Per each haul 100

litres of water were filtered. Samples were concentrated to a volume of 100 ml. Animals were anaesthetised with carbonated water and preserved in sugar-saturated formaldehyde (4% final concentration). Depending on density, zooplankton in 5, 10, 20 ml sub-samples or in total sample were counted and identified to the genera/species level. Carlson's Trophic State Index (TSI) [11] was computed from Secchi disk transparency (TSI (SD)), and from CHL *a* concentrations (TSI (CHL)).

2.2 Data analysis

Non-metric Multidimensional Scaling (n-MDS) was used to determine whether environmental variables and zooplankton community had changed seasonally, yearly and spatially. Bray-Curtis distance was used to measure the dissimilarity between samples. In this method samples were arranged in a continuum that those close together are similar and those which are far apart are dissimilar. Statistical differences between clusters identified in n-MDS plot were investigated by a randomization method, ANOSIM [12]. This method employs R statistics to examine the existence of differences between the established groups for each considered factor (groups and differences between sampling sites, seasons and years). To determine the influence of the studied environmental variables on zooplankton composition, a Canonical Correspondence Analysis (CCA) was performed. In both analyses, taxa were included only if they reached a relative abundance larger than 1%. Absolute zooplankton counts were transformed to log (x+1), and rare species were down weighted. In CCA the automatic forward selection procedure by Monte Carlo permutation tests (9999 permutations) was used to remove the redundant environmental variables, allowing the selection of those contributing to the explanation of the whole data set [13].

3. RESULTS

3.1 Environmental variables

Environmental variables showed similar values during both years in each sampling site (Table 1). Spatial and inter-annual variations in these parameters were not relevant. However, n-MDS ordination (Figure 2) was able to differentiate two groups: samples obtained in December and March (winter and spring) from those obtained in May and September (early and late summer) (2D stress: 0.02). ANOSIM test confirmed significant differences between the two groups (R= 0.829; p<0.001). The highest values for water temperature, pH, CHL *a* concentrations were observed in the samples obtained in May and September. Conversely, the highest values of Secchi disk depth were observed in December and March. According to Carlson's Trophic State Index (the two components together- TSI (SD) and TSI (CHL *a*), this reservoir was classified as mesotrophic in December and March (the values ranged between 24 and 42 for both components of the index). In May and September, it was eutrophic (values of both components of the index (SD and CHL *a* reached 57).

Table1. Minimum-maximum range of environmental variables obtained for 2010 and 2011 in the different sampling sites.

	2010			2011		
Parameter	P1	P2	P3	P1	P2	P3
Water temperature (º C)	11.9-23.0	12.2-23.2	12.8-22.8	14.7-25.0	14.2-26.0	13.4-25.3
pH	7.3-9.9	7.2-10.1	7.3-10.0	7.1-9.8	7.2-10.2	7.3-9.7

Conductivity (µS cm^{-1})	70.4-104.5	76.2-100.1	68.8-94.6	64.8-104.5	63.4-102.1	62.0-102.6
Secchi disk (m)	1.5-3.0	1.5-3.0	1.5-3.0	1.2-4.0	1.2-5.0	1.2-5.5
Chlorophyll *a* (µg L^{-1})	0.4-16.2	0.4-14.2	1.4-15.7	0.5-14.4	0.9-10.7	0.5-5.9

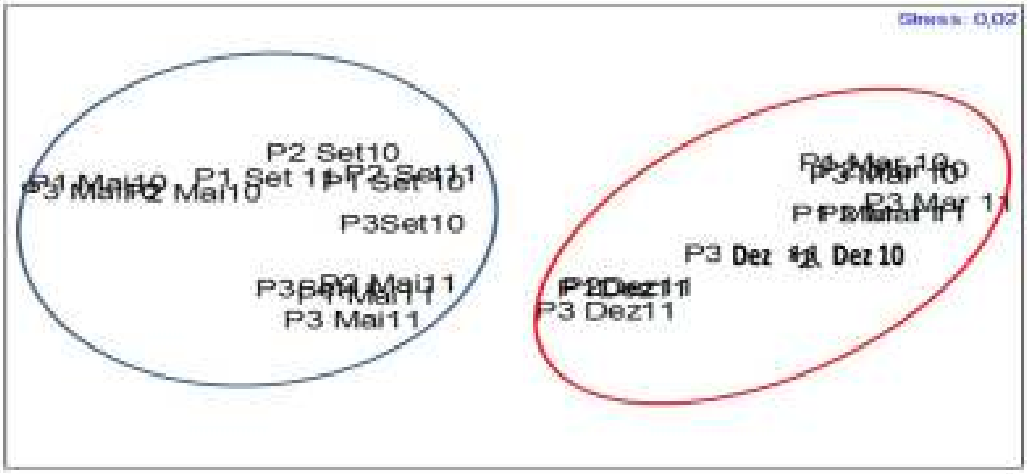

Fig. 2. Results of n-MDS ordination considering environmental variables.
Sampling sites: P1, P2, P3
Dez, Mar, Mai, Set: Samples obtained in December, March, May and September, respectively.

3.2 Zooplankton community

During the sampling period 12 taxa of Rotifera, 8 of Cladocera and 3 of Copepoda were recorded (Table 2). The zooplankton community was dominated in May and September by Rotifera (mainly *Keratella* and *Polyarthra*), whereas Copepoda (mainly *Copidodiaptomus numidicus* and *Tropocyclops prasinus)* were dominant in December and March. Cladocera was the less abundant taxon: was represented, in December and March, mainly by *Daphnia longispina* and *Bosmina coregoni*. Conversely, in May and September *Chydorus sphaericus, Ceriodaphnia pulchella* and *Diaphanosoma brachyurum* became dominant (Figures 3, 4 and 5). n-MDS ordination (Figure 6) was able to differentiate the occurring shifts between the samples obtained in December and March and those obtained in May and September (2D stress: 0.12). ANOSIM test confirmed the significant differences between the two groups (R=0.803; p<0.001).

Table 2. Taxonomic composition of zooplankton community between 2010 and 2011.

ROTIFERA	CLADOCERA	COPEDODA
Asplanchna priodonta	*Alona* sp.	*Acanthocyclops robustus*
Brachionus sp.	*Bosmina coregoni*	*Copidodiaptomus numidicus*
Conochilus sp.	*Bosmina longirostris*	*Tropocyclops prasinus*
Filinia sp.	*Ceriodaphnia pulchella*	Nauplii
Gastropus sp.	*Chydorus sphaericus*	
Hexarthra mira	*Daphnia longispina*	
Keratella cochlearis f. cochlearis	*Daphnia parvula*	
Keratella cochlearis f. tecta	*Diaphanosma brachyurum*	
Ploeosoma sp.		
Polyarthra sp.		
Synchaeta sp.		
Trichocerca sp.		

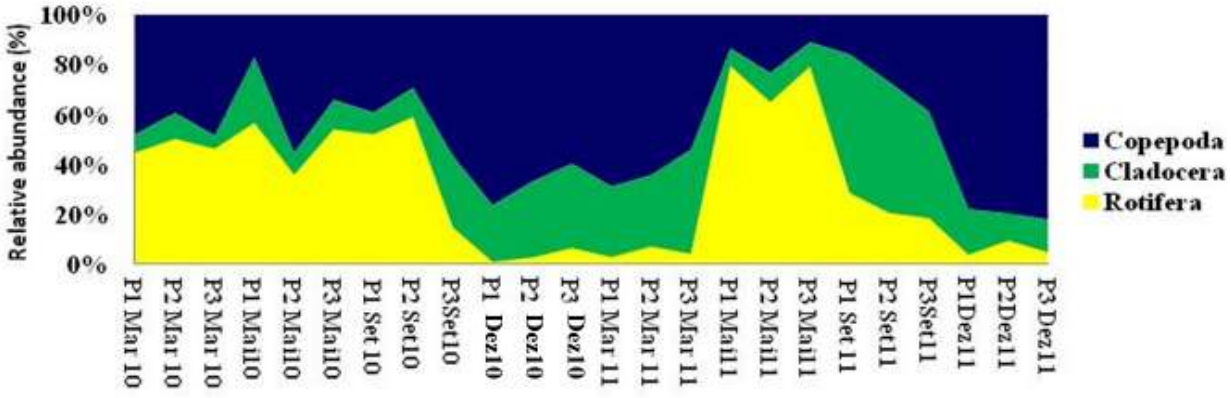

Fig. 3. Relative abundance (%) of Rotifera, Copepoda and Cladocera in the sampling sites from March to December 2010 and 2011.

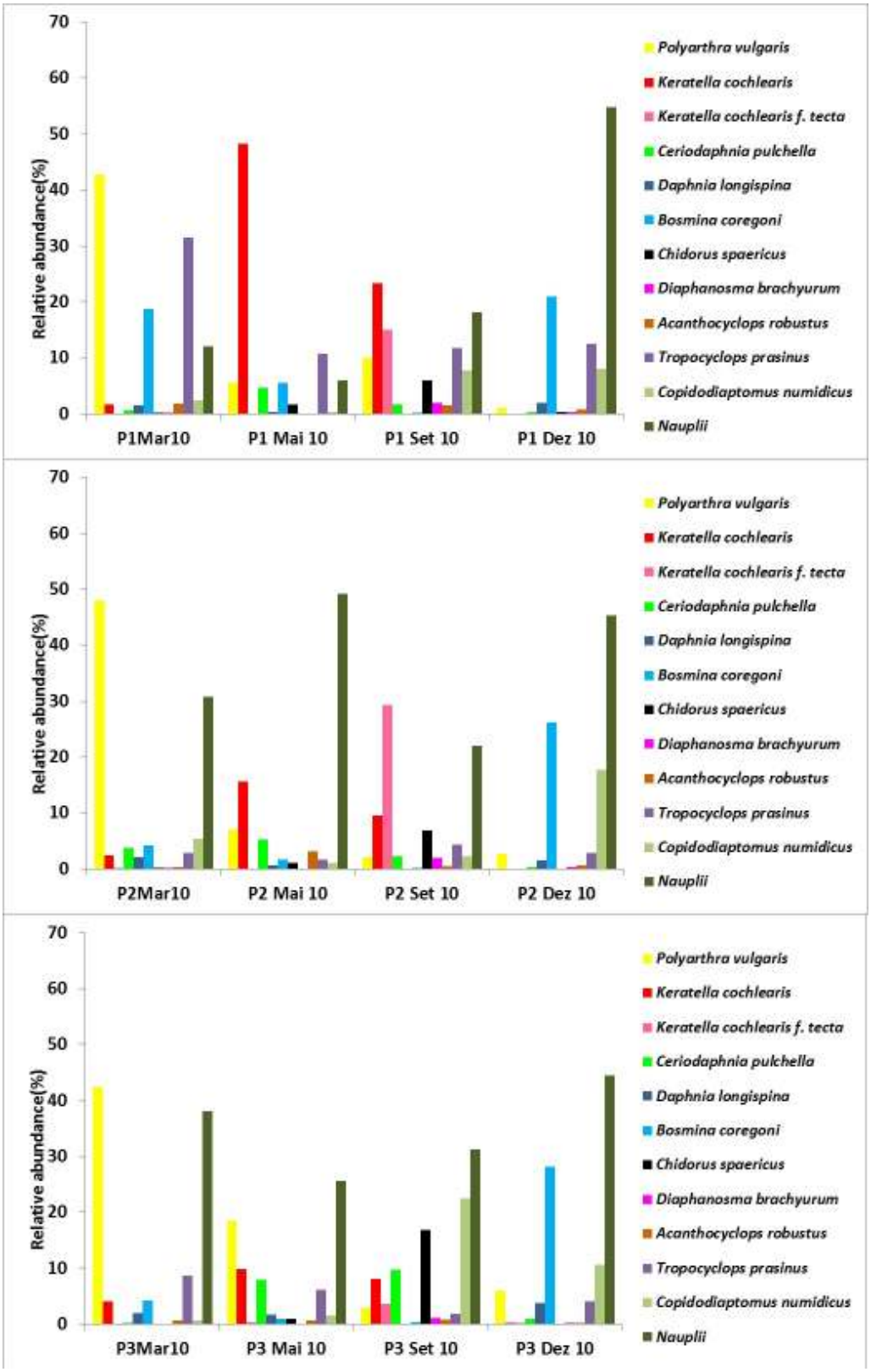

Fig. 4. Spatial-temporal variation of relative abundance and composition of the most abundant zooplankton taxa in March, May, September and December 2010.

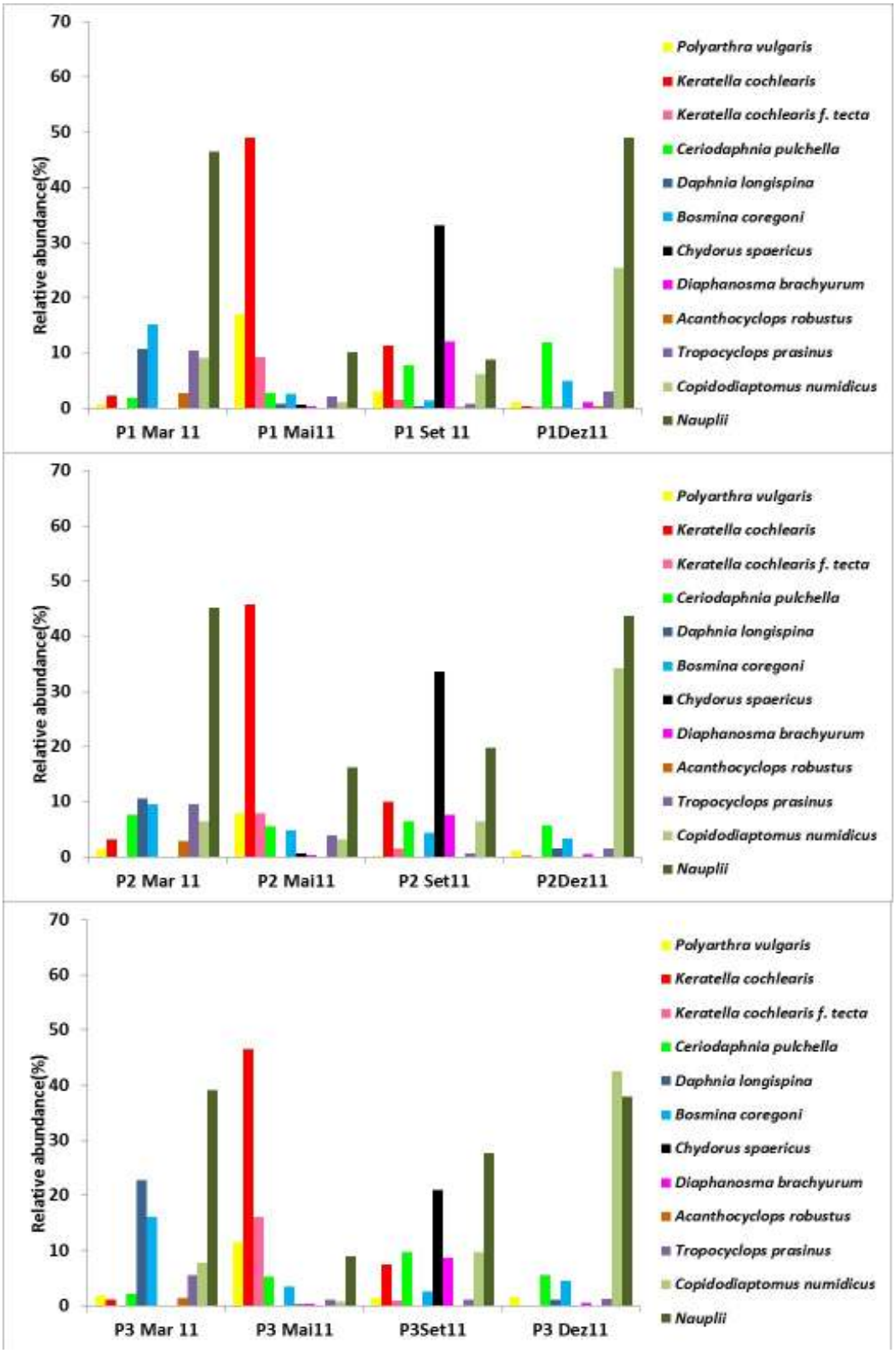

Fig. 5. Spatial-temporal variation of relative abundance and composition of the most abundant zooplankton taxa in March, May, September and December 2011.

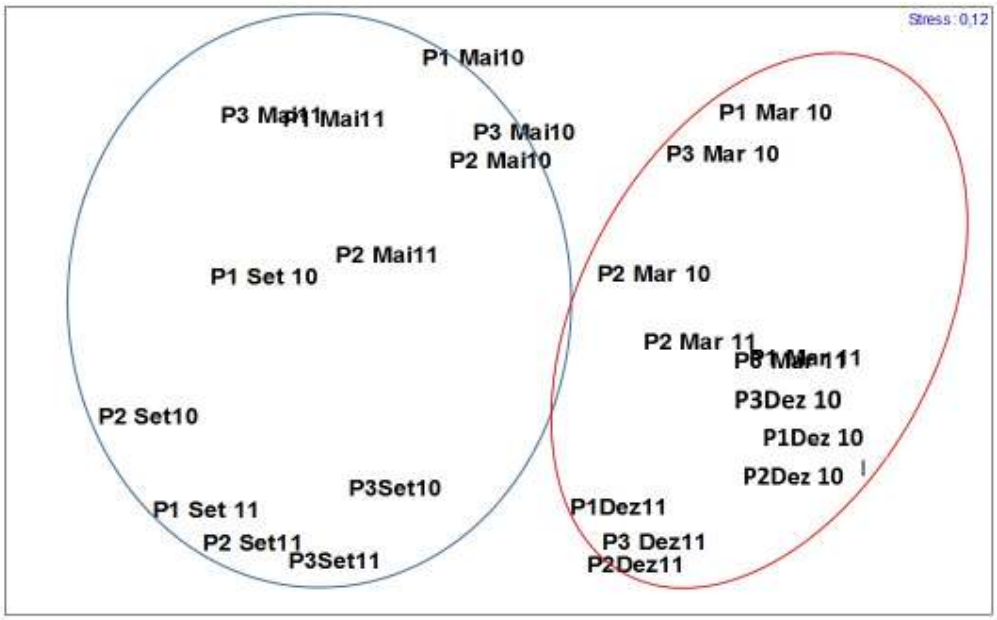

Fig. 6. Results of n-MDS ordination considering zooplankton.

P1, P2, P3 - sampling sites.
Dez, Mar, Mai Set-Samples obtained in December, March, May and September, respectively.

The diagram depicted on figure 7 resulted from CCA analysis applied to the most correlated environmental variables and zooplankton taxa. The ordination space defined by the first two CCA axes accounted for 70% of species-environment relation and represented 45% of the variation in species data. With forward selection and Monte Carlo permutation test a sub-set of environmental variables that significantly ($p<0.05$) explained the variation in species data was identified. In descending order of significance the variables included in that sub-set were: water temperature (P=0.0000), CHL *a* (P=0.004), Secchi disk depth (P=0.004) and conductivity (P=0.009). Therefore, some species/genera were found to be associated to the increase of water temperature and of algal biomass (CHL *a* concentrations). These were all the Rotifera (excepting *Gastropus* sp.) and the Cladocera *Ceriodaphnia pulchella*, *Diaphanosma brachyurum* and *Chydorus sphaericus*. Whereas, Copepoda and the Cladocera *Daphnia longispina, Bosmina coregoni* and *B. longirostris* were related to lower water temperature, algal biomass and to the increasing of water transparency (higher Secchi disc depth).

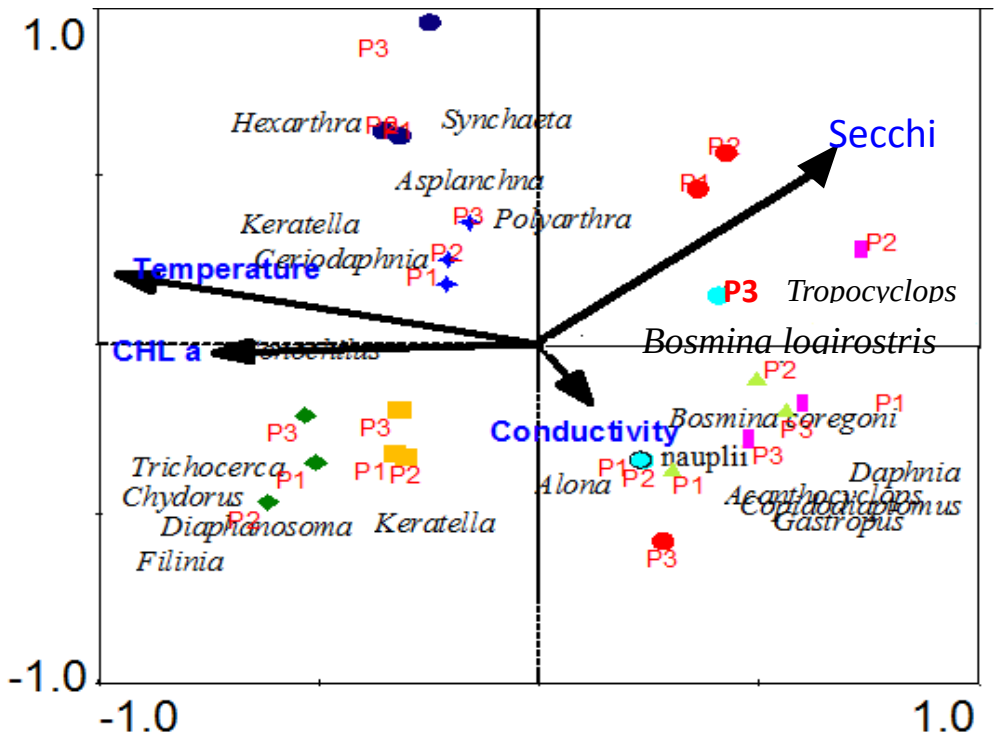

Fig. 7. Results of CCA.
Scatters with samples: March 2010 – red circles; May 2010 – blue stars; September 2010 – yellow squares; December 2010 – pink rectangles; March2011 – green triangles; May 2011 – dark blue circles; September 2011 – green diamonds; December 2011– light blue circles.

4. DISCUSSION

During the period of study, zooplankton community followed a pattern strongly influenced by two gradients: the first was the temporal gradient related to temperature, and the other was the trophic gradient related to algal biomass (CHL *a*), which, ultimately, influenced Secchi disk depth (Figures 4, 5, 6 and 7). A seasonal succession was apparent in this zooplankton community, with species dominating in turn as changing conditions became suitable for each. In March and December (winter and early spring), *Tropocyclops prasinus Copidodiaptomus numidicus, Daphnia longispina* and *Bosmina coregoni* were more abundant, and some of them became virtually absent in May and September (early and late summer), being replaced by Rotifera, *Ceriodaphnia pulchella*, *Diaphanosma brachyurum* and *Chydorus sphaericus*, which are more thermophylic and typical for more eutrophic environments [14, 15]. This shift was also influenced by algal biomass and composition: in May and September, phytoplankton community is dominated by Cyanobacteria [16, 17, authors' unpublished data]. The conditions created by late spring and summer temperatures and irradiance combined with a plausible higher level of nutrients must have been provided the ecological optimum for Cyanobacteria dominance [18, 19]. It is well known that either by being of low nutritional value, by clogging the feeding apparatus or by producing toxins Cyanobacteria may be important drivers in zooplankton composition and abundance [20, 21, 22]. In the presence of Cyanobacteria, zooplankton composition is frequently changed: large Cladocera (such as *Daphnia longispina*) and herbivorous Copepoda (such as *Copidodiaptomus numidicus*) are often replaced by Rotifera and other zooplankters specializing on small particle feeding, which food preferences are mostly

detritus-bacteria [2]. Similar results were observed in other reservoirs influenced by Mediterranean climate [23, 24, 25, 26].

5. CONCLUSION

The preliminary results of the present study suggest that temperature had a direct and strong influence on zooplankton community patterns. However, a wide range of physical, chemical and biotic interactions is likely to influence zooplankton abundance and community structure. Therefore, it is necessary to be cautious when relating the observed shifts exclusively with temperature and Cyanobacteria presence. Some of the observed changes might have been induced other complex abiotic/biotic interactions independently of those studied in the present approach. Thus, further research will be required in order to understand the complexity of the interactions between biological, environmental and climatic parameters in this reservoir.

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