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Effects of salinity and water temporality on zooplankton community in coastal Mediterranean ponds

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ABSTRACT

Some of the predicted effects of climate warming in Mediterranean climate are the increase of temperature, change of precipitation patterns and the rise in sea levels. This will have major consequences, mainly in coastal aquatic ecosystems, by the increase of salinity and the reduction of the flooding period, affecting the whole aquatic community. To assess on the possible consequences of the global change in the zooplankton community of Mediterranean coastal lakes, we analized the zooplankton diversity in a set of lakes with different salinity and water permanence time. The ponds were classified in four groups: permanent and temporary freshwater ponds, and permanent and temporary brackish ponds. Whereas we did not detect a great effect of hydroperiod on zooplankton community, the increase in salinity produced (through direct and indirect interaction) a rise in rotifer density and a reduction in cladoceran cumulative richness, richness per visit and diversity. All these differences were remarkable in Permanent Brackish lakes, the group which showed the higher dissimilarity with the other groups of lakes. The disappearance of cladocerans in these systems can lead to an increase in the eutrophication and a reduction of diversity.

1. Introduction

Most predictions suggest that human induced climate change will melt ice and raise sea levels due to the increase in temperature. Models indicate that aquatic systems in Mediterranean climate may be among the most impacted by climate change (Sala et al., 2000), since it will suffer reductions in rainfall, which will increase drought conditions (Fischlin et al., 2007). If this occurs, it will have a great impact in wetlands, as transitional environments, causing major changes of the hydrology, chemistry and sediment loads (Pearce and Crivelli, 1994; Fischlin et al., 2007). Coastal lagoon landscapes comprise peripheral wetlands along the shore of the coastal lagoon and dune-slack ponds on the lido and on the barrier islands. These systems form a part of ecotones running from freshwater, brackish to the saline water in the lagoons and the sea and their study is, therefore, also pertinent for coastal lagoon ecology *sensu lato*. Because of climate change, Mediterranean coastal wetlands, specifically, may have changes in salinity and a reduction in the time and extent of wetland inundation, due to the increase of marine influence and the rise of temperature and evaporation, respectively (Nielsen and Brock, 2009). All these changes will have consequences in species composition and food web interactions (Hughes, 2004; Fischlin et al., 2007). In zooplankton community, it is expected that these changes will have a great impact, since they are passive dispersal species creating isolated populations that will have to be capable of reproduce, disperse and recolonize in the new conditions of the lakes (Nielsen and Brock, 2009). Some studies are focussed on the combined effects of these two variables on aquatic community and all of them agree that the increase in salinity and reduction of hydroperiod will lead to a reduction in diversity and important changes in community composition (Boix et al., 2008; Waterkeyn et al., 2008). On one hand, salinity is known to be a strong mechanism of change in aquatic communities, causing the disappearence of species that cannot tolerate the increase of salt concentration. Studies centered on this variable show that the rise in salinity produces a reduction in species richness and diversity in the zooplankton community (Nielsen et al., 2007; Boix et al., 2008; Jensen et al., 2010). This fact will be especially important for cladocerans, since this group is susceptible to these rises (Jeppesen et al., 1994; Moss, 1994), except for few salinity tolerant species, as *Daphnia magna* (Ortells et al., 2005). This will cause important shifts in zooplankton communities: from a community dominated by large-sized cladocerans at low salinities, to another dominated by copepods (mainly calanoids) and rotifers (Schallenberg et al., 2003; Jeppesen et al., 2007;

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Brucet et al., 2010) at high salinities. As the second group are less efficient filter-feeders, the community changes can lead to modifications in other environmental variables, as turbidity or nutrient concentration (Jensen et al., 2010). Furthermore, an egg bank subjected to long term increased salinity is unlikely to emerge and reproduce (Nielsen and Brock, 2009). On the other hand, the reduction of flooding can cause the drought of temporary wetlands, or the conversion of permanent ponds in temporary ones (Nielsen and Brock, 2009). That means the disappearance of the whole zooplankton community in some cases, or the need to survive the dry period, throughout faster life-cycles, diapausing eggs or resting stages (Wellborn et al., 1996; Williams, 2006). In an experimental work made by Nielsen et al. (1999) to study the effect of hydrological variation, a reduced duration of flooding caused changes in aquatic community composition and a decrease in species richness. Furthermore, all these changes will affect indirectly other features of the ecosystem, such as trophic level, as said below, or predation. In brackish systems fish community changes related to the salinity gradient, with a community dominated by small planktivorous fish in the highest salinities (Brucet et al., 2010; Jensen et al., 2010). Moreover the number of macroinvertebrate predators is higher. Both predator groups will be also highly affected by the temperature, hence a rise in this variable will increase the predation pressure on zooplankton community, modifying its composition and diversity (Brucet et al., 2010).

The objective of this study is to analyze zooplankton communities in a set of ponds with different characteristics (particularly salinity and water permanence time) to infer the possible effects on these organisms of the increasing temperature and salinity in the Mediterranean region.

2. Material and methods

2.1. Study area

Eighteen shallow coastal ponds along the East Coast of Spain were selected, all under Mediterranean climate conditions. These ponds were located in four protected areas: l'Albufera Natural Park (Valencia); El Hondo Natural Park (Alicante), Salinas de Santa Pola Natural Park (Alicante) and Clot de Galvany Natural Place (Alicante). L'Albufera Natural Park has a big freshwater lagoon (l'Albufera, 22 ha), but the studied ponds were located in the sandy stretch that separates this lagoon and the sea. A set of eight small peridunal ponds were sampled: two were permanents, but the others were temporary, highly dependent of rainfall. All of them had low salt concentration, except one of the temporary ponds.

The other ponds were located in the South of Alicante (approximately 150 km south). They are the remaining water bodies of an ancient coastal lagoon, which, due to the heavy artificial modification, disappeared, creating a high amount of water bodies with differences in size: from small ponds to big lagoons. All the selected ponds were brackish, except one artificial pond filled with water from a sewage treatment plant. Most of these lakes were permanent, since the water levels were artificially maintained (in some cases for fishing and hunting), but some of them dried during the warmest months of the year. In this area there is a high anthropic pressure, causing big problems in the quality of the water, mainly due to eutrophication, salinisation and desiccation.

All the sampling stations were grouped in four sets, depending on salinity (a 3‰ threshold was chosen) and water temporality: Permanent Freshwater (PFW), Temporary Freshwater (TFW), Permanent Brackish Waters (PB) and Temporary Brackish Waters (TB).

2.2. Field sampling and laboratory analysis

All the ponds were sampled monthly during spring: three times for the permanent systems and between one and three times for the temporary ones (depending on hydroperiod length). In each one, we measured *in situ* variables: conductivity, pH, dissolved oxygen and depth. Pond area was measured from aerial photographs using the free software from the Spanish Government (SIGPAC). 1.5 L water samples were also taken for analysis of nutrients and pigments in the laboratory: dissolved phosphorus and nitrate were measured by colorimetry from filtered water through a Whatman GF/F filter (APHA, 1980). Chlorophyll *a* was measured extracting this pigment from the Whatman GF/F filters with Acetone 90%, and measuring the maximum absorbance with a spectofotometer (Hitachi U2001). The final concentration was calculated following Jeffrey and Humphrey (1975).

Zooplankton samples were taken by filtering a known volume of water (between 6 and 10 L) from the first 0.5 m in the water column through a 35 μm mesh. The organisms retained in the filters were stored in 4% formalin, then identified and the whole sample was counted in the laboratory using an inverted microscope.

In every sample station different community parameters were calculated for each of the main zooplankton groups (rotifers, copepods and cladocerans): mean density, cumulative richness (as the sum of all the species found during the sampling period in each pond), richness per visit and Shannon–Wiener diversity index.

2.3. Statistical analysis

To compare the community parameters in the four groups of lakes, Kruskal–Wallis analysis were performed using PAST (Hammer et al., 2008), and when it showed significant differences, the paired groups were analyzed through a Mann–Whitney test.

To explore the ordination of samples and species in relation to the environmental variables, a CCA was made. Moreover, to test the effect of geographical distribution of ponds in the ordination of our samples, the explanatory power of location (2 categories: Valencia and Alicante) was explored using variance partitioning through another CCA. The rarest organisms were eliminated for these analyses (the ones which appeared with a frequency lower than 5% and in less than 5 sites). Zooplankton densities and environmental variables, except pH, were log transformed.

Table 1
Mean values ± standard deviation of some environmental variables in the four groups of lakes.

	N	Depth (cm)	Conductivity (mS cm^{-1})	pH	Oxygen (mg l^{-1})	Phosphate (mg l^{-1})	NO3 (mg l^{-1})	Chla (μg l^{-1})
Permanent Freshwater PFW	3	119 ± 72	2.4 ± 1.0	8.8 ± 0.3	7.2 ± 3.8	0.89 ± 1.48	0.24 ± 0.02	89.48 ± 151.37
Temporary Freshwater TFW	5	20 ± 13	1.8 ± 0.9	8.8 ± 0.6	8.3 ± 0.9	0.04 ± 0.001	0.27 ± 0.04	3.29 ± 3.44
Permanent Brackish PB	7	57 ± 24	14.9 ± 2.5	8.5 ± 0.6	12.7 ± 4.3	0.02 ± 0.02	0.44 ± 0.33	90.64 ± 128.39
Temporary Brackish TB	3	35 ± 14	12.0 ± 5.4	8.4 ± 0.7	7.9 ± 4.8	0.08 ± 0.09	0.25 ± 0.02	7.87 ± 5.29
Total	18	58 ± 44	7.9 ± 6.8	8.6 ± 0.2	8.9 ± 2.4	0.26 ± 0.42	0.30 ± 0.09	51.11 ± 52.93