



Influence of biotic variables on invertebrate size structure and diversity in coastal wetlands of Southeastern Spain



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ABSTRACT

Biomass and size-based estimations provide relevant information regarding ecosystem functioning and biotic interactions. Our aims were to study the effect of fish and macrophytes on the size structure of invertebrate assemblages (from rotifers to insects) in a set of coastal water bodies, estimating the biomass (total and main invertebrate groups), the biomass-size spectra (model of Pareto) and size diversity. In fishless ponds, cladoceran and ostracod biomass were higher, and they presented greater size diversity. In fish ponds, rotifer biomass presented greater proportion; while in fishless ponds, cladocerans were usually the most abundant taxa and the largest organisms. The biomass size spectra showed more irregularities in fishless ponds, due to the low densities of small taxa (rotifers and copepod juveniles) and big taxa (malacostraceans or insects). Differences in size structure and diversity were also observed between spring and summer, suggesting a higher recruitment of juveniles in spring, and thus, a higher predation pressure upon zooplankton at that moment. Macrophyte cover did not apparently influence those parameters, except for the biomass of ostracods, copepods, and insects. Therefore, predation by fish strongly affected invertebrate biomass, reflecting their selective feeding, and allowing high densities of small taxa. Predation pressure decreased size diversity, by limiting the abundance of vulnerable taxa of specific size. Seasonal changes were likely related to the spring recruitment of fish juveniles. The presence of small fish and invertebrate predator taxa among the macrophytes, restrict their role as refuges for prey invertebrates.

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1. Introduction

Body size and biomass estimations have been proven as a useful tool in the study of food web ecology and biodiversity-ecosystem functioning, in order to search for a more integrative approach for ecosystem ecology, especially in multispecies systems (Rodríguez, 1994; Woodward et al., 2005; Belgrano and Reiss, 2011). They have also been proposed as indicators of ecological status in aquatic ecosystems (De Eyto and Irvine, 2007; Petchey and Belgrano, 2010). The size structure of a community can give complementary information to the traditional one provided by the taxonomic description and density, particularly when there are notorious differences in size among the diverse taxonomic groups, as occurs in zooplankton assemblages (Gaedke et al., 2004; Quintana et al., 2006). Undoubtedly, the functional role of an individual is influenced by its size, which shows a wide range of

variation (among and within species) and makes the size-based approach greatly valuable to study the organization of ecological communities and their global properties (Blanco et al., 1994; Woodward et al., 2010; Belgrano and Reiss, 2011). In addition, size-based approaches contribute joining processes occurring from an individual (growth, physiology, mortality) to an ecosystem level, such as competition, predation, or interaction with the physical environment (Lazzaro, 1987; Rodríguez, 1994). Thus, when differences among size of different organisms in a community are big, biomass and size structure estimations could be more appropriate, and could facilitate comparisons among different communities (Gaedke et al., 2004; Quintana et al., 2006). Community size structure depends on size-dependent events, such as predator:prey size ratios, or ecological and physiological laws, and it has been mostly used to analyze biotic processes, such as competition, predation or variation in diet along different stages of the same species (Zimmer et al., 2001; Quintana et al., 2002; Bruçet et al., 2005; Badosa et al., 2007; Quintana et al., 2015).

Normally, size-based approaches have been commonly

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performed in marine ecosystems (Rodríguez and Mullin, 1986; Duplisea, 2000; Simm et al., 2014). In freshwater habitats, they have been normally focused separately on limnetic (Rojo and Rodríguez, 1994; Sprules and Munawar, 1986; Cohen et al., 2003) or benthic habitats (Rasmussen, 1993; Basset et al., 2004). It has been suggested that the processes affecting the size distribution in pelagic habitats are different from the benthic ones, e.g. the latter with a smaller influence of predation (Zimmer et al., 2001). However, in very shallow lakes, benthic-pelagic communities are quite close, with tight interactions between organisms living in the water column and those inhabiting the sediment (Zimmer et al., 2001; Quintana et al., 2006; Anton-Pardo and Armengol, 2014). Additionally, the presence of submerged macrophytes reaching the water surface in extended areas of these habitats, increases the surface for benthic organisms and provides new substrates, so it makes the spatial separation of benthic and pelagic habitats quite arbitrary (Zimmer et al., 2001).

The influence of predators has been proven as a main cause of variation in prey size. Fish are the main predators in aquatic habitats, where planktivorous fish frequently select bigger invertebrates to feed (normally large cladocerans), in turn, modifying community composition and reducing the average body size of zooplankton communities (Brooks and Dodson, 1965; Brucet et al., 2010; Anton-Pardo and Armengol, 2014). Piscivorous fish in freshwater have been considered a keystone species and a paradigm for the trophic cascade hypothesis (Carpenter et al., 1985). When they are abundant, fish will invert such scenario, increasing the average body size and controlling more efficiently phytoplankton biomass (Jeppesen et al., 2010). However, in the Mediterranean region, piscivorous fish are mostly absent and fish community is dominated by planktivorous and benthivorous species (Blanco et al., 2003). Fish activity may have important seasonal variations, because it is largely affected by water temperature and other variables, which also influence the spring recruitment of juveniles (Blumenshine et al., 2000; Stoner, 2004). Therefore, the selection of preys (invertebrates) according to the visual abilities of fish as well as to the mouth gape in different developmental stages, will also influence the size structure of the invertebrate community (Nunn et al., 2012).

Furthermore, it is well established that submerged vegetation plays a key role in the functioning of shallow waters, as it changes the environmental characteristics and provide food and refuge for many aquatic organisms (Scheffer, 2004). Thus, invertebrates of certain size more vulnerable to visual predators, could use this microhabitat as a daytime refuge, moving to open water areas at night. This mechanism, known as horizontal migration, will allow the presence of these vulnerable organisms in areas where fish pressure is high (Burks et al., 2001; Scheffer, 2004; Rennie and Jackson, 2005).

To study the size structure of the community, different approaches have been used. Firstly, total and relative biomass of the different taxa can revert abundance relationships, giving more relevance to the less abundant but bigger organisms (Simm et al., 2014). Secondly, the biomass-size spectra have been commonly employed as a complementary perspective to taxonomic studies (e.g. Blanco et al., 1994; Blumenshine et al., 2000), analyzing the organism abundance classified in regular size classes, which can be adjusted to a linear or non-linear model. Normalized biomass size spectra (NB-SS) have been widely used, although the subjective selection of logarithmic size classes and the appearance of empty classes influence the results (Vidondo et al., 1997). With the use of the model of Pareto, based on probability distribution, the problems associated to the discrete model of NB-SS have been solved, since it is a continuous function and it does not need the classification of individuals in size classes (Vidondo et al., 1997). When the

sizes of the organisms are distributed according to this model, the plot of the model will display a straight line, and the obtained slope of the line and the fit to a linear model (r^2) have ecological implications (Quintana, 2002; Quintana et al., 2002; Brucet, 2003; Gaedke et al., 2004; Quintana et al., 2006). For example, a decrease in the fit (r^2) may be caused by hydrological disturbances or when the abundance or biomass of small particles is lower than that predicted by the model (Brucet et al., 2005; Quintana et al., 2006). Hydrological disturbances can also increase the slope of the spectrum, while competition within functional groups may result in steeper slopes (Vidondo et al., 1997; Quintana et al., 2006). Finally, size diversity, similar to the Shannon-Wiener diversity index, provides information not only on the range of the size distribution, but on its evenness in the studied community, contributing to the knowledge of the size-based organization of communities (Quintana et al., 2008).

In the present work, we will use the above mentioned approaches to infer the effect of fish and macrophytes on the size structure of invertebrate assemblages in a set of shallow coastal ponds. We hypothesize that (i) predation by fish will decrease the total biomass and size diversity of zooplankton, increasing the abundance of small-size organisms less vulnerable to visual predation; (ii) the effect of fish on invertebrate biomass and size distribution will be variable over time, with higher pressure in summer –with higher temperatures– compared to spring; and (iii) the development of macrophytes in fish ponds will offer a refuge against predation allowing the presence of invertebrates more vulnerable to predation, so it will positively influence size diversity, biomass and the presence of large invertebrates.

2. Materials and methods

2.1. Study area

The study was conducted in eight shallow coastal ponds located in the flood plain of the rivers Segura and Vinalopó (Southeastern Spain). The selected water bodies are enclosed in three different protected areas: one reservoir (EL) and four ponds (NO, RE, WP and SA) in El Hondo Natural Park; two ponds (CH and SF) in Salinas de Santa Pola Natural Park, and one (GC) in Clot de Galvany Local Natural Place. The number of sampling points in each of these ponds was chosen according to pond size and their heterogeneity: one point in CH, SA and GC; two in WP, NO, SF; three in RE and four in EL (Table 1). The size of the water bodies ranged from 1 to 246 ha, and the set of water bodies presented a high spatial and temporal heterogeneity in variables such as conductivity, depth, or nutrient and chlorophyll *a* concentration (Anton-Pardo and Armengol, 2014).

Regarding the fish communities in the water bodies, two of the ponds (GC and EL) were considered fishless: in GC fish were absent, while in EL fish populations were not observed during the study. EL is a big reservoir used mainly for irrigation and it is strongly subjected to artificial water level variations, causing its drought once or several times a year. Thus, fish populations cannot establish permanently, but they can recolonize the water body in low densities when it is filled. When this reservoir was sampled (June 2005), it had been dried for more than one month, so fish were considered absent at that time. In the other ponds fish were abundant (Jimenez et al., 2002): *Mugil* sp. and *Liza* sp. were the dominant species in SF and CH, but they were also found in RE, WP and NO. In these three ponds, *Anguilla anguilla*, and small fish species were also observed (*Gambusia holbrooki*, *Pomatochistus microps* and *Aphanius iberus*). Finally, only small species (*G. holbrooki* and *A. iberus*) were present in SA.

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