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Molluscs associated with a subtidal *Zostera marina* L. bed in southern Spain: Linking seasonal changes of fauna and environmental variables

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ABSTRACT

The temporal variation of the molluscan fauna associated with a deep *Zostera marina* bed (12–14 m depth) in Cañuelo Bay (southern Spain) has been studied in relation to water, sediment and eelgrass variables. Samples of molluscs from the sediment and the eelgrass (5 replicates per season) were seasonally collected using a quadrat of 25 × 25 cm. The water column was characterized by the temperature and chlorophyll *a* concentration. The grain size distribution of the sediment and percentage of organic matter (%OM) were also studied. Estimations of the shoot density, leaf/rhizome biomass and Leaf Area Index (LAI) have been obtained for each sample. Statistical analyses have been performed with SYSTAT and PRIMER software. A total of 2396 individuals and 85 species of molluscs were collected. The most dominant species were infaunal bivalves such as *Tellina distorta* (28.1%), *Dosinia lupinus*, *Tellina fabula* and *Chamelea gallina*. The gastropods *Jujubinus striatus* (4.6%), *Nassarius pygmaeus* and *Bittium reticulatum* were the dominant epifaunal species. The most frequent species was *T. distorta* (100%), followed by other infaunal bivalves such as *T. fabula*, *Solemya togata* or *Lucinella divaricata*. The most frequent gastropods were *J. striatus* (95%), followed by *B. reticulatum*, *N. pygmaeus*, *Nassarius reticulatus*, *Mitrella minor* and *Smaragdia viridis*. The abundance of molluscs displayed significant maximum values in summer and autumn (above 2500 indiv. m^{-2}) and minimum values in spring (below 1500 indiv. m^{-2}). The abundance of the epifauna was related with leaf biomass, whereas that of the infauna was positively related with %OM. The species richness also followed a significant seasonal variation with maximum values in summer (64 species in all summer samples) and minimum values in autumn (44 in all autumn samples), and was positively related with LAI. In both qualitative and quantitative cluster/MDS, samples (replicates) mainly grouped according to the season, with significantly different groupings according to ANOSIM analyses. The studied eelgrass bed is less dense, with a lower leaf biomass, than other European eelgrass beds occurring at shallower depths; however the species richness values are the highest along Europe. The latter could be due to its geographical location in the Alboran Sea, where a confluence of Atlantic, Mediterranean and African fauna occurs.

1. Introduction

Seagrass beds are distributed in intertidal and subtidal shores from tropical and temperate areas (Den Hartog, 1970; Phillips and Meñez, 1988; Green and Short, 2003), supporting rich faunistic communities (Hemminga and Duarte, 2000; Williams and Heck, 2001). In Europe, six seagrass species have been registered so far: *Cymodocea nodosa*, *Halophila decipiens*, *Halophila stipulacea*, *Posidonia oceanica*, *Zostera noltii* and *Zostera marina* (Den Hartog, 1970; Green and Short, 2003). Among those, *Z. marina* is the most widespread in the world, with a geographical distribution in temperate areas of the northern hemisphere (Green and Short, 2003). In Europe, *Z. marina* occurs in intertidal and shallow subtidal protected bays and estuaries of the Atlantic coasts and mostly in shallow coastal lagoons of the Mediterranean coasts. In southern Spain (Alboran Sea), this seagrass forms extensive beds in open bays at depths between 5 and 17 m (Bañares et al., 2002; Moreno and Guirado, 2003), which probably represent the deepest ones in Europe.

Molluscs are important components of the benthic macrofauna associated with seagrass beds in terms of number of species and abundance (Williams and Heck, 2001). Moreover, molluscs are important organisms in the food webs of the seagrass bed system (Hemminga and Duarte, 2000). The molluscan fauna associated with seagrasses (e.g. *Zostera* spp., *Posidonia oceanica*) has received much attention in different locations along Europe. In the Atlantic coasts, the assemblages of molluscs associated with *Z. marina* beds are well known in both brackish/estuarine (Jacobs et al., 1983;

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Boström and Bonsdorff, 1997, 2000; Frost et al., 1999; Hily and Bouteille, 1999) and marine conditions (Jacobs and Huisman, 1982; Currás et al., 1993; Fredriksen et al., 2004). In the Mediterranean Sea, the eelgrass associated molluscs have been insufficiently studied in comparison with other areas such as North America (Marsh, 1973, 1976; Thayer et al., 1975; Eggleston et al., 1999; Mattila et al., 1999; Bologna, 2006) or Japan (Toyohara et al., 1999; Nakaoka et al., 2001). This is probably because this seagrass is quite scarce in this area of Europe, where it is mostly limited to shallow coastal lagoons (Mars, 1966; Ledoyer, 1966; Sfriso et al., 2001; Çinar et al., 1998). This information is also scarce when compared to that of other seagrass species of the Mediterranean Sea such as *P. oceanica*.

In southern Spain, extensive beds of *Zostera marina* occur in open bays of the Mediterranean coasts (Málaga and Granada) at 5–17 m depth (Moreno and Guirado, 2003). The molluscan fauna associated with these *Zostera marina* beds are far less known than those found in other seagrass species, as commented on previously (García-Raso et al., 2004; Arroyo et al., 2006). The scarcity of information on the molluscan fauna associated with deep *Z. marina* beds around the world may justify a study on this taxon, especially when considering the bio-geographical interest of the Alboran Sea, where a confluence of Atlantic, Mediterranean and African fauna occurs.

The structure (e.g. morphology, availability of microhabitats) and nature of the habitat influence the associated floristic and faunistic communities, including molluscs (reviewed in Sebens, 1991). In *Zostera marina* beds, the influence of the leaf and/or sediment stratum on the assemblages has been studied both from a spatial (Webster et al., 1998; Frost et al., 1999; Attrill et al., 2000) or a temporal perspective (Toyohara et al., 1999; Boström and Bonsdorff, 2000; Nakaoka et al., 2001). These studies have shown that assemblages or single species may be related to characteristics of the meadow (e.g. leaf surface available) or through indirect effects (e.g. food availability). Nevertheless, this information is based on observations in shallow *Z. marina* beds (<5 m depth) and should be re-evaluated for deeper beds such as those of the Alboran Sea.

In temperate areas, *Zostera marina* beds undergo seasonal changes in their canopy (Laugier et al., 1999; Meling-López and Ibarra-Obando, 1999; Guidetti et al., 2002; Lee et al., 2006), affecting the molluscan associated fauna due to changes of (1) the habitat complexity (Webster et al., 1998; Frost et al., 1999; Boström and Bonsdorff, 2000) and (2) availability of food (Edgar and Robertson, 1992; Toyohara et al., 1999; Nakaoka et al., 2001; Saunders et al., 2003). Reproductive features of the different associated molluscan species may also display intrinsic temporal variability as found in both vegetated (Salas and Hergueta, 1986; Rueda et al., 2001; Rueda and Salas, 2003a) and unvegetated habitats from southern Spain (Rueda and Salas, 2003b). The temporal variation of the *Z. marina* environment and of their associated molluscan fauna is poorly known in deep eelgrass beds (Arroyo et al., 2006). A study on these topics is therefore desirable; taking into account that most available information is related to shallower *Z. marina* beds from other parts of the world. The starting hypothesis is that the fauna of molluscs of eelgrass beds in southern Spain is more diverse than that from shallower beds along Europe, due to its bio-geographical location. Moreover, seasonal changes of the molluscan assemblage are expected as a result of the seasonal changes of the eelgrass environment, which are probably less acute than in shallower beds.

2. Material and methods

2.1. Study area

The study site is located in the Spanish coasts of the Alboran Sea, in the westernmost part of the Mediterranean Sea (Fig. 1). This study was carried out in Cañuelo Bay (Cala de los Cañuelos)

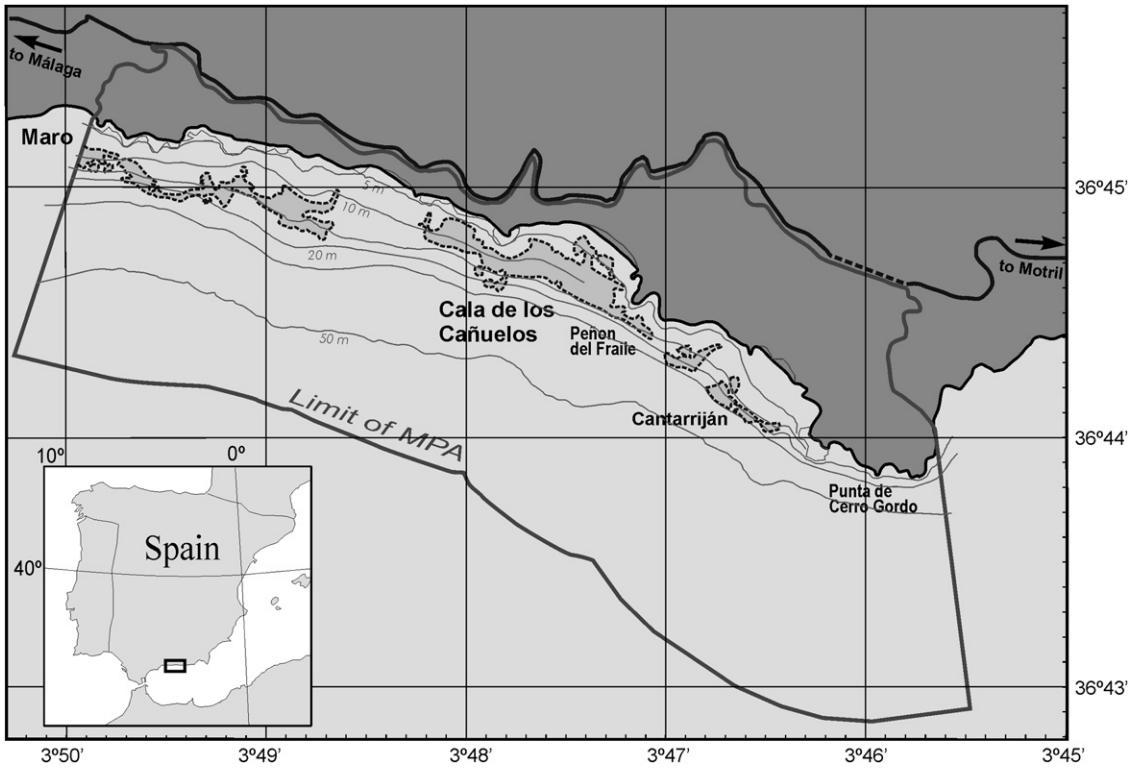

Fig. 1. Map of the studied area displaying the presence and distribution of *Zostera marina* beds within the MPA "Paraje Natural de Acantilados de Maro—Cerro Gordo" based on the study by Bañares-España et al. (2002). Cala de los Cañuelos: Cañuelo Bay.