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Limited differences in fish and benthic communities and possible cascading effects inside and outside a protected marine area in Sagres (SW Portugal)

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A B S T R A C T

Marine protected areas (MPAs) are a relatively recent fisheries management and conservation tool for conservation of marine ecosystems and serve as experimental grounds to assess trophic cascade effects in areas were fishing is restricted to some extent. A series of descriptive field studies were performed to assess fish and benthic communities between two areas within a newly established MPA in SW Portugal. We characterized benthic macroalgal composition and determined the size, density and biomass of the main benthic predatory and herbivorous fish species as well as the main benthic herbivorous invertebrates to assess indications of top-down control on the phytobenthic assemblages. Fish species were identical inside and outside the MPA, in both cases *Sarpa salpa* was the most abundant fish herbivore and *Diplodus* spp. accounted for the great majority of the benthic predators. However, size and biomass of *D.* spp. were higher inside than outside the MPA. The main herbivorous invertebrate was the sea urchin *Paracentrotus lividus*, which was smaller and predominantly showing a crevice-dwelling behaviour in the MPA. In addition, *P. lividus* size frequency distribution showed a unimodal pattern outside and a bimodal pattern inside the MPA. We found significant differences in the algal assemblages between inside and outside the MPA, with higher abundance of turf and foliose algae inside, and articulated calcareous and corticated macrophytes outside the MPA, but no differences in the invasive *Asparagopsis* spp. The obtained results show differences in predatory fish and benthic community structure, but not in species richness, inside and outside the MPA. We hypothesize these differences lead to variation in species interactions: directly through predation and indirectly via affecting sea urchins behavioural patterns, predators might drive changes in macroalgal assemblages via trophic cascade in the study area. However due to non-biological differences between the two areas it is difficult to suggest that the MPA causes increased biological parameters of targeted species and to assess predatory control and trophic cascade effects in areas where fishing pressure is reduced. It is therefor advisable to design MPAs so that their impacts can be scientifically evaluated in a proper fashion.

1. Introduction

Marine ecosystems on a global scale are increasingly degraded due to anthropogenic stressors (Halpern et al., 2008). These stressors lead to several biological and ecological changes such as habitat loss (Turner et al., 1999), depletion of fish stocks (Jennings and Kaiser, 1998, Myers and Worm, 2003) and reduction of biodiversity (Worm et al., 2006). All goods and services that marine ecosystems provide rely on the status of their habitats. Therefore, such changes harm the ocean's capacity to provide services such as food, protect livelihoods, guarantee water quality and maintain environmental resilience.

One approach to preserve marine ecosystems is using, like in terrestrial environments, protected areas. Marine protected areas (MPAs) are relatively recent management and conservation tools (Kelleher and Kenchington, 1992). The term MPA is commonly used for a wide variety of cases where any degree of protection or use of a marine area is implemented, including areas of fully protection, partial protection or areas with specific restrictions to certain activities, gear types or target species. The IUCN defines an MPA as “any area of inter-tidal or sub-tidal terrain, together with its

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overlying water and associated flora, fauna, historical, or cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher and Kenchington, 1992).

The benefits of establishing total protection MPAs, also known as marine reserves or no-take zones, are mainly increases in size, density, biomass of organisms and species richness, and in general are well documented (García-Charton et al., 2008; Lester et al., 2009). Nevertheless, the creation of no-take zones in general invoke the opposition of local communities, especially fishers; consequently, management authorities prefer to use areas of partial protection to avoid political conflicts. Although areas of partial protection are known to be less efficient compared to marine reserves (Lester and Halpern, 2008), more information is needed to understand their role as a fisheries management and conservation tool. While MPAs are being widely used, their efficiency has being criticized mainly due to unclear objectives, poor enforcement and lack of knowledge about changes in species or ecosystem functioning (Boersma and Parrish, 1999). Similarly, they are unlikely to be effective if they are situated in areas affected by external, normally uncontrollable stressors (Jameson et al., 2002), such as biological or chemical pollution. In addition, reviews of specific MPAs hardly ever refer to invasive species and their effects on the communities (Boersma and Parrish, 1999).

Generally, coral reefs are a good example for understanding how herbivores control algae biomass and growth. Many studies in tropical areas show how grazers play a main role limiting the abundance of algae, and how overfishing can lead to trophic cascade effects driving ecosystem shifts (Jompa and McCook, 2002; Bellwood et al., 2004; Littler et al., 2006). In temperate systems where algae are the main benthic primary producers, fish and benthic herbivorous invertebrates also have an underestimated importance conditioning sublittoral algae (Ruitton et al., 2000). Examples in the Mediterranean Sea indicate how variations in algal communities are importantly controlled by fishes (Sala and Boudouresque, 1997) and sea urchins (Bulleri et al., 1999). When appearing in high densities, sea urchins are able to shift the ecosystem from erect macroalgae to barren habitats dominated by encrusting calcareous algae (Andrew, 1993). Therefore, changes in the abundance of keystone species like sea urchins will be directly linked to effects on seaweed communities.

One of the most common sea urchin species in the Portuguese coast is *Paracentrotus lividus* (Lamarck) with densities ranging from a few to a dozen individuals per m^2 (Lawrence, 2006a). Human impacts can noticeably modify the ecological role of *P. lividus*, either directly by harvesting (Pais et al., 2007), or indirectly through overfishing of its predators (Sala et al., 1998). In this context MPAs provide new opportunities for assessing top-down controls in marine systems because they function as experimental tools where human impacts, such as fishing, are prevented to some extent (Shears and Babcock, 2002). Inside protected areas, *P. lividus* abundance has been recognized to be limited by the presence of predatory fish, while outside, denser populations of the sea urchins appear due to high fishing on their predators (Sala and Zabala, 1996). *P. lividus* is an active herbivore, that has the ability to regulate phytobenthic assemblages and cause differences in assemblages between inside and outside the protected area.

This work aims to evaluate whether there are fish and benthic community differences between a protected and non-protected area in SW Portugal, which can exert top-down control on seaweeds. More specifically we address whether there are differences in fish (focusing on herbivores and benthic predators) and sea urchin

(*P. lividus*) density, size and biomass between the protected and non-protected area and whether seaweed abundance (% cover) and/or community composition differ between inside and outside the MPA.

2. Materials and methods

2.1. Study area

This study was conducted in the Natural Park of the Southwest Alentejo and Vicentine coast (PNSACV, from its acronym in Portuguese) located in the southwest of continental Portugal. The marine part of the PNSACV extends over a wide area of cliffs and sandy coastline, with an extension of 110 km from Saõ Torpes beach (south of Sines) to Burgau (Algarve), covering 28858 ha. Within the marine Park different levels of protection were implemented in 2011 under the new resolution of its management plan (Anonymous, 2011), including areas of total protection (isolated islands on the West coast), partial protection and no protection. In the fully protected area only commercial fishing is allowed. The censuses of this study were conducted between February and May 2013 in two localities of the Southern coast of Sagres: the partially protected Martinhal islets MPA (37° 0′54.76″N, 8°55′7.93″W) and the only topographically comparable seascape Falesia cliffs (37° 0′21.27″N, 8°55′39.74″W). We had great difficulties in finding the best possible locations to compare between protected and basically non-protected areas. Fully protected areas could not be used as in contrast to the common idea of full protection in this marine park commercial fishing is the only activity allowed in these areas. The areas selected to compare are not ideal as they also do differ in some aspects that influence benthic and pelagic communities, for example their orientation to swell and the fact that it is a comparison between an islets and cliff seascapes. However, we do feel this study provides important information on this specific MPA in southern Portugal that with doubts are also legitimate for other MPAs. Within each area two haphazardly selected as study localities (about 250 m apart). The study area is south-facing, being sheltered from the prevalent north winds and west or north-west swells. Both localities present a very steep shore, which includes mainly rocky cliffs up to 30 m high. The sub-tidal zone begins with a vertical continuation of the intertidal cliffs. Then the slope becomes gentle and the habitat complexity increases due to predominant stones and boulders from few cm to several m in size, resulting from the differential erosion on the adjacent cliffs. Sandy bottoms are normally found beyond the rocky substratum at depths between 17 and 22 m. Maximum tidal amplitude can range ~3.5 m during spring tides. Sagres coastline is subjected to seasonal upwelling events with subsequent changes in primary productivity (Loureiro et al., 2005). Both localities are populated with organisms characteristic of rocky substrate from the south Portuguese coast with plethora of fish from the Sparidae and Labridae family, benthic invertebrates, seaweed communities dominated by calcareous algae (*Mesophyllum* sp., *Lithophyllum* sp.) and macroalgae (*Codium* spp., *Asparagopsis* spp. and *Halopteris* sp.) as well as diverse coral assemblages (*Eunicella* spp., *Leptogorgia* sp.) (Monteiro et al., 2012).

The studied MPA is a partially protected area where professional and recreational fishing are not allowed; only extraction of barnacles is permitted. The area referred in this work as "outside the MPA" is a partially-protected area subject to some fishing restrictions (bottom trawling and recreational fishing on Wednesdays is not allowed) Fig. 1.

2.2. Census of fish community

Fish abundance, size and biomass across the study localities were estimated by underwater visual censuses across transects using SCUBA. Two transects of 40 m (max depth 15 m) were