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Effect of marine protected areas on distinct fish life-history stages

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ABSTRACT

The role of Marine Protected Areas on distinct life stages of Mediterranean reef fish species (classified on the basis of their economic value and mobility categories) was assessed in a network of marine reserves in SE Spain. Only abundance and biomass of adult of both commercial and demersal species were positively affected by protection. Gradients across reserve boundaries (as a clue to the occurrence of spillover) were observed for fish abundance but not for biomass, indicating a protected fish assemblage with a predominance of small-sized individuals. Also, post-larvae of commercial species were negatively related to protected zones. Active selection of settlement preferred habitats, larval accumulation favoured by the geomorphological configuration of the coast or mixed effects has been proposed as possible explanations. Juveniles showed high spatial variability resulting in a lack of response to fishing protection measures. We highlight the need of including early life stages and overall suitable habitats for them when designing MPA networks due to the crucial importance of these stages to successful fulfillment of MPA objectives.

1. Introduction

Marine protected areas (MPAs) have been advocated as a major tool for recovery and conservation of marine resources (Fenberg et al., 2012). Their multiple benefits in protecting ecosystems and ecological processes while enhancing fisheries through density-dependence spillover and larval dispersal of target species (Roberts et al., 2001) convert them as the most powerful tool for spatial management in the marine environment. Although growing evidence supports the real benefits of MPA such as biomass or abundance increase (Russ and Alcala, 2004; Claudet et al., 2010), population structure restoration (Guidetti, 2006), spillover (Harmelin-Vivien et al., 2008), exportation of eggs and larvae (Cudney-Bueno et al., 2009; Crec'hriou et al., 2010) among others, little is known about the MPAs effect on settlement and recruitment events (Planes et al., 2000; Sale et al., 2005).

MPAs may have important effects on the resident population structure (Planes et al., 2000). Location of the MPA may determine whether nursery habitats will be protected and thus favour species settlement. In theory, mortality of juvenile fish is supposed to be higher inside MPAs due to the increase of predator abundance; however, compensatory effects such as the increase in recruitment due to high habitat quality provided by fishing protection may offset net differences (Syms and Carr, 2001). In this context, it is paramount to address the ecological effects of MPAs on the first life-history stages of fish in order to properly design and implement this management tool.

In addition, it has been hypothesized that MPAs can act as a source of propagules due to increased density and fecundity (as a consequence of the recovery of larger size classes) of protected populations, thus replenishing unprotected areas by dispersal of eggs and larvae (Planes et al., 2000). An indirect method to estimate the magnitude and importance of such export of larvae, juveniles and adults fishes from MPA to neighbouring areas is to look for the likely existence of gradients of biomass of target species across MPA limits, under the rationale that, if spillover occurs, there would be more fishes near than far away from the MPA (Chapman and Kramer, 1999; Pérez-Ruzafa et al., 2008). This research strategy has been used in several studies in the Mediterranean (e.g. Harmelin-Vivien et al., 2008; Pérez-Ruzafa et al., 2008; Goñi et al., 2008, 2010; Hackradt et al., 2014) and worldwide (e.g., Russ and Alcala, 2004; Amargós et al., 2010).

In this work, we used the beyond-ACI approach to investigate the effect of protection on distinct stages of Mediterranean reef fish life cycle (post-larvae, juveniles and adults). We addressed the following questions: Is the intensity of larval supply affected by protection? What is the response of juvenile and adult abundance and richness? Is the success of protection effects dependent on species mobility and economic importance? Moreover, we addressed the question of the

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existence of gradients of abundance of distinct fish life-history stages (post-larvae, juveniles and adults) of species and species groups constructed according to their pattern of spatial occupation and their economic importance, as an indirect way to detect and quantify the likely occurrence of spillover from no-take sites to neighbouring unprotected zones. The answer to these questions aimed to fulfil an important gap in the marine reserves science, by adding light to a complex period of the fish life-cycle and assist in the proper management of marine resources.

2. Material and methods

2.1. Study site

The Cabo de Gata–Níjar Natural Park covers 38,000 ha of both marine and terrestrial areas in the province of Almería, SE Spain and extends approximately 2 km offshore along about 60 km of coastline. The marine area under regulation extends over 12,200 ha, from which 4613.45 ha are within no-take zones, where all harvest and recreational activities are forbidden, but allowed within the park limits. There are 5 no-take zones (from South to North: Cabo de Gata, Loma Pelada, Polacra, Punta Javana and Media Naranja). The studied MPAs, namely Loma Pelada, Polacra and Punta Javana MPAs (Fig. 1), are particularly located in coastal promontories of volcanic formation, surrounded by coarse sand beaches or rocky embayments. The depth varied little among surveyed zones, reaching 20 m just tens of meters from the coast, however, slope is gentler near embayments and steeper close to the base of the promontories (Moreno, 2003). MPAs and adjacent zones are dominated by rocky reefs, which extends underwater to a depth of 60 m, surrounded by sandy and detritic bottoms interspersed with extensive patches of *Cymodocea nodosa* and *Posidonia oceanica* which forms a narrow belt following the coast extending down to 10 and 30 m, respectively (Luque and Templado, 2004). During the summer of 2011 (July to September) the cumulative rainfall was 30 mm, and the average wind velocity was 2 m s^{-1} mostly from south-east direction alternating with north-west winds (data collected from Nijar Meteorological station, provided by Consejeria de Agricultura, Pesca y Desarollo Rural, Junta de Andalucia, 2011).

2.2. Sampling design

During the settlement peak months of most rock reef fishes species (such as *C. chromis, C. julis, D. annularis* and all *Symphodus* species), namely between July and September 2011 (see Félix-Hackradt et al., 2013a, 2014 for more details), the abundance of post-larvae, juvenile and adult fish was surveyed monthly in three locations situated thousands of meters apart: Loma Pelada (LP), La Polacra (PO) and Punta Javana (PJ), and represent the spatial replication of the "Reserve effect". At each location, 3 zones were delimited: the no take-zone (Protected) and 2 zones where artisanal fishing is permitted (Unprotected), located upstream (North) and downstream (South) the MPA boundaries (Fig. 1). In each zone, 3 sites separated by hundreds of meters were randomly chosen each time.

2.3. Collection of fish post-larvae

Light-traps (CARE®, Ecocean, Montpellier, France) were used to sample the post-larval pool reaching the coastal zone. Post-larvae is defined here as a synonym of late-stage or competent larvae (Félix-Hackradt et al., 2013a). One light-trap per site (n = 9) was installed at sunset and retrieved at sunrise (~10 h) during two consecutive nights, resulting in 18 samples for each locality. Although site location was not fixed we determined a deployment area, aparted from each other to avoid light interference, in which light traps were randomly installed in each sampling day. This procedure was repeated for all 3 studied MPAs in each campaign (i.e., July, August and September months), resulting

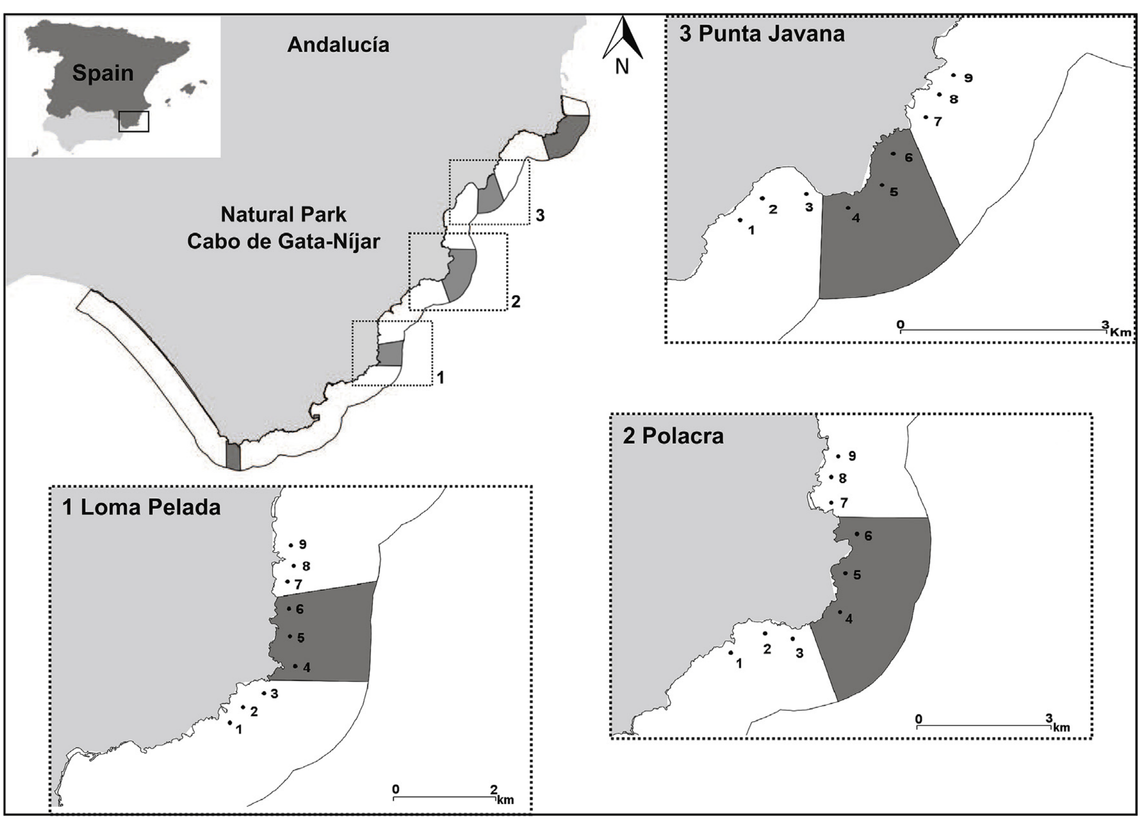

Fig. 1. Map of Cabo de Gata-Níjar Natural Park, Southeast Spain, showing the spatial delimitation of the three marine reserves studied, Loma Pelada (LP), Polacra (PO) and Punta Javana (PJ), and the location of light traps and underwater censuses within each zone (numbers 1–9). Shaded areas correspond to no-take zones.