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Changes in trophic ecology of fish assemblages after no take Marine Protected Area designation in the southwestern coast of Portugal

Tadeu José Pereira [a, *, 1], Joana Manique [b, 1], Bernardo Ruivo Quintella [a], Nuno Castro [b], Pedro Raposo de Almeida [a], José Lino Costa [b]

[a] MARE – Centro de Ciências do Mar e do Ambiente, Departamento de Biologia, Escola de Ciências e Tecnologia, Universidade de Évora, 7004-516, Évora, Portugal

[b] MARE – Centro de Ciências do Mar e do Ambiente, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal

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ABSTRACT

Changes in fish assemblage structure caused by human activities, such as fishing, can alter trophic relations in fish assemblages. In this context, Marine Protected Areas (MPA) are efficient tools for habitat recovery and ideal environments for evaluating changes on the trophic structure resulting from human activities. The present work targeted fish assemblages from two no-take MPAs from the northern half of South Alentejo and Costa Vicentina Marine Park, established in 2011. Previous works reported positive effects on local fish assemblages after no-take MPA designation, and it is therefore important to further study its impact on local fish assemblages, especially concerning trophic interactions. Local fish assemblages were sampled (summer 2011, winter 2012, summer 2013 and winter 2013) using trammel nets. Diets were characterized and digestive tract contents of the 10 most abundant fish species were compared between the no take MPAs (treatment) and adjacent areas (controls), and changes evaluated as a function of time since protection. Results revealed significant differences between the diets of fish from protected and non protected areas, with crabs being the preferential prey in both protected and control areas but being more ingested outside the no-take areas. However, these differences were evident since the beginning of the study. Fish assemblages from the northern area presented significantly larger niche breadth and significantly increasing with time. This way, the main effects of no-take MPA implementation were directly visible on the niche breadth but did not directly impact the diet composition of the sampled fish assemblages, contributing however to reinforce the already naturally existent differences. This work provides important information regarding the effect of changes in the fish assemblage caused by MPA designation on the trophic ecology of fish.

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1. Introduction

Marine Protected Areas (MPAs) have been widely implemented to stimulate the recovery of fishing stocks and preservation of biodiversity (Allison et al., 1998; Russ, 2002; Botsford et al., 2003; Chateaux and Wantiez, 2009), and can be defined as any intertidal or subtidal area that is protected by law in order to maintain its biodiversity and assure a sustainable use of its resources (Kelleher and Kenchington, 1992). Ideally, a functional MPA should have four of the following: no-take zones, size over 100km2, age over 10 years, enforcement measures, and be isolated from human activity (Edgar et al., 2014). Additionally, to be effective, an established fish population should subsist within MPA limits in order to gain benefits from protection (Kaplan et al., 2006), being its efficiency also directly dependent of the home range of the species targeted for protection (Kramer and Chapman, 1999; Sale et al., 2005; Alós et al., 2012). MPA designation does not guarantee the return of fish assemblages to or near pristine condition but the implementation and efficiency of no-take zones, where all fishing activities are prohibited, have been debated in several studies over the past years, suggesting that he majority of MPAs are effective protective tools and help the recovery of fish assemblages (e.g. García-Rubies and Zabala, 1990; Guidetti and Sala, 2007; Horta e Costa et al., 2013).

* Corresponding author. MARE – Centro de Ciências do Mar e do Ambiente, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal.
E-mail address: tjpereira@fc.ul.pt (T.J. Pereira).
[1] Both authors contributed equally to this work.

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Changes in fish community structure caused by human activities, such as fishing, can alter trophic relations (Villamor and Becerro, 2012). In this context, Marine Protected Areas (MPAs) are ideal environments for evaluating changes on the trophic structure resulting from human activities (Villamor and Becerro, 2012). By removing top predators through fishing activities, organisms from lower trophic levels may prosper and cause algae depletion together with habitat complexity to decline (Seytre et al., 2013). By eliminating fishing activities through MPA implementation, top predators abundance may increase, causing a chain of events, or cascades, that may result in the decrease of prey abundance (Halpern, 2003). Also, changes in predator density, size, or behaviour impact the entire trophic chain and influence assemblage structure, resulting in different fish assemblages from MPAs to non protected areas (Fenberg et al., 2012; Consoli et al., 2013; Sadio et al., 2015). Works focusing on trophic relations inside MPAs are becoming increasingly available (e.g. Vizzini and Mazzola, 2009; Faye et al., 2011; Villamor and Becerro, 2012; Soler et al., 2015) but most focus only on the characterization of the trophic chain regarding flows between levels and not on the impact of these protective measures on the trophic ecology of their fish assemblages (Vizzini and Mazzola, 2009; Faye et al., 2011). Additionally, some of these works that characterize trophic relations and functional groups inside MPAs, and compare those with assemblages from unprotected areas, started several years after protection designation (e.g. Villamor and Becerro, 2012; Fernandéz et al., 2016; Soler et al., 2015). The implementation of protected areas often leads to an increase in carnivore, planktivore and invertivore densities inside them (Halpern, 2003). Villamor and Becerro (2012) report that functional diversity increase inside MPAs is more evident than the increase of fish abundance and species richness, with predators and carnivores being the groups that benefited the most by protective measures. Similarly, Colléter et al. (2012) observed predator biomass increasing and prey biomass decreasing after protection designation. Yet, Soler et al. (2015), based on 79 MPAs worldwide, affirm that MPA designation has positive effects at all trophic levels, as fishing activities harm the entire trophic chain, especially in shallow waters and reefs. Altogether, MPA designation may result in higher fish abundance and consequent increase in competition for resources (Halpern, 2003). This occurrence may lead to changes in diet composition and feeding strategies, causing fish species to increase their niche breadth and thus becoming more generalists (Svanbäck and Persson, 2004). Nevertheless, studies focusing on the impact of these protective measures on the diets and trophic ecology of their fish assemblages is yet almost unavailable (Murawski et al., 2005; White et al., 2010).

For the Portuguese coast, works focusing on coastal fish feeding ecology and diet mainly target commercially important species (e.g.: Morato et al., 2000; Vinagre et al., 2005; Leitão et al., 2007; Garrido et al., 2008), being works on the diets of coastal assemblages scarce (Castro et al., 2013). The same way, studies regarding the impacts caused by MPA designation on the trophic ecology of its fish assemblages are limited to one work that focus on the impact of predator increase on prey availability rather than changes on the diets of the global fish assemblage (Fernandéz et al., 2016).

The present work targeted fish assemblages from the northern half of South Alentejo and Costa Vicentina Marine Park, established in 2011 as an extension of the terrestrial natural park (PNSACV). The main purpose of its designation was to implement a long term tool to protect the southwestern Portuguese coastal strip, including its ecosystems, habitats and marine species and assemblages, by regulating human activities inside the area (Ordinance 143/2009). The designation of this large MPA comprised the implementation of a network of small type I and no-take protected areas within its boundaries, commonly referred to as no-take MPAs,. In both MPA categories, no fishing activities are allowed, except for commercial harvesting of stalked barnacle *Policipes policipes* (Gmelin, 1790) inside type I protected areas. Previous works in this area reported positive effects on local fish assemblages after no-take MPA designation, namely in fish abundance, species richness and specimens size, at an early stage (3 years) after implementation (Silva, 2015a). It is therefore important to further study the impact of these protective measures on local fish assemblages, especially concerning trophic interactions. This need assumes particular relevance considering the almost absence of studies regarding MPA impact on trophic ecology of fish assemblages, particularly when assessed from an early stage after implementation (Colléter et al., 2012). Some of the most targeted species in this study are low mobility commercially important fish species, highly targeted by fishermen (e.g. breams, phycid hakes and soles) that find in this area ideal reproducing and feeding grounds, (Silva, 2015a, b; Belo et al., 2016), and the designation of these no-take MPAs may affect not only their abundance but also their behaviour and trophic ecology. Considering the above, the aim of this study was to assess variations in the trophic ecology of the fish assemblages from two small no-take MPAs from the PNSACV Marine Park, southwestern coast of Portugal and test if MPA designation affects fish assemblage trophic ecology. Specifically, this work aims to assess how and how fast changes in diet composition, feeding habits and niche breadth of these assemblages after no-take MPA designation. Are these parameters different between assemblages from protected and non protected areas? Did these parameters become different with time? To answer these questions, diets of fish from both protected and non protected areas were characterized and compared according to their composition and frequency of occurrence of each food item on their gut contents. Similarly, diets from specimens captured at different times after MPA designation were characterized and compared, thus allowing to capture probable temporal variations in feeding ecology after protective measures took place.

2. Material and methods

2.1. Study area

This study was conducted in the PNSACV Marine Park, southwest coast of Portugal (Fig. 1). This marine park extends 2 km offshore and along the ca. 120 km coast of the natural park, crossing through two regions, Alentejo (southwestern coast) and Algarve (southwestern and south coasts) (Fig. 1). In 2011, several no-take MPAs (no take and type I partial protected areas) were implemented along the marine park, two of which in the Alentejo coast of the park: Pessegueiro Island no-take MPA in the northern Alentejo coast and Cape Sardão no-take MPA in the southern Alentejo coast (Fig. 1). Both are relatively small, having Pessegueiro Island an area of ca. 6 Km^2 and Cape Sardão ca.7 Km^2. Maximum depth on both areas is ca. 25 m, with the bottom composed of rock and sand in Pessegueiro Island no take MPA and adjacent areas, and mainly rocky reefs in Cape Sardão and adjacent areas. The overall fish assemblage of PNSACV is highly diverse, encompassing 149 fish species, some of which of high value for regional fisheries such as breams *Diplodus sargus* (Linnaeus, 1758), *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817), conger eel *Conger conger* (Linnaeus, 1758), sole *Solea solea* (Linnaeus, 1758) and moray eel *Muraena helena* (Linnaeus, 1758) (ICNB, 2008). In fact, breams and soles, two of the most targeted fish groups in the present study, comprise about 12% and 4% of total catches (ton) by local fishermen over the past 10 years (DGRM – National Authority for Marine Resources, unpublished data) Despite relatively low percentages, the market value of these fish groups usually reaches high values, making them

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