Fish diversity in the Berlengas Natural Reserve (Portugal), a marine protected area

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Resumo
Em 1981, as Berlengas, arquipélago localizado a cerca de 7 milhas da costa de Peniche (costa Oeste de Portugal), tornou-se área marinha protegida. Censos visuais subaquáticos, nomeadamente percursos aleatórios, foram usados para fazer o levantamento das espécies de peixes na área, durante duas campanhas de Verão, 2004 e 2005, contabilizando um total de 16 horas de observação em mergulho. Este estudo visou criar um inventário mais exacto e detalhado das espécies de peixes presentes no arquipélago do que um feito anteriormente, em resultado de alguns estudos prévios. Um total de 48 espécies de peixes pertencentes a 22 famílias foram observadas durantes os dois períodos de estudo. Labridae e Sparidae foram as famílias mais representadas e *Diplodus vulgaris* e *Labrus bergylta* foram as espécies mais frequentes.

Abstract
Since 1981, Berlengas, an archipelago located about 7 miles off Peniche (Western Coast of Portugal), became a marine protected area. Underwater visual census, namely rover diver counts, were used to assess the fish species present in the area during two summer campaigns, 2004 and 2005, comprising a total of 16 hours of scuba-diving observations. This study aimed to obtain a more accurate and detailed checklist of the fish species present in the archipelago than the one already existing in result of a few previous studies. A total of 48 fish species belonging to 22 different families were observed during the two study periods. Labridae and Sparidae were the most represented families and *Diplodus vulgaris* and *Labrus bergylta* were the most frequent species.

Key words: Berlengas Archipelago, North-eastern Atlantic, fish species, underwater visual census

Introduction

Marine protected areas (MPAs) are a common tool in conservation and are widely used throughout the world to prevent overfishing and preserve biodiversity. While much of the literature on MPAs has dealt with no-take areas (e.g. Rowley 1994; Ashworth & Ormond 2005), MPAs can offer several levels of protection and many afford only partial protection, allowing certain types of fishing (Denny & Babcock 2004).

There are many documented examples where fish species have benefited from reserve establishment, in particular through increases in mean size and abundance (e.g. Westera et al. 2003; Harmelin-Vivien et al. 2008).

In situ data on reef fish assemblages can be used to evaluate community responses to natural and artificial changes in the biotope (Bythell et al. 1993).

Non-destructive techniques, such as underwater visual observation (visual census) have frequently been used to characterize reef fish communities (Bohnsack & Bannerot 1986) by quantitatively measuring relative abundances and community structure (Guidetti et al*.* 2008).

More recent studies started to address temperate reef fish assemblages (García-Charton et al*.* 2004; Guidetti et al. 2008) and fish communities on North Atlantic islands like Canaries (Falcon et al. 1996), Azores (Patzner & Santos 1993; Santos et al*.* 1994); and Madeira (Ribeiro et al. 2005). In Portuguese mainland few studies have been performed (e.g. Almada et al. 1999; Gonçalves et al. 2002; Santos et al. 2005; Beldade & Gonçalves 2007).

Berlenga Island and the nearby Estelas islets were declared a Nature Reserve in 1981, to preserve a rich natural heritage and to ensure sustainable development of human activities there. More recently, Berlengas Natural Reserve (BNR) was proposed to be a Biosphere Reserve. This denomination is attributed by UNESCO to sites where the existence of innovate approaches to conservation and sustainable development is recognized. The Reserve was enlarged in 1998 to include the remote Farilhões islets and a much wider marine area, now up to 9541 hectares overall (99 ha of land area and 9 442 ha of marine area) (Queiroga *et al.* 2009).

Current legislation does not allow the following activities inside the protected area: commercial fishing to vessels unregistered in Peniche Port Authority (nearest fishing harbor); trawl fishing, gill nets, trap fishing and shellfish collecting (Queiroga et al. 2009).

Despite its biodiversity, no marine scientific studies were done in Berlengas Natural Reserve (BNR) prior to its implementation. The few scientific work carried out to assess the species that inhabit these waters were all performed after Berlengas archipelago was declared a marine reserve. In addition, the studies concerning fish are also scarce (Henriques 1993; Rodrigues 1993; Almeida 1996; Rodrigues 2009).

The main objective of this study was to create an accurate inventory of the fish species present in the BNR area, in order to improve a previous database refering to a restricted area of this marine reserve.

2. Material and Methods

2.1 Study area

This study was performed in the BNR, an archipelago formed by 3 groups of small islands (Berlenga, Estelas and Farilhões), 7 miles off Peniche (Portugal) (Fig 1). This archipelago is located at the top of the escarpment of the Nazaré Canyon, one of the most worldwide important submarine canyons in the transition zone between the Mediterranean and European subregions. Due to this canyon, the water is rich in nutrients, especially throughout the upwelling season (April–September) (Haynes et al. 1993).

2.2. Visual census

Twelve sampling stations from the 3 groups of islands were defined in this study (Fig 2), 6 around Berlenga Island (B1-B6), 3 at Estelas islets (E1-

E3) and 3 at Farilhões islets (f1-f3). The sea floor consists primarily of irregular hard bottom substrate (i.e. rocks covered with sessile biota, including a variety of algae, sponges, hydrozoans, anemones, crustaceans, sea urchins and tunicates (Rodrigues et al. 2008). Non-destructive methods, namely visual census techniques using SCUBA gear, were used to assess the fish diversity of the archipelago during two campaigns, August 2004 and July 2005. These campaigns included sampling in the same stations, in both years.

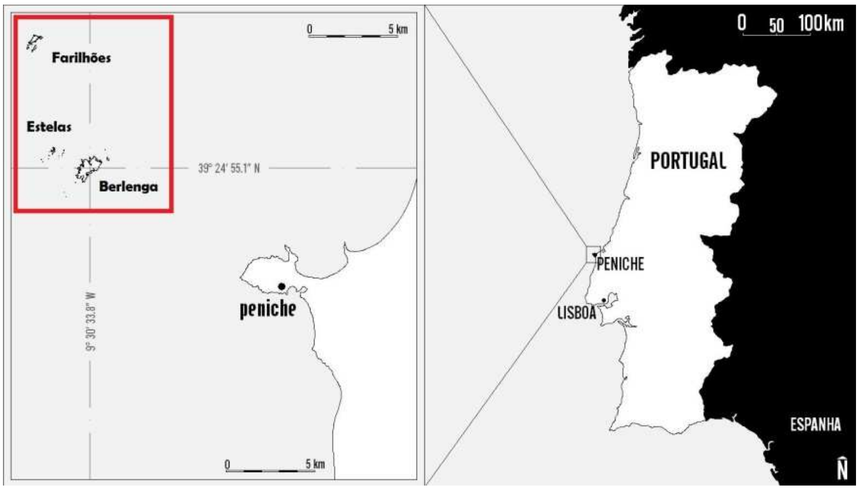

Figure 1. Geographic location and limits of the Berlengas Natural Reserve (in red) with its 3 groups of islands

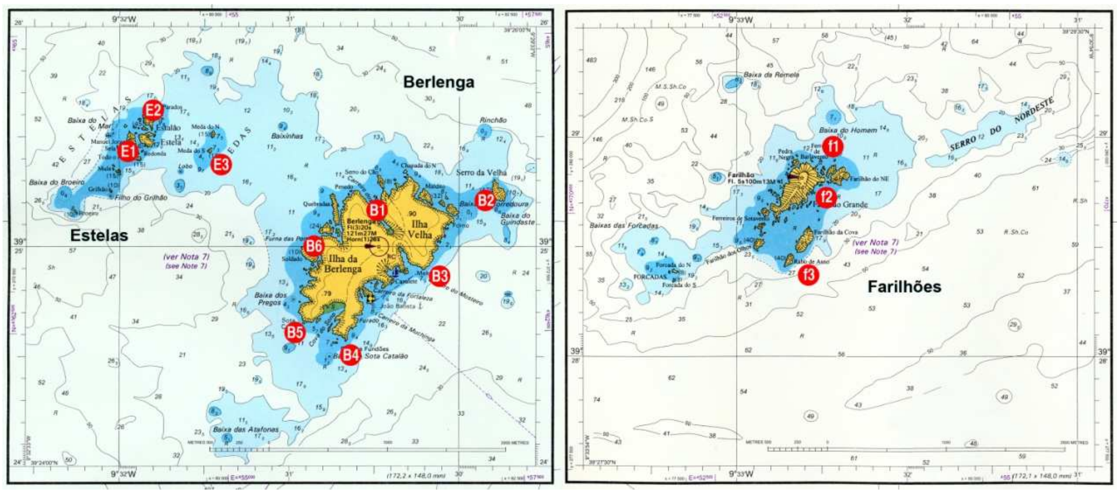

Figure 2. Location of the sampling stations in the 3 groups of islands of the Berlengas Natural Reserve

Rover-diver counts was the most suitable method, considering the goal of the study was to register specific richness regardless of abundance or mean size (Baron et al. 2004). This method consists on the diver recording all the fish species encountered during a 20 minutes interval. The diver was encouraged to look wherever in an attempt to record the maximum number of species and to register this information on a dive slate (Baron et al. 2004). No abundance or size data were recorded. The dives were performed from 5 to 30 meters deep in all type of underwater environments found in the area (sand, rocky areas, caves, water column) and were conducted between 10:00 and 16:00 hours local time (GMT).

2.3. Data analysis

2.3.1. Feeding guilds

According to Elliot et al. (2007), each species was characterized based on its feeding guild (invertivore, macrocarnivore, piscivore, omnivore, zooplanktivore and herbivore). Species were considered "invertivore" when they feed predominantly on non-planktonic invertebrates while zooplankton feeders (i.e. species that feed on planktonic crustaceans, hydroids and fish eggs/larvae) were considered "zooplanktivore". "Herbivore" species feed predominantly on macroalgae, macrophytes, phytoplankton and microphytobenthos and "omnivore" species feed on detritus, filamentous algae, macrophytes, epifauna and infauna. Species that feed on macroinvertebrates and vertebrates (mostly fish) were considered "macrocarnivores" and the species that feed almost exclusively on fish were included in the "piscivore" guild. The attribution of the feeding guild to each fish species was based on Henriques et al. (2008).

2.3.2. Statistical analysis

An initial binary matrix was constructed where species' presence/absence in the sampling sites was denoted as 1 or 0, respectively.

To derive similarity patterns from the above matrix, the Jaccard coefficient was utilized (Legendre & Legendre 1998. The overall multivariate spatial pattern was obtained from the initial matrix by using the non-metric multidimensional scaling (nMDS) (Clarke & Green 1988; Warwick & Clarke 1991). Based on scree-plot inspection, a scaling solution with three dimensions was selected, which made-up the basis for a 2D ordination plot using the nMDS. All statistical analyses were done with Canoco for Windows 4.5 (ter Braak & Šmilauer 2002) and WinKyst 1.0 add-ons for Canoco (Šmilauer 2002–2003).

3. Results

3.1. Descriptive analysis

A total of 48 fish species belonging to 22 different families were observed during the two study periods (Table I).
Two families, Sparidae and Labridae, were the most represented, with nine and six species, respectively, followed by Blennidae and Gobiidae with four species each, and Carangidae, Gadidae and Scombridae all with three species. Fourteen families were represented by a single species.

Diplodus vulgaris was the species with highest frequency (100% in 2004 and 91.7% in 2005), followed by *Labrus bergylta* (69.2% in 2004 and 91.7% in 2005). Twelve species were observed only once during the study period. Sampling station B2 was the spot where the number of species registered was highest (23 in 2004 and 19 in 2005) and station E2 was the spot where the number of species was lowest (5 in 2005).

The fish community is constituted mainly on macrocarnivores species (35%), followed by omnivorous and invertivores species (27%) (Table I). Herbivores and piscivores were represented by only one species each, *Sarpa salpa* and *Belone belone*, respectively. *Sarpa salpa* was observed in 11 sampling stations during the study period, and *Belone belone* was observed only once at station F3 during 2004.

3.2. Multivariate analysis

The multivariate analyses provided additional information on the similarity pattern: nMDS based on Jaccard coefficient and performed on the total species list for the twelve sampling sites over the two years, revealed a clear gradient along the axis 1 of the plot (Fig. 3).

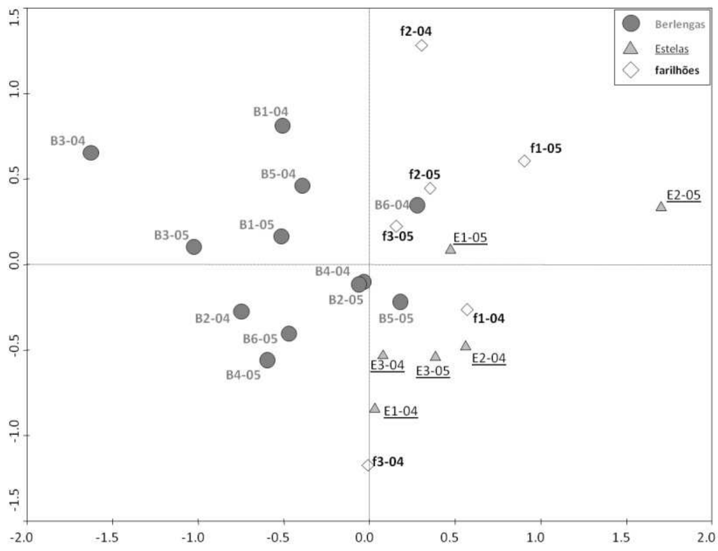

Figure 3. Non-metric MDS ordination of Berlenga Island (B1, B2, B3, B4, B5, B6), Estelas (E1, E2, E3) and Farilhões (f1, f2, f3) sampling stations based on the dimension coefficients (dimension 1 by dimension 2) of species presence/absence in 2004 and 2005. Stress 0.15.

Table I. Occurrence frequency (%) of fish species from Berlenga Natural Reserve in 2004 and 2005 and species feeding guild (he – herbivore; inv – invertivore; ma – macrocarnivore; om – omnivore; pi – piscivore; zoo – zooplanktivore).

FAMILY	SPECIES	Feeding guild	2004	2005
Mugilidae	*Liza aurata* (Risso, 1810)	om	69.2	41.7
	Chelon labrosus (Risso, 1827)	om	38.5	25
Sparidae	*Sarpa salpa* (Linnaeus, 1758)	he	76.9	58.3
	Boops boops (Linnaeus, 1758)	om	53.8	50
	Diplodus sargus (Linnaeus, 1758)	om	76.9	75
	Diplodus annularis (Linnaeus, 1758)	inv	7.7	33.3
	Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	inv	100	91.7
	Diplodus cervinus (Lowe, 1838)	om	30.8	25
	Pagrus pagrus (Linnaeus, 1758)	ma	7.7	0
	Spondyliosoma cantharus (Linnaeus, 1758)	om	46.2	41.7
	Oblada melanura (Linnaeus, 1758)	om	23.1	0
Labridae	*Labrus bergylta* Ascanius, 1767	om	69.2	91.7
	Labrus mixtus (Linnaeus, 1758)	ma	0	8.3
	Centrolabrus exoletus (Linnaeus, 1758)	inv	23.1	41.7
	Ctenolabrus rupestris (Linnaeus, 1758)	ma	30.8	16.7
	Coris julis (Linnaeus, 1758)	inv	46.2	66.7

	Symphodus spp.	inv	7.7	16.7
Gobiidae	*Gobiusculus flavescens* (Fabricius, 1779)	zoo	46.2	58.3
	Gobius xanthocephalus Heymer & Zander, 1992	inv	15.4	8.3
	Pomatochistus spp.	inv	0	8.3
	Thorogobius ephippiatus (Lowe, 1839)	om	23.1	0
Mullidae	*Mullus surmuletus* Linnaeus, 1758	ma	15.4	25
Moronidae	*Dicentrarchus labrax* (Linnaeus, 1758)	ma	23.1	8.3
Serranidae	*Serranus cabrilla* (Linnaeus, 1758)	ma	38.5	50
Atherinidae	*Atherina presbyter* Cuvier, 1829	ma	7.7	8.3
Gadidae	*Pollachius pollachius* (Linnaeus, 1758)	inv	23.1	8.3
	Trisopterus luscus (Linnaeus, 1758)	ma	7.7	8.3
	Phycis phycis (Linnaeus, 1766)	inv	7.7	33.3
Belonidae	*Belone belone* (Linnaeus, 1761)	pi	7.7	0
Carangidae	*Seriola rivoliana* Valenciennes, 1833	ma	7.7	0
	Trachurus trachurus (Linnaeus, 1758)	ma	23.1	33.3
	Trachynotus ovatus (Linnaeus, 1758)	ma	7.7	0
Ammodytidae	*Gymnammodytes semisquamatus* (Jourdain, 1879)	zoo	7.7	0
Balistidae	*Balistes capriscus* Gmelin, 1789	inv	38.5	8.3
Blennidae	*Parablennius gattorugine* (Linnaeus, 1758)	om	0	8.3
	Parablennius pilicornis (Cuvier, 1829)	om	15.4	33.3
	Parablennius ruber (Valenciennes, 1836)	om	23.1	33.3
	Lipophrys pholis (Linnaeus, 1758)	om	0	8.3
Tripterygiidae	*Tripterygion delaisi* Cadenat & Blache, 1970	inv	46.2	33.3
Triglidae	*Trigloporus lastoviza* (Bonnaterre, 1788)	inv	7.7	8.3
Gobiesocidae	*Lepadogaster lepadogaster* (Bonnaterre, 1788)	inv	7.7	0
Syngnathidae	*Syngnathus acus* (Linnaeus, 1758)	zoo	7.7	0
Scorpaenidae	*Scorpaena* sp.	ma	30.8	16.7
Scombridae	*Scomber scombrus* Linnaeus, 1758	ma	46.2	0
	Scomber colias Gmelin 1789	ma	46.2	0
	Sarda sarda (Bloch, 1793)	ma	7.7	0
Muraenidae	*Muraena helena* Linnaeus, 1758	ma	7.7	8.3
Bothidae	*Arnoglossus laterna* (Walbaum, 1792)	ma	7.7	0

The analysis showed clear differences between Berlengas island samples and all the remainder sites in the presence/absence of the 48 species. With the exception of two samples, Berlenga Island stations are placed in the negative part of axis 2; all the remainder sampling stations are grouped on the right side of the plot and particularly E2-05 and f2-04 are placed in the most distant places (on the upper right side) of the plot. Although not as evident as with Berlenga Island stations, Estelas and Farilhões islets stations also showed differences among them, regarding similarity pattern (Figure 3). In addition, the nMDS configuration yielded a plot where years did not play a major role to separate the sites and therefore do not appear to be tightly linked to individual sites.

4. Discussion

The first study developed in the area was performed by Almeida (1996) and focused on the coastal zone of Berlenga Island. Using a visual point counts technique adapted from Bohnsack & Bannerot (1986) for 1200 minutes, the author recorded 51 fish species belonging to 19 families, in a study performed between 1990 and 1992, being Gadidae, Sparidae, Labridae, Gobiidae and Blennidae the most abundant families, the same as in the present study. As pointed by Almada et al. (1999), in the north-eastern Atlantic, the temperate reef fish communities are characterized by the higher abundance of species belonging to the families Labridae, Sparidae, Gobiidae, Blenniidae and Serranidae, though including a number of other families with lower abundances (e.g. Carangidae, Syngnathidae, Mugilidae, Phycidae, Gobiesocidae, Callionymidae, Scorpaenidae, Soleidae, Triglidae). Almeida (1996) also reported the species *Boops boops*, *Diplodus vulgaris* and *Gobiusculus flavescens* as the most abundant in that period. This author recorded a total of 17 species in his study, that were not observed in the present one, but, on the other hand, the present study recorded 14 new species: *Pagrus pagrus*, *Oblada melanura*, *Gobius xanthocephalus*, *Atherina presbyter*, *Belone belone*, *Trachinotus ovatus*, *Gymnammodytes semisquamatus*, *Parablennius ruber*, *Trigloporus lastoviza*, *Scomber scombrus*, *Scomber colias*, *Sarda sarda*, *Muraena helena* and *Arnoglossus laterna*. Some of the species recorded by Almeida (1996) and absent in the present study were, however, registered by Rodrigues et al. (2008): *Conger conger*, *Gaidropsarus mediterraneus, Zeus faber*, *Pseudocaranx dentex*, *Sparus aurata*, *Gobius paganellus*, *Gobius cruentatus* and *Zeugopterus punctatus.*

Regarding *Gobius auratus* observed in the first study, it could actually be *G. xanthocephalus*. *G. auratus* has been confused in the past with *G. xanthocephalus* that has only been recognized as a separate and valid species by Heymer & Zander (1992).

The reef fish community of BNR is constituted mainly on macrocarnivores, omnivorous and invertivores species, and rarely herbivores (just one species, *Sarpa salpa*). According to Almada et al. (1999), the large majority of reef fishes in the temperate north-eastern Atlantic are benthivore and rarely herbivore or planktonivore. The high abundance of macrocarnivores in this study is mainly explained by the presence of some pelagic fish belonging to the Scombridae and Carangidae families (3 species each). Considering the BNR is an offshore archipelago, the occurrence of pelagic fish is common unlike other studied places from the north-eastern Atlantic (Gonçalves et al. 2002; Ribeiro et al. 2008).

The nMDS analysis showed clear differences between Berlenga Island and all the remainder sites, as showed on Figure 3. In this study, 22 species occurred only in Berlenga sampling stations, and some of them are typically found in coastal environments (e.g. *A. presbyter*, *Lepadogaster lepadogaster, Lipophrys pholis, Syngnathus acus, Thorogobius ephippiatus*). In Estelas and Farilhões stations we registered species which are typically found in oceanic environments and did not occur in Berlenga stations (e.g. *S. sarda*; *B. belone*). Rodrigues (2009) mentioned the existence of a coast-to-ocean environmental gradient when going from Berlenga to Estelas and from Estelas to Farilhões. The presence of the Nazaré canyon as well as the depths around Farilhões (Haynes et al. 1993) gives to this farthest area of BNR oceanic characteristics which probably enhance this gradient.

With this study, the authors provide additional data that can be useful to understand the present situation about fish diversity in BNR. This new information, could be used in future studies focusing on fish community's structure and dynamics which contribute to monitoring BNR fish populations and are also crucial to understand how effective is this Marine Protected Area.

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