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REVIEW

Marine Recreational Fishing in Portugal: Current Knowledge, Challenges, and Future Perspectives

Hugo Diogo[a,b], Pedro Veiga[c], Cristina Pita[d], Alina Sousa[e], David Lima[e], João Gil Pereira[a], Jorge M. S. Gonçalves[c], Karim Erzini[c], and Mafalda Rangel[c]

[a]Okeanos - R&D Centre, University of the Azores, Horta, Portugal; [b]Direção de Serviços de Recursos, Frota Pesqueira e Aquicultura – Direção Regional Das Pescas, Rua Cônsul Dabney - Colónia Alemã, Horta, Portugal; [c]Centre of Marine Sciences (CCMAR), University of Algarve, Faro, Portugal; [d]CESAM - Centre for Environmental and Marine Studies, Department of Environment and Planning, University of Aveiro, Aveiro, Portugal; [e]MARE – Marine and Environmental Sciences Centre, Polytechnic Institute of Leiria, Peniche, Portugal

ABSTRACT

Marine recreational fishing (MRF) in Portugal is a traditional leisure activity with considerable importance for coastal populations. In the absence of available information from the national data collection framework, this article aims to review the existing information on MRF across the country. MRF was an open access fishery until recently, but with rising evidence of overexploitation of coastal resources, a precautionary approach was imposed top-down, without consulting recreational fishers. In Portugal, the MRF participation rate is comparable to the European average (2%). The most important fishing mode (according to the official issued licenses) is shore angling. Mainland Portugal marine recreational catches (0.8% of total commercial landings) are likely underestimated, while the estimate for the Azores (6% of total commercial landings) is probably closer to the national reality. The Portuguese MRF sector faces several challenges, including: (1) the need for a definition of a national data collection framework; (2) the inclusion of MRF harvest estimates in stock assessments for key captured species; (3) management approaches which also take into account the ecosystem approach to fisheries and any potential effects of climate change; (4) additional research on post-release mortalities for the most important MRF species; and (5) a stronger involvement of all stakeholders in the decision-making process of MRF. The latter would be critical to improve the adequacy of regulations to the MRF reality, mitigate conflicts with other sectors (e.g., commercial fishing), and potentially increase fishers compliance.

KEYWORDS

Recreational fisheries; angling; spearfishing; fisheries management; climate change

1. Introduction

Portugal has an extensive coastline and a tradition of exploiting marine resources that goes back to the first human settlements in the region (Bicho and Haws 2008). Marine recreational fishing (MRF) has always been a popular activity in Portugal and it is estimated that it currently involves between 170 and 200 thousand participants yearly (DGRM 2017; Hyder et al. 2017). As in most places, the main distinctive feature between recreational and small-scale commercial fishing in Portugal is the interdiction of selling the catch; but there are other differences such as the gears allowed, licensing schemes, and catch and effort restrictions (Pawson et al. 2008; Veiga et al. 2013). For legal and statistical purposes, there are three main categories of recreational fishing in the country: (1) recreational, conducted purely for leisure purposes; (2) sport fishing, conducted as part of an organized competition; and (3) angling tourism (or charter boat fishing) (DGRM 2016). There are also four marine recreational fisheries (MRF) modes regulated and with mandatory dedicated fishing licenses (shore angling/hand harvesting, boat angling, and spearfishing). MRF takes place along all the Portuguese coast, from the intertidal zone to the shelf-break and beyond (when targeting large pelagic and highly migratory species), targeting a considerable number of marine species (Rangel and Erzini 2007; Veiga et al. 2010; Diogo and Pereira 2014).

In recent years, MRF has been subject to growing attention in European waters in terms of research and management initiatives (Ferter et al. 2013; Hyder et al. 2017). Nevertheless, and despite the

CONTACT Hugo Diogo hugo.mc.diogo@azores.gov.pt Okeanos - R&D Centre, University of the Azores, Rua Prof. Dr. Frederico Machado, 4, 9900-138 Horta, Portugal.

legal requirements of European Union (EU) legislation on estimates of recreational catches for some species since 2009, recreational fisheries in many EU countries have not yet been subject to national-scale surveys, or are at an early stage as is the case of Portugal. In the absence of national data collection programs, it is important to compile all existing knowledge, especially when some heterogeneity is likely to exist on target species, catches, effort and socioeconomic features of the different fishing modes and/or for the different regions in the country (Gupta et al. 2015; Freire et al. 2016).

This article reviews and summarizes all available information on several aspects of Portuguese marine recreational fisheries, mainly in terms of ecological impacts, socio-economic importance, and evolution of the legal framework. Based on the main findings and patterns, recommendations for future research and management will be provided. The scope of this review is restricted to information collected on recreational fishing for the four main fishing modes (i.e., hand harvesting, shore angling, boat angling, and spearfishing), published in some form (i.e., including gray literature) and publicly available as of October 2018.

2. Methodology

Scientific information on Portuguese marine recreational fisheries was compiled through an exhaustive bibliographic search. Documents consulted included peer-reviewed papers, theses, research reports, and governmental related documents (reports, statistics, or other type of official documents). Published information was selected using Scopus (https://www.elsevier.com/solutions/scopus/) and RCAAP (https://www.rcaap.pt/) databases. A sensitive "rapid" systematic search strategy was employed combining Portuguese and English terms such as "recreational fisheries," "recreation," "spear," "sport," "boat" or "angler," "marine," "fishers," and synonyms. Titles and abstracts were screened to identify studies potentially eligible for inclusion. A subsequent screening process was undertaken for any relevant documentation not detected during the first search process. References in all relevant literature were screened for additional publications about MRF surveys in Portugal as suggested by Pita et al. (2011). The criteria for inclusion in the review were restricted to the following: (1) the document included Portuguese surveys on MRF and (2) the document reported data on Portuguese MRF (e.g., participation, catch and effort, socioeconomic data). Gray literature was selected using Google and Google Scholar online databases in Portuguese; the first 150 hits were evaluated. Gray literature for which full texts were not publicly available were not included in this review. Information was extracted, when possible, at regional level using Portuguese NUTS II areas as defined for statistical purposes (north, center, Lisbon Metropolitan Area, Algarve, Alentejo, Azores and Madeira archipelagos) and consisted of: (1) participation rates (estimated from official information on issued MRF licenses); (2) gears and fishing methods used; (3) main target and captured species; (4) catch rates; (5) fishing effort; (6) total estimated catches, main shared resources (among the different recreational fishing modes and also with commercial fisheries); and (7) socio-economic features (e.g., angler demographics, expenditures).

Other important topics also covered and discussed in the manuscript have included the legal framework for MRF in Portugal, other potential ecological impacts of MRF in Portugal, and management of MRF within Marine Protected Areas (MPA).

3. Management of the marine recreational fishing activity in Portugal

Marine recreational fishing in Portugal was an open access activity until 2005, without restrictions of any kind (Rangel and Erzini 2007; Veiga et al. 2013). The first record of a legal framework for MRF is from Decree § 41444/1957 (Figure 1). According to this regulation, recreational fishing was broadly defined as any fishing activity conducted by "amateur" fishers, practicing hook and line or underwater spearfishing, both from shore or boat, and without commercial purposes (i.e., ban on the sale of fish). From 1957 to the early 2000s, the MRF regulation was subject to several revisions and adjustments, but with no clear evidence that the anticipated measures were being effectively implemented or enforced. Effective measures to restrict MRF catch and effort were only formally put in place in 2006 through Portaria § 868/2006, which included restrictions such as daily bag limits, fishing licenses, prohibited species, spatial and temporal restrictions, minimum landing sizes—MLS (same to those applied for commercial fishing), as well as anticipated measures for future monitoring of the activity. From 2006 to 2014, the regulations were subject to several amendments. Portaria § 14/2014, the latest issued MRF regulation for mainland Portugal, includes the most up to date regulations in

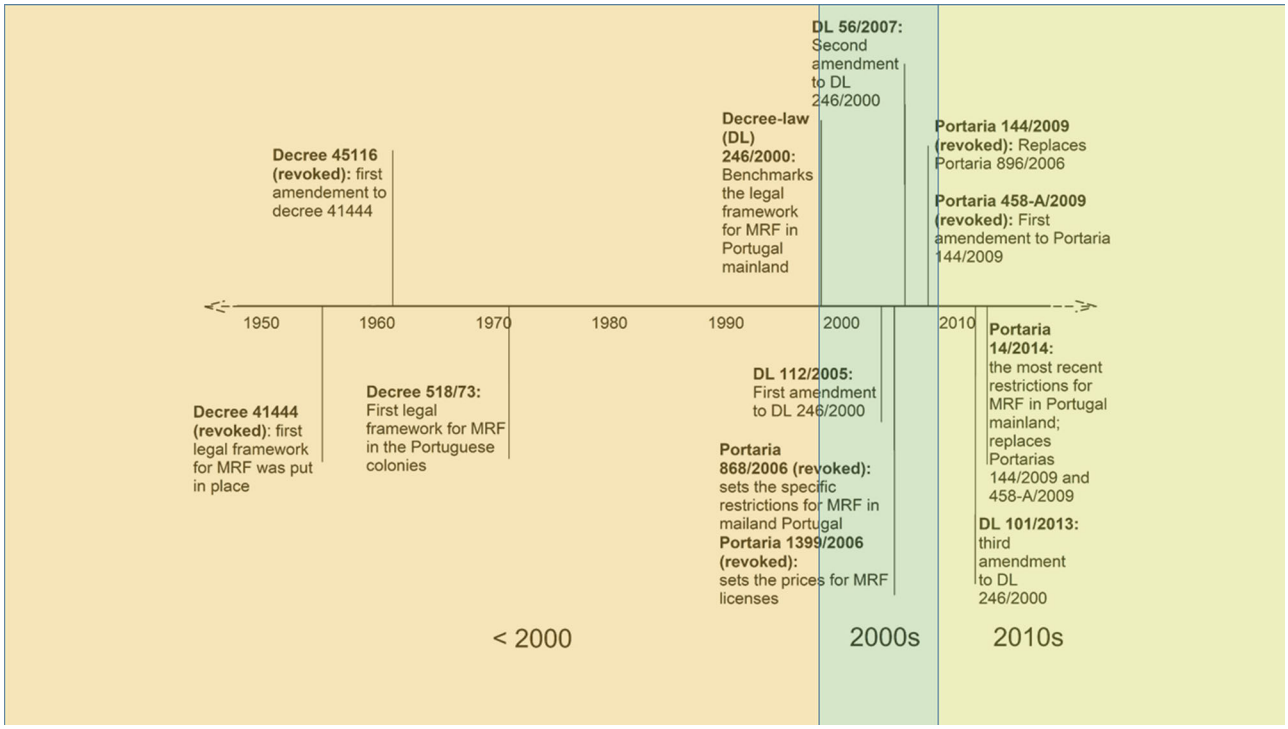

Figure 1. Timeline of the regulatory framework on marine recreational fishing (MRF) in Portugal mainland. Specific regulations on MRF in MPA and technical fisheries management measures that regulate species (e.g., minimum landing sizes and seasonal closures) are not included.

place for the activity (both at the local and national scales).

For the Azores and Madeira autonomous regions, the first regional regulations dedicated to MRF only considered spearfishing. These were issued in the mid-1980s in the Azores and a decade later (1995) in Madeira (Appendix Figures A1 and A2). Restrictions included daily catch limits (different for fish and specific crustaceans), prohibited species for specific fishing modes (e.g., dusky grouper, *Epinephelus marginatus* for spearfishing), mandatory fishing licenses, restrictions on allowed equipment, and the mandatory need to comply with existing or upcoming minimum landing sizes, and temporal and spatial restrictions for specific areas or species. More comprehensive regulations—covering all MRF modes and including measures to control user access and catch (e.g., fishing licenses, daily bag limits, temporal and spatial restrictions)—were only issued in 2007 in the Azores (Regional Legislative Decree § 9/2007/A), and in 2016 in Madeira (Regional Legislative Decree § 19/2016/M).

Despite some differences in the timing of the implementation of regulations, and in terms of species landed, both the definition of MRF and the regulations are very similar across mainland Portugal, Madeira and the Azores (Appendix Table A1).

Available information about the effects of the MRF regulations in place shows that most shore anglers and spearfishers from mainland Portugal disagreed with the restrictions introduced in 2006 (through Portaria § 868/2006) (Veiga et al. 2013; Assis et al. 2018). In both studies, shore anglers and spearfishers believed that regulations are mainly unfounded, inadequate and unfair for the MRF activity. These findings may have important implications, as the lack of acceptance of MRF regulations can potentially result in increased noncompliance (Hauck et al. 2002; Veiga et al. 2013).

4. Research on marine recreational fishing and data availability

Research on MRF in Portugal is relatively recent, and available data is still limited to a few studies. The literature review revealed fifteen published studies dedicated to MRF since the mid-1990s. Most of these studies were based on on-site surveys via roving creel or access point surveys (Table 1). Two studies applied a complementary aerial—roving creel survey for

Table 1. Technical description of recreational marine fishing surveys (ranked by survey period) carried out in Portugal.

Study	Location	Survey period	Survey type	Fishing modes	N° of questionnaires	Response rate %	Biological Sampling (number of questionnaires)	Socio-economic (number of questionnaires)
Castro (2004)	Alentejo (south mainland)	Jul 1994–Jul 1996	Aerial-roving creel	Shore angling Hand harvesting	103 226	n.i	103 226	n.a
Oliveira (2003); Rangel and Erzini (2007)	North/Center Portugal (mainland)	March–September 2001	Access-point	Shore angling	2081	90	1964	2081
Cunha et al. (2005)	Aveiro lagoon (center mainland)	May 2001–Apr 2002	Access-point	Hand harvesting	n.i	n.i	n.i	n.a
Diogo and Pereira (2013b)	São Miguel Island (Azores archipelago)	Aug 2001–May 2002	Access-point	Spearfishing	220	99.5	220	n.a
Diogo (2007)	Faial and Pico Islands (Azores archipelago)	Oct 2004–Sep 2005	Roving creel	Shore angling Spearfishing Boat angling Hand harvesting	748 27 87 n.a	95 95 87 n.a	748 27 87 n.a	n.a n.a n.a n.a
Dias et al. (2008)	Tagus estuary (mainland AML)	Mar 2005–May 2006	Roving creel	Hand harvesting	n.a	n.i	42	n.a
Lima (2006)	North (mainland)	Sep–Dec 2005	Phone - access point	Boat angling	103	89.6	45	103
Veiga et al. (2010, 2013)	Alentejo and Algarve (south mainland)	August 2006–July 2007	Aerial - roving creel	Shore angling	1321	95%	1318	1298
Marcelino (2010)	Peniche (mainland AML)	Jul–Dec 2008	Roving creel	Shore angling	627	98.3	627	423
Assis et al. (2018)	Portugal (mainland)	Jan–Feb 2009	web-based	Spearfishing	512	n/a	n/a	458
Carvalho, Vaz et al. (2013)	Douro estuary (north mainland)	Jun 2010–May 2011	Not defined	Hand harvesting	33	n.i		33
Costa (2012)	Alentejo (south mainland)	Jan–Jul 2012	Roving creel	Shore angling Hand harvesting	32 34	97.4 97.4	66 34	56 39
Aleixo (2013)	Aveiro lagoon (center mainland)	Oct 2012–Oct 2013	Roving creel	Shore angling	23	n.i	23	23
DGRM (2016)	Portugal (mainland)	Jun–Nov 2015	web-based	Shore based Boat angling Spearfishing	3884 1315 501	n.a n.a n.a	n.a n.a n.a	3884 1315 501
Pedro (2017)	Ericeira (mainland AML)	Nov 2016–Jul 2017	Not defined	Hand harvesting Shore angling	26	n.i	26	26

n.a – not applicable; n.i – not identified; AML – Lisbon Metropolitan Area.

inshore marine recreational fisheries (i.e., Castro 2004; Veiga et al. 2010) and another used a phone—roving-creel survey for recreational boats (Lima 2006). The first assessment of MRF at the national level focused on spearfishing only and was carried out by Assis et al. (2018) using a web-based survey. More recently, the Portuguese General Directorate on Natural Resources, Safety and Maritime Affairs (DGRM 2016), carried out a web-based survey for all MRF activities, for all mainland Portugal. Shore angling and hand harvesting are the best studied MRF modes in Portugal with nine surveys, followed by spearfishing (four) and boat angling (three) (Table 1). The Azores archipelago, and the south mainland (Algarve and Alentejo) were the regions with most surveys carried out, while the Madeira archipelago is the only region where no data on MRF surveys have been published so far (Table 1).

The Portuguese MRF studies are, somehow, limited in time and space, generally highly descriptive, with local or regional catch and effort estimates, but often with no associated errors for catch and effort calculations (Marcelino 2010; Santos 2014) or even for the economic value of the fishery (Santos 2014). Complementary methods to access adjustments of catch or effort data have not yet been used in Portugal, which is critical for the implementation of future national-level MRF surveys. The design of these national surveys will encounter many challenges related to the extension of the Portuguese coast, the territory dispersion (Archipelagos of Madeira and Azores, with eleven inhabited islands), the different fisheries management agencies, the bureaucratic difficulties for obtaining precise data on licensed fishers, and even with the political willingness to accomplish this task.

Portugal is however on the verge of changing paradigm. Large scale pilot studies were conducted in the meantime for Portuguese mainland, Azores and Madeira, as part of the DCF working plan 2017–2019. Nevertheless, to date, no results were made available to the scientific community.

5. Characterization of the marine recreational fishing activity in Portugal

5.1. Participation in marine recreational fishing

According to the number of emitted licenses, the total of participants in MRF in Portugal ranges between 170,000 and 200,000 individuals (DGRM 2017). This value represents roughly around 2% of the Portuguese population, and is similar to the overall Spanish participation rate in MRF (2%) (Gordoa et al. 2019) and also to the European average (1.6%). Nevertheless, the value is low when compared with some northern European countries where, in general, over 30% of the population is engaged in recreational fisheries (e.g., Iceland, Norway) (Hyder et al. 2017). According to the MRF licenses data, the most popular Portuguese mainland fishing mode is shore angling (68% of the issued fishing licenses from 2007 up to 2016), followed by boat angling and spearfishing (24% and 8%, for the same period) (Appendix Table A2). In terms of hand harvesting, the licensing scheme is different for mainland Portugal and the Archipelagos. For the Azores and Madeira no license is required for hand harvesting, while in the mainland a license is only needed when using gear in the hand harvesting. In any case, this is deemed an important and relatively popular recreational activity across the country; according to available estimates, hand harvesting represents around 10% of the shore-based recreational activities (Diogo 2003, 2007; Marcelino 2010). An improvement of the Portuguese license system, specific to this activity, could reveal the real importance of this fishing mode.

5.2. Demographic characteristics of recreational fishers

The typical Portuguese marine recreational fisher is a male in his forties (Rangel and Erzini 2007; Veiga et al. 2010; Diogo and Pereira 2013a; DGRM 2016), employed, with a high-school education level (on average 10–12 years of formal education) (DGRM 2016). Spearfishers tend to be younger than other fishers, probably due to the greater physical demands of this activity (Diogo and Pereira 2013b, 2014; Assis et al. 2018). Shore anglers generally present lower educational level compared to spearfishers and boat anglers (Table 2). Boat anglers have generally higher incomes than spearfishers and shore anglers (Lima 2006; Rangel and Erzini 2007; Assis et al. 2018), which seems consistent with the higher costs of this fishing mode.

Most marine recreational fishers have more than 10 years of fishing experience (55%; DGRM 2016), and go fishing between 11 and 60 days *per* year, although this varies according to the MRF mode (Rangel and Erzini 2007; Diogo and Pereira 2013b, 2014; DGRM 2016). The vast majority live near the coastline (84% <20 km away; DGRM 2016), as is the case with the majority of the Portuguese population

Table 2. Demographic profile of recreational fishers from the different marine recreational fishing (MRF) surveys in Portugal.

Fishing mode	Study	Region	Sex	Age (years)	Most common education levels
Shore angling	Oliveira (2003)	north/center	99% Males	40	Primary education (38.9%)
Shore angling	Veiga et al. (2010)	Algarve/Alentejo	99% Males	48	Lower secondary education (56.0%)
Shore angling	Marcelino (2010)	center	98% Males	41–64	Primary education (36.9%)
Shore angling	Diogo and Pereira (2014)	Azores	93% Males	44.4	n.a.
Boat angling	Diogo and Pereira (2013a)	Azores	100% Males	45.1	n.a.
Boat angling	Lima (2006)	North	96% Males	46	Upper secondary education (29.1%)
Spearfishing	Diogo and Pereira (2013b)	Azores	100% Males	27	n.a.
Spearfishing	Assis et al. (2018)	Portugal	n.a.	33	Lower secondary education (44.3%)
All fishing modes	DGRM (2016)	Portugal mainland	98% Males	25–45	Upper secondary education (42%)

Age is given as the mean or the main age class. Most common educational levels (Primary education – up to 4 years of formal education; Lower secondary educational – up to 9 years of formal education; Upper secondary education – up to 12 years of formal education).
n.a. – not available.

(Deville et al. 2014). Information and estimates on the overall economic contribution (direct and indirect) of recreational fishing in Portugal are still limited. Even though, a recent study by Hyder et al. (2017), using available data, estimated that direct expenses (e.g., in bait, fuel, fishing gear) in MRF in Portugal represented around 139 million euros annually.

5.3. Catch composition

Portugal is located in a biogeographical transitional zone between temperate and subtropical waters with a meridionally orientated coast particularly appropriate for the observation of latitudinal patterns (Briggs 1974; Vinagre et al. 2010). A higher number of taxa is recorded for the south of mainland Portugal and the Azores islands, and lower diversity is reported in the north and center regions of mainland Portugal (Table 3; Appendix Table A3). In part, these differences can be associated with the higher diversity of the Sparidae and Labridae families, groups typically targeted and captured by recreational fishers in southern Europe (Morales-Nin et al. 2005; Lloret and Font 2013), that have greater biogeographic affinity to subtropical regions (Vinagre et al. 2010; Froese and Pauly 2019). Similar trends are expected for other MRF modes.

In terms of catch information by fishing mode and region, there are some differences in the main captured and target species. For shore angling, the most captured species is the white seabream (*Diplodus sargus*) in south mainland and in the Azores, and the European seabass (*Dicentrarchus labrax*) in northern mainland. Studies on boat angling and spearfishing in Portugal are scarce, and thus it is highly likely that the diversity of catches, and contribution to global catches from both fishing mode in Portugal are higher than registered (Appendix Tables A3 and A4).

In the case of boat angling, the blackspot seabream (*Pagellus bogaraveo*) was the second most captured species in the Azores and the main target species in mainland north, despite the low number of reported catches which are probably due to the current low abundance of the species (Lima 2006; Diogo and Pereira 2013b; ICES 2018). Nevertheless, in the northern region the most captured species were Atlantic horse mackerel (*Trachurus trachurus*), pouting (*Tripsoterus luscus*) and Atlantic chub mackerel (*Scomber colias*) (Lima 2006), which is in line with the findings of Gomes et al. (2001) and Sousa et al. (2005). Surveys with catch composition information on boat angling in southern areas of mainland Portugal are inexistent. Nevertheless, it is likely that the meridional trends detected by Gomes et al. (2001) in terms of species abundance and distribution—with a northern shelf assemblage dominated by Atlantic mackerel (*Scomber scombrus*) and pouting (*Trisopterus* spp.) and the southern shelf assemblage dominated by Sparids—are also reflected in the regional differences for the catch composition of this fishing mode.

For spearfishing, the research of Assis et al. (2018) highlighted the main target species in mainland Portugal as *D. labrax*, *D. sargus*, common octopus (*Octopus vulgaris*), red porgy (*Pagrus pagrus*), gilthead seabream (*Sparus aurata*), European conger (*Conger conger*), while, amberjacks (*Seriola* spp.) were reported as the main target species by Madeira and Azores spearfishers (Table 3, Appendix Table A5; Assis et al. 2018).

According to the available information, hand harvesting in Portugal is a popular activity in rocky intertidal areas (Castro 2004; Rius and Cabral 2004; Diogo et al. 2016). Some of the main target species in the rocky shores of the south (Alentejo) are: common octopus (*Octopus vulgaris*), stalked barnacle (*Pollicipes pollicipes*), Mediterranean mussel (*Mytilus galloprovincialis*), and several species of crabs, limpets, sea urchins, top shell snails and others (Castro 2004; see Table 4). Despite some differences of intertidal species assemblages between northern and center/southern regions (Boaventura et al. 2002), the species reported by Castro (2004) probably represent the most

Table 3. List of the top five captured species (by weight) by marine recreational fishing in Portuguese waters, per survey/region.

Fishing mode	Common name	Species	North	Center	Algarve/Alentejo	Azores	Source of information
Shore angling	Atherina	*Atherina presbyter*	5	X	X	Ø	**Mainland north**: Rangel and Erzini (2007);
	Gray triggerfish	*Balistes capriscus*	X	2	X	X	**Mainland center**:
	Thicklip gray mullet	*Chelon labrosus*	X	X	2	3	Marcelino (2010);
	European conger	*Conger conger*	4	Ø	Ø	X	**Mainland Algarve and**
	European sea bass	*Dicentrarchus labrax*	2	X	X	Ø	**Alentejo**: Veiga et al. (2010); **Azores**: Diogo
	White seabream	*Diplodus sargus*	3	4	1	1	and Pereira (2014)
	Common two-banded seabream	*Diplodus vulgaris*	X	3	3	X	
		Mugillidae	1	X	Ø	Ø	
	Salema	*Sarpa salpa*	X	4	4	5	
	Atlantic chub mackerel	*Scomber colias*	X	1	5	4	
	Parrot fish	*Sparisoma cretense*	Ø	Ø	Ø	2	
Spearfishing	No common name	*Symphodus caerulius*	n.s	n.s	n.s	3	**Azores**: Diogo and Pereira (2013a)
	Thicklip gray mullet	*Chelon labrosus*	n.s	n.s	n.s	5	
	European sea bass	*Dicentrarchus labrax*	n.s	n.s	n.s	Ø	
	Common two-banded seabream	*Diplodus vulgaris*	n.s	n.s	n.s	Ø	
	Common octopus	*Octopus vulgaris*	n.s	n.s	n.s	1	
		Pagrus spp.	n.s	n.s	n.s	Ø	
	Longfin yellowtail	*Seriola rivoliana*	n.s	n.s	n.s	4	
	Parrot fish	*Sparisoma cretense*	n.s	n.s	n.s	2	
	Gilthead seabream	*Sparus aurata*	n.s	n.s	n.s	Ø	
Boat angling		*Diplodus* spp.	4	n.s	n.s	X	**Mainland north**: Lima
	Dusky grouper	*Epinephelus marginatus*	Ø	n.s	n.s	5	(2006); **Azores**: Diogo and Pereira (2013b)
	Ballan wrasse	*Labrus bergylta*	g.l	n.s	n.s	4	
	Axillary seabream	*Pagellus acarne*	5	n.s	n.s	X	
	Blackspot seabream	*Pagellus bogaraveo*	X	n.s	n.s	2	
	Atlantic chub mackerel	*Scomber colias*	3	n.s	n.s	3	
	Black comber	*Serranus atricauda*	Ø	n.s	n.s	1	
	Atlantic horse mackerel	*Trachurus trachurus*	1	n.s	n.s	Ø	
	Pouting	*Tripsoterus luscus*	2	n.s	n.s	Ø	

The most captured species are ranked from 1 (most captured) to 5 (5th most captured). X: Sampled species that do not belong to the top five. n.s: no survey. g.l: taxa identified to genera level. Ø – Species not identified in the survey.
Note that the work of Rangel and Erzini (2007) covers a small part of Center region (until Aveiro), in addition of the North of the mainland.

commonly captured along the rocky shores of Portugal (Castro 2004). On the other hand, mobile substrates (especially mudflats of coastal lagoons and estuaries) are also sites of intensive harvesting, of several species of bivalves, gastropods, polychaetes, sipunculid worms, mud shrimps, and green crabs (see Table 4).

5.4. Effort patterns

Most recreational fishers, regardless of the fishing mode, prefer to fish on weekends and holidays (Castro 2004; Lima 2006; Diogo 2007; Marcelino 2010; Veiga et al. 2010). Moreover, late afternoons on weekdays are also popular for northern shore anglers (Rangel and Erzini 2007). Summer months (July to September) are usually the preferred time of the year for spearfishing, shore angling and boat angling (e.g., Lima 2006; Rangel and Erzini 2007; Diogo and Pereira 2013a). This is probably related to better weather conditions and due to the traditional Portuguese summer break from school and work. Spearfishing in particular is highly dependent on favorable sea conditions (e.g., good water visibility, low wave height) which are more common in the summer (Lima 2006; Diogo 2007; Rangel and Erzini 2007; Marcelino 2010; Veiga et al. 2010; Diogo and Pereira 2013a). Nevertheless, Veiga et al. (2010) found that catch rates, for shore anglers in southern Portugal were higher during autumn and winter, a period that coincides with the onshore spawning migration of *D. sargus* in this area.

In the case of hand harvesting, summer is the season with highest harvesting effort in the south (Alentejo) (Castro 2004). In spite of this, for some locations (e.g., Azores) (Diogo and Pereira 2014;

Table 4. List of the most important target species of hand harvesting in rocky and mobile substrates in Portugal.

Rocky shores				Mobile substrates			
Family	Common name	Species	References	Family	Common name	Species	References
Lumbrineridae	"Tiagem"	*Lumbrineris fragilis*	Castro (2004)	Cardiidae	Common cockle	*Cerastoderma edule*	Leitão and Gaspar (2007)
Majidae	European spider crab	*Maja squinado*	Castro (2004)	Donacidae	Bean clam	*Donax* spp.	Gaspar et al. (2002)
Mytilidae	Mediterranean mussel	*Mytilus galloprovincialis*	Castro (2004)	Eunicidae	Rock worm	*Marphysa spp.*	Carvalho, Constantino et al. (2013)
Octopodidae	Common octopus	*Octopus vulgaris*	Castro (2004)	Muricidae	Purple dry murex	*Bolinus brandaris*	Vasconcelos et al. (2008)
Parechinidae	Purple sea urchin	*Paracentrotus lividus*	Castro (2004)	Muricidae	Banded murex	*Hexaplex trunculus*	Vasconcelos et al. (2008)
Patellidae	Limpet	*Patella ulyssiponensis*	Castro (2004)	Nereidae	Common rag worm	*Hediste diversicolor*	Carvalho, Vaz et al. (2013)
Patellidae	Limpet	*Patella vulgata*	Castro (2004)	Onuphidae	Polychaeta	*Diopatra neapolitana*	Cunha et al. (2005); Costa et al. (2015)
Patellidae	Limpet	*Patella depressa*	Castro (2004)	Pharidae	Razor clam	*Ensis siliqua*	Constantino et al. (2009)
Pollicipedidae	Stalked barnacle	*Pollicipes pollicipes*	Castro (2004)	Portunidae	Green crab	*Carcinus maenas*	Carvalho, Constantino et al. (2013)
Portunidae	Velvet crab	*Necora puber*	Castro (2004)	Semelidae	Burrowing bivalve	*Scrobicularia plana*	Carvalho, Vaz et al. (2013)
Trochidae	Common top shell	*Phorcus lineatus*	Castro (2004)	Sipunculidae	Peanut worm	*Sipunculus nudus*	Carvalho, Constantino et al. (2013)
Trochidae	Flat top shell	*Steromphala umbilicalis*	Castro (2004)	Upogebidae	Mud shrimp	*Upogebia sp.*	Carvalho, Constantino et al. (2013)
Trochidae	Flat top shell	*Steromphala pennanti*	Castro (2004)	Veneridae	Carpet shell clam	*Ruditapes decussatus*	Cravo et al. (2012)

Diogo et al. 2016) or particular species (e.g., purple sea urchin, *Paracentrotus lividus*; limpet, *Patella candei*; *M. galloprovincialis*) (Castro 2004, Ferreira et al. 2013, Diogo et al. 2016), spring and winter (or specific time periods such as Easter) can also be important for this recreational activity. This can be related with seasonal abundances, traditional harvesting periods (such as religious holidays), or with the reproduction period of the resource (Castro 2004; Ferreira et al. 2013; Diogo et al. 2016).

5.5. Catch and harvest estimates

Catch rates and fishing effort are the key components for estimating total catch and harvest in recreational fishing surveys (Pollock et al. 1997). Catch rates in Portugal, as expected, tend to vary between areas and MRF modes. For example, shore angling shows an increasing gradient from north to south (Table 5), with the highest catch rates reported for south mainland and for the Azores (Table 5). With respect to fishing mode, catch rates for shore angling in Portugal are in general lower than that those reported for boat angling and spearfishing (Table 5), a phenomenon also found in other geographical areas (Meyer 2007; Lloret et al., 2008; Font and Lloret 2014). For hand harvesting, the available estimates in the literature are not comparable with other fishing modes. Though, Castro (2004) and Costa (2012) suggested that the harvest rates by weight *per* km of coastline are considerably higher than for shore angling. This may be related with a number of factors, but especially the type of species targeted by each fishing mode; while shore anglers target mobile fish with a passive gear (hook and line), hand harvesters actively seek and capture sessile organisms such as limpets, *P. pollicipes*, *M. galloprovincialis* or clams.

The estimation of total harvest (daily, monthly, annual) is the product of fishing effort and catch rates but unfortunately due to the absence of national surveys only estimates of total catch *per* fishing mode and specific regions in limited time periods exist. Nevertheless, some authors used the available data to estimate the total catch for larger regions. For example, in the Azores Pham et al. (2013) estimated a recreational harvest of around 600 tonnes (about 6% of the commercial landings), with 96% of the recreational catch related to shore and boat angling. For the Portuguese mainland Leitão et al. (2014) estimated a mean annual MRF total catch of 1791 tonnes (0.8% of commercial landings), based on MRF licenses, catch rates, effort and catch composition provided by Veiga et al. (2010). Nevertheless, this estimate may not fully reflect the Portuguese MRF situation, given

Table 5. Catch rates per hour per angler in number and weight of different marine recreational fishing (MRF) modes at different locations of Portugal.

MRF mode	Study	Location	CPUEn (fish angler^{-1} h^{-1})	CPUEw (kg angler^{-1} h^{-1})
Shore angling	Rangel and Erzini (2007)	North/Center	0.5	0.08
	Marcelino (2010)	Center	0.5	0.15
	Veiga et al. (2011)	Algarve/Alentejo	1.1	0.21
	Diogo and Pereira (2014)	Azores	1.4	0.84
Boat angling	Lima (2006)	North	14.0	3.11
	Diogo (2007)	Azores	9.7	3.14
Spearfishing	Diogo (2003); Diogo and Pereira (2013b)	Azores	2.3	1.16
	Diogo and Pereira (2014)	Azores	2.3	1.97

Note that the CPUE of boat angling is per boat instead of per angler.

the different fishing patterns for spearfishing and boat angling (generally higher catch rates, fishing effort more dependent on sea conditions, etc.). More research on boat angling, spearfishing and hand harvesting at the regional level is needed to provide better estimates of the total mainland MRF catches. Furthermore, the absence of studies in Madeira does not allow a national estimate of MRF catch for all Portugal.

6. Release and harvest of undersized fish on MRF

Recreational fisheries effort is generally concentrated in inshore areas, including lagoons and estuarine areas that are important nurseries of many fish species targeted by recreational and commercial fishers in Portugal (Santos and Nash 1995; Ribeiro et al. 2006; Vasconcelos et al. 2009; Vinagre et al. 2009; Aleixo 2013). For this reason, research on released and kept juveniles or undersized fishes is a key component for assessing the impact of MRF (Veiga et al. 2010; Pinho et al. 2014). In Portugal, the main reason reported by recreational fishers for releasing fish is the total size (Marcelino 2010; Veiga et al. 2010; Diogo and Pereira 2014), even though, species with no (or low) gastronomic value tend to have higher release rates as well (Veiga et al. 2010; Diogo and Pereira 2014). The reported releases in number for shore angling in southern mainland Portugal (Algarve and Alentejo) represented 23% of the total catch determined by Veiga et al. (2010). In Peniche (center region) and in the Azores islands the release rates were lower (10.4% and 4.6%; respectively) (Marcelino 2010; Diogo and Pereira 2014). With the current closed seasons in place for certain areas and important commercial species (e.g., seabreams) (Decree § 115-A/2011), higher release rates of these species are expected, regardless of size.

Analyzing the main target species, in southern Portugal mainland and in the Azores, *D. sargus* had a release rate of 18% and 4.8%, respectively (Veiga et al. 2010; Diogo and Pereira 2014), while in Peniche, there are zero releases reported for the main target species *S. colias* (Marcelino 2010). Although fish size can be considered as a major reason for anglers to release (Veiga et al. 2010; Diogo and Pereira 2014), the retention of juvenile specimens is higher for particular species and regions. In Azores and Peniche for example, the retention of undersized fish was observed for a higher percentage of the captured species (38% and 71%; respectively) (Marcelino 2010; Diogo and Pereira 2014). In southern Portugal, despite the overall low percentage of undersized fish kept (11.5%), for important commercial species such as *D. labrax* most (73%) of the harvested fish is undersized (Veiga et al. 2010). The reasons for this behavior were associated with shore anglers disagreement regarding this regulation, or due to lack of awareness about the MLS in place, but also because this is a highly appreciated species (Veiga et al. 2010). Moreover, the lack of compliance with legislation by marine recreational fishers and lack of enforcement of rules and regulations is a well-known reality in Portugal, which needs to be reverted (Diogo et al. 2016).

In Portugal, as in other southern European countries, the main target species present a higher level of harvested juveniles and undersized fish, compared to northern European countries, Australia, USA or Canada (Ferter et al. 2013). These differences are probably related with consumption patterns, angling regulations and catch rates (Ferter et al. 2013). The impact of harvesting juveniles in MRF on fish stocks is important to analyze, especially for species with complex life-histories and already fully or overexploited. For example, in the Azores, *P. bogaraveo* is the most important commercial fishing resource, and despite being considered a deep-water species, the nursery grounds are located inshore, along the coastline where the species remains during the first year of life, when it is harvested by shore anglers and commercial fisheries alike. Even though, MLS is in place for *P. bogaraveo* since 2006, there is a special exception in place for recreational shore angling (Pinho

et al. 2014). A stock-recruitment projection made for this species estimated that a total ban of harvesting juveniles would provide a long-term increase of 15% and 8% in spawning-stock biomass and catch, respectively, as well as a 13% increase in the value of landings (Pinho et al. 2014).

The enforcement of existing MLS regulations with positive effects on stock size will likely vary between species, due to factors such as the species life-history, stock status and current fishing mortality levels. Nevertheless, the analysis of Pinho et al. (2014) indicated that, at least for some species, the overall decrease of harvested juveniles and undersized fish would potentially contribute to an increase in the stock size in the long term. Besides specific regulations and increased enforcement to minimize harvesting of undersized fish educational programs have also been acknowledged as an important tool to shape values and attitudes, increase anglers awareness toward regulations (e.g., MLS), minimize the capture of unwanted species and sizes (through adapting gear and fishing practices), increase the release proportions of undersized fish, and promote better handling and release procedures (Veiga et al. 2011; Ferter et al. 2013; Veiga et al. 2013).

7. Competition for shared resources between MRF and commercial fisheries

Although the overall magnitude of recreational catches in relation to commercial landings is generally low, recreational harvests of some species and/or in some areas have been found to be substantial (Veiga et al. 2010; Pham et al. 2013; Diogo and Pereira 2013b, 2014; Leitão et al. 2014). For example, Veiga et al. (2010) estimated that, in southern Portugal, although overall shore angling catches corresponded to 0.8% of the commercial landings, for *D. sargus* recreational shore angling catches corresponded to 65% of the commercial landings (39.4% of the total catch; Veiga et al. 2010). In contrast, *D. sargus* is not an important commercial species in the Azores, which might explain why the recreational catch accounts for 220% of the official commercial landing statistics (Pham et al. 2013). Some important Azorean coastal commercial species are also captured in large quantities by recreational fishing. For example, catches of blacktail comber, *Serranus atricauda* and parrot fish, *Sparisoma cretense* were estimated as corresponding to 85% and 60% of the commercial landings, respectively (Pham et al. 2013). In northern mainland Portugal, the magnitude of shore angling catch compared to the commercial sector seems much lower. Shore angling catches of *D. labrax*, for example, corresponded to only 5.8% of the local commercial landings, while *D. sargus* corresponded to 1.2% (Rangel and Erzini 2007). Nevertheless, the availability of official landings data for this region was limited at that time and new studies are needed to confirm these results.

In terms of boat angling, 25% of the catches in the Azores are from demersal/deep-water species, with some species, such as the Blackspot seabream (*P. bogaraveo*) already considered under heavy fishing pressure, and with recovery plans in place (ICES 2018; EC. Reg. 2340/2002). Even though, boat angling only accounted for 3% of commercial landings for these species (Menezes et al. 2013; Pham et al. 2013; Diogo and Pereira 2013b). In northern mainland Portugal, the main target species is *P. bogaraveo*, but deep-water species are captured in lower quantities. The impact of boat angling on particular coastal species, especially from the Sparidae family, is likely considerable. More surveys and research on this activity are required in order to better evaluate its contribution to the overall Portuguese catches.

Hand harvesting catch estimates are limited, but the Portuguese General Directorate on Natural Resources, Safety and Maritime Affairs (DGRM) highlighted the importance of hand harvesting (DGRM 2017). Although the contribution of the recreational sector is not well-known, shellfish and stalked barnacle (*P. pollicipes*) harvesting are estimated to represent around 15% of the total Portuguese mainland MRF captures according to the DGRM on-line survey (DGRM 2016). Stalked barnacle (the most important intertidal commercial resource) landings have shown a declining trend, likely associated to both recreational and commercial harvesting (Cruz et al. 2015). The same pattern has been reported in the Azores for limpets (*Patella aspera*, *P. candei*), the main commercial intertidal species (Diogo et al. 2016). Annelids are another group of species usually indirectly impacted by the recreational fishing activity. According to Costa et al. (2015), approximately 100 tonnes year^{-1} of polychaete worms are harvested for bait from Portuguese estuaries and coastal lagoons, with most of the harvesting undertaken by professionals who supply fishing tackle shops.

Even though, the available estimates reveal an important contribution of recreational fishing in terms of total catches in coastal areas and for certain resources, the overall impact of MRF catches on the stocks of harvested species at the national level is largely still unknown due to the limited dedicated research and data collection.

8. Vulnerable species

Assessing recreational harvesting of important fish species is vital but does not depict the entire story of direct impacts of recreational fishing (McPhee et al. 2002). The diversity of species captured by recreational fishing in Portugal is considerable, representing a great diversity of life histories. While some species are more resilient and can support relatively high levels of harvesting, others tend to decline even with low levels of exploitation (McPhee et al. 2002; Cheung et al. 2007). Some of the species captured by MRF that are of greatest concern to conservation in Portugal and currently categorized as threatened or vulnerable by IUCN (2018) are allis shad, *Alosa alosa*; barred hogfish, *Bodianus scrofa*; island grouper, *Mycteroperca fusca*; *E. marginatus*; bluefish, *Pomatomus saltatrix* and gray triggerfish, *Balistes capriscus*. Using a precautionary management approach, the harvest of species such as *A. alosa, E. marginatus*, European lobster, *Homarus gammarus,* spiny lobster, *Palinurus elephas* was prohibited for recreational fishing in mainland Portugal.

Though, there are other species potentially vulnerable to fishing for which the current management systems may be insufficient or inadequate to prevent overexploitation. Meager (*Argyrosomus regius*), *D. labrax*, *M. fusca*, white trevally (*Pseudocaranx dentex*) and longfin yellowtail (*Seriola rivoliana*) all characterized by slow growth, late maturation, lower reproductive potential, and limited habitat availability and may also be highly vulnerable to the current fishing pressure, and particular attention should be paid to them (Cheung et al. 2007; Veiga et al. 2010; Diogo and Pereira 2013a, 2013b). Also, some species tend to be more vulnerable in specific stages of their life cycle, especially those characterized by spawning aggregation events (Russel et al. 2012). In Portugal, inshore spawning aggregations are known for several species such as *D. sargus*, *A. regius*, and *D. labrax* (e.g., Prista et al. 2008; Veiga et al. 2010; Vinagre et al. 2012). Any assessments of fishing impacts and respective management measures should thus consider the relative vulnerability of these and other species to the various MRF modes. For example, while shore angling in the Azores accounts for a greater volume of fish and species than spearfishing, it tends to impact species with lower indexes of vulnerability to fishing (Diogo and Pereira 2014). The impact of spearfishing can be more pronounced on vulnerable species with life cycles confined to shallow waters that overlap with the operational depths of this activity (usually $<$ 25 m depth; Diogo and Pereira 2013b). This impact can be magnified in areas of limited available habitats, such as in the volcanic islands of the Azores and Madeira, where the shelf is very narrow or absent (Diogo and Pereira 2013b). Marine recreational fisheries impacts are cumulative and concurrent, and besides spearfishing, boat angling also catches a number of vulnerable coastal species (e.g., groupers, blackspot seabream), and with higher depth ranges than spearfishing, diminishing the possibility of a depth refuge for some vulnerable coastal species targeted by both fishing modes (Diogo and Pereira 2013a, 2013b; Lindfield et al. 2014). Moreover, most of these vulnerable coastal species are also sought after and captured by the artisanal commercial fishing activity. This complexity can be addressed by improving the knowledge of the combined impact of commercial and MRF on the most vulnerable species, and by adapting the respective legislation with adequate precautionary and protection measures and proper enforcement.

9. Ecological footprint of MRF

The use of natural bait by anglers represents an additional impact of MRF in the ecosystems (McPhee et al. 2002), and the harvesting of some species to be used as bait causes a potential greater impact on ecosystems than that of the retained catches and discards alone. Much of the bait used by anglers is collected on rocky shores and sedimentary intertidal areas where a wide range of invertebrates (polychaetes, crustaceans, molluscs), and algae are harvested. Bait collection is a key factor for angling success; an example of this is the harvesting of algae *Fucus* spp. in spring, which is used to capture salema, *Sarpa salpa* (Castro 2004; Diogo and Pereira 2014). The ecological effects of algae harvesting has implications for intertidal communities (Addessi 1994). Also, rock-turning to catch marble crab, *Pachygrapsus marmoratus* (Diogo and Pereira 2013b; 2014), or polychaete worms (e.g., "tiagem"; Castro 2004) may reduce the densities and even change species composition of under-rock communities (Addessi 1994). Polychaete worms are highly targeted in mudflats of lagoons and estuaries (e.g., *Hediste diversicolor*, *Diopatra neapolitana*), and are some of the most popular baits in Portugal (Oliveira 2003; Cunha et al. 2005; Diogo 2007; Marcelino 2010; Aleixo 2013; Costa et al. 2015). Catches of live bait by recreational fishers are deemed considerable, based on the live bait trade and fishing tackle shops across the country (Cunha et al. 2005; Aleixo et al. 2014). Nevertheless, the high productivity of the estuarine systems is assumed to support high

levels of harvesting impact (Carvalho, Vaz et al. 2013) and, in general, the impact of bait collection on the intertidal area seems more severe on rocky shores (Oliveira 2003; Marcelino 2010; Diogo and Pereira 2014).

It seems obvious fair to recognize that, in the context of research and fisheries management, bait collection impact has been historically overlooked as a part of the angling activity. Additionally, many shore anglers use non-indigenous live-bait species (i.e., polychaete worms), imported and commercialized in local stores. Previous cases in Portugal and elsewhere show that many of these species have generally high chances of establishment with potential negative consequences to native species and coastal ecosystems (Micael et al. 2016; Sá et al. 2017).

Other angling related impacts in the ecosystems have been also documented. For example, Rodríguez and Pham (2017) registered a high quantity of marine litter in traditional fishing grounds of recreational boat angling in the Azores. Similar patterns of pollution associated to recreational fishing were observed in several hotspots of shore angling across the country (Diogo 2003; Oliveira 2003), and elsewhere (e.g., Radomski et al. 2006; Lloret et al. 2014). Litter is recognized to lead to localized habitat alterations (Arlinghaus and Cooke 2009). Also, many kinds of birds and animals can become entangled in lost fishing lines and hooks, which can result in injury or death (Nemoz et al. 2004; Arlinghaus and Cooke 2009). Another relevant problem is lead pollution from lost fishing sinkers; Oliveira (2003) estimated that shore anglers from the north of Portugal lost approximately six tonnes of lead in one year. Spearfishing has been found to have a low indirect impact due to gear loss (Diogo and Pereira 2013b). Even so, the impact of this activity on fish that escape wounded from the harpoons, and on behavior of some fish species, is becoming a topic of increasing interest for research (Diogo and Pereira 2013b; Tran et al. 2016).

Marine recreational fishing can also impact local and even regional populations of other marine animals through trophic interactions (McPhee et al., 2002). For instance, the reduction of abundance of higher trophic levels in shallow waters is reflected in changes in the abundance and size structure of fish communities. More important is the potential to create a top-down ecosystem effect, generating ecological imbalance and changing the composition of natural communities (Dulvy et al. 2002; Lloret et al. 2008).

10. MRF and MPA

Marine protected areas (MPA) have emerged over the last decades as a key tool for fisheries management and conservation (Vandeperre et al. 2011; Pita et al. 2013). In Portugal, 52 MPA were implemented over the last three decades; these MPA currently cover 6.5% of the Portuguese EEZ, covering an area of 112364.9 km^2 with 86% located in coastal areas (Batista and Cabral 2016). Despite the growing tendency of enlarging the MPA network in Portugal, only 9.6% of the Portuguese MPA have no-take areas and the average percentage of no-take areas within MPA ranges from extremely low, 2.2% in mainland Portugal, to high (76.0%) in Madeira (Batista and Cabral 2016).

Marine protected areas in Portugal, as elsewhere, include a large variety of zoning and management schemes from single to multiple-zoning and from no-take to multiple-use areas. The multiple-use areas within MPA present different level of restriction for MRF gears and/or modes because some are considered more damaging than others (Horta e Costa et al. 2016). Spearfishing within MPA is, in many cases, completely banned, while other MRF modes, such as shore angling and hand harvesting, tend to be allowed, restricted to residents or permitted in partially protected areas but limited to some days of the week (Inglês 2010; Sousa et al. 2013; Horta e Costa et al. 2014; Pereira et al. 2017).

The management discrepancy currently observed for the different MRF modes, and between recreational and commercial fishing (Fernández et al. 2016) tends to be controversial. Certain groups of fishers feel they are being discriminated against and are of the opinion that banning only a particular activity has little positive effects on the effective protection of main coastal fish stocks (Assis et al. 2018). The success of MPA requires a better integration of stakeholders (in this case recreational fishers) in the MPA decision-making process and better-informed recreational fishers, as the lack of knowledge about the regulations and absence of involvement of recreational fishers may result in lower compliance with rules and regulation overall (Veiga et al. 2013; Diogo et al. 2016). The success of MPA also requires more integration of science, with robust fisheries data, and the importance of MRF research has been highlighted recently in several studies that integrate MRF fishing effort in the process of designing and implementing marine reserve networks (Schmiing et al. 2014; Abecasis et al. 2015). In this context, mapping MRF fishing effort is a key component of the analysis along with different users' costs and benefits (i.e., spatial patterns of the abundance and reproductive potential of different species, vulnerability of fish to fishing,

habitat type, algae biotopes, and other socio-economic costs and benefits (Schmiing et al. 2014; Abecasis et al. 2015).

11. Climate change

Temperate transition zones, such as the case of Portugal, are often recognized as hotspots of biodiversity, with species adapted to natural cyclic oceanographic fluctuations (Horta e Costa et al. 2014). The disruption of these natural cycles is already affecting shelf fish assemblages (Horta e Costa et al. 2014; Teixeira et al. 2014). Due to global warming, it is expected that cold-temperate affinity species targeted by the Portuguese MRF will tend to be scarcer in the future, while warm-temperate and tropical species will be more abundant and move north (Horta e Costa et al. 2014; Teixeira et al. 2014). This pattern is already being documented in artisanal Portuguese fisheries, where the decline of some traditional species is driving small-scale fisheries to start targeting different species using different gears, fishing grounds, and fishing tactics taking into account the market and the income, such as the increase in landing of gilthead seabream, *S. aurata*, axillary seabream (*Pagellus acarne*) and common dentex (*Dentex dentex*) (Teixeira et al. 2014). The same tendency is expected for MRF, in the absence of some traditionally targeted species, a shift to new species is expected, together with changes in catch composition, catch rates, operational methods and even fishing patterns.

12. Global MRF situation and recommendations for marine recreational fishing in Portugal

Despite FAO annual data requests for the inclusion of recreational catch data from national surveys these are still mostly unavailable in many developing countries, unlike developed countries as Australia (Henry and Lyle 2003) and Canada (Brownscombe et al. 2014), where such surveys are common and have been conducted for several decades. For this reason, global reconstruction of recreational catches are to certain point imprecise (Pauly and Zeller 2016). Even though, developing countries as Brazil and India are starting to realize the importance of implementing national level recreational fishing surveys, the available data on these countries is still time and space limited (Gupta et al. 2015; Freire et al. 2016).

Recreational fishing participation rates across the world presents a high variability since it is affected by several factors, such as socio-economic, geographic, and demographic status of the populations (Cisneros-Montemayor and Sumaila 2010). According to Hyder et al. (2017) across industrialized countries, there is a positive relationship between recreational fishing participation rates and per capita gross domestic product (GDP). In fact, globally Africa and Asia present the lowest participation rates (Cisneros-Montemayor and Sumaila 2010), followed by Europe with a participation rate of 1.6% (Hyder et al. 2017) approximately half of USA (3.3%; NMFS 2015; 2016). Nevertheless, in Europe, there are significant differences, with Iceland and Norway having high participation rates ($>$ 30%) while Germany has the lowest (0.2%). Also, participation rates are higher in the Atlantic European coast than in Mediterranean coasts, revealing the participation rate variability and complexity within Europe (Hyder et al. 2017). The highest global participation rate in MRF occurs in Oceania with participation rates in New Zealand of 17.0% and Australia of 19.5% (Henry and Lyle 2003; Wynne-Jones et al. 2014). Other factors that could account for the variability of participation rate relate to the apparent need for leisure and to the cultural importance of fish in particular countries, suggesting that effects of industrialization vary in importance across different countries (Arlinghaus et al. 2015). Though, independently of the participation rate, the average days fishing across Europe seem to be quite similar (5–10 days *per* fisher *per* year), which could indicate that despite the variability of target species and environments, between countries and within regions, the factors which can explain the time that fishers dedicate to MRF may have common elements (Hyder et al. 2017).

On the other hand, the biological and ecological impact of MRF cannot be overlooked since global catches could be 14% higher if recreational fishing is included in overall landings (Cooke and Cowx 2004). This is especially true for some species or locations where MRF can even exceed commercial landings (McPhee et al. 2002). Moreover, catch and released practices should be consider in MRF, especially because in some species the post-released mortalities are considerable high (Ferter et al. 2013). The inclusion of recreational fisheries in stock assessment is key for the proper management of several important stocks; however, there is still a deficiency of MRF time series data for many individual stocks in Europe and in many other regions of the world making inclusion of data in stock assessment a challenge (Hyder et al. 2017).

Portugal is considered an industrialized country, however in terms of research on MRF it is still behind most of the developing countries which have a long tradition in this research field. Data collection and research on MRF in Portugal has been mostly confined to academic studies, scattered in space and time. Even though, data collection of recreational fishing is a European legislative requirement since 2002 (Council Regulation No. 1639/2001 of 25 July 2001). Still, Hyder et al. (2017) have noticed that only a few countries have followed this obligation (European Union Member-States are now obliged to develop national monitoring programs on recreational fishing for several species under the Data Collection Framework (DCF) (ICES 2010; Hyder et al. 2017) and this the compilation of the available Portuguese MRF research literature could provide some insights into the Portuguese MRF sector over the last 20 years, identifying the current challenges and knowledge gaps, providing, at the same time, recommendations for future research, needs for monitoring programs, and ways to improved management of the activity.

Relevant recommendations include:

- Implementation of regular mandatory MRF national data collection surveys to estimate fishing effort, catch and economic valuation of the activity. These surveys should contemplate complementary methods and data validation (National Research Council 2006), and consider the bias effects inherent to off-site methods (e.g., recall bias, non-response bias (National Research Council 2006)) and of on-site surveys (National Research Council 2006; Diogo and Pereira 2016; Diogo et al. 2017). National MRF monitoring framework could be supported (at least partially) by funding from recreational fishing licenses.
- Introduction of an important human dimension component in all future MRF surveys and evaluation of ecological impacts, such as the effect of MRF on species richness and identification of the most vulnerable species.
- Systematic monitoring of MRF at the national level must also act as an essential tool to understand trends in fishing pressure, participation and catches, and how these relate to factors like climate change.
- Better characterization and analysis of several fishing modes, such as boat angling and spearfishing needs to be addressed; in some regions, such as the Madeira archipelago, MRF still surveys need to be implemented.
- The Portuguese licensing system should change to improve available statistics. One important step would be the removal of the multimode fishing license, which results in over or under estimation of the real number of fishers *per* fishing mode. Additionally, researchers should have permission to access the registry (i.e., phone contact) of licensed recreational fishers in order to improve survey coverage and estimates. Also, licenses should be issued, once again, at a regional level (licenses changed from regional—NUTS II level—to national wide in the beginning of 2014), to allow the analysis of MRF impacts locally. A national standardization of the licensing scheme is also important, since the Azores and Madeira archipelagos do not have a license system for shore angling, and for boat angling the license scheme is also different from the one in place in the mainland.
- Data on post-release mortalities of important MRF species is still very limited for Portugal, only available for three species, and for shore angling specifically (Veiga et al. 2011). It is extremely important to evaluate the potential post-release mortalities imposed by MRF of other important species.
- The recognition of the importance of MRF, coupled with a strong MRF research are key components to change from a top-down management approach toward co-management involving all stakeholders. In this process it is necessary to strengthen the role of MRF associations (Pita et al. 2017). The recreational fishers must be more involved in the decision-making process in order to reduce the conflicts between artisanal and MRF. More and adequate research and estimates of the socio-economic importance of MRF are also needed, in order to better understand the socioeconomic benefits of this sector. Illegal unreported and unregulated fishing under the umbrella of MRF has been registered (Diogo and Pereira 2013a; Diogo et al. 2016) or recognized based on anecdotal evidence (Rangel and Erzini 2007; Veiga et al. 2010) and is considered a problem in some areas. Illegal unreported and unregulated fishing has been one of the triggers for increased competition and conflict between the recreational the commercial fishing sectors and should thus be properly assessed and addressed.
- The current available knowledge on the species biology, population dynamics, fisheries exploitation patterns, and on the multiple resource users, needs to be integrated in the technical management tools in place (e.g., MLS, species catch limits or bans,

MPA design, and revision of seasonal closures for some species), while the harvesting and stock status of a number of potentially vulnerable and/or highly exploited species by MRF (e.g., seabreams, seabass) needs to be better evaluated and properly regulated.

The MRF potential for research through the knowledge of recreational fishers (e.g., traditional ecological knowledge, citizen science) and sport fishing (Guerreiro et al. 2011) should be considered as a potential source of data to be integrated in future management strategies. The acknowledgment use and implementation of the above recommendations would result in considerable benefits to an overall MRF regulatory framework. More adequate regulations, coupled with proper participation of all the stakeholder in the management and decision-making process, and adequate enforcement would likely result in increased acceptance and compliance with the measures in place. In addition, and as suggested by Veiga et al. (2013) programs to increase fishers awareness of regulations in place, such as a code of practice for MRF (e.g., including a summary of the main regulations, main targeted species and their biology, and maps with the restriction zones), along with other education programs to explain the reasons behind the regulations and educate recreational fishers toward best practices (e.g., on minimizing bycatch, and handling and releasing fish), would likely result in better compliance and more responsible fishing practices.

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ORCID

Hugo Diogo http://orcid.org/0000-0002-9269-3339

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Appendix

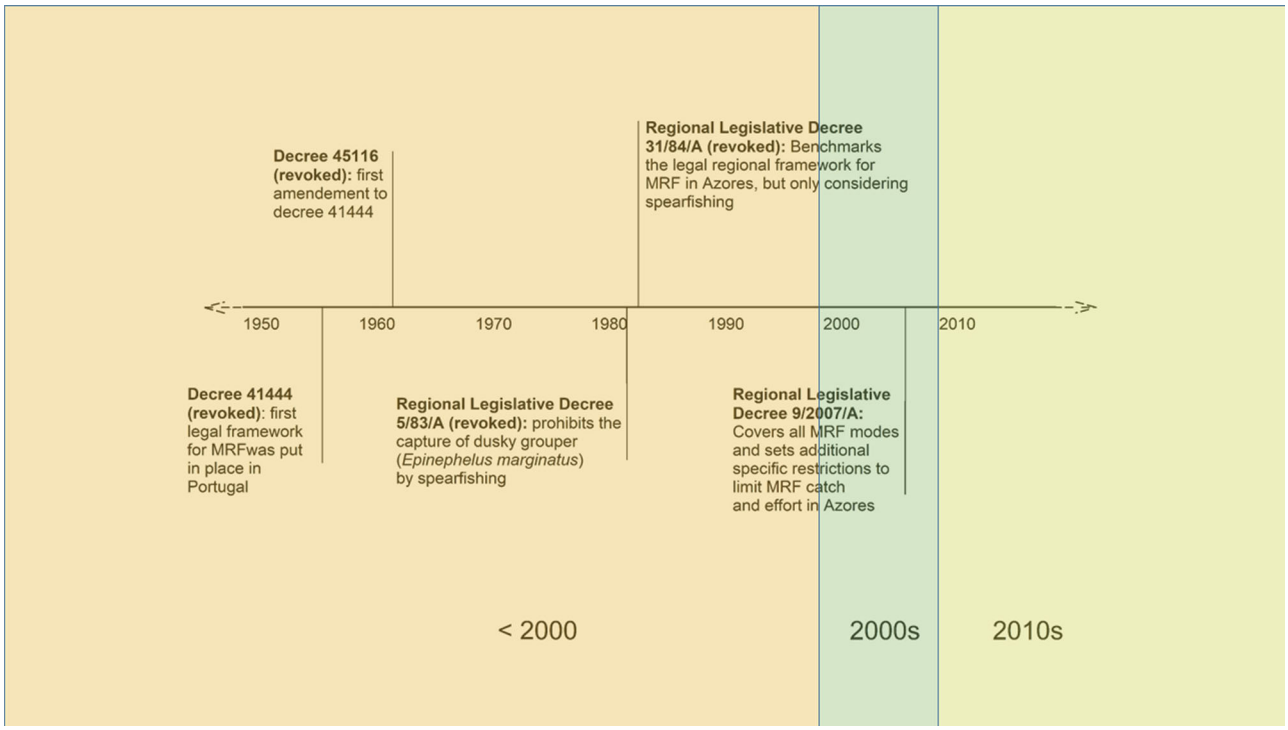

Figure A1. Regulatory history of marine recreational fishing (MRF) in the Azores archipelago. Specific regulations on MRF in MPA and technical fisheries management measures that regulate species (e.g., minimum landing sizes and seasonal closures) were not accounted.

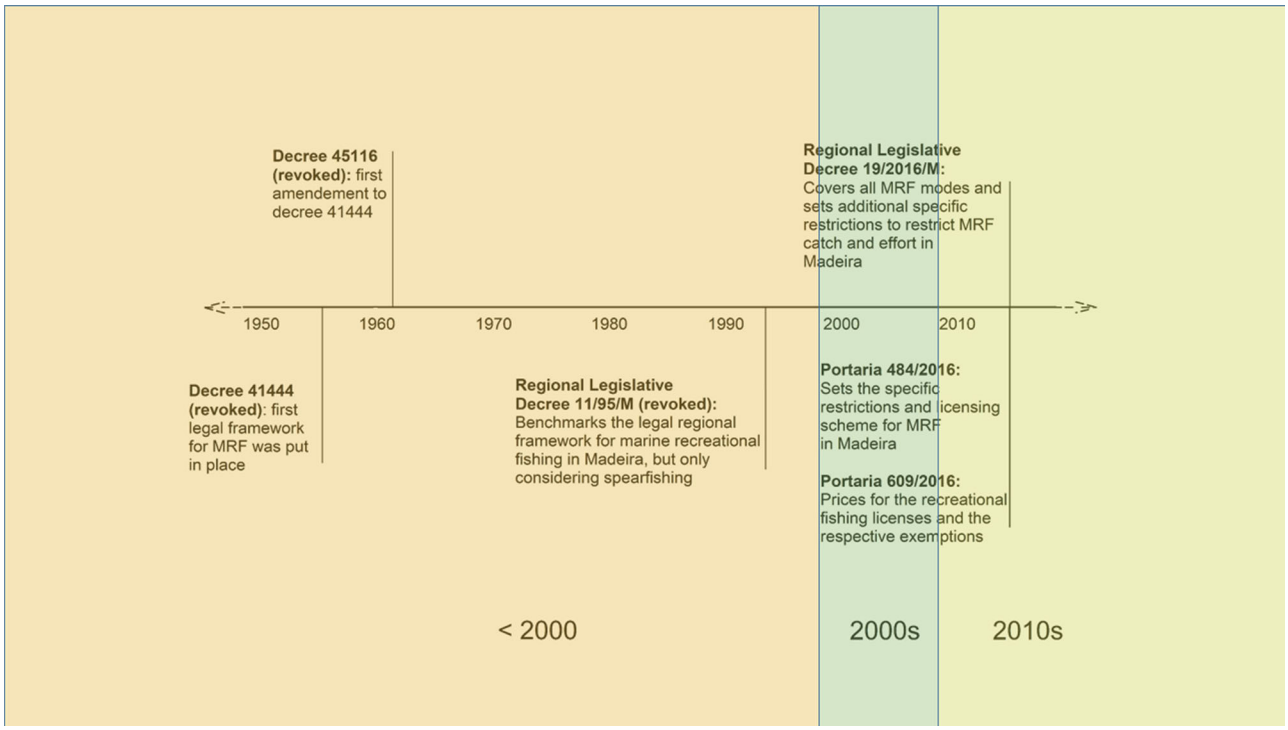

Figure A2. Regulatory history of marine recreational fishing (MRF) in the Madeira archipelago. Specific regulations on MRF in MPA and technical fisheries management measures that regulate species (e.g., minimum landing sizes and seasonal closures) were not accounted.

Table A1. Marine recreational fisheries (MRF) management measures in force for the different main regions in Portugal.

Main region	Description of MRF regulations
Mainland Portugal	**History of regulations:** First regulatory framework in 1957 (Decree 41444) included all main recreational fishing modes (i.e., spearfishing, boat-based angling, shore-based angling); First evidence of effective restrictions put in place from Portaria 868/2006. **Current regulation in force:** Portaria 14/2014. **Current main management measures:** 1. minimum landing sizes; 2. daily bag limits: fish and cephalopods: 15 kg fisher^{-1} day^{-1} (spearfishing); 10 kg fisher^{-1} day^{-1} (angling); the largest fish is not counted against the bag limit; 25 kg.boat.day^{-1} (boat angling, for crews with 3 or more anglers) shellfish: 3 kg fisher^{-1} day^{-1} (Mussels *Mytilus* spp.); 5 kg fisher^{-1} day^{-1} (oysters); 5 kg fisher^{-1} day^{-1} (Japanese cockle, *Ruditapes philippinarum*); 0.5 kg fisher day^{-1} (annelids) other invertebrates: 2 kg fisher^{-1} day^{-1} 3. fishing licenses (can be issued by fishing modality and overall fishing license) 4. temporal and spatial closures for specific fishing gears (e.g., night fishing prohibited for spearfishing) and species 5. prohibited species (e.g., shads *Alosa* spp., dusky grouper *Epinephelus marginatus*, spiny lobster *Palinurus elephas*) 6. fishers are required to answer to any MRF official surveys
Azores	**History of regulations:** First regulatory framework in 1957 (Decree 41444) included all main recreational fishing modes (i.e., spearfishing, boat-based angling, shore-based angling). First evidence of effective restrictions put in place for spearfishing from DLR 5/1985/A **Current regulation in force:** DLR 9/2007/A **Current management measures:** 1. minimum landing sizes; 2. daily bag limits: fish and cephalopods: 10 specimens day^{-1} (spearfishing); 7.5 kg fisher^{-1} day^{-1} for fish with less than 40 cm plus five fish with more (or equal) than 40 cm (angling); shellfish: 1.5 kg fisher^{-1} day^{-1} (*Patella* spp.) 3. fishing licenses 4. temporal and spatial closures for particular gears (e.g., night fishing prohibited for spearfishing), periods, species or areas 5. prohibited species for spearfishing (e.g., dusky grouper *Epinephelus marginatus*) and bag limited of 2 specimens of spiny lobster *Palinurus elephas* and slipper lobster *Scyllarides latus* 6. requirement to answer to any MRF official surveys
Madeira	**History of regulations:** First regulatory framework in 1957 (Decree 41444) included all main recreational fishing modes (i.e., spearfishing, boat-based angling, shore-based angling). First evidence of effective restrictions put in place from Portaria 484/2016. **Current regulation in force:** Portaria 484/2016. **Current management measures:** 1. minimum landing sizes; 2. daily bag limits: fish and cephalopods: 10 fish day^{-1} (spearfishing); 10 kg fisher^{-1} day^{-1} (angling); the two largest fish is not counted against the limit shellfish: 3 kg fisher^{-1} day^{-1} (*Patella* spp.) other invertebrates: 2 kg fisher^{-1} day^{-1} 3. fishing licenses 4. temporal and spatial closures for particular gears (e.g., night fishing prohibited for spearfishing), periods, species or areas 5. prohibited species Red List of IUCN and bag limited of 2 specimens of spiny lobster *Palinurus elephas* and slipper lobster *Scyllarides latus* 6. requirement to answer to any MRF related surveys

Table A2. Number of licenses issued annually for the Portuguese Mainland, Azores and Madeira.

	Mainland Portugal				Azores			Madeira	All			
Year	Shore Based	Boat anglers	Spearfishing	Combined license	Spearfishing	Boat license	Boat anglers[a]	Spearfishing	Shore Based	Boat anglers	Spearfishing	Total
2007	141046	44619	15857	n.a	n.a	n.a	n.a	n.a	141046	44619	15857	201522
2008	116884	39738	14235	n.a	3143	1282	2436	2166	116884	42174	19544	178602
2009	112939	39041	13473	n.a	3217	1349	2563	2330	112939	41604	19020	173563
2010	121003	38406	13165	n.a	3345	1314	2497	2725	121003	40903	19235	181141
2011	124224	38393	12717	n.a	3500	1343	2552	2514	124224	40945	18731	183900
2012	123095	37170	12246	n.a	3400	1404	2668	2714	123095	39838	18360	181293
2013	116827	35660	13110	n.a	3278	1289	2449	2467	116827	38109	18855	173791
2014	103530	43527	10247	2742	2814	1344	2554	2272	106242	46081	15333	167656
2015	112467	64171	9721	3458	3014	1422	2702	2444	115904	66840	15179	197923
2016	112265	71900	9718	3657	2967	1443	2742	n.a	115922	78299	16342	204692

n.a – not available.

[a]The number of Azorean boat anglers was estimated (product of the number of vessel licenses by the average of crew provided by Diogo 2007).

Table A3. List of captured species by shore angling identified in several on-site surveys. Sources of data - North/Center: Rangel and Erzini (2007); Center: Marcelino (2010); Algarve/Alentejo: Veiga et al. (2010); Azores: Diogo and Pereira (2014).

Famíly	Common name	Species	North/Center	Center	Algarve/Alentejo	Azores
Ammodytidae	Smooth sandeel	*Gymnammodytes semisquamatus*	✓	Ø	Ø	Ø
Anguillidae	Anguilla	*Anguilla anguilla*	✓	Ø	Ø	Ø
Apogonidae	Cardinal fish	*Apongon imberbis*	Ø	Ø	Ø	✓
Atherinidae	Atherina	*Atherina presbyter*	✓	✓	✓	Ø
Balistidae	Gray triggerfish	*Balistes capriscus*	✓	✓	✓	✓
Batrachoididae	Lusitanian toadfish	*Halobatrachus didactylus*	Ø	Ø	✓	Ø
Belonidae	Garpike	*Belone belone*	✓	✓	✓	✓
Blennidae	Rock goby	*Gobius paganellus*	Ø	Ø	Ø	✓
	Blenny	*Lipophrys pholis*	Ø	Ø	✓	Ø
	Red blenny	*Parablennius ruber*	Ø	Ø	Ø	✓
Bothidae	Wide-eyed flounder	*Bothus podas*	Ø	Ø	Ø	✓
Carangidae	False scad	*Caranx rhonchus*	Ø	Ø	✓	Ø
	Atlantic horse mackerel	*Trachurus trachurus*	✓	✓	✓	Ø
	Blue jack mackerel	*Trachurus picturatus*	Ø	Ø	Ø	✓
	Pompano	*Trachinotus ovatus*	Ø	Ø	✓	✓
	White trevally	*Pseudocaranx dentex*	Ø	Ø	Ø	✓
	Longfin yellowtail	*Seriola rivoliana*	Ø	Ø	Ø	✓
Clupeidae	Twaite shad	*Alosa fallax*	✓	Ø	Ø	Ø
	European pilchardus	*Sardina pilchardus*	Ø	Ø	Ø	✓
Congridae	European conger	*Conger conger*	✓	Ø	Ø	✓
Cottidae	Longspined bullhead	*Taurulus bubalis*	✓	Ø	Ø	Ø
Gadidae	Spotted rockling	*Gaidropsarus guttatus*	n.i	Ø	Ø	✓
	Pouting	*Trisopterus luscus*	✓	✓	Ø	Ø
	Blue whiting	*Micromesistius poutassou*	✓	Ø	Ø	Ø
	Tadpole fish	*Raniceps raninus*	✓	Ø	Ø	Ø
Gobiidae		*Gobius spp.*	Ø	Ø	✓	✓
Kyphosidae		*Kyphosus sp.*	Ø	Ø	Ø	✓
Labridae	Mediterranean rainbow wrasse	*Coris julis*	✓	✓	✓	✓
	Goldsinny-wrasse	*Ctenolabrus rupestris*	Ø	Ø	✓	Ø
	Ballan wrasse	*Labrus bergylta*	Ø	✓	✓	✓
	n.c.n	*Symphodus caeruleus*	Ø	Ø	Ø	✓
	Ornate wrasse	*Thalassoma pavo*	Ø	Ø	Ø	✓
	Axillary wrasse	*Symphodus mediterraneus*	Ø	Ø	Ø	✓
	Baillon's wrasse	*Symphodus bailloni*	Ø	Ø	✓	Ø
	Corkwing wrasse	*Symphodus melops*	Ø	Ø	✓	Ø
Moronidae	European seabass	*Dicentrarchus labrax*	✓	✓	✓	Ø
	Spotted seabass	*Dicentrarchus puntactus*	✓	Ø	✓	Ø
Mugilidae	Thicklip gray mullet	*Chelon labrosus*	n.i	n.i	✓	✓
	Golden gray mullet	*Liza aurata*	Ø	Ø	✓	Ø
Mullidae	Striped red mullet	*Mullus surmuletus*	✓	Ø	✓	Ø
Muraenidae	Mediterranean moray	*Muraena helena*	Ø	Ø	Ø	✓
	Black moray	*Muraena augusti*	Ø	Ø	Ø	✓
Phycidae	Forkbeard	*Phycis phycis*	Ø	✓	Ø	✓
	Great fork-beard	*Phycis blennoides*	Ø	✓	Ø	Ø
Pleuronectidae	Flounder	*Platichthys flesus*	✓	Ø	Ø	Ø
Pomancentridae	Azores chromis	*Chromis limbata*	Ø	Ø	Ø	✓
	Damselfish	*Abudefduf luridus*	Ø	Ø	Ø	✓
Pomatomidae	Bluefish	*Pomatomus saltatrix*	Ø	Ø	Ø	✓
Scombridae	Atlantic black skipjack	*Euthynnus alletteratus*	Ø	Ø	✓	Ø
	Atlantic chub mackerel	*Scomber colias*	✓	✓	✓	✓
	Atlantic mackerel	*Scomber scombrus*	✓	✓	✓	Ø
Scophthalmidae	Turbot	*Psetta maxima*	Ø	Ø	✓	Ø
	Brill	*Scophthalmus rhombus*	✓	Ø	Ø	Ø
Scorpaenidae	Small red scorpionfish	*Scorpaena notata*	Ø	Ø	✓	Ø
	Black scorpionfish	*Scorpaena porcus*	Ø	Ø	✓	Ø
		n.i	Ø	Ø	✓	✓
Soleidae	Common sole	*Solea vulgaris*	✓	Ø	n.i	Ø
Serranidae	Whiting	*Merlangius merlangus*	Ø	✓	Ø	Ø
	Comber	*Serranus cabrilla*	Ø	✓	✓	Ø
	Blacktail comber	*Serranus atricauda*	Ø	Ø	Ø	✓
	Dusky grouper	*Epinephelus marginatus*	Ø	Ø	Ø	✓
	Mottled grouper	*Mycteroperca rubra*	✓	Ø	Ø	Ø
Scaridae	Parrotfish	*Sparisoma cretense*	Ø	Ø	Ø	✓
Sparidae	Bogue	*Boops boops*	✓	✓	✓	✓
	Annular seabream	*Diplodus annularis*	✓	✓	✓	Ø
	Senegal sea bream	*Diplodus bellottii*	Ø	Ø	✓	Ø
	Zebra seabream	*Diplodus cervinus*	Ø	✓	✓	Ø
	Sharpsnout seabream	*Diplodus puntazzo*	Ø	Ø	✓	Ø
	White seabream	*Diplodus sargus*	✓	✓	✓	✓
	Common two-banded seabream	*Diplodus vulgaris*	✓	✓	✓	✓

(*Continued*)

Table A3. Continued.

Famíly	Common name	Species	North/Center	Center	Algarve/Alentejo	Azores
	Sand steenbras	*Lithognathus mormyrus*	Ø	Ø	✓	Ø
	Saddled seabream	*Oblada melanura*	Ø	Ø	✓	Ø
	Axillary seabream	*Pagellus acarne*	✓	Ø	✓	✓
	Blackspot seabream	*Pagellus bogaraveo*	Ø	Ø	✓	✓
	Common Pandora	*Pagellus erythrinus*	Ø	Ø	✓	Ø
	Red porgy	*Pargus pagrus*	Ø	✓	✓	✓
	Salema	*Sarpa salpa*	✓	✓	✓	✓
	Black seabream	*Spondyliosom cantharus*	Ø	✓	Ø	Ø
	Gilthead seabream	*Sparus aurata*	✓	Ø	✓	Ø
Scorpaenidae	Scorpaenfishes	*Scorpaena sp.*	Ø	Ø	Ø	Ø
Sphyraenidae	Yellowmouth barracuda	*Sphyraena viridensis*	Ø	Ø	Ø	✓
Synodontidae	Atlantic lizardfish	*Synodus saurus*	Ø	Ø	Ø	✓
Tetraodontidae	Guinean puffer	*Sphoeroides marmoratus*	Ø	Ø	Ø	✓
Trichinidae	Lesser weever	*Echiichthys vipera*	Ø	Ø	✓	Ø
	Greater weever	*Trachinus draco*	Ø	Ø	✓	Ø
	Weevers	*Trachinus sp.*	✓	✓	Ø	Ø
Triglidae	Red gurnard	*Chelidonichthys spp.*	Ø	Ø	✓	Ø
		n.i	✓	Ø	Ø	Ø
Asteridae	Seastar	*Marthasterias glacialis*	✓	Ø	Ø	Ø
Loliginidae	Squid	*Loligo vulgaris*	✓	Ø	Ø	Ø
Octopodidae	Common octopus	*Octopus vulgaris*	Ø	✓	Ø	✓
Portunidae	Velvet crab	*Necora puber*	✓	Ø	Ø	Ø
Total of taxa			36	25	46	44

✓ - Species identified in the survey; Ø – Species not identified in the survey; n.i – Taxon not identified to species level.

Table A4. List of captured species by boat angling identified in surveys in the Azores (Diogo and Pereira 2013a) and the North of mainland Portugal (Lima 2006).

Famíly	Common name	Species	North	Azores
Balistidae	Gray triggerfish	*Balistes capriscus*	Ø	✓
Berycidae	Alfonsino	*Beryx decadactylus*	Ø	✓
	Splendid Alfonsino	*Beryx splendens*	Ø	✓
Carangidae	Atlantic horse mackerel	*Trachurus trachurus*	✓	Ø
	Blue jack mackerel	*Trachurus picturatus*	Ø	✓
	White trevally	*Pseudocaranx dentex*	Ø	✓
	Longfin yellowtail	*Seriola rivoliana*	Ø	✓
Congridae	European conger	*Conger conger*	Ø	✓
Gadidae	Pouting	*Trisopterus luscus*	✓	Ø
	Poor cod	*Trisopterus minutus*	✓	Ø
Labridae	Barred hogfish	*Bodianus scrofa*	Ø	✓
	Mediterranean rainbow wrasse	*Coris julis*	✓	✓
	Azorean blue wrasse	*Centrolabrus caerulius*	Ø	✓
	Ballan wrasse	*Labrus bergylta*	Ø	✓
Lotidae	Blue ling	*Molva dypterygia*	✓	Ø
Moronidae	European seabass	*Dicentrarchus labrax*	✓	Ø
Muraenidae	Mediterranean moray	*Muraena helena*	Ø	✓
	Black moray	*Muraena augusti*	Ø	✓
Phycidae	Forkbeard	*Phycis phycis*	Ø	✓
Polyprionidae	Wreckfish	*Polyprion americanus*	Ø	✓
Pomancentridae	Azores chromis	*Chromis limbata*	Ø	✓
Rajidae	Thornback ray	*Raja clavata*	Ø	✓
Scaridae	Parrotfish	*Sparisoma cretense*	Ø	✓
Scombridae	Atlantic chub mackerel	*Scomber colias*	✓	✓
	Atlantic mackerel	*Scomber scombrus*	✓	Ø
Sebastes	Blackbelly rosefish	*Helicolenus dactylopterus*	✓	✓
Scorpaenidae	Offshore rockfish	*Pontinus kuhlii*	Ø	✓
	Red scorpionfish	*Scorpaena scrofa*	Ø	✓
Serranidae	Comber	*Serranus cabrilla*	✓	Ø
	Blacktail comber	*Serranus atricauda*	Ø	✓
	Dusky grouper	*Epinephelus marginatus*	Ø	✓
Scaridae	Parrotfish	*Sparisoma cretense*	Ø	✓
Scyliorhinidae	Lesser spotted dogfish	*Scyliorhinus canicula*	✓	Ø
Sparidae	Bogue	*Boops boops*	✓	✓
	White seabream	*Diplodus sargus*	Ø	✓
	Common two-banded seabream	*Diplodus vulgaris*	✓	Ø
	Axillary seabream	*Pagellus acarne*	✓	✓
	Blackspot seabream	*Pagellus bogaraveo*	✓	✓
	Red porgy	*Pargus pagrus*	Ø	✓
	Gilthead seabream	*Sparus aurata*	✓	Ø
	Black seabream	*Spondyliosoma cantharus*	✓	Ø
Sphyraenidae	Yellowmouth barracuda	*Sphyraena viridensis*	Ø	✓
Synodontidae	Atlantic lizardfish	*Synodus saurus*	Ø	✓
Triglidae	Gurnards	*Leptidotrigla spp.*	✓	Ø
Trichiuridae	Silver scabbardfish	*Lepidopus caudatus*	Ø	✓
Loliginidae	European Squid	*Loligo vulgaris*	✓	Ø
	Veined squid	*Loligo forbesii*	Ø	✓
Total of taxa			19	34

✓ - Species identified in the survey; Ø – Species not identified in the survey.

Table A5. List of captured species by spearfishing in Azorean surveys and reported species in off-site national assessment, namely: Azores (Diogo and Pereira 2013b) and National (Assis et al. 2018).

Famíly	Common name	Species	Azores	National
Balistidae	Gray triggerfish	*Balistes capriscus*	✓	✓
Bothidae	Wide-eyed flounder	*Bothus podas*	✓	Ø
Carangidae	White trevally	*Pseudocaranx dentex*	✓	✓
	Longfin yellowtail	*Seriola rivoliana*	✓	✓
Congridae	European conger	*Conger conger*	✓	✓
Kyphosidae	Yellow sea chub	*Kyphosus incisor*	✓	Ø
Labridae	Barred hogfish	*Bodianus scrofa*	✓	Ø
	Mediterranean rainbow wrasse	*Coris julis*	✓	Ø
	n.c.n	*Symphodus caerulius*	✓	Ø
	Ballan wrasse	*Labrus bergylta*	✓	✓
	Cuckoo wrasse	*Labrus mixtus*	Ø	✓
	Ornate wrasse	*Thalassoma pavo*	✓	Ø
	Axillary wrasse	*Symphodus mediterraneus*	✓	Ø
Moronidae	European seabass	*Dicentrarchus labrax*	Ø	✓
Mugilidae	Thicklip gray mullet	*Chelon labrosus*	✓	✓
Mullidae	Striped red mullet	*Mullus surmuletus*	✓	✓
Muraenidae	Mediterranean moray	*Muraena helena*	✓	Ø
	Black moray	*Muraena augusti*	✓	Ø
Phycidae	Forkbeard	*Phycis phycis*	✓	✓
Pomancentridae	Azores chromis	*Chromis limbata*	✓	Ø
Pomatomidae	Blue fish	*Pomatomus saltatrix*	✓	✓
Scaridae	Parrotfish	*Sparisoma cretense*	✓	✓
Scorpaenidae	Red scorpionfish	*Scorpaena scrofa*	✓	✓
Serranidae	Comber	*Serranus cabrilla*	Ø	✓
	Blacktail comber	*Serranus atricauda*	✓	✓
	Dusky grouper	*Epinephelus marginatus*	✓	✓
	Island grouper	*Mycteroperca fusca*	✓	✓
Scaridae	Parrotfish	*Sparisoma cretense*	✓	✓
Sciaenidae	Meager	*Argyrosomus regius*	Ø	✓
Scombridae	Atlantic chub mackerel	*Scomber colias*	✓	Ø
Soleidae	Common sole	*Solea solea*	Ø	✓
Sparidae	Bogue	*Boops boops*	✓	Ø
	White seabream	*Diplodus sargus*	✓	✓
	Common two-banded seabream	*Diplodus vulgaris*	Ø	✓
	Red porgy	*Pargus pagrus*	Ø	✓
	Salema	*Sarpa salpa*	✓	Ø
	Gilthead seabream	*Sparus aurata*	Ø	✓
Sphyraenidae	Yellowmouth barracuda	*Sphyraena viridensis*	✓	Ø
Synodontidae	Atlantic lizardfish	*Synodus saurus*	✓	Ø
Nephropidae	European lobster	*Homarus gammarus*	Ø	✓
Majidae	Common spider crab	*Maja brachydactyla*	✓	Ø
Octopodidae	Common octopus	*Octopus vulgaris*	✓	✓
Patellidae	Limpet	*Patella aspera*	✓	Ø
	Limpet	*Patella candei*	✓	Ø
Portunidae	Velvet crab	*Necora puber*	Ø	✓
Ranellidae	Triton trumpet	*Charonia lampas*	✓	Ø
Scyllaridae	Slipper lobster	*Scyllarus arctus*	✓	✓
	Mediterranean slipper lobster	*Scyllarus latus*	Ø	✓
Sepidae	Cuttlefish	*Sepia officinalis*	Ø	✓
Toxopneustidae	Purple sea urchin	*Sphaerechinus granularis*	✓	Ø
Total of taxa			38	30

✓ - Species identified in the survey; Ø – Species not identified in the survey.